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Original Article

Fuzzy Tool in Optimizing WIP for Tubular Product of Boiler

C. Hemalatha[1], K. Sankaranarayanasamy[2], N. Durairaaj[3]

[1]*Mechanical Department, National Institute of Technology, Tiruchirappalli, Tamil Nadu, India.*
[2]*National Institute of Technology, Puducherry, Tamil Nadu, India.*
[3]*Boiler Production, Bharat Heavy Electricals Limited, Tiruchirappalli, Tamil Nadu, India*

[1]*Corresponding Author : hemalatha@bhel.in*

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Abstract - *In this dynamic and digital world, the business scenario is changing at each and every moment. It is vital to maintain the optimum work-in-process inventory in the production flow of any manufacturing company. Hence a study on production process flow has been made with the Fuzzy concept, where the aim is to determine the factors affecting the Work-In-Process (WIP) inventory levels to meet the required demand for each product. The deciding parameters are identified, and their effects are analyzed. The analysis is focused on the root cause of the problem, fundamental problems associated with the systems in boiler components manufacturing. This paper deals with the activities in the manufacturing process of a particular tubular component in a boiler. The basic resources like man, machine and material required for the tubular product manufacturing process and time to maintain the load in the buffer to maintain the optimum stock are also analyzed. Manpower required to maintain the optimum WIP while loading material to the machine is studied. Balanced manpower distribution and distribution of loads suitably for efficient execution will reduce the unwanted storage of inventory. With the support of the Fuzzy concept, the operations load balancing may be arrived at.*

Keywords - *Lead time, Operation planning and control, Optimization, Tubular product, Work in process*.

1. Introduction

Materials management in a manufacturing organization is concerned with functions, starting from the purchase of materials to the dispatch of finished goods. The material directly affects the fundamental economic objective of any manufacturing organization. Since the major portion of the turnover is based on materials, effective planning and management is the basic requirement for the profitability of the organization.

The flow of materials on the shop floor is planned according to instructions of the production management to maintain the internal control of line items to maintain the inventory, which includes Work in Process and schedule of shipping of the finished product. Maintaining optimum inventory involves intelligent planning of production. Inventory is an integral part of every action in the material flow cycle. [23,26-30] Work in process, being a part of the inventory, plays a vital role in the material flow in the process cycle.

The literature review has been made to acquire knowledge about the work in the process of maintaining lean manufacturing. [1-6] The practical methodologies in the organization are studied and analysed for the optimum solution to have minimum inventory in buffer stock. Various methodologies of AI techniques are reviewed in the literature. [7-13] From the collected information, it was observed that the possibility of the following solutions like Improved energy productivity, supply Chain Management coordination, Global quality management/improvement, and Business Continuity Plan support. The limitation of conventional optimization at production sites, and improvement of each site, and the effectiveness of such improvements were studied. [39]

It was observed that the agility and implementation of agility involve radically new concepts concerning strategies, organization, people and technologies. [40-43] It takes businesses into a domain where fundamental assumptions are challenged. In order to develop a production plan reflecting the changing delivered product volume, production volume and inventory volume, a production inventory management method was suggested that would accordingly adjust production plans to each period and optimally guarantee delivery deadlines. An analytical framework for studying the effects on the design of assembly lines in the production system was reviewed. [44].

The profitability of a line can be improved by appropriately grouping the activities into workstations. Also, it was described to efficiently solve the problems of analysis and assessment of the state space of ontologies that are developing and determine and eliminate the properties of inadequacy using fuzzy logic. In line with the analysis of material flow, the suitability of the concept of Fuzzy logic is also studied; the structure of fuzzy logic, comparison with Boolean operators and the truth table formation are studied. [25,32-38]

The major objectives of materials management are material cost reduction and production cost reduction. Material cost reduction involves purchasing goods of the right quality, in the right quantity at the right time, from the right source, on the right terms and conditions and at a comparatively low cost. Production cost reduction may be achieved by properly planning the production sequence, uniform flow of materials, maintaining the optimum inventory, maintaining the continuity of production, and balancing load distribution of resources.

