International Journal of Scientific Research and Management Studies (IJSRMS)
ISSN: 23493771 Volume 1 Issue 12, pg: 396-406

RESOURCE BALANCING FOR MANUFACTURING OF CYLINDER LINERS USING CELLULAR PRODUCTION SYSTEM

[1]Manisha Baswaraj Yellale, [2]S.R.Jadhav, [3]S. S. Gawade, [4]B. R. Jadhav, [5]Swapnil S.Kulkarni
[1]M.E. Mechanical Production - Pursuing, Rajarambapu Institute of Technology, Rajaramnagar, Sakharale, India
[2]Dept.of Mechanical Engineering, KBP College of Engineering & Polytechnic, Satara, India
[3]Head, Rajarambapu Institute of Technology, Rajaramnagar, Sakharale, India
[4]P.G.Co-ordinator, Rajarambapu Institute of Technology, Rajaramnagar, Sakharale, India
[5]Director, Ethika Engineering Solutions India Pvt. Ltd., Pune, India

ABSTRACT

This work aims to review the methods for realizing higher productivity through tools and techniques as well as the process flow in the production shop. The Liner Manufacturing Process is the focus for this work. Cellular layout is discussed with its advantages as also the use of expandable Mandrels on CNC Machines and the use of Automated Crane for routine operations. The problem is analyzed with treatment given using Mathematical model named Ranked Positional Weight. This paper also deals with the layout and location for the physical facilities at the shop floor. Recommendation is made for realizing Resource Balancing while enhancing the utilization of these resources.

KEYWORDS: *Resource Balancing, RPW, Group Technology, Cellular Production System*

I. INTRODUCTION

Machining transfer lines dedicated to the mass production of a unique product or a family of similar products is widely used in mechanical industry. Designing such lines is a very complex problem due to necessity to take into account the manufacturing and design constraints at early design stage. At the same time, the manufacturers must provide their customers with the results of the preliminary design (a general line configuration and an estimation of its price) as quickly as possible. Moreover, the designers have to be able to respond interactively to all part modifications that the customer may provide them with even if the line design is already started. Therefore, the designers need the optimization computer-aided approaches to support the line design stage. Since transfer lines can be configurated differently, for example they can be equipped with machining centers with tools changers or with special transfer machines with multi-spindle heads, adequate mathematical models and efficient methods adapted to each concrete type of line are needed.

Nowadays companies around the world are producing high quality products to sell them at the lowest price possible. This is not because they don't want to earn more money through the sale of products. It is because they are facing the necessity of increasing their participation in the market because competitors also are selling products with high quality at the lowest price possible. There are several techniques to continuously improve quality and reduce operation costs. One of these techniques is called Line Balancing. The line balance problem consists on assigning approximately the same amount of workload to each workstation (worker) in a transfer line.

II. PRESENT THEORIES AND PRACTICES

Following is a list of researchers who has worked in area of resources balancing for manufacturing of cylinder liners using cellular production system.

M. Kuroda, T. Tomita has presented [1] a cellular-line production system consists of multiple flow shops which are individual sets composed of functionally different facilities. The cellular-line production system is carefully designed and controlled so as to group facilities that perform similar operations and balance the workload among facilities considering the planned product mix and its variations. Thus, a drastic reduction in production lead time is possible as long as all of the facilities composing cellular-lines in the system are reliable. The present paper deals with a design problem of the cellular-line production system which includes unreliable facilities. We assume that the times to failure and times to repair are exponentially distributed and that the latter is not lengthy, that is, that the times to repair are at most several times the cycle time, which is the input interval for the cellular-lines. A methodology for designing the system in a machine-failure environment is presented and the results of numerical experiments and simulation are shown to verify the usefulness of the proposed methodology. Finally, the practical significance of quantitative analysis and evaluation in the stochastic design problem is discussed.

Gerald R. Aase, John R. Olson, Marc J. Schniederjans have presented [2] The decision to move straight-line assembly systems to U-shaped assembly lines systems constitutes a major layout design change and investment for assembly operations. Proponents of the lean manufacturing and just-in-time philosophies assert that U-shaped assembly systems offer several benefits over traditional straight-line layouts including an improvement in labor productivity. This premise often serves as the fundamental reason why firms consider transforming their assembly systems from traditional straight-lines to U-shaped layouts. Surprisingly, little empirical or experimental data supports this assertion. The purpose of this research is to empirically confirm that U-shaped assembly lines improve labour productivity. Results indicate that labour productivity will improve significantly under certain conditions when switching from a straight-line layout to a U-shaped layout but not in all cases. The research also reveals some limitations of such a layout change when factors such as the number of tasks and cycle times are varied.

