Improvement of Plant Efficiency using Optimization Techniques in a Large Scale Foundry Industry

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Abstract— Facility layout design is a strategic issue and has a significant and lasting impact on the efficiency of a manufacturing system. An ideal facility layout provides the optimum relationship among output floor area and manufacturing process. Facility layout facilitates production process, minimizes material handling time and costs, and allows flexibility of operations makes optimum use of the building, promotes effective utilization of manpower Traditionally, the facility layout problem is solved using many methods like heuristics, mathematical programming, knowledge based approaches etc. This paper presents a case study for improvement in layout in a casting company. The first visit to the company revealed a variety of problems due to its improper layout. For modifying the present layout of the plant Group technology is used. This work studies the impact of implementing the modified layout based on Group Technology theory in a casting factory in terms of cost and production line efficiency.

Key words: Plant Efficiency, Large Scale Foundry Industry

I. INTRODUCTION

Modem manufacturing industry is facing problems that have been growing in size and complexity over the last several years. As a result, there is an immediate need for procedures or techniques in solving various problems encountered in today's manufacturing arena without extended shutdowns or expensive modifications. Computer simulation is a powerful tool that allows experimentation with various manufacturing techniques and layout without actual implementation-leveled equations, graphics, and tables are not prescribed, although Simulation can be used as a stochastic model to evaluate the randomness of events which exists. Simulation predicts the behaviour of complex manufacturing systems by determining the movement and interactions of system components.

It is capable of aiding in design of the most complex layout and also allows the user to evaluate alternative solutions to examine the flexibility of a design. The project titled "Improving Plant Efficiency Using Optimization Techniques In A Large Scale Foundry Industry" is aimed at identifying some of the major problems regarding the present layout of a public sector large scale foundry industry, and to develop an efficient layout design, so as to improve the production performance of the firm.

II. CASTING PROCESS

Casting is a manufacturing process by which a liquid material is usually poured into a mold, which contains a hollow cavity of the desired shape, and then allowed to solidify. The solidified part is also known as a casting, which is ejected or broken out of the mold to complete the process. Casting materials are usually metals or various cold setting materials that cure after mixing two or more components together.

The study is conducted at ABC Ltd. The major products are Grey Iron and Spheroid Graphite Iron Castings .The unit has an optimum capacity of 18000 tons per annum and covers an area of 21500 square meters. The plant comprises of two distinct production lines via, the conventional moulding line and the high pressure moulding line. The Company can manufacture Ferrous Castings of all grades and sizes ranging from 5kg to 8000kg.

The conventional moulding line is semi automatic system in which large Casting is manufactured, whereas high pressure moulding line is fully automated system in which smaller Casting are manufactured in large quantities. The plant manufactures intricate high precision item of mass production like cylinder block and cylinder heads for the entire range of automotive engines.

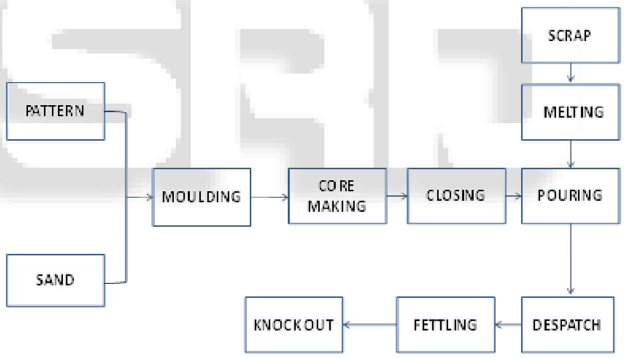

Fig. 1: Process flow diagram in a casting industry

III. LITERATURE SURVEY

A. *Facility Layout Problem*

Facility Layout Problem (FLP) is defined as the physical arrangement of the specified departments or machines in a predefined area. According to Heragu (1992), the machines or the workstations should be placed in such a manner that the material handling distance be reduced between the departments.

According to Immer (1953), 40% of the industries production cost is associated with the cost of material handling or the transportation of materials between the departments .This cost can be reduced using two techniques, fitting and moving facilities. Fitting is the process of allocation of unequal shaped departments into large objects by optimizing the given goals. Moving the facilities involve changing the facility with respect to time to preserve the fitness of the facility.

