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ABOUT NITIE

NITIE was established as a National Institute in 1963 by the Government of India with the assistance of United Nations Development Programme through International Labour Organisation.

NITIE offers 2 years Post-Graduate programmes in Industrial Engineering, Industrial Management, Industrial Safety and Environmental Management, Information Technology Management and a Fellowship Programme of Doctoral level recognized as equivalent to Ph.D of an Indian University. NITIE has been conducting several short-term Management Development Programmes of one week duration in various areas of Industrial Engineering and Management. NITIE can conduct eight courses concurrently. The training programmes of NITIE emphasize on learning with a purpose, and are accompanied by an abiding concern for man. Besides training, NITIE is also engaged in applied research and offers consultancy in the various facets of Industrial Engineering, Operations Research, Information Systems and Computers, Environmental Management, Marketing, Organisation Behaviour and Human Resource Management.

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IN THIS ISSUE...

Editorial

The Indian manufacturing sector has been badly affected by the novel coronavirus crisis. The second wave of a swift spread of the COVID-19 pandemic came as a heavy blow to our economic development.

But still, it is with great pleasure that I write a forward of the second issue of the 42nd volume of Udyog Pragati - *The Journal for Practising Managers.* This issue focuses on a need for modeling supply chain environments to measure the performance of various strategies, methods, and technologies. It enables to improve speed, quality, and reduction of production cost. The second article focuses on adopting robust design and optimization methodology in the forging industry to enhance efficiency up-gradation and adaptability to various workloads.

The following study elaborates on the improved spring back value in the seamless tube manufacturing industry using the Design of Experiment (DoE) and microstructural investigation. The subsequent research highlights how the improvement of process capability dividends the quality of product, quality of personal by choosing the best method for a given distribution of data.

Once you are done with manufacturing, it's necessary to attract your consumer for its potential use and keep the manufacturing process continuing. How do you develop trust by developing informational interpersonal influence is essential? In today's world of internet of things (IoT) people uses the various platform. Electronic word of mouth (eWoM) messages are one of them. It helps to provide cues to the customer for making decisions regarding products/services to buy. The last study highlights the factors affecting eWoM message adoption. This research addresses sequential bias in online consumer reviews by analysing star rating product companies of various brands.

I hope this will help readers to equip with the knowledge to instigate zeal in their endeavors.

Prof. Rakesh Raut
Editor in Chief

Strategic Drivers, Issues, Challenges and Performance Indicators in Software Supply Chain: An Overview

Mahesh Kumar[1], Omkarprasad S. Vaidya[2]

The importance of software and IT services has been on the increase. The firms and the customers have been demanding new standards in delivery speed, quality, and costs of the software. This has prompted the software supply chain to evolve continuously with different business models and supply chain techniques. In this paper, we present an overview of the development phases of the software supply chain. We also look at the perspective of a software supply chain in terms of its strategic drivers, focusing on the characteristics of the software supply chain. Later, we look at the various issues and challenges faced by a software supply chain in terms of environmental (market) and the process related issues. Finally, we also provide some performance indicators of software supply chain. It is hoped that this work will act as a ready reference to the researchers and practicing managers alike.

Keywords: *Software Supply chain, Drivers, Challenges, Performance Indicators.*

Introduction

The use of the software in the businesses is increasing with the traditional businesses as well as new age entrepreneurs relying on software. With the increasing dependency to deliver value, more the business output depends upon the software capability and its availability. Trends of e-commerce and improving customer experience through technology and the software has brought the Software Supply Chain (SSC) to the core of the business strategy. Certain new age organisations like Uber, Cleartrip, Amazon etc. completely depend on the software for their value delivery. It is also observed that the actual productive life of the software solutions is coming down and they need replacement and enhancements continuously, owing to the increasing pace of innovation which is outdating the existing software products and their versions. Earlier, the organisations expected to rely on a software or its version for a longer duration. However, today in the e-commerce domain, a new software version or functionality may be released every week or even less, therefore adoption of new software in the system is more frequent. Another trend visible is that the 'software' is becoming an integral part of business processes. Any change in the business plan and strategy would necessitate different/ new software(s). It means that there is a need for quicker delivery of a new software and that too for a software which is compatible with the needs of the business.

The need for a faster response to the business requirements by the software supply chains is ever

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growing. Doing it right the very first time, and that too in a more cost effectively is always desirable, while there are budget constraints which are constant (budget is not increasing) over the period. Therefore, innovation is needed in the methods and processes in the software supply chain, right from the concept to its utilisation for the various operations. The demand for quicker delivery time necessitates innovation in the software supply chain. The organisations are striving for greater agility and speed to market in serving industrial customers. They pursue faster and continuous deployment to achieve the same. There is trend to enable non-software developers to deploy the new functionality using reusable software system components (Smiley *et al.*, 2016).

In this paper we will cover the relevant literature review followed by the section discussion the software supply chain and a propose reference model for the same. Subsequently the paper discusses the software development and software supply chain with respect to the strategic drivers of the supply chains. The contemporary issues and challenges faced by the software development supply chains has been elaborated followed by the key performance indicators (KPIs) relevant for the software supply chains, In the end conclusions are drawn from the paper.

This paper provides a perspective towards studying the software as a supply chain. This will open up further application of the supply chain management techniques in the software value chain. The paper will provide a reference material for the scholars and motivate further study of the software supply chains.

Literature review

Regarding software products, a knowledge-based evolutionary approach for assisting to project managers at the early stage of scheduling software projects is required. A method is needed to optimally align resources out of the available resource pool for the software activities. Yannibelli *et al.* (2011), provide an approach that given a software project to be scheduled, the approach automatically designs feasible schedules for the project, and evaluates each designed schedule according to an optimization objective that is priority for managers at the mentioned stage. The concept of supply chain management has not only been applied systematically to improve the cooperation between vendors and customers; instead in overall software life cycle, there is a trichotomy to subsist between software development, enterprise IT processes and enterprise run-time environment. As a result, there is interruption in the information flow between developers and operational software. Oberhauser and Schmidt (2007) propose an approach titled SWLIFE to bridge the process and information flow breaks by providing a semantic integration of the software supply chain. Hartmann *et al.* (2013), discuss the implications of product lines in a software supply chain. Since the software components are developed by different parties in the supply chain often using different technologies platforms, an increasing number of intermediate components (glue components) are needed to bridge the mismatches for integration. A model driven approach to manage variability in the supply chain may be helpful. A variability management tool is used, and a prototype is implemented for the case before authors. The results show that the intermediate components are generated only when needed.

Dingsoyr and Lassenius (2016), discuss the recent trends in the continuous value delivery. The iterative development transitioning to continuous value delivery sees the most important challenge as the customer supplier relationship. There has always been a need to make the software economically more viable by spending the money more slowly and earning value more quickly. The authors argue that the ideas of continuous value delivery are old, just that the possibilities have increased with the maturing technology. The authors also delve upon defining the value of the software. Lean production emphasises on the reducing costs through eliminating "waste", where waste can be waiting time or large inventories. Waste can be reduced by the techniques like value stream mapping or Just in Time Production. There has been a trend off late by the start-ups where they focus on the early learning about the customer value.

Fitzgerald and Stol (2017), have discussed the trends in the software development and how its approach has changed over the years. The authors also compare the software practices with the established lean manufacturing practices like TPS. Most of the concepts of lean can be compared with the software development for example wastes like over-production can be compared with unwanted features, "inventory" as "unfinished features", "moving" with "task switching" and so on. While the software development function might "flow" to some extent but planning and deployment of the features is still done in batches. The authors propose of continuous software engineering in all aspects of the software development process e.g. business strategy and planning, continuous budgeting, development, continuous integration and related activities, continuous verification and continuous testing, continuous compliance, continuous security, and continuous evolution of the software.

Kumar et al (2020), proposed simulation modelling techniques to study the dynamics of the software development supply chains. They modelled the software development supply chain and simulated the software flow through the chain, identifying the bottlenecks and impact of various work priority management techniques on the throughput.

The judgement of the timelines estimation in software planning is a task with inherent inaccuracies. Moreover, unexpected changes make the things worse (Halkjelsvik and Jørgensen, 2012). In large software projects this causes the deterioration in due date performance because of the estimation of the due date planning (DDP) being inaccurate in the first place. Software efforts estimation has been an important area in the software development supply chains planning. Wińska et all (2021), suggest a model based on random forest technique for the task effort estimation in agile software development processes.

The productivity, speed to delivery, quality of the delivered software, delivery to budget, and delivery to time can be considered as the performance indicators for the software industry (Symons, 2010). The author also points out that since the three parameters can be to an extent traded-off by each other, it becomes difficult to define and monitor the same collectively.

There are various factors that lead to failure of IT projects. There is a need to differentiate between factors which are related to project and the ones which are related to project management. The iron triangle for the software development i.e. measures of cost, time and quality holds true, wherein cost and time are difficult to measure in the early stages of software project and may continue to shift over the development life cycle, but quality is highly dependent on perception and that will also change over the lifecycle (Dwivedi *et al.*, 2013). Atkinson (1999), provide some thoughts about the success criteria for the IS-IT project management. The author delves upon the cost, quality and time as the criteria for the project management which continue to be used as the criteria for the IS projects success management. Khan et all (2017) identify the barriers in the Software process improvements in the global software development environments such as organizational politics, lack of organizational support, lack of communication, lack of resources, lack of process improvement knowledge and staff turnover, amongst others

Gowan and Mathieu (2005), classify the information systems projects performance into five categories namely, schedule, budget, quality of the system, satisfaction with the project team, and business value. Their study concludes that it is neither large nor technically complex IT projects are predictors of the project poor performance. Rather it is the intervention of a formal project methodology that predicts the successful completion of a project by its target date.

Information security being a critical aspect in the software development, delivery and operations. Núñez et all (2020) discuss a model with case study for the preventive and flexible approach to develop secure software. They studied and compared the best-known models in secure software development. security activities of these well-known models, besides other security tasks, correcting the weaknesses of the proposed models and following a preventive approach. Jalil and Bakr (2017) proposed model that make up the components and subcomponents of Cloud ERP Factory. They propose factory model for ERP software with components like Product line, platform, workflow, product control and knowledge management.

With regards to the situational factors which can affect the software development process, Clarke and O'Connor (2012), identify 44 factors and 170 sub-factors. They classify the factors related to personnel, organisation, business, application, management, technology, operational and requirements. The authors point out waterfall development model, Capability Maturity Model (CMMI), and many other approaches represent significant contributions to the software development field but they all have been criticised for not adequately dealing with the dynamic nature of the software development. Cerveny and Galup (2002), emphasise that as the businesses are facing growing intensity of global competitiveness, superior speed in development and implementation of new products and services is a must. The main effort in project planning and project control are to minimise the risk of non-productive effort. Nan and Harter (2009), through an empirical research suggest that there is a significant U-shaped relationship between software development cycle time and effort, vis-a-vis budget and schedule pressure. The authors' findings suggest that budget pressure has significant relationships with software development cycle time and development effort, controlling for software process, complexity, and conformance quality. Dzvonyar *et al.* (2016), discuss the importance of user feedback process in a software evolution process. In the agile software development where we are looking at high throughput in terms of deployable functionality, developers need to be able to react to quickly changing requirements and unclear specifications. Iravni *et al.*, (2012), delve upon the issue of ongoing software development and maintenance scheduling and throughput. While they tried to solve the problem of systematic resource allocation and process management at a tax preparation Software organisation, they emphasise that the pressure on the organisations is high to incorporate changes as required by the law, statute or the customer requirement, in terms of speed as well as the quality. Kim *et al.* (2013), in their novel "The phoenix Project", bring out the problems of software supply chain in an organisations' context. They bring out how critical is the throughput of software supply chain for business performance. The authors bring out the applications of TOC's five focusing steps and the concepts of lean in the software supply chain concept.

Software as Supply chains

Software delivery chains have not been usually represented as a 'supply chain'. However, the software supply chain have few characteristics: a) The product software is not in a hardware form and can be changed later as and when the need arises, some of them being product quality issues like bugs and revisions as suggested by the customer. b) Software development process is like a job shop, most of the software required to be developed are customised to suit the requirements, like a job shop or project. Similarly, the time and resources needed to create a software are difficult to estimate. The time and resources required are dependent on many factors like the knowledge, constitution of the team, clarity of the requirements etc. (Clarke and O'Connor, 2012; Iván A. and Ranganathan C., 2015).

There have been efforts to define a reference framework for the software product management. (Weerd *et al.*, 2006), wherein attempt has been made to include various stakeholders. However, most of the project governance and not from the viewpoint of the value/ supply flow.

We propose a generic software supply chain (SSC) framework, called as software supply chain Reference Model, which depicts the flow of the supply in software. Please refer to Figure 1.

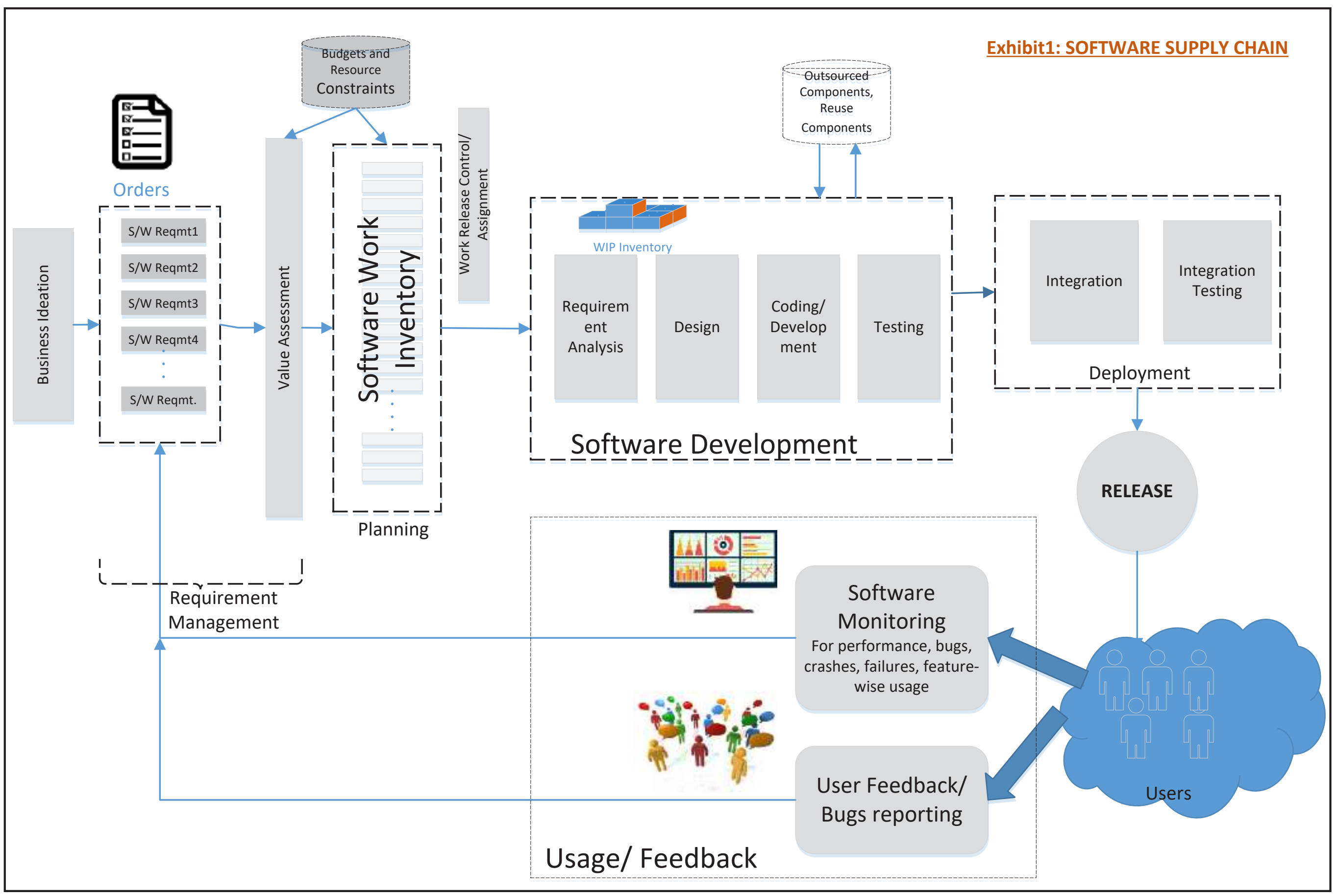

Figure 1: Software Supply Chain Reference Model

Various echelons in a software supply chain consists of the 'requirements' management, product development, deployment, distribution, usage and the feedback stages. It can be seen that mostly the software supply chain is a closed loop, with the feedback stage forwarding the requirement for further software development. The software supply chain starts and ends at the customer. It starts from the software requirement from the end user (customer) and ends at the delivery and usage of the same by the customer. At times the customer is represented by internal business users of product development teams, which envisage the customer requirement. However, the effectiveness of such representative users' requirement is measured by the acceptance of the features by the end users. If they are finally not being perceived to be of value to the user, it will tantamount to waste of time and resources.

A software supply chain possesses some interesting features, including the way in which the supply chain is being delivered from the software development to deployment, the characteristics considering various drivers of the supply chain, issues and challenges and the performance indicators. In this paper, we provide an overview of these facets of the software supply chain.

Software development

Most of the times, all software development teams share the same set of resources in terms of human resources, funds and machines etc. Therefore, there is a stage of prioritisation of the software development work. Such requirements then move to the 'software factory' for development. The Software development typically will have various stages, each of which will have different skill set requirements, hence have capacity constraints individually. There is a possibility of multiskilling of people, and there are requirements of segregation of duties.

These two streams of software requirements, namely the new software requirements and the supplementary requirements, would be subjected to the budgets and resource constraints. The requirements will also have different criticality and business value associated with them. Therefore, there is a need for the requirements prioritization mechanism. The requirements will then wait in a queue and will be released as per the software release rules. The number of queues will depend on the organization of the development teams. One or more queue may be required depending on the work assigned. Further there may be even more queues in case there are various small teams which are dedicated to specific functions or modules of the software. Supplementary requirements will belong to an existing software deployed. These requirements originate from the usage of the existing software by users in the market. These are usually bug fix requests, user enhancement requests or improvement requirements arising out of the continuous monitoring of the software usage. These requirements surge as any new software product is launched and gradually tapers down as most software issues are taken care of. The supplementary requirements can be of varied sizes as far as the quantum of work is considered.

The team which built the original software will have shorter learning curve to cater to such supplementary requirements of the software. Thus, relatively, the productivity of the development team increases in case same resources, who made the initial software, are made available to work on the bugs and enhancements. But it is difficult to retain the same resources to cater to these supplementary requirements.

The software development phase, irrespective of the stream, consists of typically five stages.

First stage: Software Requirements analysis. In this stage the user requirements are analysed from the point of view of feasibility, exploring alternative solutions, logics etc.

Second Stage: System design. System design will involve description of desired features of the software in detail. This will include the business rules, diagrams, user interface layouts and other necessary documentation.

Third Stage: Software Coding. Software coding is where the actual programs codes are written. The work requires the logics to be implemented. This is relatively the most resource intensive stage amongst all the four stages.

Fourth Stage: Testing. Testing stage involves verifying the code written in the third stage for the intended functionalities, for the correctness and adherence to the defined standards of software development. This stage will also involve bringing all the software 'pieces' together and then test for its working in the test environment. This will check for any errors or bugs when the software is run together with the other modules and the environmental software.

Fifth Stage: Installation and deployment. Here the end user gives her/his acceptance for adapting the software into use for the actual business. In commercial mass use software, this phase will also involve distribution of the software (usually, the online mode). Post deployment, a feedback with respect to the utility of the software, such as any kind of errors or bugs, and any enhancement requirements is sought from the users. Few modern software collects the user statistics and conduct an automatic monitoring of the usage patterns and capture errors or bugs, if any. Feedback of this stage, whether user initiated, or automatic feedback is analysed and the requirements are reported back to the software development team for the development cycle again. The feedback process in the software supply chain plays very important role in the value delivery of the software products. This is the service nature of the software. While the softwares may have some defects/ bugs, they are to be are identified timely and addressed promptly.

Modern software supply chains use the speed of communication to their advantage. These software are made more self-diagnosing and they report back almost instantaneously [Dzvonyar *et al.*, 2016]. The software also provides features for the users to report bugs and requests conveniently. All these features provide an opportunity to the software development agencies to close the loop of the supply chain and to deliver continuous value. Out of such requirements new software delivery models emerge. Therefore, software to be supplied is looked as a 'product' to software being provided as a 'service'. With this understanding, we present the various drivers of the supply chain as applied to the software.

Drivers of the Software Supply Chain

Supply chains design is related to the strategy of the organisation. The organisation needs to attain the balance between the responsiveness and the efficiency which best fits the strategy of the organisation. Chopra and Meindl, 2007, discuss the 6 strategic drivers of the Supply Chains. These drivers are a) Facilities, b) Inventory, c) Transportation, d) Information, e) Sourcing and f) Pricing.

The drivers namely, Facilities, Inventory, Transportation are categorized as the Logistical drivers, whereas Information, Sourcing and Pricing are categorized as the Cross-functional drivers. Together these drivers are key to the design, planning and operations of any Supply chain. These drivers will position strategically the firms and define its responsiveness and efficiency. We elucidate the software supply chain with respect to these drivers.

a. Facilities

Facilities in a software supply chain will consist of the physical location of the teams that develop the software and the facilities with respect to the servers and other equipment which is necessary to create, ship and host the software. The facilities will also include the software and tools which facilitate the software development. A firm can be classified based on following choices with respect to the SSC and their strategic implication:

- Onsite v/s Offsite
- Dedicated v/s shared
- Owned v/s outsourced
- Capacity of the facility

With respect to the facilities, it is pertinent to measure capacity utilization, cycle times of the development, and the efficiency. It is also important to measure the capability of the facility with respect to the variety of products that it can develop. The variety of the software that can be developed will reflect on the skills and experience of the facility. Capacity utilization in the facility of the SSC is reflected in the measures like the bench strength of the personnel. Also, performance can be measured using the terms such as the booked man-hours in the project sheets and the skill development activities etc. A facility's performance can also be measured by the due date performance of the facilities in terms of the requirements that are completed on or before the due date.

These choices with respect of the software supply chain will enable the firm to strike the desired balance between the efficiency and the responsiveness. The efficiency parameters will consist of cost and quality. The responsiveness is reflected by the ability of the firm to quickly adopt and churn out the software product fast and of differing varieties. Efficiency in the design of the software development facility will be preferred if the firm focusses on fulfilling automation requirements of established processes. Here, quickness of the completion may be of lesser importance than the cost effective and quality software products delivery. For example: software(s) related to accounting, purchasing and human resources etc.

Responsiveness however, will be preferred in case of 'quick response' is a priority of the firm, for example, the firms which are catering to software requirements in security domain, where new software threats (like viruses) are prone to appear frequently and therefore software products need to be upgraded quickly.

b. Inventory

Inventory in a software supply chain is cannot be seen in a physical form. However, it is essentially the work done which has not been delivered to the customer and thus not generating value. The inventory includes the software waiting to be processed by the subsequent phase in the development cycle and the software modules which are waiting for the other modules to get integrated. Sometimes, the software work, waiting for the resources for deployment, cause the inventory to accumulate. Software supply chains may not have any 'Raw Material' inventory, but there is work-in-process inventory and finished goods inventory van be seen. The finished goods inventory in software supply chain are the modules which are developed but not released due to, a) deployment phase not initiated b) customer requirements change over the period.

The quantification of the software supply chain inventory can be estimated by the number of Software Change Requests (SCRs). This measure works well for the operational measurement especially where the SCRs are of similar work size. However, if the size (variety of features) of the software varies the count may not be the best measure to represent the inventory. In such scenario other measures such as 'function points' may be useful. Function points consider the complexity and the amount of business functions involved in fulfilling the requests.

In the software supply chains, the work inventory will reflect lumpiness in the supply chain flow. Such supply chains will have higher work in progress and are relatively less responsive relative to the agile software development methodology [Fitzgerald and Stol, 2017].

c. Transportation

Transportation in a software supply chain is different in terms of logistics and strategy. There is very little movement if physical goods here. Nevertheless, transportation is a very important aspect in the design of the software supply chains. The transportation in supply chains is the movement of information (or software) in the form of documents and software files. There "goods" move across the various stages of the software development. They are stored, moved, queued, and grouped across the resources which process them. These are humungous in number and are dynamic in nature, that is, in extreme case, the structure of the supply chain varies, as a new supply chain is being developed. This results in an immediate update of the software version. Unlike the physical goods supply chain, in a software supply chain there is a need to keep track of older versions as well, for traceability and rework purposes besides other uses. The challenge for the transportation is to make the right version available at the right time for the timely delivery of the products. In this age of internet and communication, the actual movement of the software "good" is mostly not a challenge unless it is very time sensitive product like antivirus security codes etc. However, the storage of these goods and distribution in a secured manner to the desired recipient is a big challenge. For example, when we require to distribute the software, update to the millions of customers, it is considered as a huge task. If the software that needs to be delivered is time sensitive in nature, for example: antivirus patch or antidote, or a new tax software update, etc. time becomes a big constraint and the design of the software supply chain needs to consider the same. One needs to consider the heavy load (traffic congestion) on the servers which are going to support these updates. In case it is not so time sensitive software then the designers of the supply chain can take it easy accordingly.

