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PERFORMANCE IMPROVEMENT USING LAYOUT PLANNING IN THE MANUFACTURING INDUSTRY- A CASE STUDY

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ABSTRACT

In the manufacturing industry, metal casting is one of the oldest basic metal forming process and most important to industry. The casting process incurs various defects leading to high casting reject levels and customer returns which have adverse effect on productivity, delivery performance, customer satisfaction and employee morale. In addition excessive rejection reduces yield, wastes valuable raw materials, wastes process time and involves management time in problem solving. This study was carried out to reduce the rate of rejection in casting and increase the profitability of the company using Layout Planning. Pouring temperature, Pouring time, Distance travelled by ladle and Strength of sand were key factors that contribute towards rejections. While moving through large distance, rejections were on high side. Whole process was studied and new layout was implemented with modified material handling techniques. This reduced the rejection by 6.53% and total savings to the company came out to be Rupees 589425 during first month after implementation and commissioning of new layout.

KEYWORDS: Layout Planning, Manufacturing and Rejections.

1. INTRODUCTION

Quality improvement process accepts, and even requests that group of specialists in field and in addition organization authority effectively utilizes quality apparatuses in their change exercises and basic leadership process. Quality Planning can be utilized as a part of all phases of generation process, from the earliest starting point of item improvement upto item promoting and customer satisfaction. The fundamental objectives of the quality tools are consumer loyalty by conveyance of deformity free items at quality cost. The essential target of value control in any association is to lessen the cost of its task. On the off chance that control endeavors don't prompt any sparing in expenses or cost lessening at that point, on a basic level there is no need of value control. The conducted research has investigated possibilities of successful application of seven quality control tools (Saleem et al., 2012).

Rao (1994) shows the companies which are using quality planning tools to achieve higher customer satisfaction but more stress on work culture. Grewal and Gupta (2005) conducted a case study in automobile Industry and found the improvements in process capability and reduction in rejections. In this research, the rejection of the casting components has been reduced by the applications layout planning technique. This study is an attempt to reduce rejection using application of Layout Planning in a casting unit of Northern India and the results are highly encouraging.

2. LITERATURE REVIEW

Shayan and Chittilappilly (2004) defined that the facility layout problem as an optimization problem that tries to improve layout efficiency, considering all the interactions between facilities and material handling systems while designing layouts. During this optimization phase, there are a lot of elements to be considered: safety, flexibility for future design changes, noise and aesthetics are examples of basic qualitative factors in the facility layout planning process.

Watanapa et al. (2011) aimed to improve the plant layout of pulley's factory to eliminate obstructions in material flow and thus obtain maximum productivity. The present plant layout and the operation process of each section (i.e. sand mold, core ware house, core making, disassembly surface finishing, furnace, and inspection sections) have been investigated. The problem in term of material flow of each operation section was indentified. The result showed that disassembly surface finishing and inspection sections should be allocated to make the good material flow. The suitable of new plant layout can decrease the distance of material flow, which rises production.

Manivel and Sandeep (2014) found out most efficient arrangement of machines in the machine shop that will improve the efficiency of workflow in the shop floor allowing workers and equipment being more productive. The study tries to illustrate how the plant layout problem can be solved using simulation technique. It also helps to modify the plant layout so as to improve the efficiency. This study delivers the evidence of valid advantage when the above given suggestions are applied in the industry. The pro-posed suggestions will overcome the drawbacks of the existing layout and thus the productivity can be improved. These suggestions will be very useful for the industry to avoid the problems in existing layout.

Naik and Kallurkar (2016) explained that the most important reasons of the redesign of facility layouts are the continuously fluctuating customer demands and changing market environment. Changes in the product portfolio, production volume, as well as changes in the manufacturing process and technology can result in bad utilization of space, huge work in progress at the plant, high material handling distances, bottlenecks at workstations, idle time of facilities and workers, etc.

3. INTRODUCTION TO THE INDUSTRY AND PROBLEM FORMULATION

Company ABC is located in Northern region of India and manufacture pulleys of different section, bearing brackets and agriculture parts. These pulleys and bracket are used in oil expeller and also in the engineering industries. These items are made from graded cast iron or S.G. Iron. Available in different sizes and sections, pulleys and brackets are well known for their high quality and durability.

Area: Covered area: 30,000 sq. ft.