To have a strategic framework to eliminate delays and to improve the product flow in the shop involves creativity, specialized skills, and effective deployment of organizational resources. In order to maintain an effective supply chain management(SCM), the major factors are cycle time reduction and maintaining optimum inventory. Cycle time reduction is influenced by redesign, rework, machine failures, non-moving or slow-moving buffer stock, improper planning and lack of expertise. [14,17]

The flow of material from one operation to another operation depends on many factors. The non-availability of any of the resources may lead to a stock of partially manufactured items which is termed as Work in Process (WIP) inventory. This study has been performed to optimize the WIP inventory, which involves the cash flow of the organization. Although there are various studies related to the Fuzzy concept and materials, it has been identified that there is no study regarding the application of the Fuzzy tool to maintain WIP in the production of tubular components in the heat transfer area of the boiler product.

This paper aims to determine the optimal Work-In-Process (WIP) inventory levels for operating the system to meet the required demand for each product in the tubular parts of the boiler. The decision variables are required to be identified, analyzed and to be optimized to minimize the total WIP inventory across the tubular parts of boiler components manufacturing. To maintain the optimum inventory of WIP in the production line of Heat transfer coils, it is required to analyze their end-to-end product development and manufacturing processes and recommend a list of opportunities to improve. [21,22,24,31]

The more time-consuming operation is identified from the process sequence of the tubular boiler product to select the critical factors for optimization. The approach to get the optimum value of the required resource to achieve the target is studied by varying the combinations of critical factors.

Artificial Intelligence technique is studied and analyzed for the suitability of the research. [15,16,18,19] Fuzzy system is identified to study the strategic framework of maintaining optimum inventory in buffer stock.

Fuzzy logic is based on the observation that people make decisions based on imprecise and non-numerical information. These models have the capability of recognizing, representing, manipulating, interpreting, and utilizing data and information that are vague and lack certainty. The fuzzy logic works on the levels of possibilities of input to achieve the definite output.

With the concept of Fuzzy logic, the critical factors identified are analysed for various probable ranges and categories are formulated. For various possible Boolean combinations of the input categories of critical factors, the output to maintain the optimum buffer stock is designed based on the fuzzy concept. The critical and time-consuming activity considered is STB (Straight Tube Butt Welding), for which the process sequence details received from the Operation Process control agency of the organization and other relevant inputs are studied.

2. Methodology

In the process of tubular product manufacturing, the tubes are received as raw material for the process. The received tubes will undergo the straightening test and be stored as a stock of tubes in the buffer. The tubes are measured and cut per the length specified in the operation process instructions. The tubes are inspected randomly, and the tubes are built for Straight Tube Butt (STB) welding. Tube handling involves the availability of cranes, crane operators and riggers.

Before the process of STB welding, the tubes will be edge prepared and aligned and undergo prior welding procedures. The prepared tubes are welded in the STB Welding machine per the production requirement. There are various types of STB machines for welding different build-up lengths. The welded joints are inspected in Radiography. In STB welding, the welding of two tubes is performed. Once the welding is over, the joined tubes will be moved to an online Radiography testing center, where the joints will be tested online by image processing techniques. If any defect is found, the joint will be rejected. Otherwise, joined tubes can be moved to the next activity. These defective joints are rejected. This rejection increases production time and production costs. With the availability of experts' knowledge, loading the tubes in the machine will be performed in sequence to maintain the optimum stock in the buffer to eliminate nil stock and avoid overstocking, which is the basic reason for inventory in the shop line. However, due to a shortage of manpower and time, it is required to make the system expertise with AI techniques to find the optimum solution. The fuzzy concept is found to be suitable for analyzing the various categorical conditions to arrive at the solution for the optimum target value to have a balanced stock.

A case study has been carried out to produce heat transfer coils starting from the basic straight tubes from tubular stores. The sequence of activities performed is studied and analyzed. [20] The pre-processing operations, manpower involved in each activity on shift-wise obtained from SAP, activities performed by each manpower in each shift, machines used by manpower and also the shift are analyzed. The system data are studied and tabulated to have various categories of input range. The fuzzy analysis is made to find the optimum value considering the manufacturing feasibility.

The details collected are grouped based on the activities. The variation is found and categorized according to the requirement of each activity. The categorized inputs are tabulated. The fuzzy concept of AI is applied. From the Graphical outputs of Fuzzy logic, the analysis is made to find the area where optimization is required.