Secure transmission and control of the software is another big challenge in the software supply chain. The software is a commodity which can be tempered, duplicated, or copied easily which means a significant revenue loss to the firm which produce these softwares. Software piracy and copyright related laws are becoming more and more stringent, still the firms need to develop their software transportation and distribution mechanisms such that the software reaches only the desired recipients and is used only by the desired recipients. This may involve identifying the users through unique identifications, securing the transportation through encryption, and keeping a check on the distribution of the software, after it is sold and shipped to the customer.

The transportation strategy will involve decisions like:

- Weather to use public platforms like Google Play or Apple store etc. or to distribute the software or establish and use firm's own distribution channel?
- Whether to use internet, local area network, or physical media for the content distribution?

- What type of encryption and/or other security mechanisms to use? Simple software keys methods can be used wherein genuine customers are provided a key separately from the software. Public key cryptography and other advanced mechanisms are also emerging as alternate options.
- What software tools and technologies to be used to manage new version and their distribution?

The key management metrics involved in the software supply chain transportation will be the timeliness of the delivery. Another management metrics that may also involve is the ratio of number of the unauthorized copies of the software being used, to the authorised copies used.

d. Information

The role of information systems in a software supply chain is elucidated as follows:

- *Information about the status of delivery of the software requirements:* The scheduling of the software requirements is a key to the efficiency of the software supply chain. Constant feedback and visibility to the progress of the software development, testing and release is necessary for planning and execution. A centralized development environment records such information.
- *Information about resource utilization and availability:* Information about the operations of the supply chain, e.g. resource utilizations, resource availability etc. is important for the tactical planning and strategic planning. It will also help in manpower planning. Further it will help in planning for process improvements and training requirements. Servers and communication systems are also key facilitators, hence there is a need to monitor and planning is required for them.
- *Statistical (Data) Information:* 'Software usage' data or statistics is yet another piece of information required in the modern software supply chains as the modern software products are dynamic in nature. The data helps in future planning of the software design and features. The user behaviours captured using the information helps to target them with right products for their needs. This information flow needs to be planned well in advance before releasing the software products.
- *Customer requirements and feedback:* Customer requirements and feedbacks are required not only for improving the future products but also to fix bugs as warranty obligations or to fulfil the obligations as per the support contracts. Support contracts form a big revenue stream for the software firms therefore it is important to gather feedbacks, requirements and complaints from the users. Call centres, and web pages have been used to let the customers report these situations. The requirements or feedback can be obtained from same channels along with other contemporary channels like mobile phones and emails provide such. Some modern software products which are connected to Internet may have this reporting facility inbuilt in the products itself.

A Software Supply chain can be both a pull-based system and a push-based system. The information becomes a key strategic driver in both the cases. Software supply chain is a closed loop ecosystem. Information flow allows for the looping back for requirements.

e. Sourcing

Sourcing in the software supply chain includes those of software modules, the computing resources, and the communication. Software module is a piece of functionality available or pre-built in a software package, thereby reducing the software development efforts, and hence reducing the time to market for the products.

The sourcing decisions about the outsourced modules include the choice between open source modules and bought out modules from the other firms. The costs of such sourced modules will depend on its source and the availability in terms of the number of sources. The open source modules are available with a minimal cost but usually don't come with any explicit support assurance. The support is an important aspect in the sourced software since the sourced modules need to be fixed for any bugs or should take care of the technological advancements. On the other hand, there are commercially available modules libraries which will come with a cost but gives assurance about the support and enhancements.

Sourcing decisions in the software supply chain greatly determine the competitive strategy of the firm. For critical applications, the software sourcing strategy must be in-house developed, or the use of commercially available software modules should be preferred. On the other hand, for not very critical applications where the cost effectiveness is a key criterion, use of open-source modules will be a preferred choice.

Sourcing decisions also determine the strategic positioning of the firm. For example, a firm developing software for sales force automation will use the software modules of GPS tracking related functionalities from the libraries supplied by other firms. It may not be prudent for the firm to get its resources develop those modules.

Sourcing decisions also depend on the uniqueness of the functions available in a particular module. If the firm feels that the functions in the software is a business differentiator for the firm, it would like to keep the development in-house rather than relying on the outsourced modules. Whereas if the functions are standard, the company will decide to use the outsourced modules to achieve them.

The software supply chains are becoming extremely complex from the point of view of sourcing and using outsourced modules. The number of such modules and services is increasing. Components of the sourcing decisions:

- In-house v/s outsource
- Source selection
- *Procurement* decisions- Upfront purchase or pay per use
- Support levels that are sought from the outsourced software

The sourcing metrics involve the cost of acquisition of such modules and the effective prices of their usage. The ratio of the costs between in-house development verses cost of the outsourced software is also a key consideration in the software supply chain.

f. Pricing

With no physical commodities involved, software pricing is largely dependent upon the contribution profit margins. The variable cost involved in the sale per unit is usually very low. However, the variable cost per unit will largely consist of the distribution cost if any.

The Software pricing has two components:

- *The per unit price*: The price of the right of usage granted to the customer usually on the relevant metrics like per user, device or per customer.
- *The Support and maintenance price*: The price charged to the customer for rectifying any bugs and to support with any other type of service. This service may involve providing future enhanced versions of the software.

Economies of scale vary in the software supply chains and depend on the strategic positioning of the firm. If the product being offered caters to very specialized needs of a customer, the per unit price of the software will be high. Whereas a mass used software will distribute the costs more efficiently hence will be able to have relatively lower per unit cost of the product. The competition and uniqueness of the product will allow the firm to charge premium for the product.

Pricing of support services is a widely used revenue model by the software firms. Almost all commercial software firms charge a maintenance fee for the upgrades and bug fixing. Such revenue model makes the software supply chains unique. Thus, requires the software supply chain to have customer requests and feedback channels established, feeding into software delivery framework.

Price differentiation in the software products is based on the version of the software. A version of software assembled in a manner that gives certain set of functions. This differentiation allows the segmentation of the customers and helps increasing the revenue. Basic versions have limited functions, or limited usage rights and will be priced lower than the premium models. The firms may also package products as per the customer niche, e.g. students, professionals and organizations may be charged differently and be shipped or entitled to different functionalities for each of them.

Price differentiation is also prevalent in the support and maintenance contracts. The firms offer different set of services under the differentiated service products. This differentiation may happen on the service level agreement, level of involvement like deputing of on site or dedicated resources etc. The supply chain will usually use the same facilities to deliver these differentiated products. Therefore, the supply chain needs to be configured as per the product pricing on offer. Price differentiation is also not uncommon based on the negotiation which pivots around the buyers' keenness to use the software based on the business value derived on usage.

Pricing incentives to the customers to buy larger usage rights of the software product is a common practice. This is so because there is virtually no incremental cost if the customer buys higher usage rights.

Issues and Challenges in the Software Supply Chain (SSC):

The changing trends in the business and the technology environment are leading to issues and challenges in the traditional software supply chains [Kim *et al.*, 2013]. The software supply chains are going through very rapid environmental changes. The issues and challenges can be broadly classified based on environmental (market) trends and managerial practices which in turn affect the key performance indicators (KPIs) of the supply chains (Refer Figure 2).

Environmental Trends:

a. *Shorter Life cycle of Software Products:* The software life cycles is getting shorter. On one hand, it means more demand for the software supply chains, while on the other hand, it means a configuration management and ensuring the effectiveness and efficiency of software in the fast-changing environment.

b. *Demand for faster Response:* The software supply chains are expected to have a quick response. The dependency on the software for the businesses and the society, makes the software a critical component. This puts tremendous pressure on the software supply chains to cope up with the demand as per users requirements and therefore at times, exposes the flaws or constraints in them.

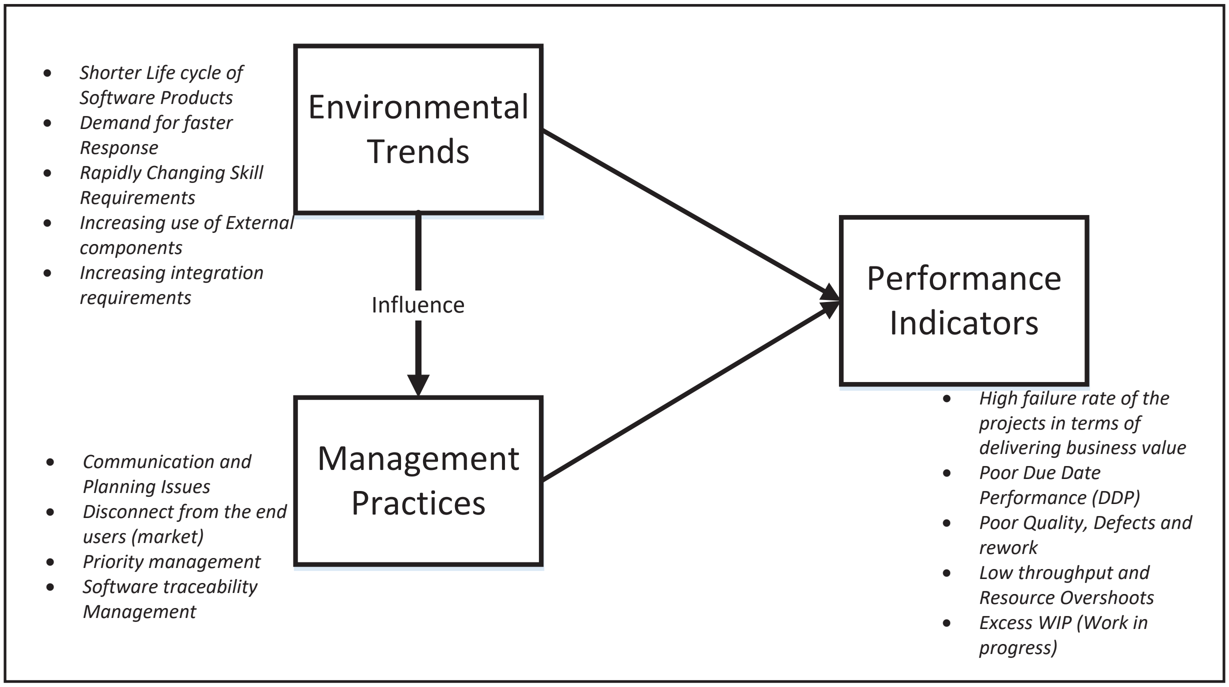

Figure 2: Issues and Challenges in Software Supply Chain

c. *Rapidly Changing Skill Requirements:* The skills required in the software supply chain are dynamic in nature. There is constant upgrade in technologies and new capabilities are being incorporated. This trend of constant change in the technology and immergence of new technologies require quick upgradation of the skills for the software industry professionals.

The changing technology landscape creates an ever-lasting challenge of skilled resources. The existing resources need to be trained with new developments in the technology. Recent developments will have shortage of readily available skilled resources.

To add up the complexity, the different stages of the 'software development' will possess varied skill requirements, hence will have capacity constraints. There is a possibility of multiskilling of people, but there are also requirements of segregation of duties, given a specific software requirement.

d. *Increasing use of External modules:* Use of external modules will reduce the software development time. These are available at a cost or as a freeware. However, there is no guarantee of a freeware for its performance, when put to actual use. There has been significant increase in the use of external software modules and services in the software development and software deployment. The software supply chain is critically dependent on the availability of the correct versions at the right time. The dependency of such components came into limelight in March 2016, (https://qz.com/646467/how-one-programmer-broke-the-internet-by-deleting-a-tiny-piece-of-code/) when one of the software programmers deleted few lines of his code which was available as a shareware and was being used by many softwares. This virtually ruptured the internet services. Eventually when the programmer came to know about the same, the code restored.

e. *Increasing integration requirements:* From the stand-alone software era, we have come a long way where every software or part of the software needs real time integration with so many other software/s in the ecosystem.

Management Practices

a. *Communication and Planning Issues:* Issues regarding harmful disconnects between important activities such as planning, development and implementation, is a concern especially when there is a urgency of work with respect to speed of delivery or throughput.

b. *Disconnect from the end users (market):* In the software supply chain, the end user requirement is captured with the help of representatives of the organisation or third party agents. Very often there is a mismatch between the delivered features of the product and the requirement of the customer because of the following reasons:

- The market requirement has changed.
- The product is not performing as desired.
- The product features are either under-emphasised or over emphasised than the actual requirement. The non-value adding features are more elaborate and prominent than those actually needed.
- There is lack in communication of the feedback to the developer. Sometimes the prioritisation is carried out as the development does not gel with the requirement of the customer.

c. *Priority management (Conflicting Priorities and the unplanned work):* The software development and projects face the issue of conflicting priorities. At times there are change requests, and prioritising is difficult given the apparent perpetual shortage of resources. The prioritisation needs to be carried out considering the different types of tasks to be executed like new projects, modifications, bugs in the existing deployments, changes related to functions of a software etc. All these share the same resources. With the increase in the software usage in more business process and increased automation, resource allocation seems to be a problem. These may have impact on revenues, operational efficiencies, statutory requirements and compliances (Kim *et al.*, 2013).

d. *Software traceability Management:* Software product delivery will usually have large number of modules which will need to work together. Almost all these are in the constant state of change. For example, a software will be using a) some software libraries from the development platform, b) some operating system, c) some database on which the software is being tested. However, because of priorities or preferences from the customer, there could be a need of modifications. This can create complexity in the software resulting in malfunction or stop working. These may lead to catastrophic consequences at times. Similar issue arises when a heavy software uses sub-modules from other sources. It is important to maintain the traceability with regards to which module is being used from which source. It is required so that the module can be traced back if the product is not working properly or requires changes. Therefore, managing the configuration and traceability of the software is crucial for the supply chain.

Performance Indicators

a. *Failure rate of the projects in terms of delivering business value:* The project failures can be more often attributed to the non-fulfilment of the business objectives with which it was created. Also, the requirements change over the period when the software supply chain is being prepared to deliver the software (Symons, 2010; Dwivedi *et al*, 2013).

b. *Due Date Performance:* The expectations from the customer end are ever increasing in terms of the new functions in the software as well as fixing bugs and enhancements. The reasons for the poor due date performance are usually due to deficient supply chain practices, excess work inventory, and lack of focus on the throughput [Kim *et al.*, 2013], [Symons, 2010].

c. *Quality of the software:* Quality of the software plays an important role in the choice of the development strategy. Like manufacturing or product development, the later the quality defect is detected in the supply chain, more is the cost of quality. Because of the increase in the complexity of the modules and components involved in the software development, consistency of quality in software is important. Quality problems can arise because of bad development, configuration issues, etc (Kim *et al.*, 2013).

d. *Throughput and Resource budget overruns:* Because of the long project lifecycles, improper user requirement, the resource utilization is an issue in the software supply chains. The problem is accentuated in case of complex and tedious requirements from the customers, where the chances of mismatch of user expectations increase. The variation in software development projects, results in variations in skill required to develop a project, and hence the team development issues. (Halkjelsvik and Jørgensen, 2012; Iván and Ranganathan, 2015).

e. *Work in progress in the software supply chain:* With the increased delivery requirements, the software delivery teams may end up in working too many requirements at a given time. This increases the work in progress content, in the system. The impact of increased work in progress can be reflected on the customer satisfaction level (Kim *et al.*, 2013).

Managerial Implications of the study

This study indicates that there is need to look at the supply chain aspects of the software development value chains. The predominant non-material nature of the software differentiates it from the manufacturing supply chains. However, the product nature of the software, and the fact that its creation requires a set-up and resources, under the ever increasing demands from the customer in terms of the speed, quality and throughout, necessitates the study of the software as a supply chain. The aspects of the team compositions, software flow, work breakdown, work allocation are the managerial discretions which need to be studied for the software firms with different goals. The work priority management and secure and reliable distribution of the software needs its supply chain management. The number of software development requirements from a software organisation are increasing, and many of the development requirement are like repetitive work. In such situation the project management methodology to manage software development needs to be applied in conjunction with the aspects of the software flow management, the work-in progress inventory management and throughput management of the firms.

Conclusions

The 'software' can be looked as a product that has become a pervasive requirement of the human society. The search for better productivity, cost competitiveness and higher throughput has led to the concept of software supply chain which needs to adopt state of the art operations management theories. This paper provides an overview of the development phase of the supply chain, and the strategic drivers that impact the overall functioning of the software supply chain. The drivers of the software supply chain translate to the various choices involved and their role in the strategic positioning of the firms with respect to responsiveness and efficiency of the software supply chain.

We have discussed the issues and challenges being faced by the software supply chains. There are environmental trends which are mostly, not in the control of the firms. The issues related to management practices impact the decisions of the managers. We also discussed various performance indicators which are significant to improve customer satisfaction.

This paper provides a glimpse of the software supply chain management and provides a foundation stone to conduct an in-depth analysis and research in this area. We find limited academic literature which discusses the supply chain aspect of the software development. Most of the literature focusses around the project management aspect of the software development. This paper attempts to bring out the supply chain aspects of the software development value chain. As an extension to this work, a survey from various organizations may help in evaluation of various issues and challenges presented in this paper. The paper also provides scope to look into the application of various classical operations management techniques and development of new operations management techniques to address the issues expressed in this work. We hope our work would act as a reference manual to the researchers and the practicing managers in this area.

References

Cerveny J. F. and Galup S. D., (2002), "IS/IT Project Failures: A Review of the Extant Literature for Deriving a Taxonomy of Failure Factors", Production and Inventory Management Journal; Third Quarter 2002; 43, 3/4; ABI/INFORM Collection, pg. 55

Chopra and Meindl, (2007), "Supply Chain Management- Strategy Planning and Operation", Pearson Prentice Hall, ISBN: 0-13-208608-5

Clarke, P. and O'Connor R.V., (2012), "The situational factors that affect the software development process: Towards a comprehensive reference framework", Journal of Information Software and Technology, Vol. 54, Issue 5, May 2012. pp. 433-447

Dingsoyr T. and Lassenius C., (2016), "Emerging themes in agile software development: Introduction to the special section on continuous value delivery", Information and Software Technology 77 (2016) 56–60

Dwivedi Y.K., Ravichandran K, Williams M.D., Miller S, Lal B, Antony G.V., and Kartik M, (2013), "IS/IT Project Failures: A Review of the Extant Literature for Deriving a Taxonomy of Failure Factors", IFIP International Federation for Information Processing, AICT 402, pp. 73–88, 2013

Dzvonyar D., Krusche S., Alkadhi R. and Bruegge B., (2006), "Context-Aware User Feedback in Continuous Software Evolution", International Workshop on Continuous Software Evolution and Delivery - CSED, May 2016, Austin, TX, USA.

Fitzgerald B. and Stol K.J., (2017), "Continuous Software engineering- a roadmap and agenda", The Journal of Systems and Software 123 (2017) 176–189

Gowan J. A. and Mathieu R. G., (2005), "The importance of management practices in IS project performance: An empirical study", Journal of Enterprise Information Management; 2005; 18, 1/2; ABI/INFORM Collection, pg. 235

Halkjelsvik T, and Jørgensen M., (2012), "From origami to software development- A review of studies on judgment-based predictions of performance time", Psychological Bulletin, 2012, Vol. 138, No. 2, 238–271

Hartmann H., Keren M., Matsinger A., Rubin J., Trew T., Yatzkar-Haham T., (2013), "Using MDA for integration of heterogeneous components in software supply chains", Science of Computer Programming 78 (2013) 2313–2330

Iravani F., Dasu S. and Ahmadi R., (2012), "A Hierarchical Framework for Organizing a Software Development Process", Operations Research 60(6):1310-1322. http://dx.doi.org/10.1287/opre.1120.1111

Iván A. and Ranganathan C., (2015), "Software Quality and Development Speed in Global Software Development Teams", Bus Inf Syst Eng (2015) 57: 91. https://doi.org/10.1007/s12599-015-0372-6

Jalil, D. and Bakar, M.S.A., (2017), "Adapting Software Factory Approach into Cloud ERP Production Model", International Journal of Computer Science and Information Security, 15(1), p.221.

Khan, A.A., Keung, J., Niazi, M., Hussain, S. and Ahmad, A., (2017), "Systematic literature review and empirical investigation of barriers to process improvement in global software development: Client–vendor perspective", Information and Software Technology, 87, pp.180-205.

Kim G., Behr K. and Spafford G., (2013), "The Phoenix Project", IT Revolution Press, Portland, Oregon. ISBN13: 978-0-9882625-8-4

Kumar, M., Vaidya, O.S. and Srivastava, R.K., (2020), "Impact of task priority on software supply chain: a simulation approach", South Asian Journal of Business Studies.

Nan, N. and Harter, D.E., (2009), "Impact of budget and schedule pressure on software development cycle time and effort", IEEE Transactions on Software Engineering, 35(5), pp.624-637.

Núñez, J.C.S., Lindo, A.C. and Rodríguez, P.G., (2020), "A Preventive Secure Software Development Model for a Software Factory: A Case Study", IEEE Access, 8, pp.77653-77665.

Oberhauser R., Schmidt R., (2007), "Improving the Integration of the Software Supply Chain via the Semantic Web", Software Engineering Advances, DOI: 10.1109/ICSEA.2007.42

R., (1999), "Project management: cost, time and quality, two best guesses and a phenomenon, its time to accept other success criteria". International Journal of Project Management Vol. 17, No. 6, pp. 337-342, 1999

Smiley K., Harding J. and Pate P., (2016), "From Ideas to Implementations: Closing the Gaps between Technical Experts and Software Solutions", Conference: ICSE CSED'16 (International Workshop on Continuous Software Evolution and Delivery), At Austin, TX. DOI: 10.1145/2896941.2896945

Symons C, (2010), "Symons- Software Industry Performance- What you measure is what you get", IEEE Software November/December 2010. 0740-7459/10/

Weerd I., Brinkkemper S., Nieuwenhuis R., Versendaal J., and Bijlsma L., (2006), "Towards a Reference Framework for Software Product Management", 14th IEEE International Requirements Engineering Conference (RE'06)

Wińska, E., Kot, E. and Dąbrowski, W., (2021), "Reducing the Uncertainty of Agile Software Development Using a Random Forest Classification Algorithm", In International Conference on Lean and Agile Software Development (pp. 145-155). Springer, Cham

Yannibelli V. and Amandi A., (2011), "A knowledge-based evolutionary assistant to software development project scheduling", Expert Systems with Applications, 38 (2011) 8403–8413

Industrial furnace combustion system by Robust Design for Efficiency up gradation & adaptability to different Loads

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The present study focuses on the robust design & optimization of a 16 ton (MS) capacity of Bogie Hearth Furnace used for forging application of dish ends used for pressure vessels. By applying Robust design methodology, the furnace firing done earlier by oil only may run with Oil / PNG / LPG as Dual fuel by making necessary small changes in combustion system only. Further different loads adaptability for the same & one furnace only can be done by applying robust design principle. The furnace has an overall combustion volume of 48 m^3. It is having facility of bogie hearth to move the charge in & out of the furnace via rail tracking. Automatic door handing for open / close is provided. The main objective of the work is to make an efficient design and optimize combustion controls by robust design principle to improve efficiency as well as different load adaptability as per demand in the market. The big challenge was to maintain the temperature uniformity inside the furnace as well as maintaining the rise in temperature by 50^{o}C per hour after 300^{o}C to 1050^{o}C (+ /- 10^{o}C) uniformly. The same is achieved by controlling various parameters like pressure, volume of fuel /air with the help of automation system, Positioning of multiple thermocouples at different locations, Independent burner temperature control system & so on. The temperature control is drawn in graphical representation & temperature uniformity inside the furnace is validated by NABL (National Accreditation Board for laboratory testing & calibration). It was a job meant for export requirement from quality point view. Another important task was to run the same furnace for half load capacity than its original one i. e. the furnace designed for 16 ton capacity was supposed to run with 8 ton capacity only without replacement of furnace or any capital equipment of existing furnace. This is the situation demanded from the market on odd season. This task is also completed successfully without replacement of furnace or any major capital equipment. Only a small component requirement like oil & air nozzles replacements done to reduce & fine control of fuel / air flow without extinguish of burner flame at low fire. This required analysis of pressure & flow in the combustion system & maintainenece 0f the same during the entire process. The furnace is in use at M/s Icem Engineering Pvt. Ltd., Wada, Dist. Palghar, Maharashtra.

Index Terms: *Bogie Hearth Furnace, Robust, Combustion system, Efficiency, Load (Charge / Job).*

I. Introduction:

Combustion system is called the heart of the furnace. Industrial furnace design is changing with the invention of new technology, computer software, and computer integration with the advanced manufacturing technique. Accuracy of the product specification enhanced from MM to Micro/Nano scale. For 100% safe & comfortable working conditions, industries are supposed to be geared up with advanced manufacturing technology, customized parametric design, cloud computing, industrial automation, rapid manufacturing, and digital technology marching towards 100 % paperless work.