B. Group Technology

In 1940's classification and coding systems that were widely used in sciences and libraries were yet to find their entry in the manufacturing of products. The situation began to change in late 1940's and in early 1950's fundamental coding systems were created. It was during late 1950's Group Technology enthusiasts started to develop the concept that parts grouped together by common manufacturing attributes could be manufactured in a manner similar to mass production. Their idea was that, creating a large family of similar parts would help the manufacturers to allot groups of machine tools to manufacture the parts, develop common tooling and comfortably reduce setup times.

In simple terms, Group Technology can be defined as grouping of parts with similar operations and machines corresponding to these operations, which makes Group Technology to be recognized as one of the key factors to improve productivity in any manufacturing system. Group Technology has got different definitions such as (Ranson, 1972).

- Identifying and grouping similar or related machines, parts in a production process in order to make use of their similarities by considering the inherent economies of flow production methods.
- Logical arrangement and sequence of all facets of company operation to bring in the benefits of mass production to high variety, mixed quantity production.
- Development of technological processes, efficient setting up of machine tools and equipment planning, so as to ensure the most profitable technical planning of production in the shortest time.

When viewed from a manufacturing perspective, GT can be defined as the decomposition of manufacturing system into various subsystems by categorizing parts into part families and machine into machine cells depending on the similarity of part manufacturing characteristics. The advantage of grouping machines into cells is that it reduces the number of production centers that needs to be scheduled. Also grouping of parts into families reduces the complexity and number of parts for scheduling purposes.

Implementation of GT may result in the following benefits (Hall, 1975),

- 30% reduction in new shop drawings
- 10% reduction in number of drawings
- 42% reduction in raw material stocks
- 53% reduction in new part designs
- 62% reduction in work-in-process inventory
- 82% reduction in overdue orders
- 70% reduction in throughput time
- 60% reduction in industrial engineering time
- 69% reduction in setup time
- 20% reduction in production floor space required

Implementing GT in general will yield benefits in areas such as productivity, effective machine operation, component standardization, and accuracy in cost prediction, reliability of estimates, customer service and sales potential. GT will focus on reducing unnecessary variation intensity by using part family formation scheme and also simplify design and process planning of new products by making use of similarities in part design and manufacturing characteristics. The main aim of classification in any manufacturing environment is to provide an efficient and rapid method of information retrieval for decision making. But still today in most companies, production decisions are solely based on guess work. The need for GT classification can be for the following purposes

- To find the parts for tooling and material families
- To find the optimal components for parts
- To find the optimal scheduling sequence for loading

Part classification is a method by which slightly dissimilar parts are identified and grouped together to take advantage of their basic similarities in manufacture and design. Once the parts have been organized, GT cells can be designed around the part family; with each cell handling one or more part families and all parts in a given family are expected to be more or less identical and able to be processed by a standardized/customized process plan. Some of the recent papers discussed in this review give an idea on different methodology for part family formation by grouping them into several categories of importance

1) Computerized Relative Allocation of facilities Technique

Computerized Relative Allocation of facilities Technique (CRAFT) is used for the reallocation. Craft algorithm is developed by Armour and Buffa. It starts with an initial layout and improves the layout by interchanging the department pair wise so that the transportation cost is minimized. The algorithm continues until no further interchanges are possible to reduce the transportation cost. The essential CRAFT Requirements are

- Initial layout
- Flow data
- Cost per unit distance
- Total number of departments
- Fixed departments, No: of such departments
- Area of departments

Several inputs like distance matrices, cost matrices and flow matrices are used. Area of each department is also required for the designing the new layout.

IV. STUDY OF EXISTING LAYOUT

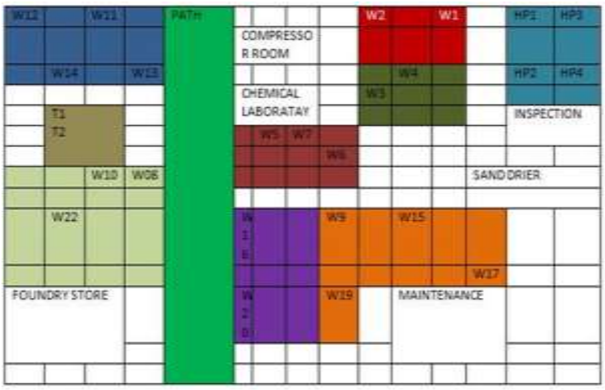

Fig. 2: Existing layout

- W1,W2- Induction furnace
- W3,W4- Core making
- HP- High pressure molding
- W5,W,6W7- Shot Blast
- W9,W15,W17,W19- Machining Centre
- W16,W20- Fettling