Steve Ah kioon, AkifAsilBulgak, TolgaBektas, have presented [3] this paper presents and analyzes a comprehensive model for the design of cellular manufacturing systems (CMS). A recurring theme in research is a piecemeal approach when formulating CMS models. In this paper, the proposed model, to the best of the authors' knowledge, is the most comprehensive one to date with a more integrated approach to CMS design, where production planning and system

Reconfiguration decisions are incorporated. Such a CMS model has not been proposed before and it features the presence of alternate process routings, operation sequence, duplicate machines, machine capacity and lot splitting. The developed model is a mixed integer non-linear program. Linearization procedures are proposed to convert it into a linearized mixed integer programming formulation. Computational results are presented by solving some numerical examples, extracted from the existing literature, with the linear zed formulation.

KursadAgpak, HadiGokcen, have presented [4] in this paper, a new approach on traditional assembly line balancing problem is presented. The goal of proposed approach is to establish balance of the assembly line with minimum number of station and resources. For this purpose, 0–1 integer-programming models are developed. These models are solved using GAMS-CPLEX mathematical programming software for a numerical example.

NimaSafaei, Reza Tavakkoli-Moghaddam have presented [5] In this paper, an integrated mathematical model of the multi-period cell formation and production planning in a dynamic cellular manufacturing system (DCMS) is proposed with the aim of minimizing machine, inter/intra-cell movement, reconfiguration, partial subcontracting, and inventory carrying costs. This paper puts emphasis on the effect of the trade-off between production and outsourcing costs on the re-configuration of the cells in cellular manufacturing systems (CMSs) under a dynamic environment, in which the product mix is different from a period to another resulting in the operational dynamism in the cells. The proposed model is verified by a number of numerical examples and related sensitivity analysis.

SurjitAngra, Rakesh Sehgal, Z. SamsudeenNoori, have presented [6] A cellular manufacturing system is an application of group technology principles to production. This involves processing groups of similar components in a dedicated cluster of dissimilar machines. In this paper, an approach that forms the cluster based on the processing time is suggested. For even distribution of workload, workload balancing is carried out in the second phase of the model, i.e., a time-based model. The time-based model is compared with the workload-based model using a commonality score. The performance of the time-based model is compared by means of workload deviation and deviation index. The validity of the approach is tested by application to the problems from the literature and the results are presented. The results indicate that the time-based model gives better even distribution of workload as compared to the workload-based model.

IrajMahdavi, B. Mahadevan have presented [7] Cell formation problem in CMS design has received the attention of researchers for more than three decades. However, use of sequence data for cell formation has been a least researched area. Sequence data provides valuable information about the flow patterns of various jobs in a manufacturing system. Therefore, it is only natural to expect that use of sequence data must result in not only identifying the part families and machine groups but also the layout (sequence) of the machines within each cell. Unfortunately, such an approach has not been taken in the past while solving CMS design problem using sequence data. In this paper, we fill this gap in the literature by developing an algorithm that not only identifies the cells but also the sequence of machines in the cells in a simultaneous fashion. The numerical computations of the algorithm with the available problems in the literature indicate the usefulness of the algorithm. Further, it also points to the untapped potential of such an approach to solve CMS design and layout problem using sequence data.

Satya S. Chakravorty, Douglas N. Hales [8] Using an implementation experience, Hyer et al. [J. Operat. Manage. 17 (1999) 179] developed a model for implementing cell design consisting of strategic, structural, and operational decisions. While their model was applicable in explaining the implementation experience, it failed to include an analysis of the existing system, operator assignment to cells, and management involvement in the implementation process. In complement, our case study examined the model using an implementation experience in a millwork manufacturing operation. We describe how analysis of the existing system and the assignment of operators to cells were performed. We also find that management played an important role in the implementation process.