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The research work focuses mainly automation in industrial furnaces that are used for high temperature applications like melting, reheating, heat treatment of ferrous and non-ferrous metals and their alloys. The efficiency of the furnace is considered 30% for design calculations globally for metal & its alloys treatment. This indicates that almost 70% of the heat is wasted. Hence the study is mainly focused on recovering these heat losses to improve efficiency by robust design principle. Further depending upon the market requirement there is variation in demand of product which leads to necessity of different load adaptability. The same & one furnace can be used for different loads instead of making new another one by applying principle of robust design. Robust design is a concept from the teachings of Dr. Genichi Taguchi, a Japanese quality Master. It is defined as reducing variation in a product without eliminating the cause of variation. In other words, making the product or process insensitive to variation. This Variations (Sometimes called noise) classified into internal, external & unit to unit variation. Internal variation is due to detrition such as wear of the machine, external relating to environmental conditions like temperature, Humidity & dust. Unit to unit variation is variation between parts due to variations in material, processes & equipment.

II. Designing the Combustion System:

To start design activity, following key points to be noted so as to have better adaptability for different load capacity, durability for long standing, safety & better control for efficiency up gradation during the process.

1. Select the equipment for maximum load capacity with good factor of safety at least 1.2.
2. Oversizing of combustion equipment as well as furnace equipment's for furnace combustion chamber & wall are allowed.
3. Strictly no undersized equipment's like blowers, heating & pumping unit, Gas train, Fuel/Air control valves in the piping.
4. MS pipe class for Air – A (Light) class, for Oil – B (Medium) class & for gas – C class (Heavy) needs to be used from safety point of view.
5. When hot air is used use the ID fan for suction of exhaust with SS impeller.
6. Coupling drive is to be used for ID fan for suction of flue gases from the furnace chamber to the chimney escape to the atmosphere.
7. When preheated air is used for combustion use control valves with SS flapper & shaft.
8. Use expansion flexible pipe to allow expansion of air in the piping in case of hot preheated air is used.

Table II.1: Minimum furnace data required for designing the combustion system

Sr.	Description	Quantity
1.	Charge	MS
2	Capacity	16T
3.	Temperature	1050°C
4	Cycle Time	15 Hours
5	Fuel	FO*** / LDO* / Diesel* / PNG** / LPG**
6	Air Pressure at Burner	38" WC
7	Oil Pressure of Pumping Unit	25 to 35 PSI
8	Application	Forging
9	Auto temperature System	Yes
10	Auto Ignition system	Yes

Note: * - No heating of oil required for light oil. Only pumping station to be used. Depending upon cold climatic conditions heating up to 55 to 60°C may be allowed.

** No heating & pumping unit required. Instead Gas train is used to regulate safely the flow of gas.

*** Furnace Oil heating from 70°C to 105°C is allowed depending on the climate.

Heating for Oil is required to improve its fluidity through the pipe.

9. Blower, Heating & pumping unit, gas train foundation must be on the ground with proper foundation (Refer Manufacturer's catalogue for installation, operation & maintenance) to avoid vibrations & damage to the parts mounted on them for better accuracy.
10. Keep Blower, Heating & pumping unit, gas trains as close as possible to the furnace with piping in minimum bends to reduce pipe frictional losses.

III. Design/Installation/Commissioning - Description

The Furnace is Manufactured & Installed by M/s Agnee Engineering, Vasai. The modified combustion system having advantage of independent burner control over the existing single valve or zone control. The independent burner control gives independency to all burners for modulation. This new developed system gives better temperature uniformity. The modified combustion system having advantage of independent burner control over the existing single valve or zone control. The independent burner control gives independency to all burners for modulation. This new developed system gives better temperature uniformity.

Design of Combustion System:

A. Burner capacity –

Heat Input = Mass x Specific heat of the charge x Temperature Gradient / (Furnace Efficiency x Cycle Time) Hence Heat input
= 16 x 1000 x 2.52 (LB) x 0.129 (BTU / LB - °F) x (1922-72) (°F) / (0.3 x 15)
= 2138304 BTU / Hr. = 53.45 LPH* x 1.5 (FOS) **
= 80 LPH Minimum
= 100 LPH (Maximum with Turn down)

*1 LPH (Liter per Hour) = 40000 BTU (British thermal unit)
** Factor of safety

Maximum Burners capacity required = 100 LPH.

Hence 04 Burners of 25 LPH Maximum each were selected for uniform heat distribution.

B. Blower Capacity –.

Flow = Burner Capacity (LPH) x 400 x 1.699 / 60
= 100 x 400 x 1.699 / 60
= 1132 x 2 (FOS)
= 2264 Cubic meter per Hour

Pressure required for perfect atomization of fuel
= 38" + 6" (Pressure loss in pipe bend)
= 44" of WG. = 1120 mm of WG

Blower HP = Pressure x volume x 0.65 / (3600 x 75)
= 1120 x 2264 / 3600 x (1/75) x (1/0.65)
= 14.44 HP

Hence Blower selected of 15HP

C. Heating & Pumping Unit Capacity KW = GPH of Fuel x Specific heat of Fuel x rise in temperature x FOS (Factor of Safety).

= (100 / 4.54) x 0.0018 (KW / Gallon x deg. F) x 142 x 1.5 = 8.44 KW = 9.00 KW (Std. Oil pipe line as per chart is ¾"). Hence Std. Pumping unit only (For LDO / Diesel) of ¾" oil pipeline selected.

D. Outflow Heater from Service Tank – KW = GPH of Fuel x Specific heat x Raise in Temperature.in deg. F x FOS (Factor of safety) = (100 / 4.54) x 0.0018 (KW / Gallon x deg. F) x 72 x 1.5
= 4.54 KW
= 6 KW
(Std. size with Oil pipe line as per chart is ¾")
^ - Heating is required when Furnace Oil is used.

E. Air Pipe Line (Main Header) Control Valve – Std. Outlet for blower 15 HP from chart is, the main header pipeline of 8" std. port selected. Branch pipe lines of combustion air & atomizing air to the burner are as per burner std. Port size are 2.5" & 1" respectively.

F. Auto Temperature control & Auto ignition system for independent Burner control instead of zone wise (Existing practice) with the help of Air-Oil ratio regulator of ¾" size in the Oil line & Modulating Motor 4 – 20 MA power output of Honeywell make – 04 nos. each selected. Auto Ignition system with the help of Pilot & UV flame detector –01 no. each.

G. Temperature Control: The most commonly control process parameters which are measured & monitored /controlled are temperature & pressure in all kind of furnaces.

Temperature control system consists of the following elements:

A] Temperature sensors

B] Controllers

C] Control equipment of Automation

Temperature uniformity can be achieved by independently controlled burner in low & high firing automatically by sensing the temperature at different locations with the help of thermocouples. PID controller receive signal from thermocouple and modulate air valve to control the flow of air. The oil line get controlled by impulse line given from air piping to oil regulator which works on the basis of impulse pressure received from air pipeline.

Temperature sensors:

i) Bi-metallic strips: Uses the difference in coefficient of thermal expansion of two different metals. The principle is used in simple thermostats.

ii) RTD: Resistance of most metals increase in a reasonably linear way with temperature. Resistance measured is converted to temperature.

iii) Thermocouples: The thermocouple is based on the thermoelectric effect/e.m.f. generated when two conductive wires of different metals at different temperatures are connected to form a closed circuit. In classical physics this is known as siebeck-peltier effect. Because of the wide range of temperatures covered, good sensitivity to change of temperatures and linearity of output [over a wide span of temperature], thermocouples is widely used for measurement of temperature.

By arresting leakages through various openings, controlling the Damper of exhaust gases, Proper Insulation etc., efficiency of the furnace can be optimized. By making small changes of oil /air nozzles as well as running the furnace with lowest fire by automation, part load can be heated uniformly while the furnace is loaded with job & in operation.

IV. Conclusion :

The prime objective of the work was to enhance the efficiency when the furnace is fully loaded & run the furnace with part (Half of the full load) without any trouble & replacement of capital equipment. The same is achieved by selecting the combustion equipment on the basis of full load with factor of safety & then controlling the flow of fuel & air with the help of automation system by independent burner control instead of zone wise control. This is shown with the help of figure & flow charts at the end.

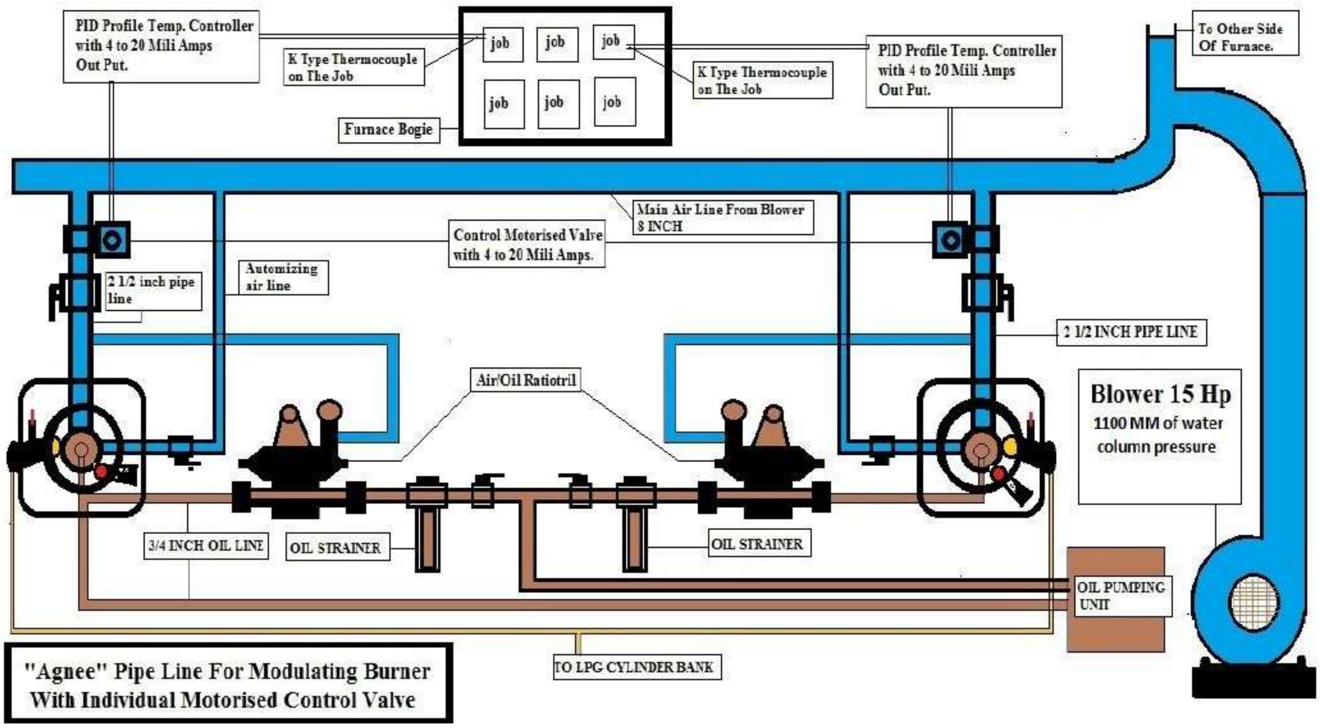
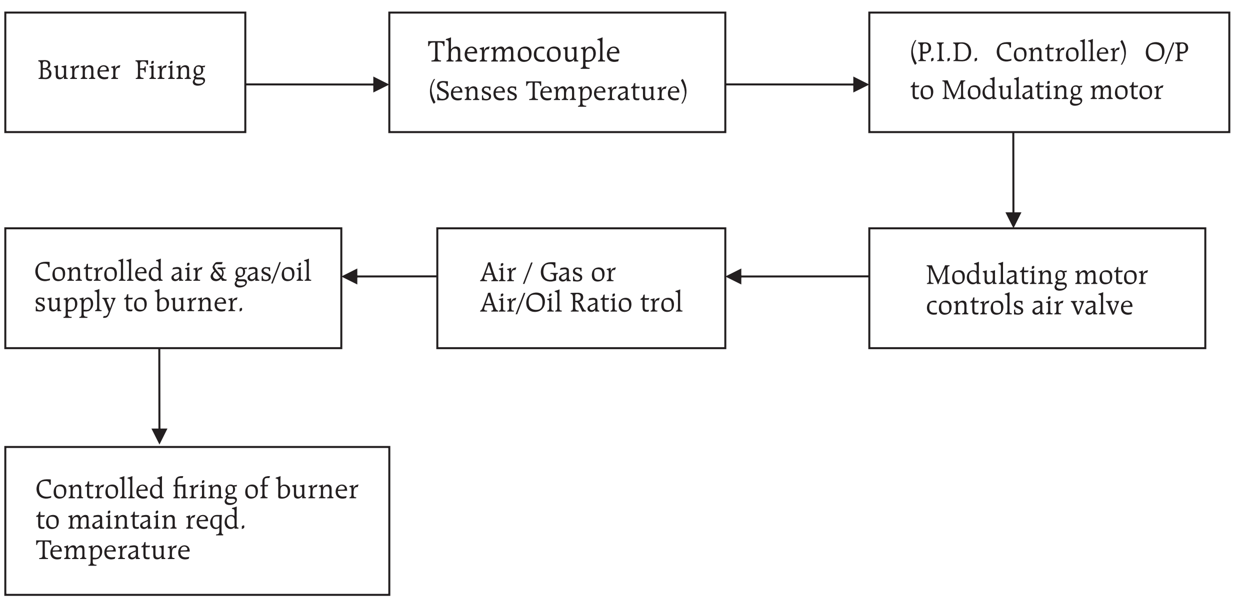
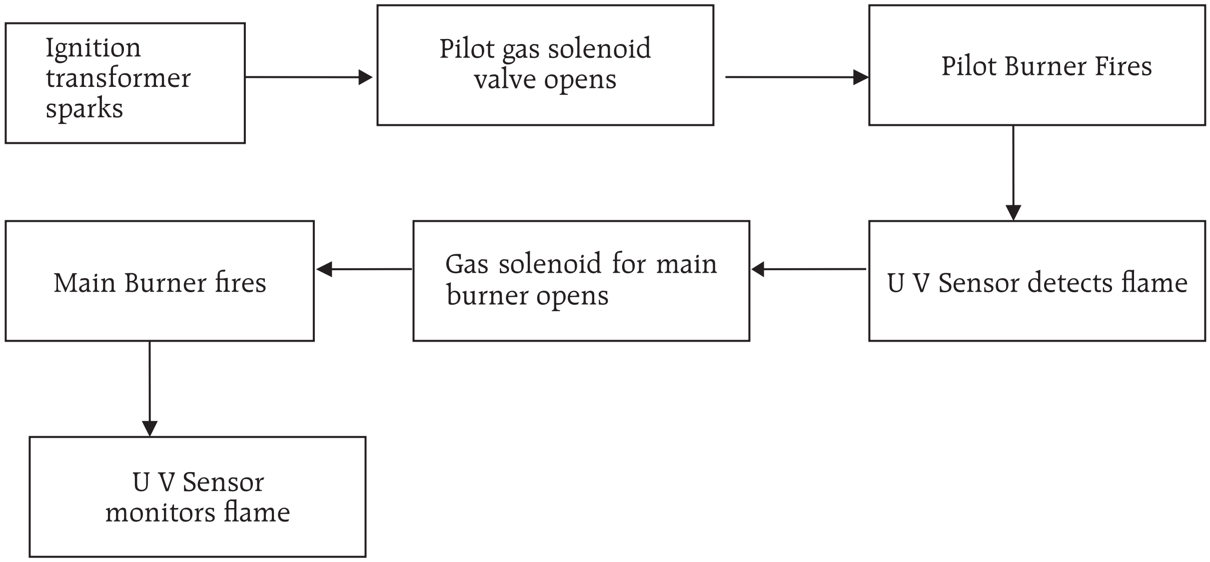


Fig. IV.1: Schematic of combustion system



Flow chart IV.1: Auto temperature control system



Flow chart IV.2: Auto ignition system

Fig. IV.2: Furnace 3D – view

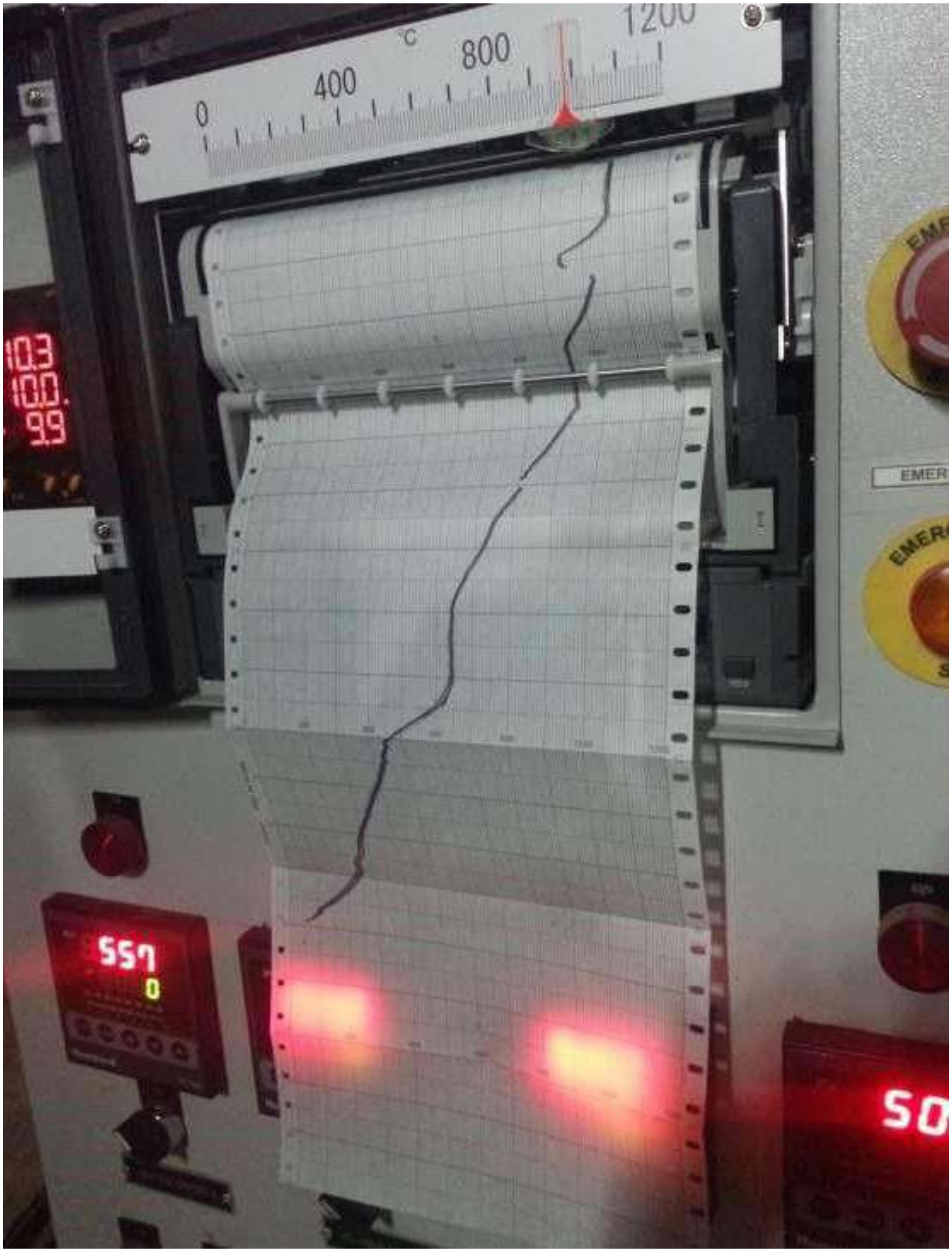


Fig. IV.3: Actual Thermal profile – Graphical representation

References

Book

[1] Mr. Brown, Mr. R. J Reed, North American Combustion Handbook, North American Manufacturing Co., USA.

[2] Mr. W. Trinks, Mr. M. H. Mawhinney, Text Book of Industrial Furnaces, Vol. II, Sixth edition(Furnace Mans Bible), John Wiley & Sons Inc., USA..

[3] Mr. Richard W. Heine, Mr. Carl Loper, Text Book of Principle of Metal Casting

Journal Paper

[4] IOSR Journal of Engineering , Increasing efficiency of cupola furnace of a small size foundry, Vol. 2, issue 9, PP 50-57, Sept. 2014

[5] IOSR Journal of Mechanical & Civil Engineering, Performance analysis of recuperator , Vol. 11, issue 6, pp.66-72, Dec. 2014

[6] The Data Furnace, Heating up with cloud computing. By Jie Liu, Christan Belady, Kamin whitehouse of University of Virginia, Charlottesville, VA 22904

[7] Mr.Asibeluo, I.S.,Ogwor O.E., Nizeria March 2015, "Design of 50 Kg. Capacity Cast Iron Crucible Furnace Using Locally Available Material", International Journal of Research in Engineering & Technology, ISSN 2319-1163.

[8] Mr.V.N. Chougule,Mr. G.R. Gupta, Mr. V.S. Shelke, "Numerical Analysis of Combustion Performance by CFD (Computational Fluid Dynamics)", International Journal of Mechanical & Civil Engineering, ISSN 2278-1684.

Thesis

[10] Mr.Radhakrishnan P., "Furnace Modeling", submitted to Worcester Polytechnic Institute for his partial fulfilment of Degree of Doctor of Philosophy in June 2008.

Bulletin & Literature

[11] Wesman Thermal Engineering Processes Pvt. Ltd.

[12] Honeywell

[13] Agnee Engineering

[14] Honeywell

[15] IS 15562 (2205) - Guidelines for Design & Construction of Fuel Fired Bogie Hearth Furnace.

[16] Combustion Tool Kit – Industrial Heating (The International Journal of Thermal Technology) has published in Feb. 2008,

[17] NABL Guidelines to compile their requirement for calibration - National Accreditation Board for Testing & Calibration laboratories is an autonomous body under the aegis of Department of science & Technology, Government of India.

Systematic Improvement in Springback Values for Cold Drawing Process of Seamless Tubes using Design of Experiments and Micro-structural Investigations

D. B. Karanjule[1], S. S. Bhamare[2], T. H. Rao[3]

Purpose: *This paper analyses cold drawing process of seamless tubes in a view of minimizing springback defect occurring in their manufacturing.*

Design/Methodology/Approach: *This work is systematic investigations of optimized parameters to minimize springback viz., reduction ratio, die semi angle, land width and drawing speed through Design of Experiments and microstructural investigations using X-Ray Diffraction, Scan Electron Microscopy and Metallurgical Microscope.*

Findings: *The results of this study indicates that 10-15 % reduction ratio, 15 degree die semi angle,10 mm land width and 8 m/min drawing speed gives least springback for ST 52 tube material and AISI D3 die-plug material.*

Practical implications: *This study has improved springback value significantly through series of experimentation and reduced the rejection by 3 % in precision tubes saving substantial amount of the cold drawing manufacturing industry.*

Originality/Value: *The paper is original and such systematic investigation to minimize springback in cold drawing of seamless tubes is not attained till the moment.*

Keywords: *Cold Drawing, Springback, Reduction Ratio, Design of Experiments, ANOVA*

1. Introduction

Cold drawing operation consist of pulling a tube through a tapered or curved converging die with various types of plugs. The various types of plugs include fixed, floating and movable. This process is one of the widely used metal forming process having inherent advantages like better surface finish, closer dimensional tolerances, adaptability to economical mass production and improved mechanical properties as compared to hot forming processes (Ahmed, 2011). Cold drawing process using draw bench device is also used to produce tubes of various shapes such as round, rectangular, square, hexagonal and other shapes.

Seamless tubes are manufactured with piercing and hot rolling processes, often are cold finished by drawing process. The raw material used for manufacturing seamless tubes are different types of steels i.e. carbon steels and alloy steels. Seamless tubes are used in both low and high temperature applications such as refrigeration, boilers, transporting liquids and gas automobiles and commercial vehicles, oil and petrochemical industries, refineries and fertilizer plants, heat exchangers, pressure vessels,

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etc. However, high pressure hydraulic and pneumatic cylinders, drilling deep bores, truck axels, bearings, steering columns, structural tubes, banjo spanner tubes, etc. are also made out of seamless tubes.

As the requirements of tubular products increased, an associated manufacturing processes also constantly improved. Apart from this, an appropriate systems for effective production control as well as quality assurance were also introduced. Though cold drawing process provides ease of manufacturing seamless tubes, but it is subjected to various defects like eccentricity, internal cracks, external cracks, ovality, scores on the tube, chattering, bending of tubes, wavy surface, tube thickness oversize, inner and outer diameter scores and the most severe defect is springback (Neves, 2005). Springback varies with many parameters, hence it becomes critical to overcome this phenomenon for seamless tubes to achieve tighter tolerances and avoid rejections.