3. Development of the FUZZY system

To develop the Fuzzy logic, the major variants identified for WIP are (1) Current buffer stock, (2) Tube handling capacity and (3) Machine output. On various combinations of the inputs, the output required to find the action to perform the optimum value is the Advance loading of the tubes in the machine.

Tubes required for the machining process are stocked in a waterfall rack. The availability of cranes and crane operators decide the tube handling capability. The machines' efficiency and the operators' performance will decide the number of quality joints produced per shift. Based on the above criteria, the time of advance loading of the tubes in the machine may be decided.

The number of tubes in the buffer stock has been studied and discussed with the concerned agencies in the organization. As per the expert opinion, it has been decided to keep the maximum stock value at 250 nos. The values range from 0 to 250, termed as “Universe of Discourse”. The worst case is NIL stock, and it has to be identified, and steps have to be taken in advance to load the tubes in the buffer. The range has been categorised into LOW, MEDIUM and FULL. LOW indicates the range from 0 to 75 nos., and FULL ranges from 150 to 250 nos. In between, the Medium occupies the partial end portion of Low and Part of the prelim of FULL. (Figure 1) Membership value ranges between 0 to 1 and is a truth constant.

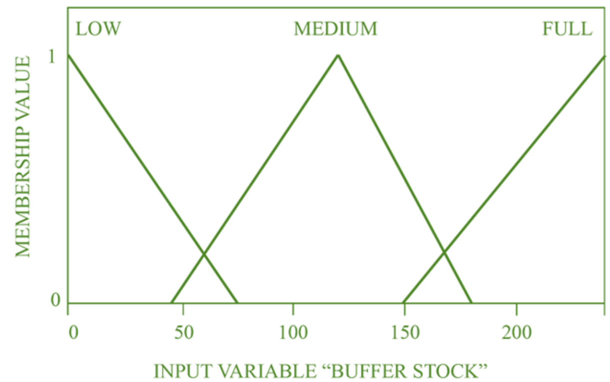

Fig. 1 Buffer stock Vs Membership value

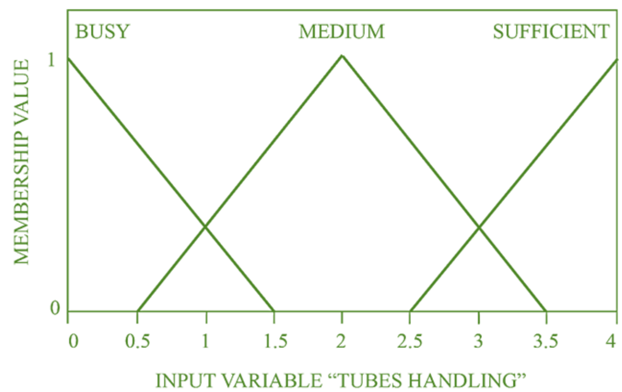

Fig. 2 Tube handling Vs Membership value

The variant “Tube handling” depends on many factors, like the availability of cranes with required handling capacity, experienced crane operators and riggers. The categories of the variants are defined as BUSY, MEDIUM and SUFFICIENT. (Figure 2) BUSY is the non-availability of cranes as well as operators. Sufficient manpower and cranes and riggers to handle the tubes belong to the SUFFICIENT category. MEDIUM represents cranes or operators' availability to complete the task partially.

The variant MACHINE OUTPUT depends on the machine's efficiency, performance and expertise of the machine operator and intelligence to handle the process conditions. If both machine and machine operators perform well, the condition may be categorised as HIGH. (Figure 3) If the effort and effect of the machine are below normal execution, the condition may be termed as LOW. Neither expert nor the lowest belongs to the category MEDIUM. The values are numerically defined to study the system.

3.1. Analysis

With the three criteria as inputs, the Fuzzy logic has analysed a truth table. The outputs have arrived for various combinations of inputs to maintain the optimum stock in buffer stock by advance loading of the tubes.