- W10 ,W22- Knockout machine
- W11,W12,W13,W14- Molding machine

V. PROBLEM IDENTIFICATION

The facility employs process layout as it caters to wide variety of components .But the layout was not originally designed solely for casting industry. This leads to higher material and man movement times, more in-process inventory and comparatively higher manufacturing lead times.

Also the power consumption due to transportation and working of furnaces were found as the main area of concern. Hence, this area was considered for problem statement as it was felt that group technology could be applied to a group of hardware being realized in the facility to cut down on the larger schedules and cost. It also improves machine utilization of induction furnaces and thereby improves overall plant efficiency.

VI. RESEARCH DESIGN

A. *Introduction*

The research design involves the selection of a suitable tool to address the above identified problem so that the work flow is smoothened. The issues addressed will be rectified by the selection of appropriate tool.

B. *Methodology*

- The existing layout is studied and modeled.
- Then the grouping of similar products and machines has to be performed. For that Production Flow Analysis is done.
- After Production Flow Analysis, the similar hardware and machines identified are arranged into cells for plant layout optimization.
- Rank Oder Clustering Algorithm is used for part family and machine cell formation. Software has been developed for the same . As a result cellular layout is formed.
- The layout is optimized using CRAFT algorithm
- The existing layout and cellular layout are modeled and simulated using ARENA 10.0 simulation software

1) *Assumptions Taken*

- The focus of the study is limited to the three parts which are in continuous production.
- The parts selected are of batch production type
- There is no shortage of raw material
- There is need for minimum repair and maintenance
- There is regular supply of material

VII. PLANT LAYOUT OPTIMIZATION

A. *Rank Order Clustering*

In order to identify the parts or products to be selected PFA Chart is analysed and a product machine incidence matrix is formed and clustering is performed on the PFA matrix to identify groups, and then a product is been selected from each cell to perform optimization and analysis

Work Stations	Products: 4	2	5	8	12	9	15	1	3	7	11	13	10	6	14	16
W13	1	1	1	1	0	1	0	0	0	0	0	0	0	0	0	0
W9	1	1	1	1	0	1	0	0	0	0	0	0	0	0	0	0
W5	1	1	0	0	1	0	1	1	0	0	0	0	0	0	0	0
W10	0	1	0	1	1	1	1	1	0	0	0	0	0	0	0	0
W11	1	0	0	0	1	0	1	1	0	0	0	0	0	0	0	0
W22	0	0	1	0	0	1	0	1	0	0	0	0	0	0	0	0
W2	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0
W1	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1
W12	0	0	0	0	0	0	0	0	1	0	1	0	1	1	0	0
W3	0	0	0	0	0	0	0	1	0	0	0	1	1	0	0	0
W16	0	0	0	0	0	0	0	0	1	1	1	0	1	0	1	0
W7	0	0	0	0	0	0	0	0	1	0	1	0	1	0	0	1
W8	0	0	0	0	0	0	0	0	1	0	1	1	1	1	0	1
W14	0	0	0	0	0	0	0	0	0	1	0	1	0	0	1	1
W19	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0

Fig. 3: Result of ROC Algorithm

B. *Cell Formation*

Using ROC 2 cells have been formed and the resulting Figure is given below.

Cell NO.	Work Centres in Each Cell	Products Processed
1	13,10,9,5,4,2	1,2,4,5,6,7,8,9,11,12,15,19
2	12,1,8,7,16	3,10,13,14,16,17,18,20,21,22,23,24,25

Fig. 4: Cells Formed

Then one product from each cell is selected which are

- Dome (Product 2)
- Brake Disc(Product 10)

These are selected based on their PFA chart and are subjected to simulation for the performance comparison of the layouts

C. *Plant Layout Optimization Using CRAFT*

This algorithm accepts as data: a list of departments, the physical size of departments, material handling cost between departments and the size of the proposed facility. The program tries to find the layout of the departments within the facility that minimizes the total cost of material handling. Here instead of departments work centres are taken for the study

The main objective of CRAFT algorithm is to find out the minimum transportation cost by interchanging of departments.