1.1 Springback in cold drawing

Springback phenomenon has found during many cold working manufacturing processes including cold drawing process of the seamless tubes. While deforming a metal into the plastic region, it's total strain is composed of elastic and plastic part. After removal of deforming load, stresses will be reduced and accordingly the total strain will decreased by the elastic part which results in springback. Due to limited modulus of elasticity, as soon as the load is relieved from the material, elastic improving is followed. Due to flexibility characteristics of the material, the material on compression side tries to enlarge and the material on tensile side tries to shrink. This results in springback (Tekaslan, Seker & Ozdemir, 2006). When a load is applied, beyond the yield strength the material is over-stressed to induce a permanent deformation. When the load is removed, the stress returns to zero value along a path parallel to elastic modulus. Hence the permanent deformation value becomes lesser than the designer intended deformation. The material will not return to a zero stress state as the stresses are highest at top and bottom surfaces. This causes springback at an equilibrium point where all the internal stresses get balanced. Springback varies with composition, material properties and dimensional range of outer diameter and thickness. Springback causes deviation from designed target shape, downstream quality problems and assembly difficulties. Determination of springback by trial and error technique not only increases the cost of manufacture and repair of tool but also waste of time causing delay in the development of the product. This indicates that springback has an important role in industry and required to study how this permanent variation can be avoided.

2. Literature review

The quality of manufactured seamless tubes depends upon many factors. A compromise solution to the problems of meeting these requirements is achieved economically by the selection of appropriate tool material, die angle, lubricants, surface treatments of undrawn tubes, heat treatment and drawing conditions such as draw speed and reduction of area. However, as there is a continuing and an increasing need to reduce cost i.e. to draw at higher speeds and at higher reductions and to eliminate or minimize cold drawing defects, different researchers have proposed different techniques in the literature. Number of studies on the analysis of cold drawing process carried out by researchers are discussed below under different criteria. This section indicates the various groups under which research studies has been categorized. Different parameters like process, metallurgical and geometric parameters along with various tools related to cold drawing process are shown in figure 1.

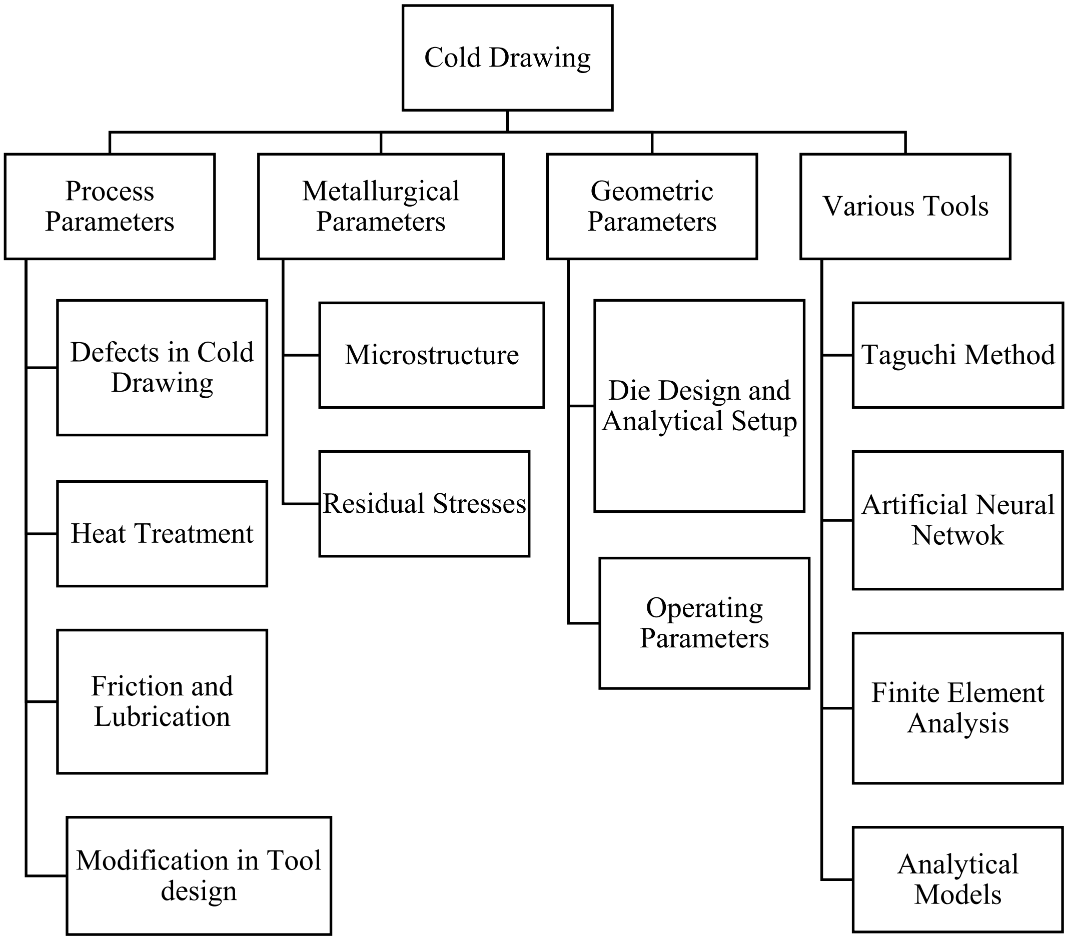

Fig.1: Approach adopted for research in cold drawing

2.1 Process parameters

Process parameters are the key variables influencing the production process. These attributes monitors the deviations in the standardized production procedures and quality of the formed product.

2.1 Defects in cold drawing

Appropriate standard operating procedure is much needed for any manufacturing process in order to be free from defects. Different defects incurred in the process causes deviations from targeted shape in the final product. These defects affects the performance and leads to early failure of the system.

The surface flaw defect (Yoshida, Uemori & Fujiwara, 2002) of a drawn product has a considerable impact on its quality which are similar in drawn tubes also. Mamalis and Johnson (1987) studied different defects while processing both metals and composites. The authors reported segregation and seams as a metallurgical metal working defects. Similarly defects like central bursts or chevron cracks are also occasionally en- countered in cold drawing process. Many researchers including Moritoki (1991), Mcallen and Phelan (2005), Ko and Kim (2000), Alberti, Barcellona, Masnata and Micari (1993), Zimerman, Darlington and Kottcamp (1971) reported qualitative methods to eliminate central bursts, prevention of this defect and supported an analytical investigation of the mechanics of central burst formation along with mathematical studies. Rajan and Narasimhan (2001) observed defects like micro cracks, fish scaling, diametral growth, premature burst, macro cracks and springback in case of high strength SAE 4130 steel tubes. Other defects like stress corrosion cracking (Toribio & Ovejero, 1997), fatigue crack propagation (Carpinteri, 2010), damage evolution (Tang, Li & Wang 2011), breakage (Li, Li , Wang & Ma, 2010) were also found in the literature. Similarly wrinkling and fracture defects are studied by Atrian and Saniee (2013). Among all these defects springback is more severe as it varies with material combinations, mechanical properties and composition of the materials, tool wear, aging process of the material, deformation rate etc. Hence it is cardinal important to reduce this severe phenomena without cracking and damaging the final product.

Similar literature review by different researchers is with the authors. Going through ample literature, it is found that most of the work is done on springback in sheet metal. Empirical research has done only in developed countries like USA, China, Germany,UK etc. Limited research has done on springback during cold drawing of seamless tubes. All the selected parameters by authors in their research articles does not mentioned interrelationship of parameters with each other. The literature review can be extended to classify as shown in figure 2 in terms of cause and effect diagram. Several techniques have been used by different researchers in their research. For experimental design of many manufacturing processes, Taguchi method and design of experiments (DOE) are found most usage. The finite element analysis (FEA) and analytical models were also applied by many researchers for the development of seamless tube drawing technology.

Process parameters like friction and lubrication, type of heat treatment, tooling are very important for the success of cold drawing process. The artificial neural network (ANN) and fuzzy logic techniques are also observed profound tools in the research. Metallurgical study including microstructure and residual stresses have high impact on the properties of formed material. Hence accuracy in this domain can affect the drawn seamless tube after cold drawing. Different manufacturing defects are altered by many researchers, but springback during seamless tube cold drawing process have not been investigated in detail so far. Hence there is a need of predictive models to

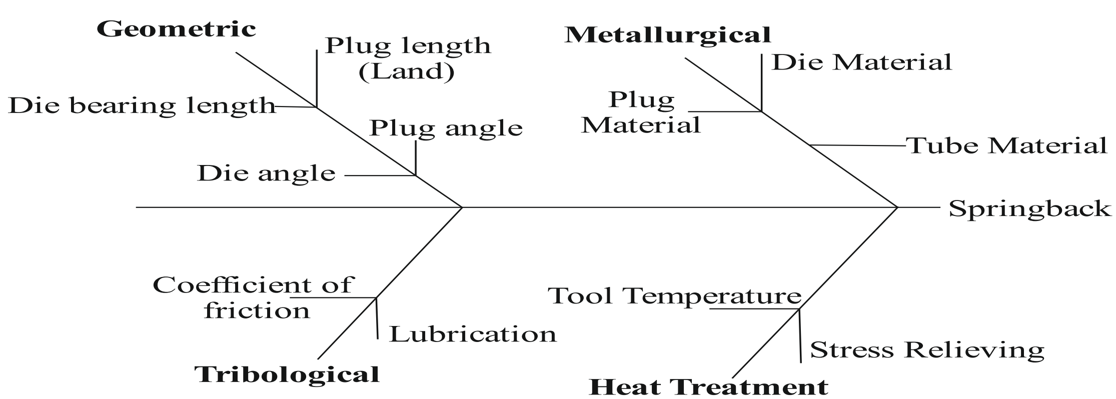

Fig.2: Fishbone diagram of cold drawing process parameters influencing springback

be developed in order to get better understanding and relationship of the process, its parameters and its influence on springback.The utilization of DOE as a tool to predict the springback in cold drawing of seamless tubes was rare in the literature.

A research gap is identified in the areas of cold drawing of seamless tubes in investigating springback phenomenon. Under optimized process conditions, minimization of springback is the focus of this research. This research will provide a foundation for the cold drawing manufacturing industry, an optimized reduction ratio and process parameter viz. die semi angle, land width, drawing speed to minimize springback.The study will further investigate the microstructural behaviour of seamless tubes during cold drawing process affecting springback.

3. Methodology

The present study pertains to various issues related to springback and the means to control it with appropriate strategies. The approach adopted for this study is as follows:

1. Study the various process parameters affecting springback in cold drawing process of seamless tubes.
2. Classify them into different groups like process parameters, metallurgical parameters, geometric parameters etc.
3. Optimize die semi angle by different multi attribute decision making (MADM) methods.
4. Optimize reduction ratio by Taguchi's L12 Design of Experiments (DoE) technique.
5. Optimization of process parameters like die semi angle, land width and drawing speed by Full Factorial technique and Response Surface Methodology.
6. Optimization of process parameters by advanced optimization algorithms.
7. Validation by Finite element analysis.
8. Microstructural investigations to study effect of pass schedule, Young's modulus, heat treatment, microstructure on springback.
9. Numerical simulation of cold drawing process using Ls-Dyna to validate the results.

Major highlights of the above mentioned steps are given in flow chart in figure 3.

In this study die semi angle, reduction ratio and process parameters viz. land width and drawing speed are needed to optimize as they influence springback phenomenon. Prior to the design of experiments, different process parameters along with their ranges in cold drawing process should be determined depending upon the equipment conditions, expert opinion from industry personnel and literature base. Die semi angle selection is done based on multi attribute decision making (MADM) methods. Taguchi methods and full factorial experiments are conducted for optimization of reduction ratio and process parameters like die semi angle, land width and drawing speed respectively. Further advanced optimization algorithms viz. Particle swarm optimization (PSO), Simulated annealing (SA) and Genetic algorithms (GA) are used. Land widths are optimized for optimized parameters and settings for shaped seamless tubes viz. square and rectangular cross sections. Microstructural investigations carried out on universal testing machine (UTM), X-ray Diffractometer (XRD), scanning electron microscope (SEM), metallurgical microscope to find influence on springback.

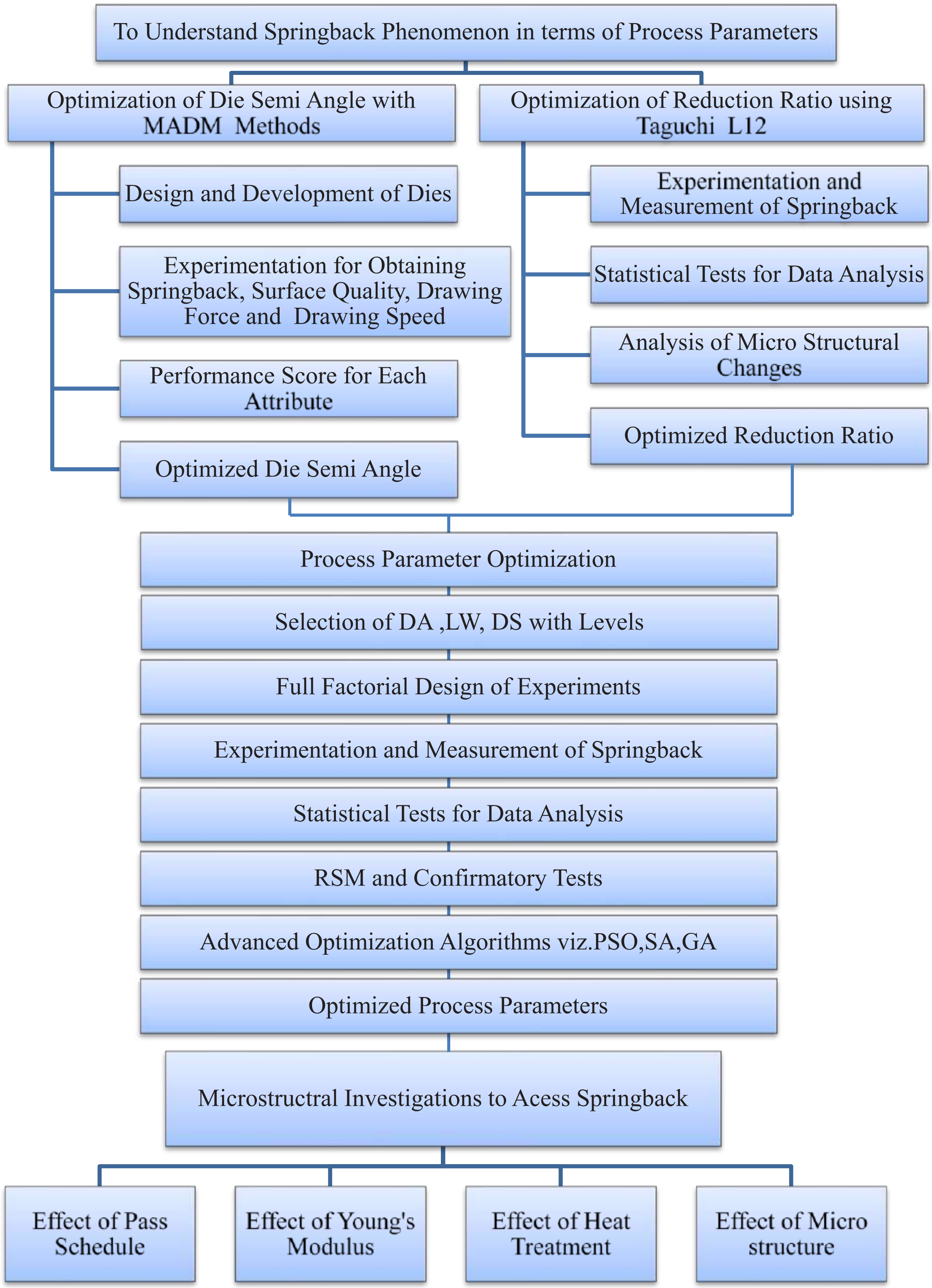

Fig. 3: Experimental Design Framework

3.1 Experimental procedure

Seamless tubes are cold drawn through a die of 30.0 mm. The drawn tube outer diameter is measured using digital micrometer of 1 micron accuracy. The variation from 30.0 mm is referred to be springback. From the literature review and discussions with industry persons, process parameters and their levels considered are viz. two levels for die semi angle (10 and 15 degrees),two levels for land width (5 and 10 mm) and three levels for drawing speed (4,6 and 8 m/min).

3.2 Work material

AISI D3 die steel is selected for die and plug materials having high wear, abrasion resistance and resistance to heavy pressure. D3 material is high carbon, high chromium cold-work tool steel. The specifications of this tool steel are according to ASTM A681 (D-3), DIN 1.2080, SAE J437, SAE J438 and UNS T30403.A typical D3 material consists of chemical composition tabulated in Table 1.

Table 1: Typical D3 material chemical composition

Carbon, C	Silicon, Si	Chromium, Cr	Manganese, Mn	Nickel, Ni
2.10 %	0.30 %	11.50 %	0.40 %	0.31 %

Seamless tubes of ST 52 material are considered for experimentation which are cold drawn from a hollow size of 33.40 mm outer diameter and 4.00 mm wall thickness.

3.3 Machine tool

The experimentation is carried out on draw bench having maximum drawing speed of 10 m/min and maximum width of drawn tube obtained is 30 mm. A draw bench for cold drawing seamless tubes consist of die and plug control devices and a draw unit. The die is held firmly in die holder and gripper provided pulls the tube through die plug assembly. Drawn tube deforms plastically in the draw bench changing its cross-sectional area, reducing its diameter and increasing its length.

4. Results and discussions

The summary of the work done on each of the research objectives is elaborated as follows:

4.1 Screening test

Die semi angle selection is one of the critical activities during cold drawing of seamless tube for optimized performance. The purpose of this step is to adopt structured approach to select optimized die semi angle for cold drawing of seamless tubes. The study uses Analytic Hierarchy Process (AHP) based structured approach to select optimum die semi angle by estimating the overall performance score for different values of die semi angles. Springback, Surface Quality, Drawing Force and Drawing Speed are considered for optimization of die semi angle as shown in Table 2.

Table 2: Attribute data for different alternatives

Die Semi Angle (Degree)	Springback (mm)	Surface Quality	Drawing Force (KN)	Drawing Speed (m/min)
8	0.085	Above average	95.5	12
10	0.065	High	91	11
12	0.072	Average	87.5	10
14	0.080	Below average	85	9

Overall performance score is obtained by different multi attribute decision making methods using standard procedure and ranked as shown in Table 3.

Table 3: Ranking by different methods

Die Semi Angle	SAW	WPM	AHP	Revised AHP	TOPSIS	VIKOR
8^0	3	3	3	3	3	3
10^0	1	1	1	1	1	1
12^0	2	2	2	2	2	2
14^0	4	4	4	4	4	4

Table 4: Reduction ratios

Reduction Ratio (%)	Hollow Tube Dimensions (mm)			Final Tube Dimensions (mm)			Reductions (%)		
	OD	TH	ID	OD	TH	ID	OD	TH	C/S
A (10-15)	33.4	4.00	25.4	30.0	3.85	22.30	10.18	3.75	14.39
B (15-20)	33.4	4.00	25.4	30.0	3.60	22.80	10.18	10.0	19.18
C (20-25)	33.4	4.00	25.4	30.0	3.40	23.20	10.18	15.0	23.10

The same findings are reported by Sawamiphakdi (1991)in which the authors found that for 10^0 die semi angle and 0.05 coefficient of friction value, minimum drawing force is required. The outcome of this study suggests that 10^0 is better die semi angle for both ST 52 tube materiel and AISI D3 die and plug material.

4.2 Optimization of reduction ratio

The important parameters affecting drawing load are mechanical properties like yield stress, ultimate strength, also percentage of reduction, die semi angle, friction coefficient and peak load during start up. The springback phenomenon is also influenced by reduction ratio. The springback effect of seamless tube that has undergone cold drawing has been handled in this step for three different reduction ratios viz. 10-15 %, 15-20 % and 20-25 % as shown in Table 4 with the aim of reducing it. Experiments are conducted under different reduction ratios with working conditions of Die Semi Angles of 10 and 15 degree, Land Width of 5 mm and 10 mm as well as Drawing Speed of 4, 6 and 8 m/min for ST52 tube material.

Optimum reduction ratio is finalized using Statistical Package for Social Science (SPSS) software of data analysis using statistical tests viz. Kruskal-Wallis, ANOVA, Post-hoc etc. Metallurgical and mechanical properties for different reduction ratios are also studied for validation purpose.

The result of this research objective is that 10-15 % reduction ratio yields minimum springback as shown in figure 4.This can be used to help design of tools in the metal forming industry to minimize springback and improve the quality of the product.

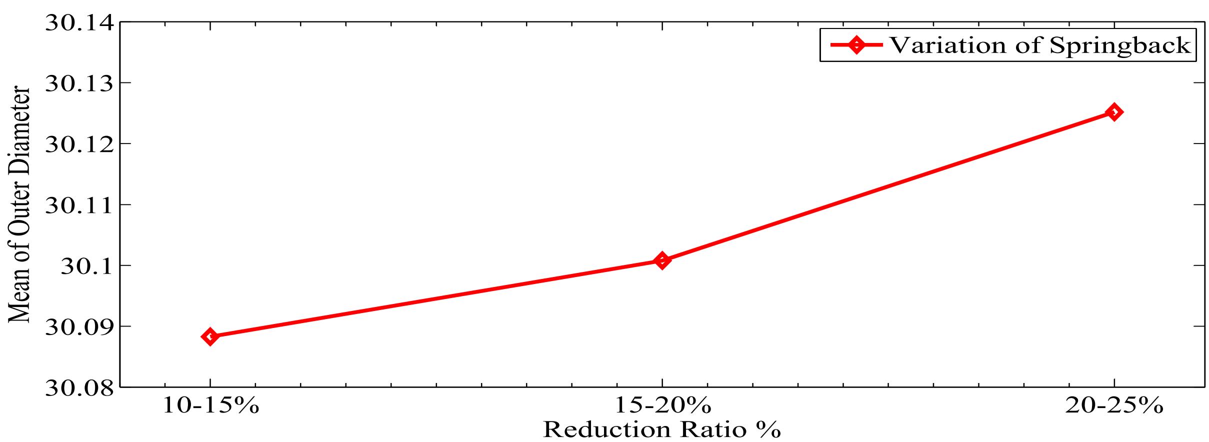

Fig.4: Optimized reduction ratio

4.3 Optimization of process parameters:

Once the reduction ratio is finalised i.e. 10-15 % which gives least springback. Next step is to optimize process parameters. Taguchi's L36 orthogonal array is used to conduct the experiments and then optimization is done in data analysis software Minitab 17.The main effect of the factors on springback for each level is calculated and the optimum level of each parameter is identified. From the results obtained, it shows that die semi angle of 15 degree, land width of 5 mm and drawing speed of 6 m/min gives the least springback.

After identifying the optimum levels using statistical technique, the confirmation experiments were conducted and the springback obtained was compared with that one obtained from initial parameter setting as shown in Table 5.

Table 5: Confirmatory test results

Optimum Factors	Regression Model Springback	Experimental Value Springback	% Variation
15 degree die semi angle 5 mm land width 6 m/min drawing speed	0.021	0.0251	16.99

The results of ANOVA as shown in Table 6 reveals that 15 degree die semi angle,5 mm land width and 6 m/min drawing speed yields least springback.

Table 6: Analysis of Variance (ANOVA) of S/N Ratio

Source	DF	Adj SS	Adj MS	F-Value	p-Value
LW	1	0.005675	0.005675	32.19	0.000
DS	2	0.001600	0.000800	4.54	0.021
DA×LW	1	0.003600	0.003600	20.42	0.000
DA×DS	2	0.001448	0.000724	4.11	0.029
LW×DS	2	0.084801	0.042400	240.53	0.000
DA x LW×DS	2	0.055845	0.027922	158.40	0.000
Error	24	0.004231	0.000176		
Total	35	0.271895			

The signal to noise is the ratio of useful data to inapt data and it is a performance measure of Taguchi's technique. Smaller is the better response is considered being objective of minimization of Springback. Delta values determines the ranks, it also represents overall change in the value of factors. Since delta value for Die Semi Angle is more, so it can be concluded that Die Semi Angle has the highest impact on Springback as shown in Table 7.

Table 7: Response Table

Level	Die Semi Angle	Land Width	Drawing Speed
1	0.07111	0.14011	0.13300
2	0.18400	0.11500	0.13150
3			0.11817
Delta	0.11289	0.02511	0.01483
Rank	1	2	3

Further optimization algorithms viz. Particle Swarm Optimization (PSO), Simulated Annealing (SA) and Genetic Algorithm (GA) are applied and the results are tabulated as shown in Table 8.This table shows that die semi angle of 15 degree, land width of 10 mm and drawing speed of 8 m/min is the best parameter set in cold drawing process to minimize the springback. This set has successfully proven almost 10.5% improvement in the springback values.