Manpower: 120-130 employees

- It has been observed that there are many quality related problems in case company under study. The rejection/ rework is on higher side i.e. 10-11% from January 2016 to March 2016.
- The required range of temperature for pouring the metal is 1464°C -1360°C, but it has been observed that the pouring is done below specified range. The time required for pouring the metal is 8 minutes; but in actual it is poured in 11 – 12 minutes. Hardness of mould was also below 80. Mould paint was not used to increase the hardness of mould. Runner/riser used without shot blast and rusty raw material were causing more slag in the casting.
- It has been observed that due to improper layout and poor material handling was leading to defects in casting.
- There were following casting defects which were leading to rejection: Sand crush defect, Slag inclusion defect, Pin hole defect, Mold shift/ Mold broken defect, Shrinkage defect, Cold shut defect.

Total 11775 housings were casted in the months of January, February and March 2016. Out of which 1392 pieces were rejected. These were re-arranged on the basis of defects as shown in Table 1.

Table 1: Casting rejection defect wise

S. No.	CASTING DEFECT	REJECTION	REJECTION %
A	Pin hole	303	2.57%
B	Sand crush	282	2.39%
C	Mold shift	259	2.12%
D	Slag inclusion	204	1.73%
E	Shrinkage	196	1.67%
	TOTAL	1392/11775	11.73%

4. ROOT CAUSE ANALYSIS

The root causes of the defects including Sand crush defect, Slag inclusion defect, Pin hole defect, Mold shift/ Mold broken defect, Shrinkage defect and Cold shut defect have been identified. Table 2 shows the root causes of the problems using 4M technique.

Table 2: Root causes of the casting defects

Defect	4M's	Root Cause
Sand crush defect	MAN	Work instructions not implemented properly
		Insufficient knowledge of operators
	MACHINE	Low air pressure
		Improper ramming of green sand
		Molding box quantity on lower side
	METHOD	Re-pouring
		Loose fixing of pattern
		Lack of mold paint
		Erosion of molding sand by flowing molten metal
	MATERIAL	Strength of sand on lower side
		Permeability on lower side
		Improper clay content

Slag inclusion defect	MAN	Work instructions not implemented properly
		Insufficient knowledge of operators
	MACHINE	Ladle not cleaned properly
		Improper ramming of green sand
	METHOD	Ladle not covered with insulating material
		More pouring time
		Low pouring temperature
		Lack of slag filter
	MATERIAL	Use of runner/riser without shot blast
		Use of rusted scrap/ plating
Pin hole defect	MAN	Work instructions not implemented properly
		Insufficient knowledge of operators
	MACHINE	Low air pressure
		Improper ramming of green sand
		Leakage of air from jolting machine
	METHOD	Improper ventilation of gases from the mould
		High pouring temperature
		Pouring metal from large height
	MATERIAL	Higher moisture content
		Permeability on lower side
Mold shift/ Mold broken defect	MAN	Work instructions not implemented properly
		Insufficient knowledge of operators
	MACHINE	Dents on the faces of molding flasks
		Improper ramming of green sand
	METHOD	Mold releasing powder not used for each mold
		Worn out of C-clamps used
	MATERIAL	Strength of sand on lower side
		Moisture content on lower side
		Improper composition of molding sand
Shrinkage defect	MAN	Work instructions not implemented properly
		Insufficient knowledge of operators
	MACHINE	Over ramming of green sand
		Defective molding flask
	METHOD	Re-pouring
		Pouring at very high temperature more than 1464^0C
	MATERIAL	Excess value of Mg and S
		Less amount of feed metal
		Permeability on lower side