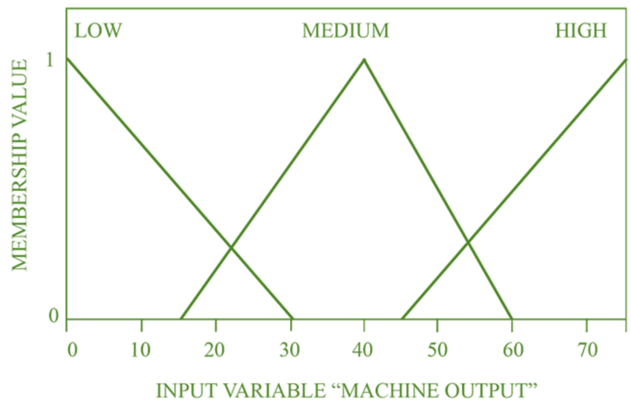

Fig. 3 Machine output Vs Membership value

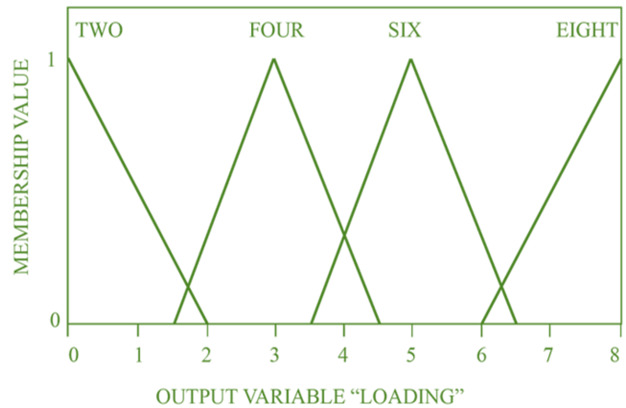

Fig. 4 Loading Vs Membership value

Table 1. Truth table

Current stock	Tube handling	Machine output	Advance loading
FULL	SUFFICIENT	HIGH	6
MED	SUFFICIENT	HIGH	4
LOW	SUFFICIENT	HIGH	4
FULL	MEDIUM	HIGH	4
MED	MEDIUM	HIGH	2
LOW	MEDIUM	HIGH	2
FULL	BUSY	HIGH	4
MED	BUSY	HIGH	4
LOW	BUSY	HIGH	2
FULL	SUFFICIENT	MEDIUM	8
MED	SUFFICIENT	MEDIUM	6
LOW	SUFFICIENT	MEDIUM	6
FULL	MEDIUM	MEDIUM	6
MED	MEDIUM	MEDIUM	4
LOW	MEDIUM	MEDIUM	4
FULL	BUSY	MEDIUM	6
MED	BUSY	MEDIUM	4
LOW	BUSY	MEDIUM	2
FULL	SUFFICIENT	LOW	8
MED	SUFFICIENT	LOW	8
LOW	SUFFICIENT	LOW	4
FULL	MEDIUM	LOW	6
MED	MEDIUM	LOW	6
LOW	MEDIUM	LOW	4
FULL	BUSY	LOW	8
MED	BUSY	LOW	6
LOW	BUSY	LOW	4

Considering a case with FULL current stock, sufficient capacity of tube handling and maximum Machine output, the tube may be required to be loaded 6 hours in advance, whereas in a case with LOW current stock, Busy status of cranes and operators in tube handling and with low Machine output the tube may be required to be loaded 4 hours. in advance.

Comparatively, if the machine output is LOW, frequent tube loading is not required.

The range of advanced tube loading is designed from 2 to 8, and the variations are shown in the visual. (Figure 4)

Further analyzing the Truth table (Table 1), it is found that if the full stock is available, the advance loading duration of the tubes ranges from 4 to 8 hrs. For low current stock, the loading of tubes advances from 2 – 6 hours. Also, it is observed that during low and medium stock levels, the advance loading in the range of 2 to 4 hours. is found as an optimum condition.

While analyzing based on the tube handling, during busy conditions, advance loading duration ranges from 2 to 8 hours in medium handling, and advance loading duration ranges from 2 to 6 hours. Whereas at a sufficient level, it varies from 4 to 8 hours. Also, during busy and medium states, the time duration of advance loading between the range of 2 to 4 hours. is found as optimum.