1) *Optimization for cell 1*

Various inputs to the CRAFT algorithm are given below

Scale-m/unit	1	Cells
Length-m	14	14
Width-m	12	12
Area-Sq.m	168	168

Fig. 5: Facility information for cell 1

Work centre Name	F/V	Area	Cells
W2	F	10.5	11
W4	V	5.25	6
W5	V	5.25	6
W9	V	13.5	14
W10	V	8.4	8
W13	V	6	6

Fig. 6: Work centre information for Cell 1

	TO					
FROM	W2	W4	W5	W9	W10	W13
W2		1		1	1	
W4	1		1	1		1
W5						
W9	1	2				
W10	1					
W13		1	2			

Fig. 7: Flow Matrix for Cell 1

	TO					
FROM	W2	W4	W5	W9	W10	W13
W2	0	1	1	1	1	1
W4	1	0	1	1	1	1
W5	1	1	0	1	1	1
W9	1	1	1	0	1	1
W10	1	1	1	1	0	1
W13	1	1	1	1	1	0

Fig. 8: Cost matrix for Cell 1

Next the facility is well defined. Which is given in Fig 9.

Work centres	Colour	Area Required	Area Defined	x-centroid	y-centroid	Sequence
W2	1	11	11	2.77272725	0.95454544	1
W4	2	6	6	3	2.3333325	2
W5	3	6	6	3	3.3333325	3
W9	4	143	14	3	5	4
W10	5	8.4	8.4	5.64285707	10.4404764	5
W13	6	6	6	9	7.33333349	6

Fig. 9: Facility information for cell 1

The next step is to find out the optimum sequence. The initial layout is given in the figure below

	1	2	3	4	5	6	7	8	9	10	11	12
1	1	1	1	1	1							
2	1	1	1	1	2							
3	2	2	2	2	3							
4	3	3	3	3	4							
5	4	4	4	4	4							
6	4	4	4	4	4							
7	4	5	5	5	5	6						
8	5	5	5	5	5	5	6	6	6	6	6	6
9	5	5	5	5	5	5	5	5	5	5	5	5
10	5	5	5	5	5	5	5	5	5	5	5	5
11	5	5	5	5	5	5	5	5	5	5	5	5
12	5	5	5	5	5	5	5	5	5	5	5	5
13	5	5	5	5	5	5	5	5	5	5	5	5
14	5	5	5	5	5	5	5	5	5	5	5	5

Fig. 10: Initial Layout of Cell 1

The optimum sequence method starts with an arbitrary initial solution and tries to improve the layout by switching two departments in the sequence. At each step the method computes the cost changes for all the possible switches and selects the most effective pair. The process stops when no switch results in reduced cost. The Optimum facility information and modified cell layout is shown below

Department	Colour	Area Required	Area Defined	x-centroid	y-centroid	Sequence
W2	1	11	11	9.13636398	8.77272701	1
W4	2	6	6	9	10.166667	2
W5	3	6	6	3	0.5	3
W9	4	143	14	8.71428585	11.785714	4
W10	5	8.4	8.4	3.42857146	7.92857112	5
W13	6	6	6	9	7.33333349	6

Fig. 11: Optimized Facility Information

	1	2	3	4	5	6	7	8	9	10	11	12
1	3	3	3	3	3	3						
2	5	5	5	5	5	5						
3	5	5	5	5	5	5						
4	5	5	5	5	5	5						
5	5	5	5	5	5	5						
6	5	5	5	5	5	5						
7	5	5	5	5	5	5	6					
8	5	5	5	5	5	5	1	6	6	6	6	6
9	5	5	5	5	5	5	1	1	1	1	1	1
10	5	5	5	5	5	5	2	2	1	1	1	1
11	5	5	5	5	5	5	4	4	2	2	2	2
12	5	5	5	5	5	5	4	4	4	4	4	4
13	5	5	5	5	5	5	4	4	4	4	4	4
14	5	5	5	5	5	5	5	5	5	5	5	5