5. LAYOUT BEFORE UP GRADATION

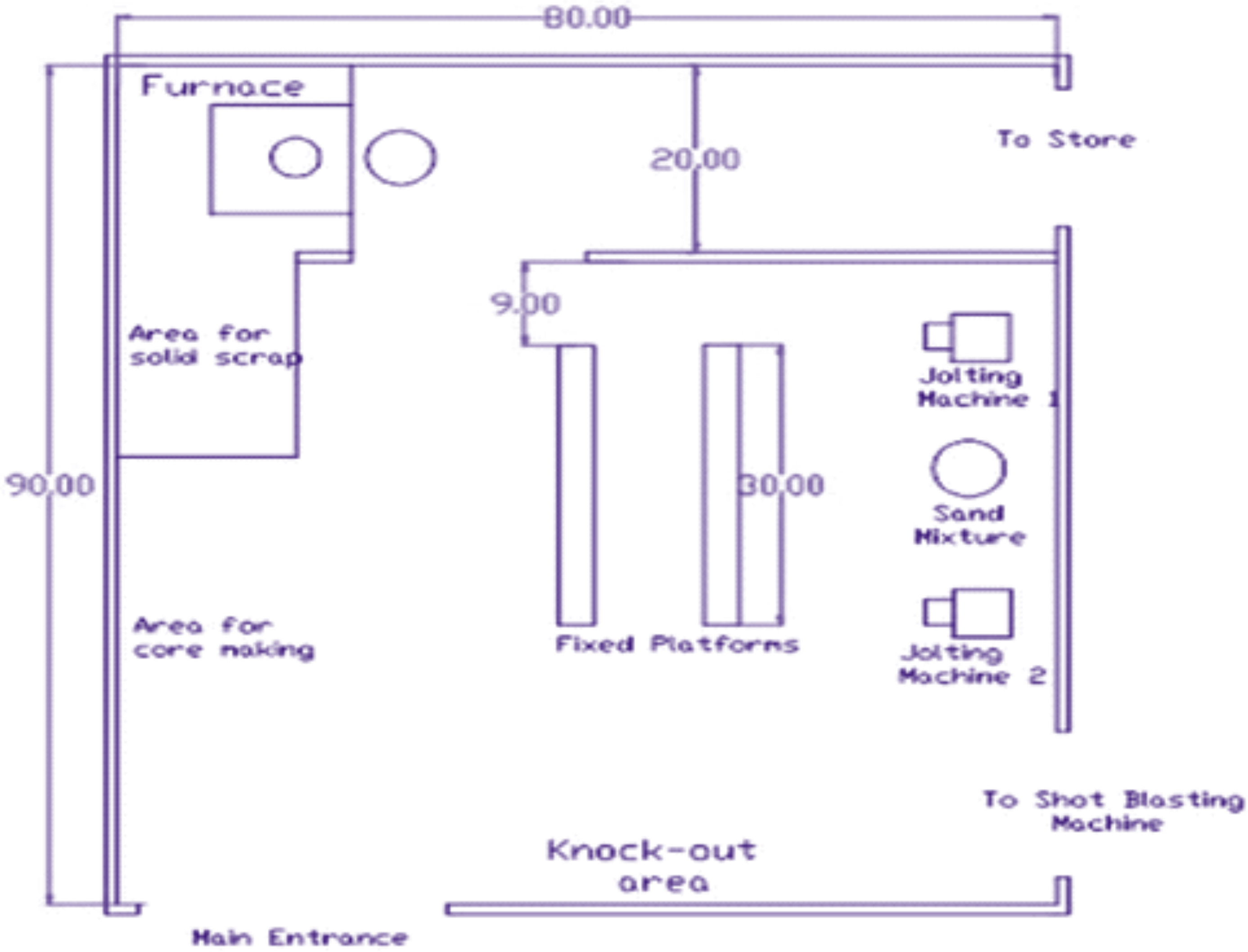

Figure 1: Old Layout

Furnace capacity: 500 kg

Sand mixture: 500 kg

Dimension of platforms: Two platforms of length 30 feet and width 3 feet each.

Number of molding boxes accommodated: 13 (on two platforms)

1.1 Process before up gradation

Workers used to mix different ingredients of casting sand i.e. casting sand, bentonite, benzacoal and water into the sand mixture by guess only which leads to improper sand composition and less binding strength of sand. This leads to sand crush during mould making and even during metal pouring process.

Cope and drag were made on jolting and squeezing machines with the help of matching plates. Workers then carry it and shift to fixed platforms. Core was placed into drag on these platforms and then cope and drag were clamped together.

The molten metal is first poured into small ladles and workers themselves carry it and bring it towards fixed platforms to pour it into the moulds. This leads to temperature drop of metal being poured below specified last box temperature as more time was wasted during bringing small ladles towards the moulds.