Viviana I. Cesaný, Harold J. Steudelb have presented [9] the objective of this research is to study labor flexibility in cellular manufacturing systems characterized by intra-cell operator's mobility. The special focus of the investigation is to explore the impact that using different labor allocation strategies have on system performance. This internal aspect of labor flexibility is referred to as labor assignment flexibility. Labor strategies are classified according to the type of machine-operator assignments including dedicated (when only one operator is responsible for a machine or group or machines), shared (when more than one operator is responsible for a machine or a group of machines) or combined assignments (when the operator has both dedicated and shared machine assignments). This work proposes a classification scheme and a framework that is composed by a set of propositions that evolved from an empirical study and includes the concepts of workload balancing, workload sharing, and the presence of bottleneck operations. The suitability of the framework is tested using simulation modeling in an actual cell implementation. The experimental results based on labor strategies using two and three operators show that the balance in the workload assigned to the individual operators and the level of shared workload are significant factors in determining the performance of the system.

Cristo balMiralles, Jose Pedro Garcý a-Sabater, Carlos Andre, Manuel Cardos have presented [10] Current practices for the treatment of the physically and/or mentally handicapped prescribe meaningful job activity as a means towards both a more fulfilling life and societal integration. In many countries, these practices have facilitated the development of many Sheltered Work Centres for Disabled. In the case study presented, a reengineering process is done starting from individual workplaces where only certain workers were capable of assembling the entire product, and finishing with an assembly line implementation. It is revealed how the traditional division of work in single tasks, typical in assembly lines, becomes a perfect tool for making certain worker disabilities

invisible, providing new jobs for disabled people; always taking into account certain special constraints that are analyzed.
N. M. Karim, H. M. EmrulKays, A. K. M. N. Amin and M. H. Hasan have presented [11] To sustain in business under the current global situation of fierce competition a company needs to reduce or eliminate the idle and/or down time of operations in addition to improvement of the current working methods. In this case study, the problems and challenges of an auto company engaged in assembling car rear window assembly are attributable to non-optimal operations with inefficient capacity planning. The whole assembly line suffers due to the absence of established standard time for activities carried out by operators, the non-value added activities involved and the inefficient methods such as manual screwing, unplanned aisle and walking distance, material wastages and imbalance in the material flow. This study is conducted through application of Maynard Operation Sequence Technique (MOST) in the rear window assembly section to capture the workflow activities using systematic and descriptive workflow data block for the value adding, value engineering and methods engineering analysis. Subsequently, new methods and work standards are developed in advance for capacity planning, workplace layout design and manning analysis. Thus through the process redesign and process flow analysis, material handling and workflow are improved. Consequently, it has been possible to reduce the production cycle time to cater the higher level of demand with shorter takt time maintaining the current level of manpower.
DalgobindMahto, Anjani Kumar have presented [12] the concept of mass production essentially involves the assembly of identical or interchangeable parts of components into the final product at different stages and workstations. The relative advantages and disadvantages of mass or flow production are a matter of concern for any mass production industry. How to design an assembly line starting from the work breakdown structure to the final grouping of tasks at work stations has been discussed in this paper using two commonly used procedures namely the Kilbridge-Wester Heuristic approach and the Helgeson-Birnie Approach. Line Balancing (LB) is a classic, well-researched Operations Research (OR) optimization problem of significant industrial importance. The specific objectives of this paper is to optimize crew size, system utilization, the probability of jobs being completed within a certain time frame and system design costs. These objectives are addressed simultaneously, and the results obtained are compared with those of single-objective approaches.
Abdolreza Roshani, Arezoo Roshanihave presented [13] a multi-manned assembly line is a type of production line that tasks are performed in multi-manned workstations where groups of workers simultaneously perform different tasks on the same individual product. In this paper, multi-manned assembly line balancing problem with the objective of minimizing the cycle time for a pre-defined number of multi-manned workstations is addressed. This kind of multi-manned assembly line balancing problem generally occurs when the organization wants to produce the optimum number of items using a fixed number of multi-manned workstations without adding new ones. The problem is well known as NP (nondeterministic polynomial-time)-hard. Thus, a meta-heuristic approach based on ant colony optimization algorithm is developed to solve the problem. Through computational experiments, the performance of the proposed algorithm is examined. The experimental results validate the effectiveness and efficiency of the proposed algorithms.
Hsiu-Hsueh Kao, Din-HorngYeh and Yi-Hsien Wang have presented [14] study a resource constrained assembly line balancing problem (RCALBP) presented by Ağpak and Gökçen, who developed a 0-1 integer programming model to find the optimal solution. However, this model is inefficient in solving large-scale problems. In this paper, we propose a simple efficient heuristic that is based on the widely-used ranked positional weight (RPW) rule. The example given by Ağpak and Gökçen is used for illustration, and numerical results of sample problems selected from the literature are given to show the effectiveness of the proposed heuristic.