Considering the machine output as a basic variant, during high output of the machine, advance loading duration ranges from 2 to 6 hours. At low machine output, advance loading duration ranges from 4 to 8 hours. If machine output is medium, loading in advance of 2 to 8 hours. Also, while analyzing high machine output, the advance loading is between 2 to 4 hours.

4. Results and Discussions

The results obtained based on the truth table are visually displayed. The analysis is with multiple inputs and a single output system. The inputs are processed using the rule base to determine the output value of advanced loading of the tubes.

The input-output relationship of buffer stock and loading (Figure 4. a), tube handling and tube loading (Figure 4. b), and machine output and loading of the tube (Figure 4. c) are shown.

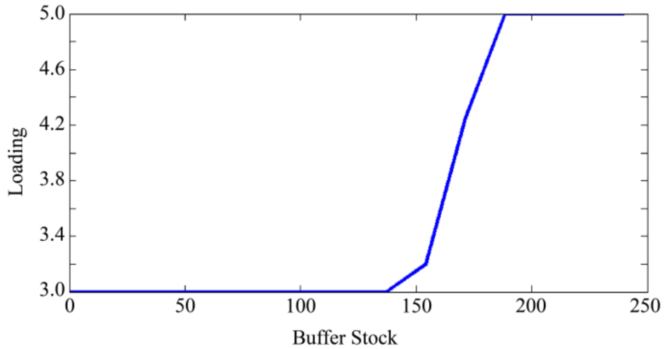

Fig. 4(a) Buffer stock Vs Loading

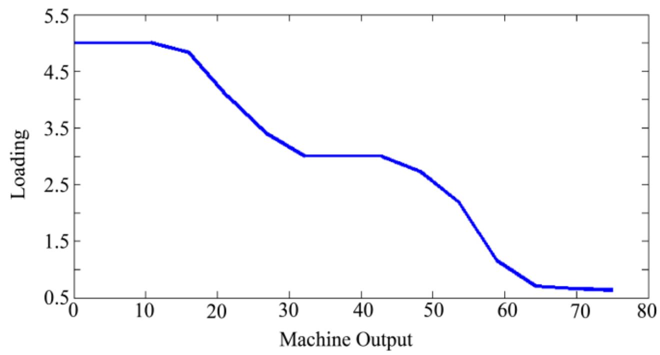

Fig. 4(b) Machine output Vs Loading

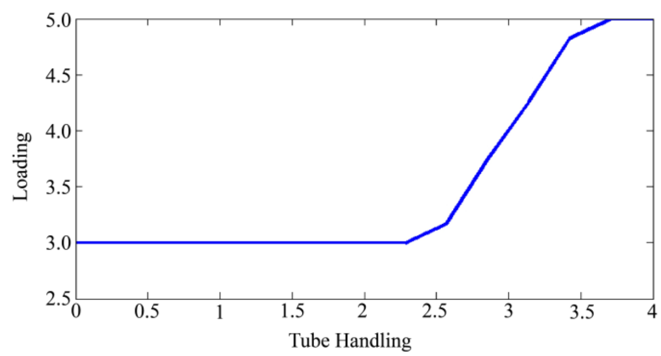

Fig. 4(c) Tube handling Vs Loading

From Figure 4. a, it is clear that during low and medium buffer stock levels, the loading of the tubes is maintained 3 hours in advance. From Figure 4. b, it is found that during the medium level of machine output, the tubes' loading is maintained 3 hours in advance. From Figure 4. c, it is observed that during the busy and medium levels of tube handling, the loading of the tubes is maintained 3 hours in advance.

The response surface of the input-output relations of buffer stock, tube handling, machine output and tube loading are shown in Figure 5. a, Figure 5. b, Figure 5. C.

While comparing the two-phase data analysis from Figure 5. a, it is clear that during the medium level of machine output and medium level of tube handling, the advance loading of the tubes is maintained at 3 hours. From Figure 5. b, it is found that during the medium level of buffer stock and a medium level of machine output, the loading of the tubes is maintained at 3 hours in advance. From the Figure 5. c, it is observed that during the medium level of tube handling and a medium level of buffer stock, the advance loading of the tubes is maintained at 3 hours.

Figure 6 shows the way how the proposed system will respond to different working conditions; for instance, while considering the stock value of 120, tube handling as 2 and machine output as 37.5, the tubes may be required to be loaded in advance of 3 hours to maintain the optimum stock.