6. LAYOUT AFTER UPGRADATION

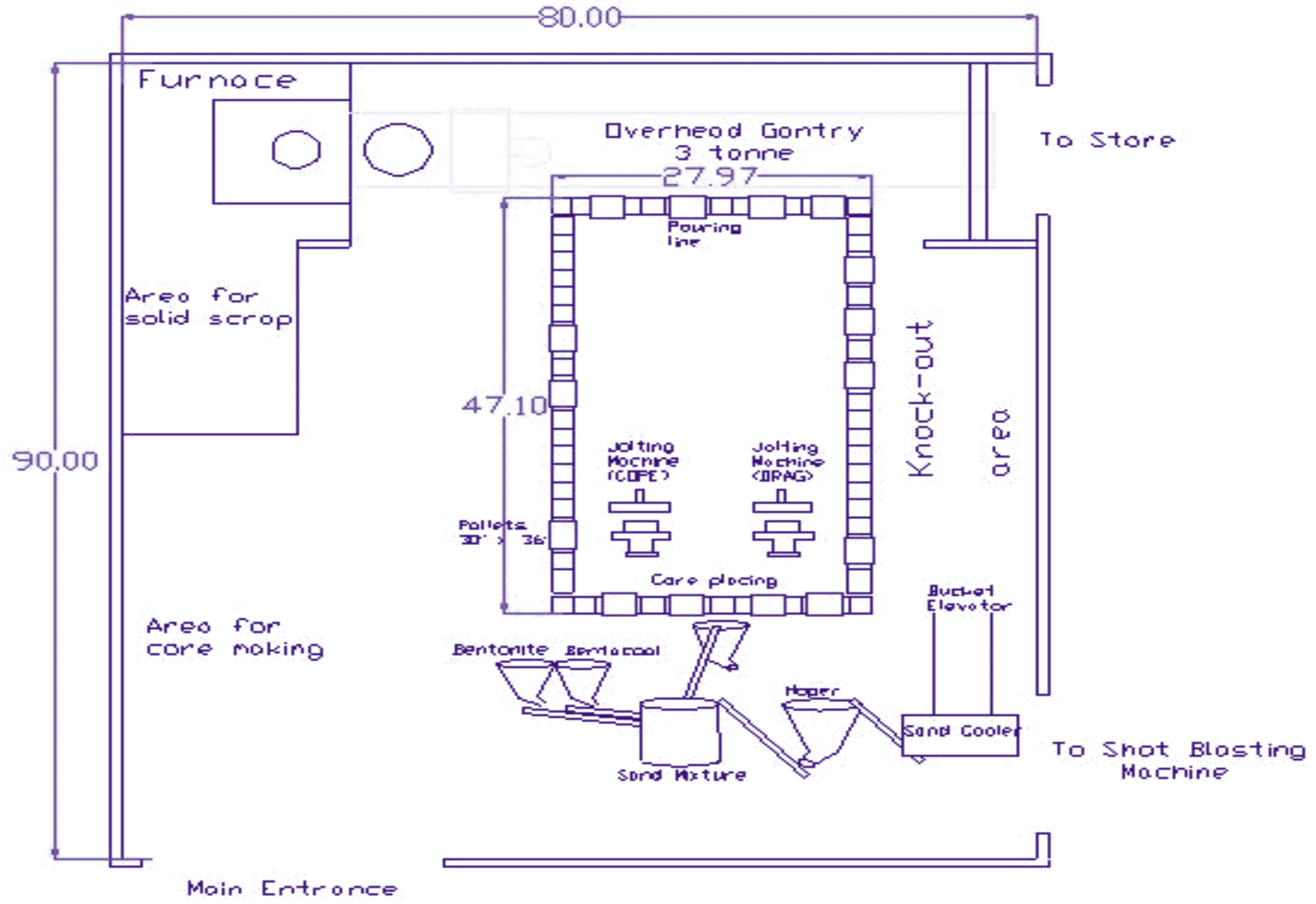

Figure 2: New layout

Furnace capacity: 500 kg
Sand mixture: 2 tonne
Hoppers (for bentonite and benzacoal): 1 tonne each
Hopper (for return sand): 10 tonne
Overhead gantry: 3 tonne capacity
Railway track loop: 47 feet x 28 feet (2 feet width)
Size of pallet: 30” x 36”
Number of pallets accommodated on pouring line: 9

6.1 Process After Upgradation:

Return sand from knock-out area goes into the sand cooler through bucket elevator. The sand is then transferred to the sand mixture via conveyor. Sand composition is first tested and then bentonite and benzacoal are added from their respective hopers as required. The opening of these hopers is time-controlled. Water is then sprinkled into the sand mixture and casting sand is prepared. This sand is then transferred via conveyor into a hopper placed above the jolting machines. This sand is used by the workers during mould making by opening the shutter of hopper via switch.