Table 8: Comparison of springback for initial and optimal parameter setting

Response Parameter	Initial Parameter Setting	Optimal Parameter Setting using PSO	Optimal Parameter Setting using SA	Optimal Parameter Setting using GA
Die Semi Angle	15 degree	15 degree	15 degree	15 degree
Land Width	5 mm	10 mm	10 mm	10 mm
Drawing Speed	6 m/min	8 m/min	8 m/min	8 m/min
Springback	0.055	0.0492	0.0491868	0.049182
Improvement		5.8E-3	5.8132E-3	5.818E-3
% improvement		10.54 %	10.57 %	10.58 %

Similarly, Scanning Electron Microscopy (SEM), Micro-hardness testing and mechanical testing using UTM reveals that 10-20% degradation occurs in Young's

Modulus for 5-7% plastic strain. It is found that this springback depends upon Young's modulus of the material. It is also found that the springback and Young's modulus are inversely proportional. More the percentage of carbon, more the strength, less the value of Young's modulus and more will springback. The microstructural evaluations showed that there is grain elongations.

4.4 Effect of pass schedule, microstructure, property changes and characterization on mechanical properties and springback during cold drawing of seamless tubes:

An experimental study in this domain shows Young's Modulus decreases with plastic strain for ST 52 material. It is found that with increase in plastic strain, Young's Modulus reduces rapidly initially then reduces more slowly and finally settles to stable value due to increase in plastic deformation and ultimately increased residual stresses. This variation of Young's' Modulus is related to internal stresses, residual stresses, micro cracks, dislocations during plastic deformation.

4.5 Numerical simulation using Ls-Dyna:

In this work, the cold drawing of tubes with fixed plug was simulated by Explicit Finite Element Analysis for validation purpose. The numerical analysis supplied results for the reactions of the die and plug and the stresses in the tube, the drawing force and the final dimensions of the product. Tube drawing process was simulated using LS-dyna Explicit Dynamic code using a 3D finite element model. This length was tested in order to obtain the steady-state condition. The geometry was analyzed for 10° and 15° die semi angle with a land width of 5 mm and 10 mm. The drawing speed considered was 4, 6, 8 m/min. Friction between die and tube and between tube and plug was estimated at and static friction 0.1 and dynamic friction 0.01. Die and plug were modeled with a rigid material (with assumed no deformation). Tube was modeled with MAT24 material card (MAT_PIECEWISE_LINEAR PLASTICITY).The results of LS dyna shows better agreement with those obtained experimentally.

5. Conclusions

In this research the spring back effect of seamless tube that has undergone cold drawing has been handled with the aim of reducing it. This study has identified optimum parameter setting which reduced 3 % rejections due to springback in case of high precision tubes. For a single tube manufacturing industry of 1000 tonnes of production per month, this optimization resulted around 2 lakh savings per month without incurring extra efforts like rework. This setting applied to other industries may save substantial amount monetary value of the industries and nation. The major findings of this research study can be summarized as follows:

i. The study carried out systematic investigations to understand the effect of optimum parameters which leads to minimization of springback by 15 % and increased dimensional accuracy, significant profit in the business and the reputation of the industries.

ii. The study optimized the Reduction Ratio from random Reduction Ratio to 10-15 % Reduction Ratio in order to minimize springback during cold drawing of seamless tubes.

iii. Among process parameters this study identified die semi angle as a major contributing factor to the springback and the study further concluded optimum die semi angle which was found to be 15°. However, 10 mm is an optimized land width of die for the least springback of seamless tubes during their cold drawing process.

iv. Springback value for optimized die semi angle was 0.065,for optimized reduction ratio it was 0.055, for optimized process parameter the obtained value was 0.042 whereas for microstructural investigations the value for springback attained was 0.0251,thus systematically improvement in the springback values as per every objective was achieved through this research.

v. This study identified that for high carbon steel tube material 4 m/min and for low carbon steel 8 m/min is the optimized Drawing Speed on draw bench in order to minimize the springback. It was also found that springback phenomenon is more severe in advanced high strength steels than plain carbon steels.

vi. Numerical simulation of cold drawing process carried validates with experimental results.

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References

Ahmed, M. (2011).Manufacturing Technology: Materials, Processes and Equipments. CRC Press.

Alberti, N., Barcellona, A., Masnata, A., & Micari, F. (1993).Central Bursting Defects in Drawing and Extrusion: Numerical and Ultrasonic Evaluation. *CIRP Annals*, 42, 269-272.

Atrian, A. & Saniee, F. (2013).Deep Drawing Process of Steel/Brass Laminated Sheets. *Composites Part B: Engineering*, 47, 75-81.

Brooks, C. (1996).Principles of Heat Treatment of Plain Carbon and Low Alloy Steels. ASM International.

Broome, J. (1997).Development of a Robust Heat Treating Process for Rockwell B-Scale Hardness Test Blocks. Massachusetts Institute of Technology.

Carpinteri, A. (2010).Influence of the Cold-Drawing Process on Fatigue Crack Growth of a V-Notched Round Bar. *International Journal of Fatigue*, 32(7), 1136-1145.

Chuiko, V., Savin, G., & Kalashnikov, A.(1973).Cold Drawing of Stainless Steel Tubes on Short Mandrel. *Metallurgy*, 3, 32-33.

Janosec, M., Schindler, I., Vodarek, V., Palat, J., Rusz, S., Suchanek, P., Ruzicka, M.,& Mistecky, E.(2007). Microstructure and Mechanical Properties of Cold Rolled, Annealed HSLA Strip Steels. *Archives of Civil and Mechanical Engineering*, 7, 29-38.

Jia, Y. (2008).Effect of Cooling Rate on Solidified Microstructure and Mechanical Properties of Aluminium-A356 Alloy. *Journal of Materials Processing Technology*, 207(1-3), 107-111.

Jurkovic, M. (2018).An Experimental and Modelling Approach for Improving Utilization Rate of the Cold Roll Forming Production Line. *APEM Journal*, 13(1), 57-68.

Kang, S. (2010).Effects of Recrystallization Annealing Temperature on Carbide Precipitation, Microstructure and Mechanical Properties in Fe-18Mn-0.6C-1.5AI Twip Steel. *Materials Science and Engineering: A*, 527(3), 745-751.

Kim, H. & Koc, M. (2008).Numerical Investigations on Springback Characteristics of Aluminum Sheet Metal Alloys in Warm Forming Conditions. *Journal of Materials Processing Technology*, 204(1-3), 370-383.

Ko, D. & Kim, B. (2000).The Prediction of Central Burst Defects in Extrusion and Wire Drawing. *Journal of Materials Processing Technology*, 102, 19-24.

Li, F., Li, L., Wang, X., & Ma, X. (2010).Optimizing the Seamless Tube Extrusion Process using the Finite Element Method. *Journal of the Minerals, Metals & Materials Society*, 62(3), 71-74.

Mamalis, A. & Johnson, W. (1987).Defects in the Processing of Metals and Composites. *Studies in Applied Mechanics*, 15, 231-250.

Mcallen, P. & Phelan, P. (2005).Ductile Fracture by Central Bursts in Drawn 2011 Aluminium Wire. *International Journal of Fracture*, 135(1-4), 19-33.

Moritoki, H. (1991).The Criterion for Central Bursting and its Occurrence in Drawing and Extrusion in Plane Strain. *International Journal of Plasticity*, 7(7), 713-731.

Neves, F. (2005).Numerical and Experimental Analysis of Tube Drawing with Fixed Plug. *Journal of the Brazilian Society of Mechanical Sciences and Engineering*, 27(4), 426-431.

Olokode, O., Bolaji, B., & (2007).Effects of Process Annealing on Mechanical Properties of Strain Hardened NS 34 LC. *International Journal of Agricultural Sciences, Science, Environment and Technology*, 6(1), 12-20.

Oyinlola, A. & Obi, A. (1996).Frictional Characteristics of Fatty-based Oils in Wire Drawing. *Wear*, 194, 30-37.

Phelippeau, A., Pommier, S., Tsakalakos, T., Clavel, M., & Prioul, C. (2006).Cold Drawn Steel Wires-Processing, Residual Stresses and Ductility-Part I: Metallography and Finite Element Analyses. *Fatigue Fract Engg Mater Struct*, 29, 243-253.

Pussegoda, L. (1991).Effect of Intermediate Cooling on Grain Refinement and Precipitation during Rolling of Seamless Tubes. *Materials Science and Technology*, 7(2), 129-136.

Rajan, K. & Narasimhan, K. (2001).An Investigation of the Development of Defects during Flow Forming of High Strength Thin Wall Steel Tubes. *Practical Failure Analysis*, 1(5), 69-76.

Rajan, K., Deshpande, P., & Narsimhan, K. (2002).Effect of Heat Treatment of Preform on the Mechanical Properties of Flow Formed AISI 4130 Steel Tubes- A Theoretical and Experimental Assessment. *Journal of Materials Processing Technology*, 125-126,503-511.

Sawamiphakdi, K., Lahoti G., & Kropp, P. (1991). Simulation of a Tube Drawing Process by the Finite Element Method. *Journal of Materials Processing Technology*, 27(1-3), 179-190.

Schindler, I. (2009).Effect of Cold Rolling and Annealing on Mechanical Properties of HSLA Steel. *Archives of Material Science and Engineering*, 36(1), 41-47.

Tang, K., Li, Z., & Wang, J. (2011).Numerical Simulation of Damage Evolution in Multi-Pass Wire Drawing Process and its Applications. *Materials and Design*, 32, 3299-3311.

Tekaslan, O., Seker, U., & Ozdemir, A. (2006). Determining Springback Amount of Steel Sheet Metal has 0.5 mm Thickness in Bending Dies. *Journal of Material and Design*, 27, 251-258.

Toribio, J. and Ovejero, E. (1997). Effect of Cold Drawing on Microstructure and Corrosion Performance of High Strength Steel. *Mechanics of Time Dependent Materials*, 1(3), 307-319.

Yoshida, F., Uemori, T., & Fujiwara, K. (2002).Elastic–Plastic Behavior of Steel Sheets under In-Plane Cyclic Tension–Compression at Large Strain. *International Journal of Plasticity*, 18(5), 633-659.

Yu, H. (2009).Variation of Elastic Modulus during Plastic Deformation and its Influence on Springback. *Materials and Design*, 30, 846-850.

Zimerman, Z., Darlington, H., & Kottcamp, E.(1971). Selection of Operating Parameters to Prevent Central Bursting Defects during Cold Extrusion. Metal Forming: Interrelation between Theory and Practice. Springer, Boston, MA.

Performance comparison of methods evaluating process capability metric in non-normal process

Gangaram Lambor*

The process capability is often measured in almost all industries, so as to conclude about the quality of the products manufactured. In the present era of six sigma quality levels, measurement of process capability is a common task in any industry. Most of the process capability studies assume that the process data is normally distributed. However, many of the processes in day today world, do not follow normal distribution. Calculating process capability using the supposition that data is normally distributed in such cases may lead to inaccurate analysis and wrong conclusions. Thus, it becomes very much essential to deal differently with the non-normal data. The circumstances and cases where the process data is non-normal, the special techniques such as distribution fit, Clements percentile method, Box-cox and Johnsons transformation methods have been proposed. Although these methods are found in most of the literature, there is insufficient literature to assess the performance of these methods. The objective of this paper is to hold forth the importance of dealing with non-normal data, discuss various techniques and finally compare the performance of these methods. To achieve this objective, the methodology adopted in this paper is, initially the various methods are discussed and then a data following Weibull distribution is generated using Minitab software. After the generation of data in the software, it is tested for normality and then the process capability indices are calculated for this data using above said methods. The key finding with this study is that, the results obtained with all above methods, though differ slightly are almost identical. However, it is observed that process capability values measured using Clements percentile method are slightly higher for the data considered. Thus, as per our study, the best method for the Weibull data would be Clements percentile method. This study is helpful for managers and quality personnel involved in Choosing the best method for a given distribution of the data amongst the four methods considered.

Keywords: *Non-normal, process capability index, data transformation, distribution fit, Box-cox transformation, Johnson's transformation and Clements percentile method.*

1. Introduction

In today's world of stiff competition, the industries are facing a tough challenge to sell their products and services in the market. Both, the cost as well as quality of the product and service have assumed very high importance among manufacturers. Thus, manufacturers and service providers everywhere are focusing on providing economical processes which are also able to meet the customer's quality expectations. Six Sigma has emerged as a powerful tool for quality improvement and reducing cost in many industries and its importance is growing day by day. Six Sigma is a systematic, planed, disciplined, and data-driven approach and methodology for eliminating defects. The Basic objective of the Six Sigma practice is to implement a measurement-based approach that focusses on enhancement of process and decrease in variability. In an industry, it is often essential

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to know what quality of products are supplied to the customers. However, cent percent inspection is not practically feasible and acceptable from a cost point of view and lot of time involved in inspection. In addition, it also does not give any predictive information about the process. Process capability indices can easily give this information. Most of the Six Sigma process capability studies are based on the assumption that the process data is distributed normally. However, many of the processes in real life, do not follow normal distribution. Calculating Process Capability using the supposition that data is normally distributed in such cases may lead to inaccurate analysis and wrong conclusions. In the circumstances and cases, where the process data does not follow a normal distribution, special techniques need to be used to deal with non-normal data.

1.1 Process capability

Process Capability is the ability of the process to meet customer specifications. In other words, it is the ability of a process to produce output within specification limits. It compares output of process with specifications limits. Every process has got inherent variability due to common causes. When the process is in control, the six-sigma spread of inherent variation in a process is taken as a measure of process capability. Thus, the process data spread is its capability, which is equal to six-sigma. Process capability analysis helps in determining how the process is performing relative to its requirements or specifications, where a vital part is the use of process capability indices. Process Capability study is an important part of overall quality improvement assignment.

1.2 Determining process capability

For the process which is out of control, the calculated process average and standard deviation for such a process are wrong and not reliable. Process capability is required to be found out once the process has attained the stability. In other words, before calculating process capability the special causes of variation pertaining to process have to be identified and removed. Once the process has become steady, the process average and standard deviation are calculated. Most of the times for calculating process capability, the specification limits are needed. As the process capability is the ability of the process to meet the specifications, it is very important to first determine the specification limits correctly. Inaccurate or wrong specification limits may not give correct value of process capability. Calculating the process capability by using a histogram or a control chart is based on the assumption that the process data follows a normal distribution. Tough this assumption of normality is true in many of the processes; there are situations where the process data do not follow a normal distribution. Utmost care should be taken in cases where data does not follow normal distribution. In the cases where the data is not normally distributed, it is essential to determine the appropriate distribution or transformation techniques to calculate process capability. This paper deals with process capability analysis for non-normal process data. For a process which is following normal distribution, the process capability is the ratio of the distance from the process mean to the nearest specification limit divided by measure of process variability. Mathematically, it can be expressed as:

Process capability Index,

$$Cp = Min\{\frac{(USL-\mu)}{3\sigma}, \frac{(LSL-\mu)}{3\sigma}\} \quad \text{... (1)}$$

Where μ and σ are the process mean and standard deviation of the measured characteristic of interest concerning to process. USL and LSL are the upper specification limit and lower specification limits respectively. Generally, these values are taken from the data collected from the production process.

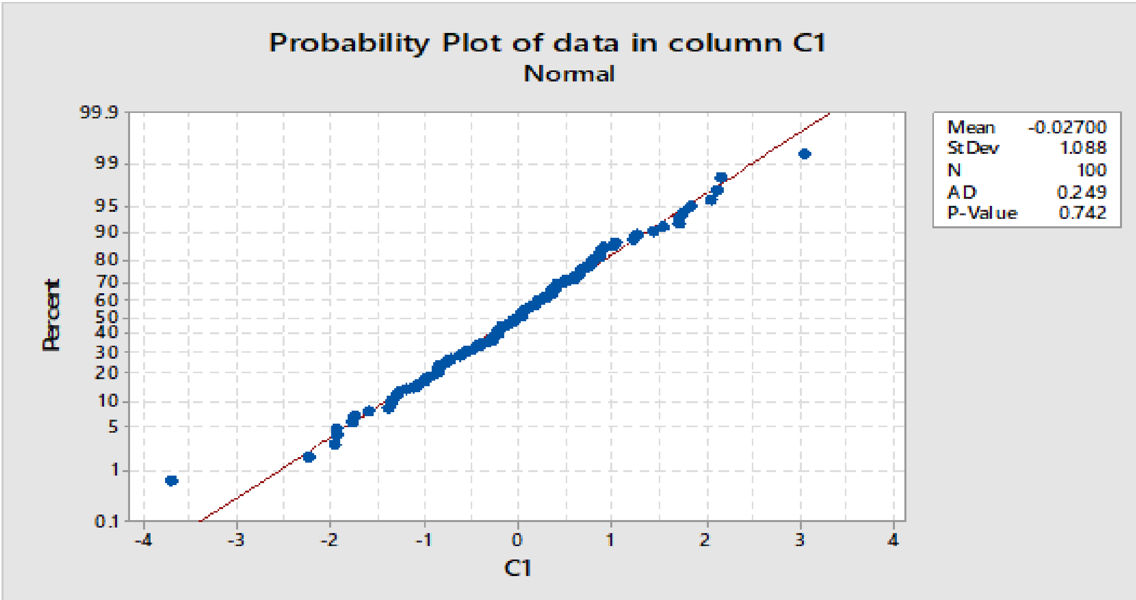

Fig. 1. Probability plot of normally distributed data

1.3 Non-normal data

Processes which are having similar features will produce distributions which are approximately normal. However, there are number of processes in day today world which do not follow normal distribution. Some examples of data that does not follow normality would be component life data, reliability, cycle time data, customer waiting time, or number of calls arriving etc. calculating Process Capability using the assumptions of normality in such cases may lead to inaccurate estimation and wrong conclusions. In cases, where the process measurements do not follow a normal distribution, special methods are required to be used to handle non-normal data. The easiest first assessment whether the process in consideration is normal or not is done by observing the properties of normal distribution. In a histogram of the data, the Mean, Median and Mode, all should be approximately equal. Histogram should be around the mean i.e. 65-70% of data ,should be within Mean $\pm 1\sigma$, 95% within $\pm 2\sigma$, and less than 1% outside $\pm 3\sigma$. If it is approximately "normal", a normal probability plot is generated and looked for the deviations from the best fit line. The slope of the line should be close to 1.0 and the data be closely grouped about the best fit line. The normal probability plot shown in Fig.1 is an example of normally distributed data. Here it is clearly seen that the data is grouped around best fit line without much deviations. Also, the p value in Anderson darling test need to be more than 0.005. If the process meets these criteria, with the plot like that presented in Fig.1, then the process is considered as normal. If the criteria are not met than the process data is considered to be non-normally distributed. It is seen in Fig.1, that the p value is 0.742 which is more than 0.005, which confirms that the data is normally distributed.

The probability plot of non-normally distributed data is presented in Fig.2, in which the data points are deviated and are not along the best fit line. Also, the p value displayed as less than 0.005 which indicates that the data is not normally distributed.

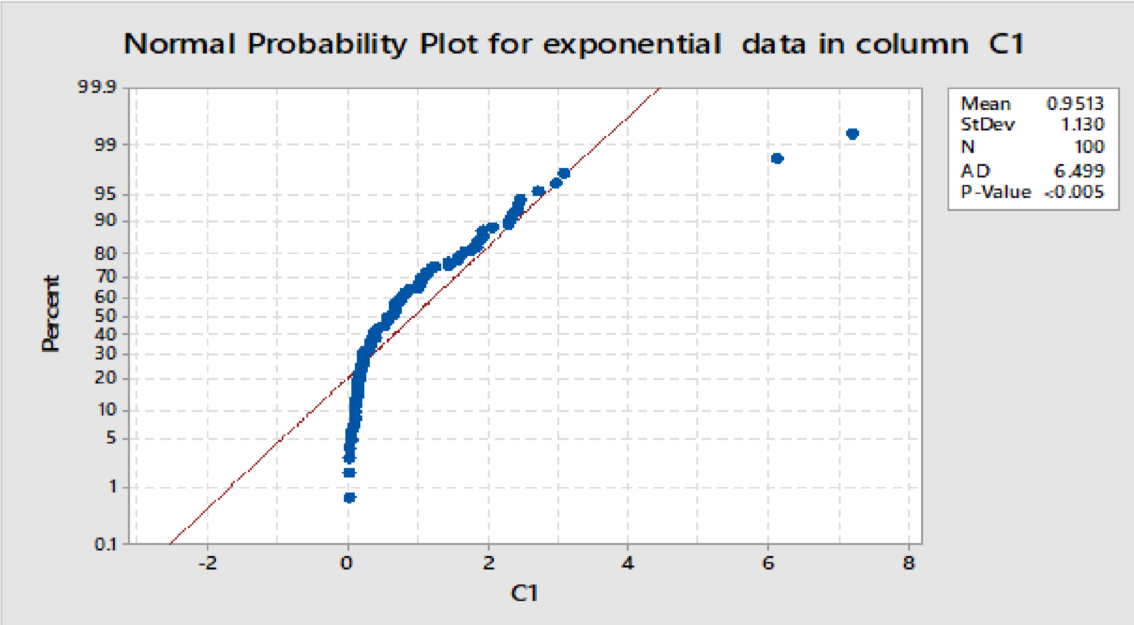

Fig. 2. Probability plot of Exponentially distributed data

2.Brief Literature review

The two most extensively used indices in the industry are C_p and C_{pk} which were proposed by Juran (1974) and Kane (1986) respectively. (Arcidiacono & Nuzzi, 2017) have done the detailed review of the fundamental concepts and applications of process performance and process capability indices. Also an overview of features of each metric and their applicability in process performance evaluation is offered. (Adeoti & Olaomi, 2017) proposed the process capability index-based control chart which is able to address the issue of control and capability simultaneously. (Liu & Chen, 2005) put forth the modification of Clements method using the Burr XII distribution. They compared their novel technique with Clements method with the help of simulation. (Pina-Monarrez & Ortiz-Yanez, 2016) proposed PCIs for Weibull and Lognormal distributions based on and by using direct relations among Weibull, Gumbell & Lognormal distributions. (Aldowaisan, Nourelfath & Hassan, 2015) proposed that, when a process data is non-normal the quality improvement effort required to achieve six sigma level is higher as compared to normally distributed data. (Abbasi, Ahmad, Abdollahian &Zeephongsekul, 2007) measured the process capability indices for bivariate non-normal process using the bivariate burr distribution. (Chen & Pearn, 1997) considered the generalizations for basic PCIs C_p, C_{pk}, C_{pm} & C_{pmk} to cover non-normal distributions. Their results show that the proposed generalizations were more accurate than those basic indices in measuring process capability. (Pan & Wu, 1997) investigated process capability indices for non- normal data by dividing quality characteristic into three categories as bilateral specifications, unilateral specifications with target value and unilateral specification without target value. Comparison is made so as to show the effect of overlooking the theoretical distributions and analyzing data assuming it as normal.

3.Methodology

When the process data are not normal, the first thing to do is try and identify the causes for nonnormality and settle such causes. Once such issues are detected and settled and the process is in statistical control and if the process data is still not normal, other methods of analysis must be employed to deal with non-normal data. There are four methods widely used for calculating the process capability when the data is non- normal. In the present study, initially a data following Weibull distribution was generated using Minitab software. After the generation of data, it was tested for normality and then the Cp, Cpk values were calculated using distribution fit method, Box-Cox transformation method, Johnson transformation method and Clements percentile method.

3.1 The distribution fit approach

In This method, the most appropriate distribution fitting the data is identified and that distribution is then used to find process capability. The appropriate distribution can be identified using the probability plots and the information about the Anderson darling test. If more than one distribution appears to be fitting data than the one with the larger p value is considered. Once the real distribution is applied, the appropriate C_{pk} based on the actual shape of the distribution is calculated. For non-normal cases, the median (M) is used for the central tendency, rather than the mean. The software will plug in the distribution values ($X_{0.99865}$ at the 99.865th and $X_{0.1350}$ at the 0.135th percentiles) and will define C_{pk} as the minimum of C_{pu} and $C_{pl.}$ using the equations (2), (3) and (4) where $X_{0.9865}$ is the value of distribution function at 99.865th percentile and $X_{0.135}$ is the value of distribution function at 0.135th percentile.

$$Cp = \frac{(USL-LSL)}{(X0.99865-X0.1350)} \quad \text{... (2)}$$

$$Cpu = \frac{USL-M}{X0.99865-M} \quad \text{... (3)}$$

$$Cpl = \frac{M-LSL}{M-X0.135} \quad \text{... (4)}$$

3.2 Box-Cox Transformation

In this method, the non-normal data is transformed to a normal data or approximately normal data using equations (4), (5) and (6). George E. P. Box and David Cox had proposed this transformation that allows the transformation of selected data to normal data. The transformed data can then be used to assess the process capability using the normal distribution. Here the one important requirement is that the data must be positive. This transformation is expressed as:

$$Y = y^{\lambda} \quad \text{if} \quad \lambda \neq 0 \quad \text{... (4)}$$

$$Y = \log_e y \quad \text{if} \quad \lambda = 0, \quad -5 \leq \lambda \leq +5 \quad \text{... (5)}$$

where, y is the geometric mean of the original data and λ is determined using

$$y^{\lambda} = \frac{y^{\lambda}-1}{\lambda y^{(\lambda-1)}}, \qquad (y^0 = y \ln y) \quad \text{... (6)}$$

This equation is recursively tested for values of λ between -5 and +5. The maximum likelihood function is one for which sum of squares is minimum. After the data is transformed to normal distribution, a process capability is calculated considering normal distribution using equation (1) for normally distributed data.