The defuzzified output variables are processed to determine the advance loading of the tubes. Thus the simulation results prove that the proposed fuzzy system is capable of generating reliable and optimum inventory in the buffer stock.

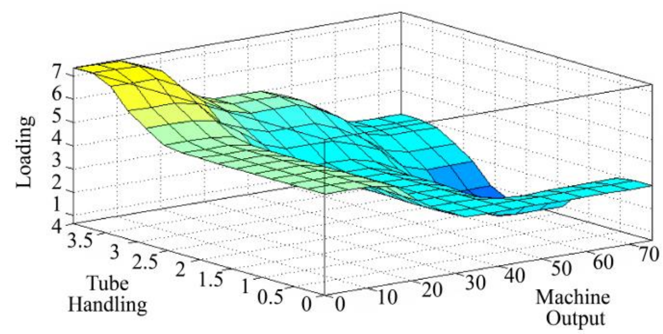

Fig. 5(a) Tube handling Vs Machine output Vs Loading

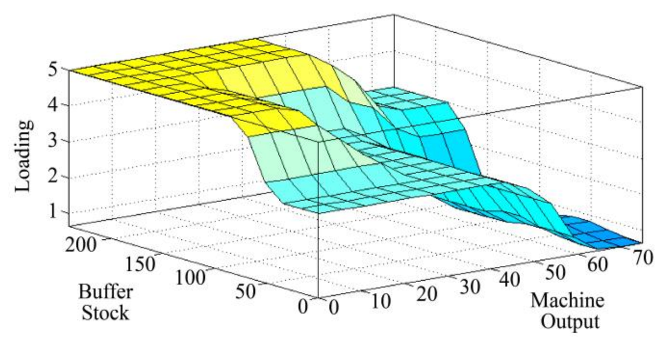

Fig. 5(b) Buffer stock Vs Machine output Vs Loading

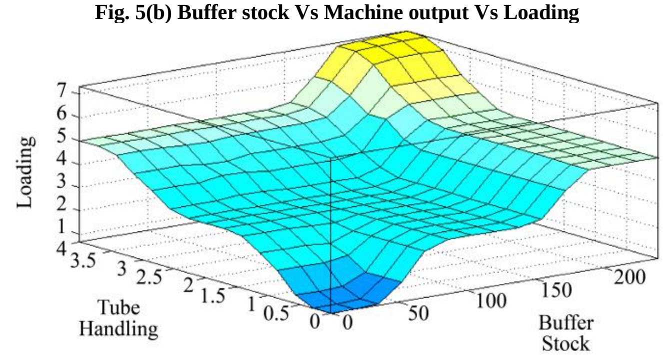

Fig. 5(c) Tube handling Vs Buffer stock Vs Loading

Fig. 6 System response to various working conditions

The current investigation pertains to optimizing the work process in the selected production operation. This analysis indicates the advanced loading of the tube in the machine to maintain the optimum number of tubes in the buffer stock to have a uniform flow of tubes in the STB machines. While comparing the buffer stock, tube handling and machine output, the tube handling plays a major role in reducing the cycle time so as to have the optimum WIP.

This analysis is focused on the critical factors affecting heat transfer coil manufacturing in the boiler production industry. The optimization of stock, tube handling and machine performance will support maintaining the uniform flow of tubes in the shop line process.

5. Conclusion

This study shows that better load distribution along the shop line is critical to concentrate more. Also, optimization can be done by maintaining suitable buffer stock, efficient tube handling process with available cranes with operators and better machine performance with operators' expertise. In particular, to maintain the above criteria, it is required to load the buffer in advance with minimum and maximum variations. The case study's findings are suitably systemised to reduce the time consumption wherein the more WIP in the process sequence. The tube handling operation requires further analysis for the simplification to standardize or automate to reduce the number of working days /manpower, which has a considerable effect on process lead time, reducing the WIP inventory in the former and subsequent operations. A similar study may be performed for the other type of heat transfer coils.

Conflicts of Interest

Declaration by Authors

We confirm that we agree to the contents of the ethical guidelines of the author. We confirm that we do not have any conflicts of interest.

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The research and publication of their article are Academic.

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