III. METHODOLOGY FOR DESIGNING CELLULAR-LINE SYSTEMS IN UNRELIABLE CIRCUMSTANCES

3.1. Overall procedure for designing systems

As we know the most important manufacturing development, which led to progressive flow is the concept to interchangeable parts and the concept of the division of labour. These permit the progressive flow of the product, as it is transported past relatively fixed flow stations, by a material handling device such as a crane. The work elements, which have been established through the division of labor principal, are assigned to the work stations so that all stations have nearly an equal amount of work to do. Each worker, at his station, is assigned certain of the work elements. The worker performs them repeatedly on each production unit as it passes the station.

The flow line balancing problem is generally one of minimizing the total amount of idle time or equivalently minimizing the number of operators to do a given amount of work at a given flow line speed. This is also known as minimizing the balance delay. 'Balance delay' is defined as the amount of idle time for the entire flow line as a fraction of the total working time resulting from unequal task time assigned to the various work stations.

3.2 Grouping of Tasks for Work Stations and efficiency Criteria

Depending on the desired production rate of the line, the cycle time (CT) or the time between the completions of the two successive flow can be determined.

The individual work elements or task are then grouped into work stations such that

a) The station time (ST), which is the sum of the times of work elements performed at that stations and should not exceed the cycle time, CT.

b) The precedence restrictions implied by the precedence diagram are not violated.

There are many possible ways to group these tasks keeping the above restrictions in mind and we often use criteria like line efficiency, balance delay and smoothness index to measure how good or bad a particular grouping is. These criteria are explained below:

3.2.1 Line efficiency (LE): this is the ratio of total station time to the product of the cycle time and the number of the work stations. We can express this as

$$LE = \frac{\sum_{i=1}^{k} STi}{(K)(CT)} \times 100\%$$

Where

S Ti = station time of station i

K = total number of work stations

CT = cycle time

3.2.2 Balance delay (BD): This is a measure of the line efficiency and is the total idle time of all stations as a percentage of total available working time of all stations. Thus

$$B\,D = \frac{(K)(CT) - \sum_{i=1}^{k} STi}{(K)(CT)} \times 100\%$$

Balance delay is thus (100-LE) as a percentage.

3.2.3 Smoothness index (SI): this is an index to indicate the relative smoothness of a given flow line balance. A smoothness index of 0 indicates a perfect balance. This can be expressed as:

$$SI = \sqrt{\sum_{i=1}^{K} (STmax - STi)}$$

Where S Tmax = maximum station time

S Ti = station time of station i

K = total number of work stations.

It may be noted that in designing an flow line the number of work stations, K can not exceed the total number of work elements, N (in fact K is an integer such that $1 \leq K \leq N$). Also the cycle time is greater than or equal to the maximum time of any work element and less than the total of all work element times, that is

$$Tmax \leq CT \leq \sum_{i=1}^{N} Ti$$

Where

Ti is the time for the work element i

N is the total total number of work elements

Tmax is the maximum work element time

CT is the cycle time

In this dissertation work it is proposed to carry out resource balancing for manufacturing of cylinder liners using cellular production system.

IV. FLOWCHART FOR AN DLW LINER MANUFACTURING PROCESS

A process flow chart is an instrument that visualizes and analyses the various systems and procedures (e.g. delivery of services, decision-making, funds allocation, accounting and monitoring) within an organization. The flow chart analysis helps to identify the bottlenecks in the different processes within the organization. It identifies unnecessary involvement of people, loopholes in decision making or unnecessary delays in the process. It assists to make the organization more efficient in its operations.
The process flow chart helps to design new processes for the primary process, support processes and supervisory processes, and helps to analyze the bottlenecks in existing. It is very useful to help participants understand the interrelation of the work activities and to realize how the work of one person influences the others.