3.3 Johnson transformation method

This method is used to transform a non-normal data to normal data. Normal Johnson created this transformation. One among the following three types of equations (7), (8) and (9) is used to transform the data depending upon whether the data is bounded, lognormal or unbounded.

For a bounded random variable:

$$y = a + b.\ln\frac{(x+C)}{(d-x)} \quad \text{for } b > 0;\ -c < x < d \quad \text{... (7)}$$

For log-normal distribution of random variable:

$$y = a + b.\ln(x+c) \qquad \text{for } b > 0; -c < x \quad \text{... (8)}$$

For non-bounded random variable;

$$y = a + b.A\sinh\frac{(x-c)}{d} \quad \text{for } b > 0; d > 0 \quad \dots (9)$$

Once the data is transformed to normal distribution, the process capability can be calculated using equation (1) for normal distribution.

3.4 Clements percentile Method

It calculates the indices using a Pearson family of Curves. This method consists of estimating process capability indices as if they were normal but with two simple slight changes. Instead of using values of percentile points from normal distributions it takes them from non-normal distributions, and instead of taking the mean as the measure of central tendency it uses the median. It is proposed that 6σ in equation for calculating C_p in the case of normal distribution is replaced by the length of the interval between the upper and lower percentile points of the distribution of X. Therefore, the denominator in equation for C_p in the case of normal distribution can be replaced by (U_p-L_p).

i.e. $$Cp = \frac{(USL-LSL)}{(Up-Lp)} \quad \dots (10)$$

where,

Up - is the upper percentile i.e. 99.865 percentile of observations and

Lp - is the lower percentile i.e. 0.135 percentile of observations.

Since the Median "M" is the preferred central value for a skewed distribution, so C_{pu} and C_{pl} as follows:

$$Cpu = \frac{(USL-M)}{(Up-M)} \quad \dots (11)$$

$$Cpl = \frac{(M-LSL)}{(M-Lp)} \quad \dots (12)$$

$$Cpk = Min\{Cpu, Cpl\} \quad \dots (13)$$

In Clements' Method, the percentiles required in the above equations are obtained through estimating the first four moments (i.e. process mean, standard deviation, skewness and Kurtosis) of the unknown underlying distribution of the empirical data, matching these moments to a suitable Pearson system distribution and using the percentile values of the Selected distribution. The advantage of this method as compared to distribution fitting method is, the task of complicated distribution fitting is eliminated.

4. Results

The data used for this study is initially tested so as to check whether it is normally distributed or it is having some other distribution. Fig.3 presents the graph of normality test for the data considered. In this graph, the plotted points are not along straight line which clearly indicates that the data is not normally distributed.

Once it is confirmed that data is not normally distributed, it is essential to identify which distribution it is following so as to do accurate process capability analysis. If this data is analyzed assuming the data to be normal than it will give wrong results. Now for this data, an appropriate distribution needs to be identified. To identify which distribution is being followed by the data, various distributions are fitted to the data using Minitab software so as to select the most appropriate distribution for the data.

It is seen in Fig.4 that the only distribution for which data is lying along the straight line is Weibull distribution. For the rest of the distributions data points are not on the straight line. Also, the pvalue pertaining to Anderson-darling test is 0.213 for Weibull distribution which is more than 0.05. This clearly confirms that the data is following Weibull

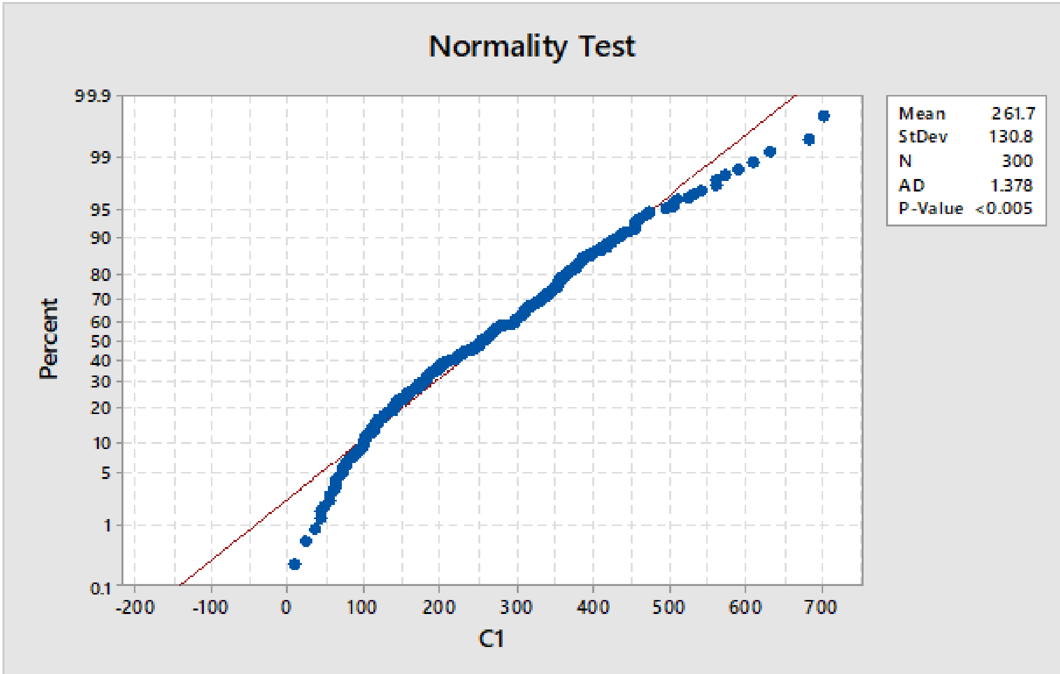

Fig.3. Normality test for Weibull distributed data

distribution. Once the appropriate distribution is fitted to the data, the process capability analysis using distribution fit approach is done using Minitab software. The Fig.5 shows the process capability report generated in Minitab using the distribution fit approach. The USL and LSL values considered are

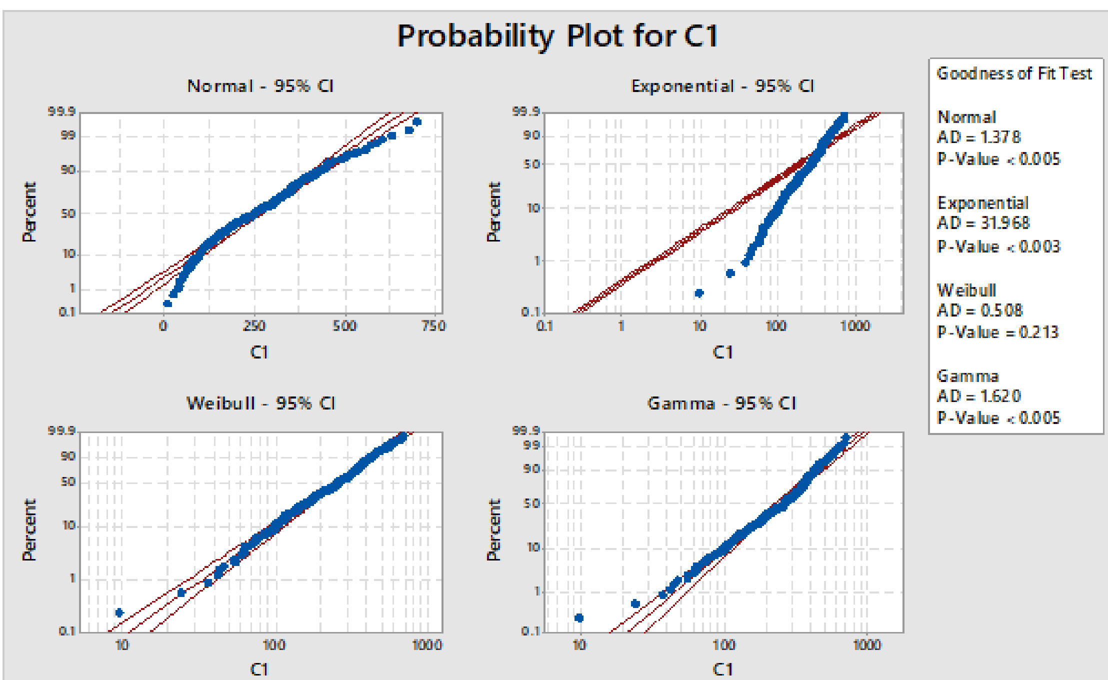

Fig. 4. Appropriate distribution fitting for the data

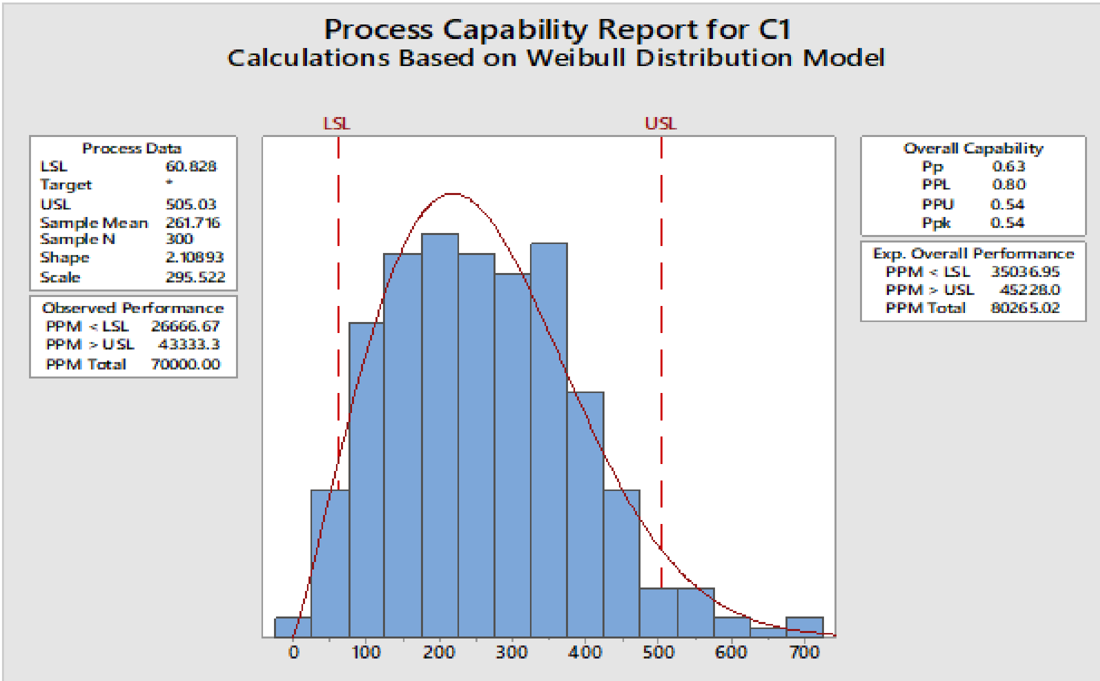

Fig. 5. Process capability report of Weibull data using distribution fit approach

505.03 and 60.828 respectively for the sample of 300 points. The analysis shown in the report gives the overall process capability values Pp and Ppk as 0.63and 0.54 respectively, indicating that the process is not meeting the specifications. Also, further the report indicates that PPM (Parts per million) less than LSL as 26666 and PPM greater than USL as 43333. Thus, a sufficient idea about the performance of the process is derived from the process capability report based on distribution fit approach. Now that the process capability results are obtained with the distribution fit approach, the analysis are done on the same data using Box-Cox transformation method. Initially a data is transformed using Box -Cox Transformation and then the transformed data is analyzed as if it was normal data. Fig.6 presents the process capability report based on Box-Cox transformation method. The overall process capability values Pp and Ppk are shown as 0.58 and 0.54 respectively. PPM less than LSL and PPM greater than USL using this method are 26666 and 43333 respectively. Process capability results obtained using Box-Cox transformation are almost identical to the values obtained using distribution fit approach and these results too indicate that the process performance is low. Next, using the Johnson transformation method the Weibull data is transformed to normal data. The Fig.7 presents the probability plots of original data and the transformed data. Here, it is clearly seen that the original data is not grouped along the best fit line which indicates that it is non-normal whereas the transformed data is grouped along the straight line which confirms that the data is transformed and now it is normally distributed. Also, the p value of Anderson darling test, for original data is less than 0.05 whereas the same p value for transformed data is 0.104 which is more than 0.005 further indicates that it is transformed to normal distribution. Now that the data is transformed, it is solved using process capability analysis for normal data as if it is a normally distributed data.

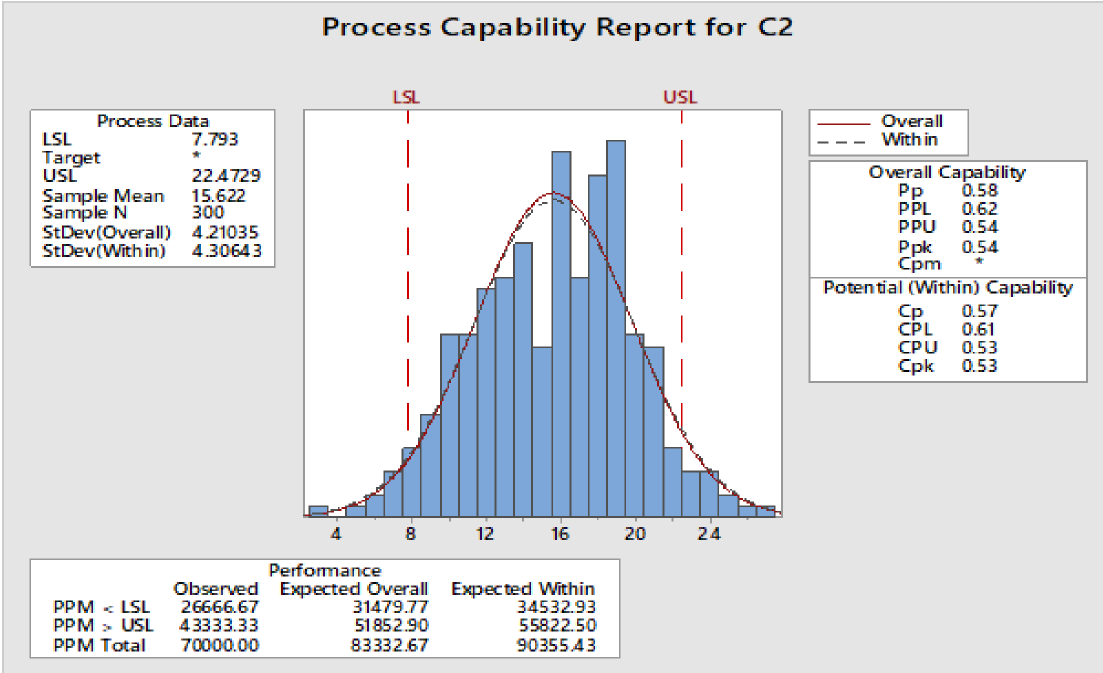

Fig. 6. Process capability report of Weibull data using Box-Cox transformation.

Process capability report for the analysis done using Johnson transformation is presented in Fig.7. The Pp and Ppk values for the same data using Johnson method are 0.58 and 0.54 respectively.

Finally, the process capability was calculated analytically using Clements method. The process capability values Pp and Ppk obtained using this method are 0.62 and 0.57 respectively.

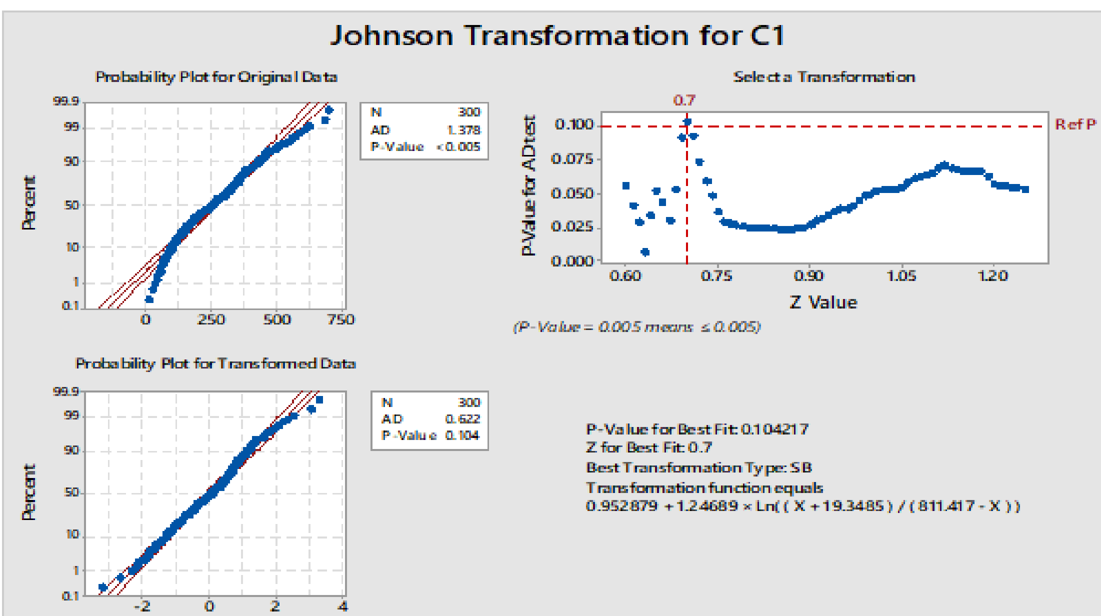

Fig. 7. Probability plots of original data and Johnson transformed data

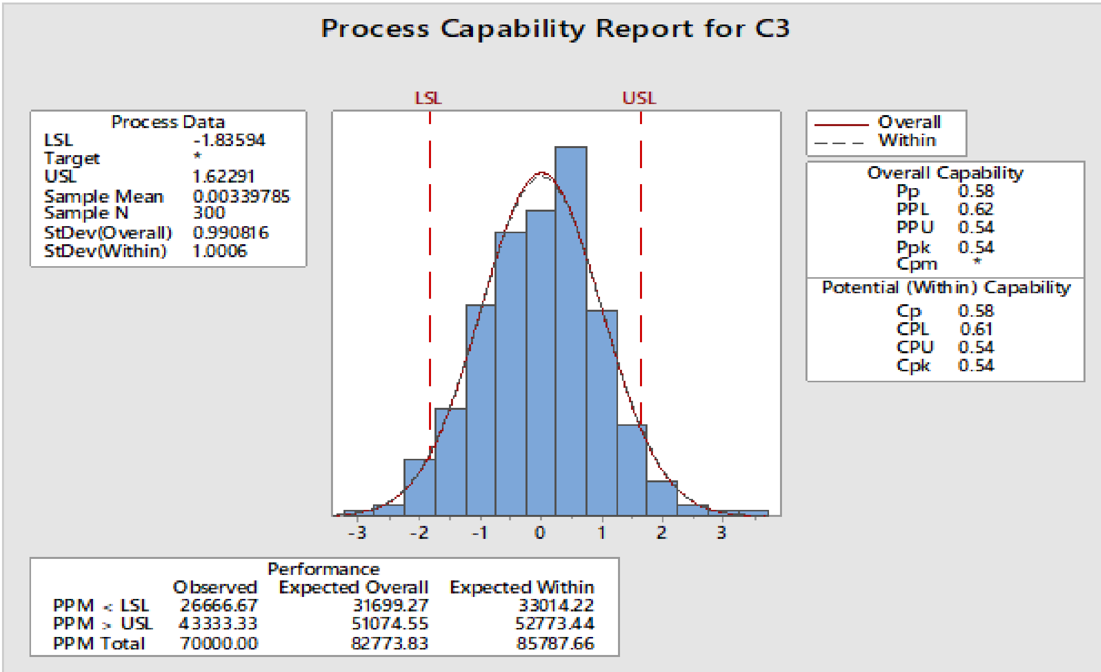

Fig. 8. Process capability report of Jonson transformed data

The overall process capability values obtained using all four methods though differ slightly are almost identical. Table 1 presents the overall process capability values obtained using all four methods. Amongst all the four methods the Clements method gives the highest Ppk value.

Fig.6.3 displays the comparison graph of the process performance index in the case of data following Weibull distribution. It is reflected in the graph that the Clements method gives the highest value for the process performance index whereas in the rest of the other cases the index value is 0.54 and is the minimum

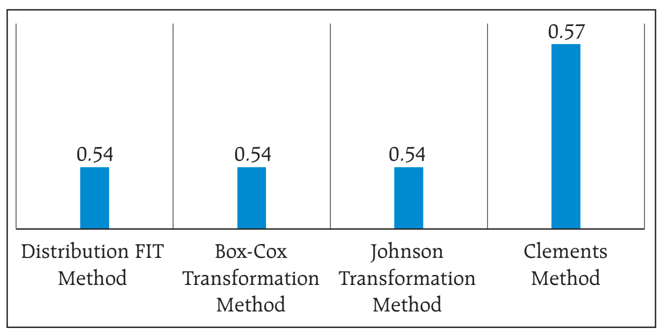

Fig.9 Process performance index comparison of Weibull data

value. The message communicated by the results in every method is same that process performance is low and requires an improvement.

Table 1: Process Capability indices using various methods

Sr. No.	Method	P_p	P_{pk}
1	Distribution fit	0.63	0.54
2	Box-Cox Transformation	0.58	0.54
3	Johnson Transformation	0.58	0.54
4	Clements Method	0.62	0.57

5. Conclusion

In an industry process capability assumes a very important role. Process capability indices shows the relationship between the customer specification limits and the capability of a process. A wrong estimation of process capability results in the wastage of lot many resources. Instead of simply assuming normal distributions in six-sigma projects, practitioners need to make substantial efforts and a sense of responsiveness to identify the right probability distribution for each process. Thus, it is very much essential that the data showing quality characteristic to be tested for identifying the distribution it follows and then if it is following a non-normal distribution, an appropriate method needs to used for analyzing Process capability analysis. Also, amongst the many methods available, it is essential to find out which method would give optimum results of process capability for a data following particular distribution. Any given process data related to quality characteristic can be checked for normality before calculating its process capability by assumption of normality. Once the distribution followed by the data is known, an appropriate method can be applied to infer about the process capability. In the above Weibull distributed data, process capability is calculated using four methods discussed above and the results obtained are compared. Process capability calculated using all four methods vary slightly. The comparison of values of process capability index becomes significant in opting for the suitable method which would give the best estimate of the process performance. The Process capability results in the table 1 indicate that the results obtained through various processes though differ slightly, are almost identical. It is observed that the Pp and Ppk values measured using Clements percentile method are slightly higher for the data considered. This study is helpful in selecting the best method out of the four methods for the given Weibull data. Thus, for the Weibull data the best suitable method to calculate process capability indices is Clements method.

The purpose of this study was to put forth the importance of identifying the underlying data distribution before the analysis of data for process capability, present the systematic approach for testing the data for normality and then review and implement some of the methods mentioned in the literature for evaluating process capability of non-normal data. Further study was intended to compare the four most commonly suggested methods by applying them on the different data types. Accordingly, in this study the data following Weibull, distribution, is considered and the process capability is calculated for the data distribution using four methods discussed above and the results obtained are compared. Process capability calculated using all four methods vary slightly. The comparison of values of process capability index becomes significant in opting for the suitable method which would give the best estimate of the process performance. The following managerial implications are arrived at using this study

(1) For any data, initially it has to be tested for normality using the approach discussed.

(2) If the data proved be non- normally distributed than an appropriate distribution fitment to be done for the data.

(3) In case the data is fitted to a Weibull distribution, the Clements method can be applied to measure process capability.

(4) Use of Clements method would ensure the optimal process capability values pertaining to the process.

(5) Quality manager will get actual picture of process performance avoiding false image about process thus leading to saving of lot many resources.

(6) This study is useful for the managers and quality engineers to select directly the appropriate method for the Weibull distributed data set. This is would save lot of time and resources required for the process performance analysis.

(7) In particular, the study would of much use for the organization going for six-sigma quality systems as the process capability analysis is inseparable part of Six-sigma methodology.

(8) Finally, the findings in this study would be helpful in deciding the selection of appropriate methods for process capability evaluation with non-normal data.

Though all methods can be used for solving non-normal data, in particular it can be concluded

from this study that for the Weibull distributed process data the suitable method to calculate process capability indices would be Clements method The above comparison was done by creating data without subgroups and therefore *ppk* is used instead of using *cpk* for process capability analysis in this study. The transformation methods though provide evaluations which truly reflect process capability, are more cumbersome in nature.