Fig. 12: Optimized layout cell 1

2) Optimization for cell 2

The procedure for optimization is same as that of cell 1 and the results of the optimization for cell 2 are given below

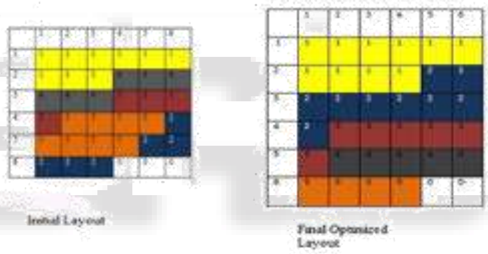

Fig. 12: Initial and optimized layouts of Cell 2

The modified layout after optimization is given below

Fig. 13: Optimized Cellular Layout

VIII. SIMULATION EXPERIMENTATION AND RESULTS

A. Simulation

The simulation experimentation is conducted to evaluate the effect of cellular layout generated .The performance measures which will be evaluated are Average Machine Utilization, Average Work In Progress, Average Machine Utilization and Distance Travelled.

The simulation is conducted under steady state conditions .The maximum Simulation Length is 720 hours .The Simulation are conducted for a period of one month. The number of replications for both product is 1 due to small variation in each observation. Also the two products are in separate product flow modules and are manufactured independently.

The major inputs to ARENA are the distance matrix of the current and modified layout, it also includes station names processes involved and transporter details

B. Result analysis of simulation model

A batch size of 4 is taken for the analysis of the performance parameters and the scheduling rule is First In First Out.

The various parameters consider under study are

- Average Machine Utilization
- Average Work In Progress
- Average Transport Utilization
- Total Distance Travelled

	Part 1	Part 2
Scheduling rule	FIFO	FIFO
Average Machine Utilization	11.48	12.73
Average WIP	3	2
Average Transporter Utilization	82.42	12.19
Total Distance Travelled	2461	2490

Fig. 14: Simulation Result of Existing Layout

	Part 1	Part 2
Scheduling rule	FIFO	FIFO
Average Machine Utilization	17.23	18.22
Average WIP	2	1
Average Transporter Utilization	72.88	10.26
Total Distance Travelled	1100	1020

Fig. 15: Simulation Result of Modified Layout

The simulation results for the layouts in which the two parts taken together and the performance measure comparison is shown below

Perfomance Measures	Process Layout	Cellular Layout
Average Machine Utilization	46.68	72.03
Average WIP	8	6
Average Transport Utilization	106.64	93.74
Total Distance Travelled	3063	1414

Fig. 16: Comparison of Layouts

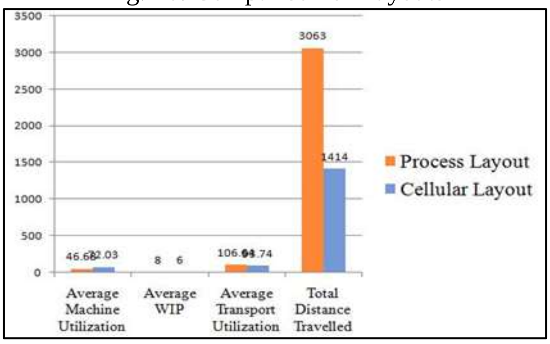

Fig. 17: Comparison of Performance Measures of Layouts

IX. CONCLUSION

A. Conclusion

To conclude this project, based on the results generated from the simulation, the objectives of his study have been achieved. The problem faced by this company has been identified and improvement alternative is proposed using CRAFT. ARENA modules have been created to build the simulation model. The alternative has been chosen based the significant improvement in performance measures. The best layout alternative which is cellular layout is recommended to the company. And by implementing such a layout a financial benefit in the range of 2.3-2.5 lakhs can be made.(Rs 5900 reduction for a batch size of 4 is obtained common order size is in the range of 140 – 160)

B. Findings

After completing the simulation, it is found that the modified layout yields the best results compared to the existing layout in terms of total travel distance, average machine utilization, average transporter utilization and average flow time. On top of that no extra space is needed during the re-layout. This will enable smooth process of machine transfers within the production floor. The cost of the re-layout will be less. The layout suggested after the study is Cellular type. Since each cell is dedicated to producing a group or family of similar parts, switching between similar parts in the family is quick and easy.

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