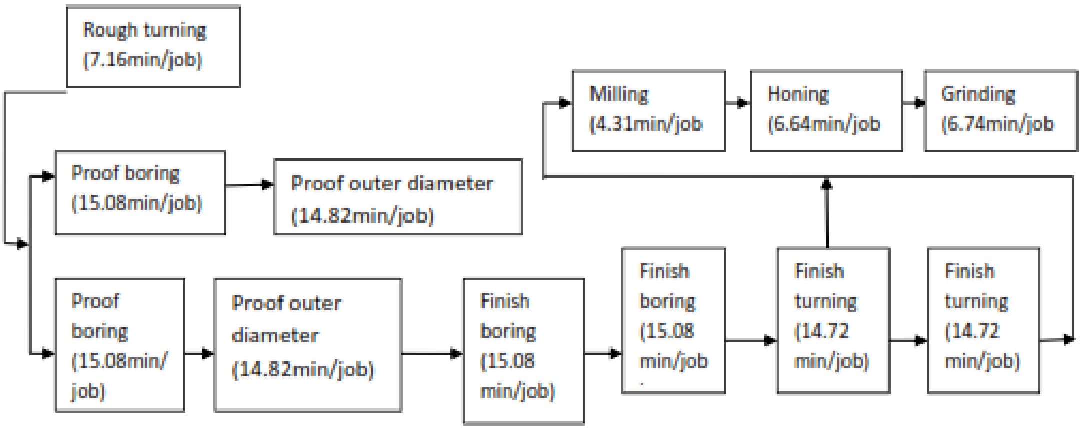

Fig.1 Detailed Process Flow chart

4.2.2 Operational steps

Unlike mass production systems which tend to be organized as product layouts with machines or equipment arranged according to the product flow, batch production normally is done employing a process layout. Here similar machines or equipment are grouped in departments and different jobs will follow their own route depending on requirements. Apart from the greater flexibility afforded by process layout as compared to product layouts. In process layout better utilization of of machine is possible; consequently, fewer machines are required. A high degree of flexibility exists is-a-vis equipment or manpower allocation for specific tasks. Comparatively low investments in machine are needed. There is generally greater job satisfaction for the operator owing to the diversity of job handled. Specialized supervision is possible.
The sequence of operation is as given below:

Table 1: Operational steps

Sr. No.	Operation Description	Target/shift	Cycle time	Available M/C	Man power used
10	Rough turning	56unit/shift	*7.16*	01	01
20	Proof boring	27unit/shift	*15.05*	02	02
30	Proof outer diameter	27unit/shift	*14.75*	02	
40	Finish boring	27unit/shift	*15.02*	02	01
50	Finish turning	25unit/shift	*16.25*	02	02
60	Milling	93unit/shift	*4.2*	01	01
70	Honing	60unit/shift	*6.64*	01	01
80	Grinding	60unit/shift	*6.64*	01	01

V. MATHEMATICAL MODEL

In this paper from above three method we use the following method

5.1 Heuristic: helgeson-birnie (ranked positional weight) method:-

The positional weight of each element is calculated by adding the durations of the other elements that follow the element chosen. After calculating all the elemental positional weights, arrange them in a table according to their rankings, from highest to lowest.
The assigning of task elements to the work stations follows the ranking order.
Following steps are followed:

Step 1:
Draw the precedence diagram.

Step 2:
For each work element, determine the positional weight. It is the total time on the longest path from the beginning of the operation to the last operation of the network.

Step 3: Rank the work elements in descending order of ranked positional weight (R.P.W). Calculation of RPW would be explained in the example to follow.

Step 4:
Assign the work element to a station. Choose the highest RPW element. Then, select the next one. Continue till cycle time is not violated. Follow the precedence constraints also.

Step 5:
Repeat step 5 till all operations are allotted to one station.

Solution

$T_{we} = \sum^{N}_{i=1} T_{iN}$
= Total work content
= 6.20+13.67+13.67+13.65+13.65+13.56+13.56+4.2+6.64+6.64
=132.78
Range of cycle time:
=32.78
Desired cycle time C = 13.67 min

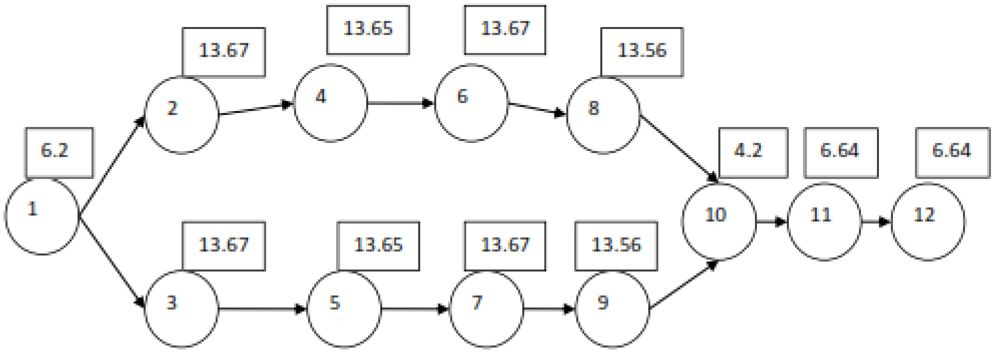

Figure 2 Precedence diagram for layout

Table 2 Minimum Rank Position Weight (RPW) method:

Task	RPW	Idle time
2	13.67	0
3	13.67	0
6	13.67	0
7	13.67	0
4	13.65	0.02
5	13.65	0.02
8	13.56	0.11
9	13.56	0.11
11	6.64	7.03
12	6.64	7.03
1	6.20	7.47
10	4.2	9.47

Now, grouping on the basis of weight:

(a) Balance Delay = $[I = \sum N_{i=1} T_{iN} / nT_c]$ = Total Ideal Time / Cycle Time X No.Of Stations
= (31.67/12×13.67)
=19.05%
(b) Line Efficiency = [1– Balance delay] * 100
= [1 – 0.19] * 100
= 81%
(c) Smoothness Index = $\sqrt{\sum N_{i=1} [(T_s)_{max} - T_{si}]^2}$
= $\sqrt{(13.67 - 13.67)^2 + (13.67 - 13.67)^2 + (13.67 - 13.67)^2 + (13.67 - 13.67)^2 + (13.67 - 13.65)^2 + (13.67 - 13.65)^2 + (13.67 - 13.56)^2 + (13.67 - 13.56)^2 + (13.67 - 6.64)^2 + (13.67 - 6.64)^2 + (13.67 - 6.20)^2 + (13.67 - 4.2)^2}$
= $\sqrt{0 + 14.94 + 0.08 + 0.44 + 18.94 + 28.12}$
= $\sqrt{62.82}$
= 7.90

VI. RESULT AND DISCUSSION

As the cycle time of operation 60 is very small as compared to the other operation so for balancing purpose the cycle time of other operation is reduced and quantity is increased so that line is balanced productivity is increased.

Operation 10 gives an o/p of 55unit/shift is controlled by one operator. Operation 30 is carried out on a computer numerical control (CNC) machining centre. Whilst operation 30 is running through its programmed cycle, the operator carries out operation 20, which has a shorter cycle time. This allows the one operator to run both machines simultaneously. Normally operation 20 is worked within the cycle of operation 30, thus providing the next part for the CNC machining centre to use as soon as its previous part cycle is completed. Two lines of proof boring, proof outer diameter, finish boring & finish turning machines are used for operations 20,30,40 and 50. The 25 cylinder liners are machined on both line borer for operation 20,30,40,50, then return later for operation 60. But the operation 60 gives an output of 90unit/shift. Operation 70 &80 gives an output of 56unit/shift.

By changing the boring bar of operation 40 which is hollow boring bar instead of solid boring bar without changing the insert we can achieve the o/p of 60unit/shift. Increase the speed (RPM) decrease the feed for controlling the accuracy for bore. Hollow boring bar is used to avoid the vibration in the machine,

Table 3; Speed and Feed for fine boring operation

Condition	Speed (RPM)	Feed (mm/min)
Before	148 RPM	50 mm/min
After	192 RPM	40 mm/min

In the operation 10 and 20 by reducing the loading and unloading time by using the automatic crane and robot instead of manual crane we can reduce the cycle time of that operation and increase the number of quantity that will be 60 job per shift.

By using the special type of expandable mandrel on CNC machine on which operation 20 and 60 is performed i.e. proof outer diameter and finish turning we can achieve the output of 30 job per shift per machine.

After using the fully automatic crane on operation 10 and by changing the hollow boring bar instead of solid boring bar on operation 40and by exchanging the mandrel and robot on the operation 20 and 50 the results will be increased.

VII. PLANT LAYOUT AND LOCATION

Plant layout is often a compromise between a numbers of factors such as:

- The need to keep distances for transfer of materials between plant/storage units to a minimum to reduce costs and risks;
- The geographical limitations of the site;

- Interaction with existing or planned facilities on site such as existing roadways, drainage and utilities routings;
- Interaction with other plants on site;
- The need for plant operability and maintainability;
- The need to provide access for emergency services;
- The need to provide emergency escape routes for on-site personnel;
- The need to provide acceptable working conditions for operators.