References

Abbasi, B., Ahmad, S., Abdollahian, M. & Zeephongsekul, P. (2007). *Measuring Process Capability for Bivariate Non-Normal Process Using the Bivariate Burr Distribution.* WSEAS Transactions on Business and Economics, Volume 4, Issue 5, pp.71-77.

Adeoti O., & Olaomi J. (2017). *Process capability index based control charts for variables.* South African journal of industrial engineering. Volume82(2), pp.28-36

Aldowaisan, T., Nourelfath, M., & Hassan, J. (2015) *Six-sigma performance for non-normal processes.* European Journal of operational research 247, pp.968-977.

Arcidiacono, G., & Nuzzi S. (2017). *A review of fundamentals on process capability, process performance, and process sigma, and an introduction to process sigma split.* International journal of applied engineering research, Volume12, pp.4556-4570.

Chen, K. & Pearn, W. (1997). *An Application of Non-Normal Process Capability Indices.* Quality and Reliability Engineering International, Volume 13, pp.355-360.

Liu, P. & Chen F. (2005). *Process Capability analysis of non-normal process data using the Burr XII distribution.* Springer-verlag London Limited.

Pan, J. & WU, S. (1997). *Process capability Analysis for Non-normal relay test data.* Microelectronics Reliability, Volume37, No.3, pp.421- 428.

Pina-Monarrez, M., Ortiz-Yanez, J. & Rodrigues-Borbon, M. (2016). *Non-normal Capability Indices for the Weibull and Lognormal Distributions.* Quality and Reliability Engineering International, 32, pp.1321-1329.

Detection of Systematic Bias in Star rating

Sudhakar Vijayakumar[1], R. Venkatesakumar[2], M. Pachayappan[3]

Star rating of online consumer reviews is important information for the consumers, researchers and decision-makers. In the eWOM context, the star ratings assigned in the consumer reviews often symbolise the quality of products. Instead of processing voluminous data, reading of each review, consumer predominantly depends upon the star rating to summarise the information faster. There is a direct relationship between star ratings and, quality of products and, researchers have established an inverse relationship between the helpfulness of reviews and star ratings. Even though there is a belief that online reviews are free from bias, the star ratings are the most vulnerable part in the review and is a potential candidate for bias. Research result shows that a chronological presentation of reviews as a source bias. Managers try to reduce the bias in the online review system by creating various measures like showing critical or negative reviews separately; showing reviews randomly and, providing reviews only for the products purchased in the e-retailer store. Researches addressing bias in online sources are in the preliminary stage and, few studies explore this phenomenon. This research work addresses the presence of sequential bias in the online consumer reviews by analysing star ratings of 11 products comprise of 34 brands that are commonly available in two popular e-retailers. We establish the presence of sequential bias in consumer evaluations by showing distribution patterns of star ratings are varying between two e-retailers for the same brand and the sentiment scores distributions are inconsistent from star ratings distribution. From the results, we suggest that online review system should add more robust metrics like sentiment scores to mitigate the reviewer bias.

Keywords: *Sequential Bias, Sentiment Analysis, Star Rating, eWOM, e-retailer, Online Consumer Reviews*

Introduction

Internet penetration, smartphone penetration and e-retailers active presence drive e-commerce growth in the country. Video websites, online product review sites, consumer blogs and social media platforms are new generation information sources for many consumers. A specific source that gets more research attention is the manufacturer website or the marketer website. E-retail firms like Amazon, Flipkart and Hospitality services like Goibibo, Trivago or Tripadvisor facilitate to post online reviews. However, the procedure and prerequisite for registering opinions vary from firm to firm. Promoting online consumer reviews in the decision process impose challenges not only for the marketers but for the consumers also. Through appropriate marketing mix elements, the marketers have to manage the harmful contents in the online reviews proactively (Septianto, Kemper, & Choi, 2020). The marketers have to ensure accurate and needed information reaching through the right sources to the decision-makers. On the other hand, voluminous information in the search stage of decision process creates confusion for the consumer rather than clarity (Sturiale & Scuderi,

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2013); (Baek, Ahn, & Choi, 2012). The consumers have to use effective search strategies to collect the right information for decision-making. There is a belief that online consumer reviews are free from bias.

Among the components of an online review, star rating assumes a significant role in the consumer decision process. Star ratings provide a quick summary of the evaluation to the consumers and hence a focal point for researchers. Studies are establishing relationships between various review components and the star rating. The relationship between star rating, sentiment scores and helpfulness often produced inconsistent relationships between the variables across different product categories studied (Chua & Banerjee, 2016). For instance, a one-star rating provides information that is more helpful rather than a five-star rating. However, the star rating and sentiment score show a positive relationship. A study on eWOM proves that consumers engaging in eWOM activities register extreme positive or negative attitudes and, hence the star rating shows J-shape distribution (Askalidis, Kim, & Malthouse, 2017a). Researcher proves that products with more number of reviews and higher star ratings are perceived as a symbol of quality by the consumers (Li, Chen, & Zhang, 2020). Moreover, along with the brand name, star rating reduces information asymmetry and, brands with higher star rated reviews perceived as quality brands (Manes & Tchetchik, 2018). Thus, the star rating brings an array of dynamics and continues to retain a niche place in the practical as well as research contexts.

A severe drawback of star rating, which gains research attention in recent times, is the consumer bias. Consumer bias in evaluation is not a unique phenomenon to online sources. Star ratings are a highly vulnerable component in the online consumer reviews, and researchers are addressing the reasons for bias in consumer evaluations. In the long run, bias rating and assessments will bring negative and deteriorating effect on the brand name (Sikora & Chauhan, 2012). Researchers suggested methods to estimate bias from the event; chain-like structure leads to over-estimation of information and, funnel-like appearance leads to under-estimation of information (Tversky & Kahneman, 1974). These findings are a valid criterion in evaluating the bias in online sources. Managers are also a victim of prejudice while handling online reviews. Cognitive language like insights and discrepancy words create diagonally opposite interpretation while seeing causality words and future tenses in online reviews (Antioco & Coussement, 2018).

An alternate mechanism suggested in the literature to reduce bias is that obtaining invited reviews (Antioco & Coussement, 2018) or showing reviews in a random order rather than chronologically (Kapoor & Piramuthu, 2009). However, research results show that self-motivated reviews versus retailer-prompted reviews show a different pattern in star ratings (Askalidis, Kim, & Malthouse, 2017b). Firms like Amazon organizes a separate panel for critical reviews and most influential reviews. Amazon and Flipkart follow entirely different procedures for registering online reviews. For example, to post an online opinion in Amazon, mere sign-in is sufficient whereas, Flipkart, one can post his review only for the product, which he has purchased. These practices, however, create different types of bias in online reviews.

Research works addressing systematic bias are gaining attention in recent years. Systematic bias is a situation where a retailer may show more number of positive reviews, whereas another retailer may show a lesser number of positive reviews for the same brand (Ivanova & Scholz, 2017). Retailers could moderate the reviews and systematically present the data as part of their communication strategies. For the same brand, if online reviews and star ratings are considerably different between two retail firms, it will lead to a collection of conflicting information during the search stage by the decision-makers. We aim to prove the presence of systematic bias by comparing the online consumer reviews from Amazon and Flipkart websites. Our research findings expect to provide caveats in using online user-generated contents in the purchase decision process for the consumers.

We demonstrate the systematic bias in assigning star ratings in the reviews by comparing the star rating and sentiment scores and prove that star rating is consistently higher for the 11 product categories in Flipkart websites than Amazon reviews. To show the consumer bias in evaluations, we ascertain that the distributions of sentiment scores show a different pattern from that of the star ratings of the same brands. In the absence of bias in the review process, we expect star rating and sentiment scores of the products will have a similar distribution. These 11 product categories consist of 34 brands, which are commonly available in both the retailer. From the consumer efforts and involvement to register their views through written phrases, we suggested the role of more robust measures like sentiment analysis scores to be presented in the online review systems to overcome the bias in star ratings. The research gap is identified by reviewing earlier studies and derive the hypotheses and the methodology section explains the process of online review data collection and pre-processing. The results section provides a summary of One-way ANOVA; followed by discussions and managerial implications.

Review of Earlier Studies and Hypotheses

Online consumer reviews are a popular source of information in the purchase decision process. Within the limited time available to consumers, it is often impossible to understand the information asymmetry and dynamics among the online sources of information. Studies have reported the dysfunctional effects of data available in the online sources on consumer purchase process rather than providing clarity to the process (Sturiale & Scuderi, 2013); (Baek et al., 2012). Online reviews that are valuable and create a positive attitude in the purchase process (Mumuni, Lancendorfer, O'Reilly, & MacMillan, 2019), but identifying those reviews is an intimidating task for the consumers. Before identifying useful and helpful sources, they have to eliminate a volume of unnecessary data. The reviewer has to remember that online reviews are affected by the product category (Sen & Lerman, 2007) and consumer social media characteristics (Anastasiei & Dospinescu, 2019). Few product categories, by its popularity or consumption patterns, attract more reviews than other products and the consumer's ability and knowledge on handling social media platforms is another dimension that drives the quantum of online reviews.

To overcome the hurdles of information processing, consumers often focus the star rating as a proxy for the content, instead of reading the entire review content. Many online service providers have the option to get the star ratings in term of a visual representation as a routine feedback measure. This visual cue provides not only a faster summary of the content to the consumers; but provides the signal of product quality as well (Filieri, Raguseo, & Vitari, 2018). Moreover, it is proved that the star ratings are a reflection of several products and firm characteristics. Star ratings are influenced by consumer involvement (Pelsmacker, Dens, & Kolomiiets, 2018), sales (Chiu, Chen, Wang, & Hsu, 2019), product liking (Moe & Trusov, 2011) and post-purchase satisfaction (Chua & Banerjee, 2016). Review components like the length of the review also influence the star rating (Yoon, Kim, Kim, & Choi, 2019).

Researchers prove that star ratings have a significant influence on the helpfulness of reviews (Singh et al., 2016). In purchasing a few categories of goods, star ratings are useful in comprehending the content (Zhu, Liu, Zeng, & Huang, 2020). Another development in text mining technique is to measure the sentiment and emotion in the review content. Popularly known as sentiment analysis, this technique quantifies the subjective opinions as a numerical measure (Baek et al., 2012). Study finding shows that the firms can use sentiment analysis scores as a proxy to measure customer satisfaction (Chamlertwat, Bhattarakosol, Rungkasiri, & Choochart Haruechaiyasak, 2012). Besides, the star rating is considered as a reflection of consumer's sentiment also (Al-Natour & Turetken, 2020). Research work on the sentiment analysis proves that online review sentiments are influential for material purchases than experiential purchases (Kim, 2020). Researchers also suggest that the firms can provide personalised feedbacks by combing the sentiment scores with star ratings (Bali, Agarwal, Poddar, Harsole, & Zaman, 2016). Thus, the star rating and sentiment analysis are continuing to be focal constructs in any online consumer researches.

However, another dimension of online reviews that got lesser attention in the past is reviewer bias. Even though one would expect the online reviews are unbiased, but the reality is not so. Research outcomes show that language style creates prejudice, and it is proved that certain words in online reviews misreading effect on feedbacks given by the consumers (Antioco & Coussement, 2018). Despite the efforts by the marketers, researchers show that negativity bias exists when the consumer sees more negative content (Zhou, Liu, & Tang, 2013) while processing the data. To mitigate bias, retailers often provide average star ratings and other summary statistics (Sikora & Chauhan, 2012). However, it is argued that when the consumer has more overall positive valence about the product, negative reviews are considered as helpful (Wu, 2013). Further, it is argued that consumers with net utility higher and positive will buy the product and opportunity to evaluate the product, leading to assign skewed ratings (Han & Anderson, 2020).

However, we are interested in addressing a specific bias, viz., the sequential bias in the online review systems. In particular, a consumer might be influenced by the sequence in which he sees the online review. Researchers have classified these unintentional reviews as sequential bias in the online review system (Eryarsoy & Piramuthu, 2014). Due to the order sequence in which a reviewer sees the review contents alter, his intended opinion and forced register in line with other reviews for the products. Reviews that appear first have a significant influence in forming an idea about the products (Kapoor & Piramuthu, 2009). Consumer happy mood state systematically bring bias in influencing consumer evaluations (Howard, 1992). Another study result shows that new user to the online review system brings systematic bias, where he assigns a similar rating that of the previous reviews (Eryarsoy & Piramuthu, 2014). A study finding shows that review length systematically influences consumer evaluation and giving helpfulness votes (Eslami, Ghasemaghaei, & Hassanein, 2018). If sequential bias exists, the brands in first e-retailer websites expect to carry consistently more or less several star ratings than the star rating assigned in another, but similar e-retailer's website. This will result in consistently higher or lower ratings on a retailer website. Thus, we expect star ratings, which are just far of a mouse click, are more vulnerable in the online review systems, affect by the sequential bias.

Firms are making efforts to address the mechanism of reporting bias and try to eliminate its impact on the firm's goodwill (Dellarocas & Wood, 2008). Signaling theory emphasises the reduction of asymmetry in the information exchange between the stakeholders in the process (Connelly, Certo, Ireland, & Reutzel, 2011). The signaling theory and cue theory suggest that when the buyer visits unknown or new stores, he extensively process the cues presented in the website (Wang, Beatty, & Foxx, 2004) to make effective decisions. Further, the insights from Information Integration Theory suggests that the consumer's beliefs and attitudes are shaped by the cues presented in the stimulus (Simonin & Ruth, 1998). Thus, the marketers are often inspecting the presence of bias and researchers focusing on various types of bias in the online review system. To test the presence of sequential bias in the review system, we further expect the sentiment scores would be showing a different pattern than the star ratings assigned for the reviews. We prefer to use sentiment scores rather than other parameters because the sentiment scores are computed from the review expressions of the consumer, which are unintentional and require more efforts from the reviewers to place his views in the online platforms. Thus, we expect the sentiment scores derived from the views are a more robust measure than star ratings or helpfulness votes.

Hence, we propose the following hypotheses to address the sequential bias in star ratings assigned in the online product review websites.

***H_1*: *There are significant differences in the mean star ratings of products between Amazon and Flipkart reviews.*

***H_2*: *There are significant differences in the mean sentiment scores of products between Amazon and Flipkart reviews.*

Methodology

To study the inadequacy of star rating and reviewer bias in the product evaluations, we consider the online consumer reviews from Amazon and Flipkart websites. Brands that are common in both the e-retailers display are chosen for the study. The reviews are collected for 34 brands representing 11 product categories from experience goods. Products are classified as search and experience goods based on the product attributes (Mudambi & Schuff, 2010). Search and experience goods are classified based on the attributes they possess and consumer ability to get information on product quality prior to purchase without sampling or purchase (Senecal & Nantel, 2004). For each review, we have considered the star rating and computed sentiment score for further analyses. We compare the differences in consumer evaluations of the products [Star rating assigned and Sentiment Scores] from Amazon and Flipkart. Hence, this study, with a pre-specified set of variables [E-retailer Brand, Product Category, Star Rating & Sentiment Scores] and hypotheses fits into the category of descriptive research design (Cooper & Schindler, 2002). Summary of samples collected, details of product and brands used for the study are provided in the Table-1.

Table-1: Summary of sample profile

Sample distribution	**Amazon Product reviews – 24704 [58.2%]**	**Flipkart Product reviews – 17753 [41.8%]**	**Total Product reviews - 42457**
Products	Beverages, Biscuit, Floor Cleaners, Hair Care, Health Drink, Juice, Paste, Shampoo, Soap, Talcum Powder, Washing powders/cakes		
Brands	Ariel, Bournvita, Bru Gold, Colgate Herbal Toothpaste, Colgate Strong Teeth Anti, Colgate Toothpaste Max free, Dark Fantasy, Dove Cream Beauty Bathing, Gatsby Hair Cream, Harpic Clean, Head & Shoulders Anti Dandruff, Horlicks, IFB, KrackJack, Lizol, Lizol Citrus, Nescafe, Nivea Musk Talk, Pantene Advanced Hair Fall, Parachute Advansed Men Hair care, Pears Naturale Aloe Vera, Pediasure, POND'S Dream flower Fragrance, Ponds Sandal, Real Apple, Red Label Tea, Rin, Santoor Sandal and Turmeric, Sun Rise, Sunsilk Coconut, Taj Mahal Tea, Tang Juice, Tata Gold Tea, Ustraa Hair Cream		

Pre-processing the data and Computing Sentiment score

To pre-process the text data and compute sentiment scores, we use R-Studio and its Plugins like '*tm*', '*wordcloud*', '*wordcloud2*' and '*sentimentr*'. In lines with earlier studies, the text column is treated for data cleaning process (Al-Otaibi et al., 2018; Gaikar & Marakarkandy, 2015). This process includes removal of punctuations/special characters/numbers/symbols to lower casing the words, removal of stem words and blank spaces. In R-Studio, using these packages, and the command 'gsub', the data were cleaned. Once the comments are converted to simple 'plain' English, we use 'sentiment' package to compute the sentiment score for each review. These scores are added back to the same data set for further analyses. To compute the sentiment scores and processing of data, we follow the steps suggested by (Al-Otaibi et al., 2018; Gaikar & Marakarkandy, 2015). We use a standard, widely accepted package in R-Studio to compute the sentiment scores. This process ensure the reliability and validity of our measures used in the study.

Results

To test the hypotheses on the mean differences in the evaluations of star rating of various product categories between the retailers, we use One-way Anova with the e-retailer brand as the factor variable and star rating as the dependent variable. The results are indicating that there are significant differences between the mean star ratings of Amazon and Flipkart reviews across the 11 product categories and the results are in support of the hypothesis $\mathbf{H_1}$. Except for the 'Floor Cleaner' category, mean star ratings of Amazon reviews are consistently lower than means of the product reviews in Flipkart. This is a notable observation in the star rating distribution between the retailers.

Table-2: Differences in the Mean Star Ratings between Retailers

Product Category	Retailer	Number of reviews	Mean Star Rating	Std. Deviation	95% Confidence Interval for Mean Star Rating		F-Ratio [Sig.]
					Lower Bound	Upper Bound	
Beverages	Amazon	4689	4.1702	1.30569	4.1328	4.2076	93.316 [0.000]
	Flipkart	2346	4.4655	.98684	4.4255	4.5054	
	Total	7035	4.2687	1.21666	4.2402	4.2971	
Biscuit	Amazon	2534	4.2332	1.33156	4.1814	4.2851	12.358 [0.000]
	Flipkart	312	4.5064	.94883	4.4007	4.6121	
	Total	2846	4.2632	1.29781	4.2155	4.3109	
Floor Clean	Amazon	2930	**4.3802**	1.03580	**4.3427**	**4.4177**	20.778 [0.000]
	Flipkart	354	**4.1045**	1.35606	**3.9628**	**4.2463**	
	Total	3284	4.3505	1.07807	4.3136	4.3874	
Hair Care	Amazon	2709	3.7556	1.44191	3.7013	3.8100	140.518 [0.000]
	Flipkart	3982	4.1479	1.24593	4.1092	4.1866	
	Total	6691	3.9891	1.34254	3.9569	4.0213	
Health Drink	Amazon	3290	4.3213	1.17092	4.2813	4.3613	23.076 [0.000]
	Flipkart	704	4.5469	.92111	4.4787	4.6150	
	Total	3994	4.3610	1.13406	4.3259	4.3962	
Juice	Amazon	607	3.9522	1.44173	3.8373	4.0671	97.683 [0.000]
	Flipkart	1331	4.4921	.92933	4.4421	4.5421	
	Total	1938	4.3230	1.14282	4.2721	4.3739	

Product Category	Retailer	Number of reviews	Mean Star Rating	Std. Deviation	95% Confidence Interval for Mean Star Rating		F-Ratio [Sig.]
					Lower Bound	Upper Bound	
Paste	Amazon	1230	4.2992	1.12371	4.2363	4.3620	30.629 [0.000]
	Flipkart	1009	4.5372	.85731	4.4842	4.5901	
	Total	2239	4.4064	1.01906	4.3642	4.4487	
Shampoo	Amazon	762	3.7835	1.52993	3.6747	3.8923	100.258 [0.000]
	Flipkart	1679	4.3264	1.08548	4.2744	4.3783	
	Total	2441	4.1569	1.26635	4.1066	4.2072	
Soap	Amazon	2161	4.3739	1.10258	4.3274	4.4204	94.204 [0.000]
	Flipkart	4346	4.5983	.74174	4.5762	4.6203	
	Total	6507	4.5237	.88443	4.5023	4.5452	
Talcum Powder	Amazon	1167	4.2614	1.18716	4.1932	4.3295	23.736 [0.000]
	Flipkart	1282	4.4696	.92130	4.4191	4.5201	
	Total	2449	4.3704	1.06125	4.3283	4.4124	
Washing	Amazon	2625	4.1013	1.37279	4.0488	4.1539	5.019 [0.025]
	Flipkart	408	4.2623	1.19060	4.1464	4.3781	
	Total	3033	4.1230	1.35065	4.0749	4.1711	

Estimated Marginal Means of Star Ratings

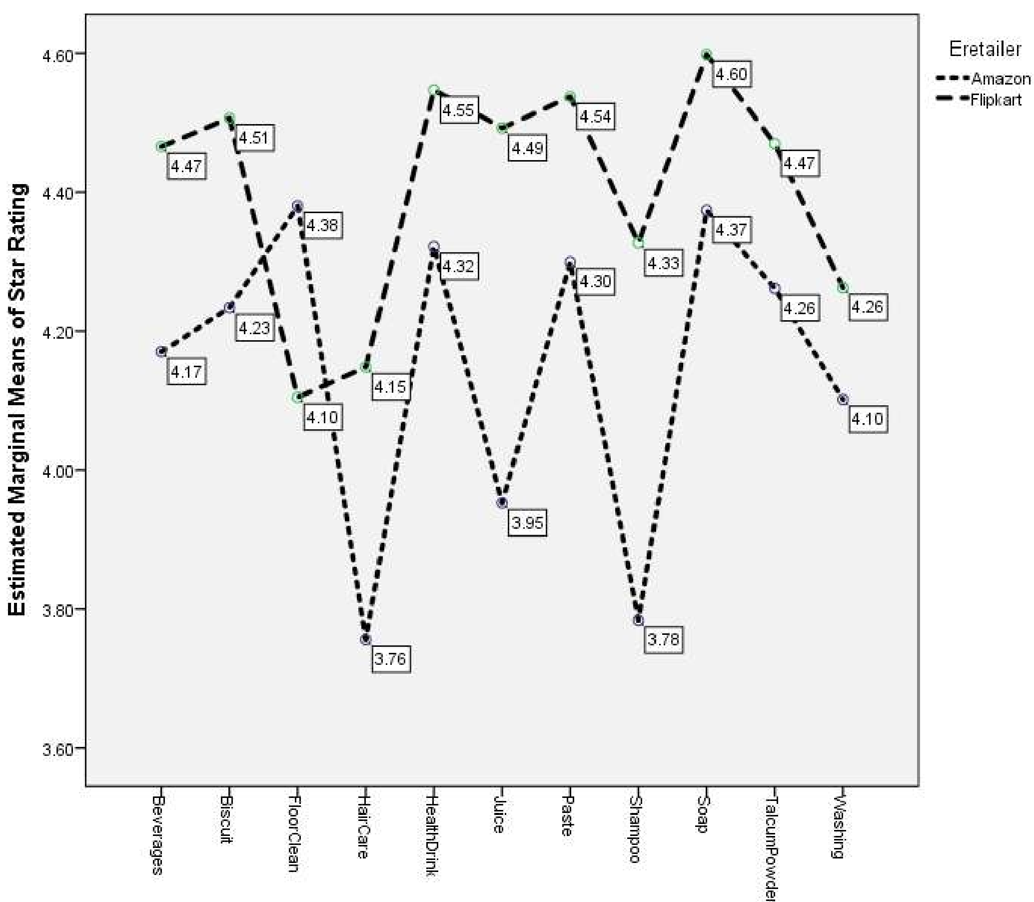

Figure 1- Differences in the Mean Star Ratings between Retailers

Further, to bring out the mean differences in the evaluations of sentiment scores of various product categories between the retailers, we use One-way Anova with the e-retailer brand as factor variable and sentiment scores as the dependent variable. The results indicate that there are significant differences between the mean star ratings of Amazon and Flipkart reviews across the 11 product categories and the results are in support of the hypothesis $\mathbf{H_2}$. Except the 'Tooth Paste', 'Shampoo' and 'Soap' categories, mean sentiment scores of Amazon reviews are consistently higher than Flipkart mean sentiment scores, which is another notable observation in the sentiment scores distribution between the retailers.