Taking those factors in to consideration, a preliminary layout of the plant is proposed in Fig 8-1. The main factor considered while making the layout in this specific project is the flow of materials. After passing the raw material quality control point, the material will be temporarily stored in the stock position. Basically there are of raw material, those which require a cutting operation. Therefore the machines are arranged parallel to the hydraulic lathe machine so that they can get the material to be processed with the minimum possible material travel time. It is also proposed to have two temporary finished part stock points because there are also parts which require a machining operation only on a lathe or milling center. The hydraulic lathe machine and CNC machines are located in the center owing to the fact that the material to be processed there comes from the lathe machines then processed to milling to honing to grinding. Then the final part passes through a Quality control point and will go out of the plant via the packaging and Shipment point. Due to lack of the exact dimension of the machineries, this layout was carried out with a random dimension and needs to be revised once those data are known.

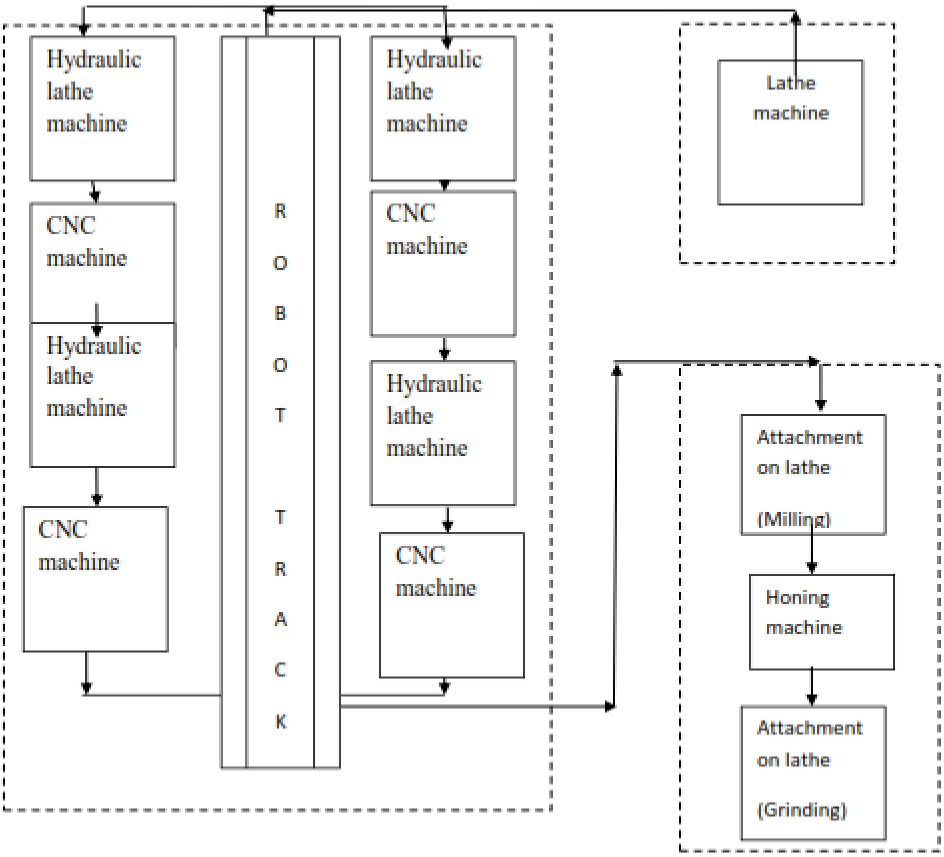

Fig 8-1. The Layout of DLW Cell

VIII. CONCLUSION & FURTHER SCOPE

This paper presents a new approach on traditional line balancing problems. The goal of proposed approach is to establish balance of line with minimum number of stations and resources.

For this purpose, here we used Ranked positional weights method for the analysis of cycle time, line efficiency, balance delay, smoothness index.

This paper provides an effective task assignment that may serve as a starting balance for further improvement. In this paper we studied minimize the cycle time for a given number of workstations & resources.

Also, further scope such as:

1. Minimization of number of the stations for a given number of resources, and
2. Minimization of cycle time for a given number of the stations and resources can be examined, and
3. Some heuristic algorithms can be developed for the large-scale problems.
4. To improve the quality and productivity of the assembled products.
5. To reduce waste of production and delay.
6. To maximize the manpower utilization by minimizing the idle times of the operators.
7. To maintain the morale of workers since the work content of the different workers will not be of great difference.
8. To eliminate bottlenecks, ensuring a smoother flow of production.