Table-3: Differences in the Mean Sentiment Scores between Retailers

Product Category	Retailer	Number of reviews	Mean Sentiment Score	Std. Deviation	95% Confidence Interval for Mean Sentiment Scores		Maximum
					Lower Bound	Upper Bound	
Beverages	Amazon	4689	.4207	.36408	.4103	.4311	474.386 [0.000]
	Flipkart	2346	.2316	.29742	.2196	.2437	
	Total	7035	.3576	.35466	.3494	.3659	
Biscuit	Amazon	2534	.4310	.41219	.4149	.4470	73.342 [0.000]
	Flipkart	312	.2246	.30151	.1910	.2582	
	Total	2846	.4083	.40665	.3934	.4233	
Floor Clean	Amazon	2930	.4873	.32795	.4754	.4992	396.895 [0.000]
	Flipkart	354	.1277	.25338	.1012	.1542	
	Total	3284	.4485	.33956	.4369	.4601	
Hair Care	Amazon	2709	.3259	.37407	.3118	.3400	259.179 [0.000]
	Flipkart	3982	.1957	.28661	.1868	.2046	
	Total	6691	.2484	.33107	.2405	.2563	
Health Drink	Amazon	3290	.4678	.35445	.4557	.4799	246.235 [0.000]
	Flipkart	704	.2427	.29973	.2205	.2649	
	Total	3994	.4281	.35589	.4171	.4392	
Juice	Amazon	607	.4104	.39364	.3790	.4418	118.350 [0.000]
	Flipkart	1331	.2333	.30022	.2172	.2495	
	Total	1938	.2888	.34222	.2735	.3040	
Paste	Amazon	1230	**.4393**	.34350	**.4201**	**.4586**	23.870 [0.000]
	Flipkart	1009	**.5082**	.31731	**.4886**	**.5278**	
	Total	2239	.4704	.33365	.4566	.4842	
Shampoo	Amazon	762	**.3456**	.39574	**.3175**	**.3738**	41.642 [0.000]
	Flipkart	1679	**.4477**	.34573	**.4311**	**.4642**	
	Total	2441	.4158	.36508	.4013	.4303	
Soap	Amazon	2161	**.4636**	.34278	**.4492**	**.4781**	60.343 [0.000]
	Flipkart	4346	**.5258**	.28306	**.5174**	**.5343**	
	Total	6507	.5052	.30558	.4978	.5126	
Talcum Powder	Amazon	1167	.4292	.32775	.4104	.4480	113.095 [0.000]
	Flipkart	1282	.2917	.31194	.2746	.3088	
	Total	2449	.3572	.32680	.3443	.3702	
Washing	Amazon	2625	.4233	.36699	.4092	.4373	156.503 [0.000]
	Flipkart	408	.1865	.27201	.1600	.2129	
	Total	3033	.3914	.36472	.3784	.4044	

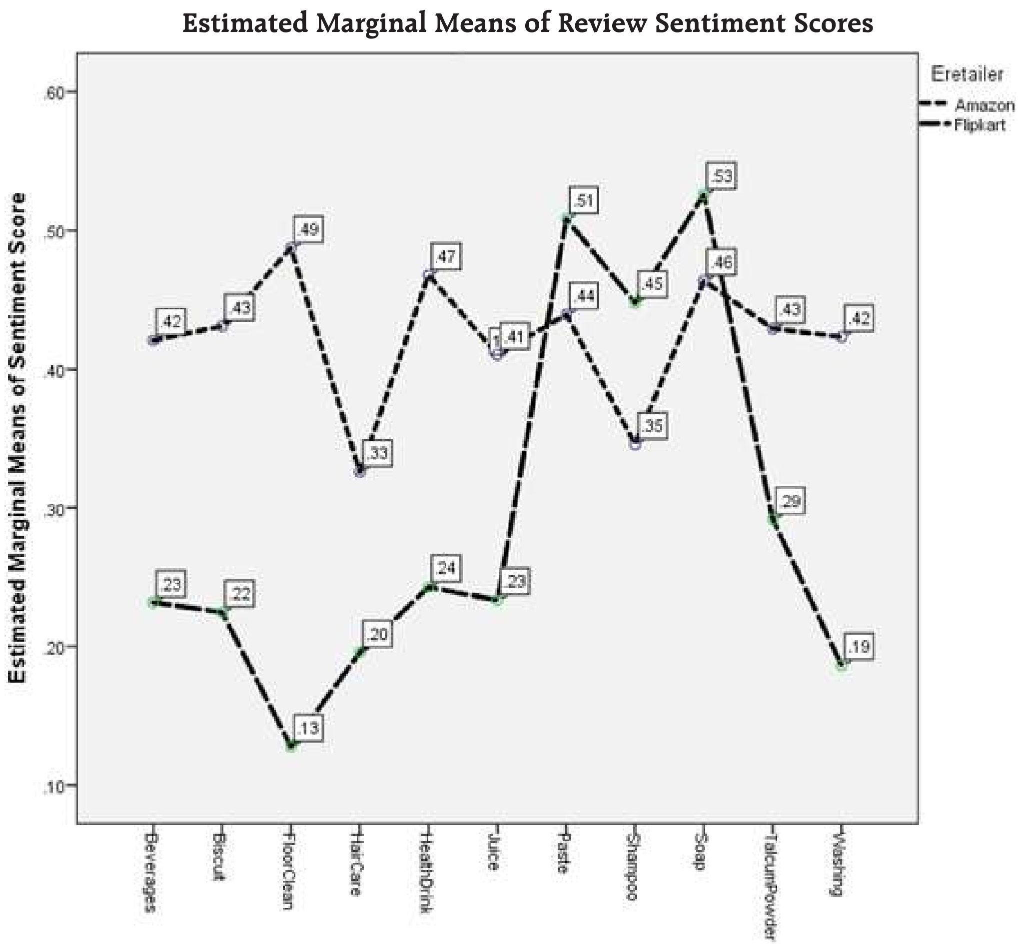

Figure 2-Differences in the Mean Sentiment Scores between Retailers

From the results, it is very evident that star ratings show a different distribution than sentiment scores' distribution in Amazon and Flipkart websites. Many product categories sentiment scores are higher for the Amazon reviews than Flipkart reviews, but this consistency is not evident in the star rating distribution. Absence of sequential bias, we expect sentiment scores and star ratings will have a similar distribution in Amazon and Flipkart websites. However, the star ratings are consistently higher in Flipkart and lower in Amazon suggest the presence of sequential bias in the reviews.

Discussion

Researchers argue that transforming the user-generated content as an actionable outcome is a critical activity for organisations (Antioco & Coussement, 2018). This argument valid for the consumers also, who use online review content a source of information in their purchase decision process. To demonstrate the presence of bias in the online consumer reviews, first, we analyse the star rating in the reviews and establish star ratings are consistently higher in a retailer website than the other retailer is. Then we prove the distribution pattern of sentiment scores are not in similar lines that of star ratings. From the data analysis, we show that mean star ratings are consistently higher for consumer reviews in Flipkart than Amazon reviews for 10 product categories out of the 11 product categories studied. However, a research work result on sequential bias suggests since there is no control over the presentation of reviews to consumers and consumer accessing and reading the reviews. Thus, the appearance of one-sided reviews need not be due to sequential bias of consumers (Eryarsoy & Piramuthu, 2014). To address this issue and strengthen our findings, we further considered the role of sentiment scores of each review and compared them between the retailers.

To support our hypotheses on the sequential bias, we have found out that the distribution of mean sentiment scores are showing a pattern between the retailers across the product categories. Flipkart mean sentiment scores is higher only for three products [*Soap, Paste and Shampoo*] and the remaining eight product categories Amazon reviews have better sentiment scores than Flipkart reviews. Despite the online reviews of the same brands considered for study purpose from both the sites, star rating distribution and sentiment scores distribution are not in similar lines in the e-retailers websites. Nevertheless, star ratings are highly one-sided in Flipkart and, hence, the findings are clear evidence of sequential bias in consumer evaluation of star ratings in Amazon and Flipkart websites.

From our findings on the sequential bias, we argue the inadequacy of star ratings and the need for more robust measures like sentiment score as an additional indicator in the online consumer review panel. Researchers show that due to voluminous review availability in online sources for the consumers, it is becoming difficult to identify the right sources and, use them in the purchase decision process. Various references and volumes of information, often leading to erroneous decisions (Godes & Silva, 2012). Added to this, if a source contains biased details such as sequential bias, the consumer decision process will be erroneous while using online reviews. Continuously seeing positive or negative rating would impose constraints on processing the information content. As suggested by the researchers, since it is not feasible to eliminate the sequential bias, the firms may present the reviews in random order to overcome the bias (Kapoor & Piramuthu, 2009). Research work on negative word-of-mouth shows that integrity is a significant influencing element than the competence of the review (Yin, Bond, & Zhang, 2010). The authors further suggest that firms should take measures to eliminate the negative word-of-mouth and more positive deeds needed to overcome the negative impact of the reviews. Our study findings of sequential bias is in similar lines with an earlier study on sequential bias presence using a panel from Amazon users (Sikora & Chauhan, 2012).

Research work on topic modelling from online reviews suggests that it is essential to understand the latent structure and factors in the online review system to bring out hidden information (Heng, Gao, Jiang, & Chen, 2018). In this study, we use sentiment scores of the review as a latent variable and prove the presence of sequential bias in the online consumer reviews. Sentiment scores are considered as a robust measure to understand consumer views, and ignoring them might create disadvantageous brand positioning for the firms (Mostafa, 2013). In this study, we proved that sentiment scores and star ratings are not in parallel with each other. If a consumer read the reviews and notices star ratings are diagonally opposite direction, he may lose credibility on the review system itself. Another explanation on the sequential bias is evident from social interaction theory, which suggests that consumers are affected by the online reviews is not only the pre-consumption stage but post-consumption stage as well (Yoon et al., 2019). Thus, there is a need to provide additional computations like sentiment scores, which would eliminate the bias in online consumer evaluations.

Managerial Implications

Research results prove the inadequacy of online reviews in reflecting product quality and, the results are varying for different countries (Koh, Hu, & Clemons, 2010). In this study, we bring out another limitation of online reviews, namely the sequential bias and process of detecting them. In particular, we have proved the presence of sequential bias and, hence, the reviewers are influenced by the earlier reviews, they have seen. In an extreme instance, if a reviewer happens to see continuously negative online reviews, his evaluations will be seriously affected by this bias. The firms may provide reviews in random order or may create a separate panel for critical and most positive reviews as done by Amazon.

Star rating is considered as an alternative mechanism to comprehend message content and a complement for the sentiment analysis (Al-Natour & Turetken, 2020). From our research work, we show the systematic influence of sequential bias on star ratings and prove how a robust measure like the sentiment analysis can overcome the sequential bias in the online reviews. We feel, as value addition in the online review systems, the firms may provide sentiment scores for the product as an additional measure to inform the consumers. This add-on display will create a favourable opinion about the retailers. For instance, Amazon website shows the most critical reviews in a separate panel, which will be a mostly negative opinion about the products. This practice has created a favourable perception of the online review systems itself.

Conclusion

Amazon and Flipkart website use different entry-level criteria to post online reviews on the websites. One must just login to post reviews in Amazon whereas, the user must have bought the brand/product to register the online reviews in the Flipkart. Due to this condition, users have free access and motive to post views in Amazon and, this is not possible in Flipkart. We have chosen 11 products categories from experience goods and, the users register online reviews in Flipkart consistently assigned higher star ratings whereas, significantly lower star ratings are given to the same brands in Amazon website. To strengthen our findings on sequential bias in the Amazon and Flipkart websites, we further prove that the sentiment scores have different distribution pattern in Amazon and Flipkart and there is no consistency between star ratings and sentiment scores.

This research work has theoretical implications on various theories. Dual-process theory suggests that consumers might use peripheral cues such as product ranking or star ratings during the information search stage. However, central information processing like analysing review length or sentiment scores influence the evaluation of alternatives or formation of the choice set (Liu & Park, 2015). The retailers should ensure that peripheral cues [s*uch as star ratings*] and central cues [*review length, sentiment score, negative words*] are consistent with each other. The theory of deception detection suggests that the consumer expertise is a critical component in detecting the deceptive content in the communication (Xiao & Benbasat, 2011). If a consumer senses inconsistency in the information presented in the online reviews, he might develop a negative opinion on the source itself. Signaling theory suggests measures to overcome information asymmetry between the stakeholders in the process (Connelly et al., 2011). Since the sentiment expressed in the online review reflect product evaluations, it may act as a signal to the consumers (Siering, Muntermann, & Rajagopalan, 2018). Since it is not customary to show the sentiment scores in the online review system, the consumers often use star rating as a proxy for sentiments. This situation will lead to disastrous post-purchase evaluations for the product by the consumers since the star rating and reviews are not consistent with each other.

Limitations and Future Research Directions

We have analysed the reviews from Amazon and Flipkart for 11 product categories, consist of 34 brands, commonly sold by both the retailers. However, we have a constraint on the sequence in which the reviews are read. Even though we have proved by analysing the sentiment scores and presence of sequential bias, we unable to incorporate panel data to study the results. The product category creates another limitation. We have learned experience goods and, hence the findings are more suitable for products and brands in the experience goods category rather than search or credence category. Due to website policy restrictions, we could not analyse the data on select demographic variables, which could influence the results significantly.

On replicating this research, work on search and credence goods will add value to the existing literature on online review systems. Health care service websites and product comparison websites are providing specialised services to the consumers and, studies on the reviews will broaden the horizons of online consumer reviews. Comparison of product websites and third party blogs may provide further insights on the sequential bias.

References

Al-Natour, S., & Turetken, O. (2020). A comparative assessment of sentiment analysis and star ratings for consumer reviews. *International Journal of Information Management*, *54*(April), 102132. https://doi.org/10.1016/j.ijinfomgt.2020.102132

Al-Otaibi, S., Alnassar, A., Alshahrani, A., Al-mubarak, A., Albugami, S., Almutiri, N., & Albugami, A. (2018). Customer Satisfaction Measurement using Sentiment Analysis. *International Journal of Advanced Computer Science and Applications*, *9*(2), 106–117.

Anastasiei, B., & Dospinescu, N. (2019). Electronic Word-of-Mouth for Online Retailers : Predictors of Volume and Valence. *Sustainabiliity*, *11*(814), 1–18. https://doi.org/10.3390/su11030814

Antioco, M., & Coussement, K. (2018). Misreading of consumer dissatisfaction in online product reviews : Writing style as a cause for bias. *International Journal of Information Management*, *38*(1), 301–310. https://doi.org/10.1016/j.ijinfomgt.2017.10.009

Askalidis, G., Kim, S. J., & Malthouse, E. C. (2017a). Understanding and overcoming biases in online review systems. *Decision Support Systems*, *97*(December), 23–30. https://doi.org/10.1016/j.dss.2017.03.002

Askalidis, G., Kim, S. J., & Malthouse, E. C. (2017b). Understanding and overcoming biases in online review systems. *Decision Support Systems*, *97*(2016), 23–30. https://doi.org/10.1016/j.dss.2017.03.002

Baek, H., Ahn, J., & Choi, Y. (2012). Helpfulness of Online Consumer Reviews : Readers' Objectives and Review Cues. *International Journal of Electronic Commerce*, *17*(2), 99–126. https://doi.org/10.2753/JEC1086-4415170204

Bali, A., Agarwal, P., Poddar, G., Harsole, D., & Zaman, N. M. (2016). Consumer ' s Sentiment Analysis of Popular Phone Brands and Operating System Preference. *International Journal of Computer Applications*, *155*(4), 15–19.

Chamlertwat, W., Bhattarakosol, P., Rungkasiri, T., & Choochart Haruechaiyasak. (2012). Discovering Consumer Insight from Twitter via Sentiment

Analysis. *Journal of Universal Computer Science*, *18*(8), 973–992.

Chiu, Y. L., Chen, K. H., Wang, J. N., & Hsu, Y. T. (2019). The impact of online movie word-of-mouth on consumer choice: A comparison of American and Chinese consumers. *International Marketing Review*, *36*(6), 996–1025. https://doi.org/10.1108/IMR-06-2018-0190

Chua, A. Y. K., & Banerjee, S. (2016). Helpfulness of user-generated reviews as a function of review sentiment, product type and information quality. *Computers in Human Behavior*, *54*, 547–554. https://doi.org/10.1016/j.chb.2015.08.057

Connelly, B. L., Certo, S. T., Ireland, R. D., & Reutzel, C. R. (2011). Signaling Theory: A Review and Assessment. *Journal of Management*, *37*(1), 39–67. https://doi.org/10.1177/0149206310388419

Cooper, D. R., & Schindler, P. S. (2002). *Business Research Methods.* Tata McGraw-Hill, New Delhi.

Dellarocas, C., & Wood, C. A. (2008). The sound of silence in online feedback: Estimating trading risks in the presence of reporting bias. *Management Science*, *54*(3), 460–476. https://doi.org/10.1287/mnsc.1070.0747

Eryarsoy, E., & Piramuthu, S. (2014). Experimental evaluation of sequential bias in online customer reviews. *Information & Management*, *51*, 964–971. https://doi.org/10.1016/j.im.2014.09.001

Eslami, S. P., Ghasemaghaei, M., & Hassanein, K. (2018). Which online reviews do consumers find most helpful? A multi-method investigation. *Decision Support Systems*, *113*, 32–42. https://doi.org/10.1016/j.dss.2018.06.012

Filieri, R., Raguseo, E., & Vitari, C. (2018). When are extreme ratings more helpful? Empirical evidence on the moderating effects of review characteristics and product type. *Computers in Human Behavior*, *88*(October 2017), 134–142. https://doi.org/10.1016/j.chb.2018.05.042

Gaikar, D., & Marakarkandy, B. (2015). Product Sales Prediction Based on Sentiment Analysis Using Twitter Data. *International Journal of Computer Science and Information Technologies*, *6*(3), 2303–2313.

Godes, D., & Silva, J. C. (2012). Sequential and temporal dynamics of online opinion. *Marketing Science*, *31*(3), 448–473. https://doi.org/10.1287/mksc.1110.0653

Han, S., & Anderson, C. K. (2020). Customer Motivation and Response Bias in Online Reviews. *Cornell Hospitality Quarterly*, 1–12. https://doi.org/10.1177/1938965520902012

Heng, Y., Gao, Z., Jiang, Y., & Chen, X. (2018). Exploring hidden factors behind online food shopping from Amazon reviews : A topic mining approach. *Journal of Retailing and Consumer Services*, *42*, 161–168. https://doi.org/10.1016/j.jretconser.2018.02.006

Howard, D. J. (1992). Gift-Wrapping Effects on Product Attitudes: A Mood-Biasing Explanation. *Journal of Consumer Psychology*, *1*(3), 197–223. https://doi.org/10.1016/S1057-7408(08)80036-8

Ivanova, O., & Scholz, M. (2017). How can online marketplaces reduce rating manipulation? A new approach on dynamic aggregation of online ratings. *Decision Support Systems*, *104*, 64–78. https://doi.org/10.1016/j.dss.2017.10.003

Kapoor, G., & Piramuthu, S. (2009). Sequential bias in online product reviews. *Journal of Organizational Computing and Electronic Commerce*, *19*(2), 85–95. https://doi.org/10.1080/10919390902820764

Kim, R. Y. (2020). When does online review matter to consumers? The effect of product quality information cues. *Electronic Commerce Research*, 1–20. https://doi.org/10.1007/s10660-020-09398-0

Koh, N. S., Hu, N., & Clemons, E. K. (2010). Do online reviews reflect a product ' s true perceived quality ? An investigation of online movie reviews across cultures. *Electronic Commerce Research and Applications*, *9*, 374–385. https://doi.org/10.1016/j.elerap.2010.04.001

Li, K., Chen, Y., & Zhang, L. (2020). Exploring the influence of online reviews and motivating factors on sales: A meta-analytic study and the moderating role of product category. *Journal of Retailing and Consumer Services*, *55*, 1–11. https://doi.org/10.1016/j.jretconser.2020.102107

Liu, Z., & Park, S. (2015). What makes a useful online review? Implication for travel product websites. *Tourism Management*, *47*, 140–151. https://doi.org/10.1016/j.tourman.2014.09.020

Manes, E., & Tchetchik, A. (2018). The role of electronic word of mouth in reducing information asymmetry: An empirical investigation of online hotel booking. *Journal of Business Research*, *85*(January), 185–196. https://doi.org/10.1016/j.jbusres.2017.12.019

Moe, W. W., & Trusov, M. (2011). The Value of Social Dynamics in Online Product Ratings Forums, *XLVIII*(June), 444–456.

Mostafa, M. M. (2013). Expert Systems with Applications More than words : Social networks ' text mining for consumer brand sentiments. *Expert Systems With Applications*, *40*(10), 4241–4251. https://doi.org/10.1016/j.eswa.2013.01.019

Mudambi, S. M., & Schuff, D. (2010). What makes a helpful online review? A study of customer reviews on amazon.com. *MIS Quarterly: Management Information Systems*, *34*(1), 185–200. https://doi.org/10.2307/20721420

Mumuni, A. G., Lancendorfer, K. M., O'Reilly, K. A., & MacMillan, A. (2019). Antecedents of consumers' reliance on online product reviews. *Journal of Research in Interactive Marketing*, 1–22. https://doi.org/10.1108/JRIM-11-2017-0096

Pelsmacker, P. De, Dens, N., & Kolomiiets, A. (2018). The impact of text valence , star rating and rated usefulness in online reviews. *International Journal of Advertising*, 1–21. https://doi.org/10.1080/02650487.2018.1424792

Sen, S., & Lerman, D. (2007). Why are you telling me this? An examination into negative consumer reviews on the web. *Journal of Interactive Marketing*, *21*(4), 76–94. https://doi.org/10.1002/dir

Senecal, S., & Nantel, J. (2004). The influence of online product recommendations on consumers' online choices. *Journal of Retailing*, *80*(2), 159–169. https://doi.org/10.1016/j.jretai.2004.04.001

Septianto, F., Kemper, J. A., & Choi, J. (Jane). (2020). The power of beauty? The interactive effects of awe and online reviews on purchase intentions. *Journal of Retailing and Consumer Services*, *54*(February), 102066. https://doi.org/10.1016/j.jretconser.2020.102066

Siering, M., Muntermann, J., & Rajagopalan, B. (2018). Explaining and predicting online review helpfulness: The role of content and reviewer-related signals. *Decision Support Systems*, *108*, 1–12. https://doi.org/10.1016/j.dss.2018.01.004

Sikora, R. T., & Chauhan, K. (2012). Estimating sequential bias in online reviews : A Kalman filtering approach. *Knowledge-Based Systems*, *27*, 314–321. https://doi.org/10.1016/j.knosys.2011.10.011

Simonin, B. L., & Ruth, J. A. (1998). Is a Company Known by the Company It Keeps ? Assessing the Spillover Effects of Brand Alliances on Consumer Brand Attitudes. *Journal of Marketing Research*, *XXXV*(February), 30–42.

Singh, J. P., Irani, S., Rana, N. P., Dwivedi, Y. K., Saumya, S., & Kumar Roy, P. (2016). Predicting the "helpfulness" of online consumer reviews. *Journal of Business Research*, *70*, 1–10. https://doi.org/10.1016/j.jbusres.2016.08.008

Sturiale, L., & Scuderi, A. (2013). Evaluation of Social Media Actions for the Agrifood System. In *6th International Conference on Information and Communication Technologies in Agriculture, Food and Environment (HAICTA 2013)* (Vol. 8, pp. 200–208). Elsevier B.V. https://doi.org/10.1016/j.protcy.2013.11.028

Tversky, A., & Kahneman, D. (1974). Judgment under Uncertainty : Heuristics and Biases. *Science*, *185*(September), 1124–1131.

Wang, S., Beatty, S. E., & Foxx, W. (2004). Signaling the Trustworthiness of Small Online Retailers. *Journal of Interactive Marketing*, *18*(1), 53–69. https://doi.org/10.1002/dir.10071

Wu, P. F. (2013). In Search of Negativity Bias : An Empirical Study of Perceived Helpfulness of Online Reviews. *Psychology and Marketing*, *30*(11), 971–984. https://doi.org/10.1002/mar

Xiao, B., & Benbasat, I. (2011). Product-Related Deception in E-Commerce : A Theoretical Perspective. *MIS Quarterly*, *35*(1), 169–195.

Yin, D., Bond, S., & Zhang, H. (2010). ARE BAD REVIEWS ALWAYS STRONGER THAN GOOD ? ASYMMETRIC NEGATIVITY BIAS IN THE FORMATION OF ONLINE CONSUMER TRUST. In *Thirty First International Conference on Information Systems, St. Louis 2010* (pp. 1–18).

Yoon, Y., Kim, A. J., Kim, J., & Choi, J. (2019). The effects of eWOM characteristics on consumer ratings: evidence from TripAdvisor.com. *International Journal of Advertising*, *38*(5), 684–703. https://doi.org/10.1080/02650487.2018.1541391

Zhou, M., Liu, M., & Tang, D. (2013). Do the characteristics of online consumer reviews bias buyers ' purchase intention and product perception ? A perspective of review quantity , review quality and negative review sequence. *International Journal of Services Technology and Management*, *19*(4/5/6), 166–186.

Zhu, Y., Liu, M., Zeng, X., & Huang, P. (2020). The effects of prior reviews on perceived review helpfulness: A configuration perspective. *Journal of Business Research*, *110* (July 2018), 484–494. https://doi.org/10.1016/j.jbusres.2020.01.027

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