REFERENCES

[1]. M. Kuroda, T. Tomita, " Robust design of a cellular-line production system with unreliable facilities" Computers & Industrial Engineering 48 (2005) 537–55

[2]. Gerald R.Aase, John R.Olson, Marc J.Schniederjans, "U-shaped assembly line layouts and their impact on labor productivity: An experimental study" Production, Manufacturing and Logistics

[3]. Steve Ah kioon, AkifAsilBulgak, TolgaBektas, "Integrated cellular manufacturing systems design with production planning and dynamic system reconfiguration" Production, Manufacturing and Logistics

[4]. KursadAgpak, HadiGokcen,"Assembly line balancing: Two resource constrained cases" Int. J. Production Economics 96 (2005) 129–140

[5]. NimaSafaeia, RezaTavakkoli-Moghaddamb "Integrated multi-period cell formation and subcontracting production planning in dynamic cellular manufacturing systems", Int.J.ProductionEconomics

[6]. SurjitAngraa, Rakesh Sehgalb, Z. SamsudeenNooria, " Cellular manufacturing—A time-based analysis to the layout problem" Int. J. Production Economics 112 (2008) 427–438

[7]. IrajMahdavia, B. Mahadevan, " CLASS: An algorithm for cellular manufacturing system and layout design using sequence data" Robotics and Computer-Integrated Manufacturing 24 (2008) 488–497

[8]. Satya S. Chakravorty, Douglas N. Hales, "Implications of cell design implementation: A case study and analysis" European Journal of Operational Research 152 (2004) 602–614

[9]. Viviana I. Cesaný, Harold J. Steudel, " A study of labor assignment flexibility in cellular manufacturing systems" Computers & Industrial Engineering 48 (2005) 571–591

[10]. Cristo balMiralles, Jose Pedro Garcý-Sabater, Carlos Andre, Manuel Cardos "Advantages of assembly lines in Sheltered Work Centres for Disabled. A case study" Int. J. Production Economics 110 (2007) 187–197

[11]. A. N. M. Karim, H. M. EmrulKays, A. K. M. N. Amin and M. H. Hasan "Improvement of Workflow and Productivity through Application of Maynard Operation Sequence Technique(MOST)" Proceedings of the 2014 International Conference on Industrial Engineering and Operations ManagementBali, Indonesia, January 7 – 9, 2014.

[12]. By DalgobindMahto, Anjani Kumar "An Empirical Investigation of Assembly Line Balancing Techniques and Optimized Implementation Approach for Efficiency Improvements" Online ISSN: 2249-4596 Print ISSN:0975-5861

[13]. AbdolrezaRoshani, ArezooRoshani "Multi-manned Assembly Line Balancing Problem: Minimizing Cycle Time" Proceedings of the IIE Asian Conference 2012

[14]. Hsiu-Hsueh Kao, Din-HorngYeh and Yi-Hsien Wang "Resource Constrained Assembly Line Balancing Problem Solved with Ranked Positional Weight Rule" Article ID: 1923-7529-2011-05-71-10.

[15]. Assembly Systems and Line Balancing

[16]. MS-5 Management of Machines and Material

Authors Biography

Subhash R. Jadhav Working-as a Professor in Department of Mechanical Engineering in Karmveer Bhaurao Patil College of Engineering & Polytechnic, satara. Teaching Experience-28 years ,B.E.- Walchand college of Engineering, Sangli (1978) ,M.Tech- IIT Madras (1979-1981) Area of Specialization- Machin Design

Manisha Baswaraj Yellale Currently working- as a Assistant Professor in Department of Mechanical Engineering in Yashoda Technical Campus, College of Engineering & Polytechnic, satara.

S.S.Kulkarni Director, Ethika Engineering Solutions (I) Pvt. Ltd., Pune. The Company offers Engineering Services Automotive OEM's and Tier I and Tier II Companies. He is a Graduate in Industrial Engineering with PG in Operations Management. With around 20 years of working experience in the domain of R&D, Product Design and Tool Engineering, he has executed projects in the Automotive, Medical and Lighting Industry. His area of interest is Research and Development in the Engineering Industry as well as the emerging sector of Renewable Energy.