Firstly drag is prepared and is placed on a pallet which is moving on a track. Then core is placed into it. Then cope is prepared and as pallet with drag and core moves towards the second jolting machine, cope is placed onto it and clamped. The pallet then moves towards the furnace. 13 moulds are prepared in similar way and are arranged in pouring line in queue. When the heat is prepared, it is first transferred into the pouring ladle. Overhead gantry them picks up this pouring ladle and metal is poured into the molding boxes which are there on pouring line.

6.2 Counter Measures by Changing Layout

With changing the layout, modification are done in the previous process as shown in Table 3.

Table 3: Counter measures by changing layout

S. No.	PREVIOUS PROCESS/METHOD	MODIFICATION	OUTCOME
1.	Fixed platforms for molding boxes	Replaced by Rail tracks with movable trolleys having molding boxes Boxes move towards the furnace instead of workers come to molding boxes and pour the metal.	· Reduced process time · Pouring is done in specified time · Pouring is done within Specified temperature range
2.	Portable ladles for pouring metal	Overhead gantry system	· Eliminated problem of re-pouring · Eliminated problem of less amount of feed metal · Eliminated problem of pouring metal at low temperature · Maintained constant height of pouring metal · Less pouring time
3.	Mixing sand and other Ingredients by assumption with showels		· Improved Strength of sand · Proper composition of sand

Figure 1(a) Molten metal poured into boxes manually
with small ladles before modification

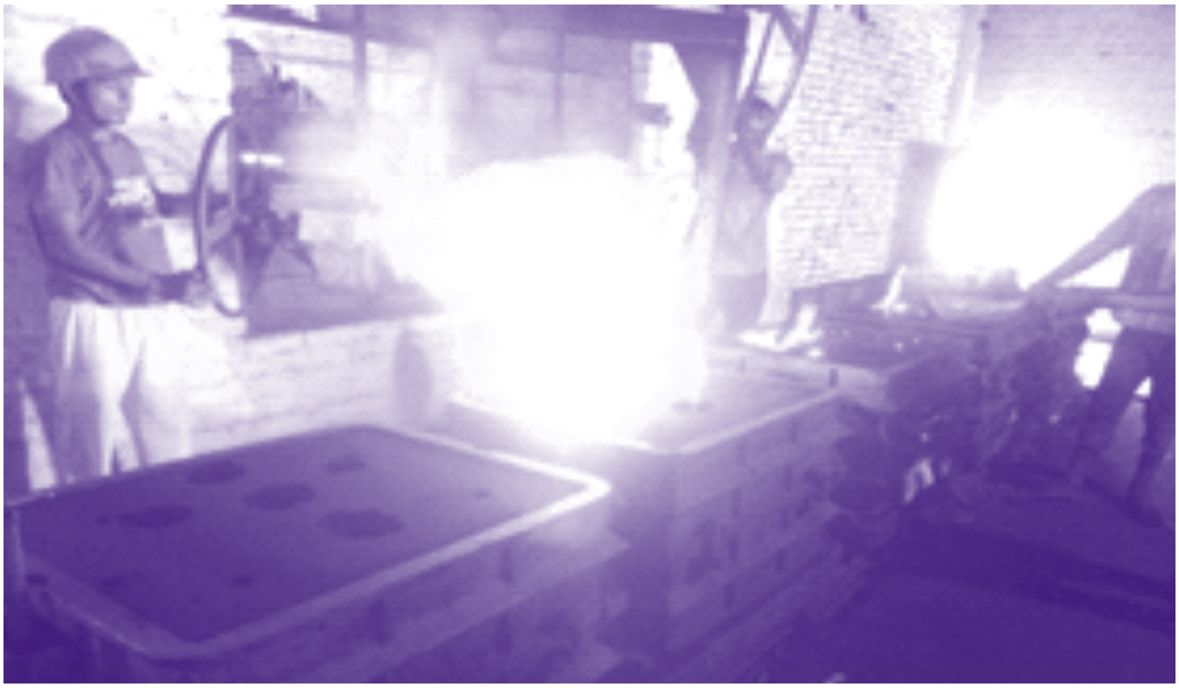

Figure1(b) Molten metal poured into boxes using pouring ladle lifted by overhead gantry after modification

7. RESULTS AND DISCUSSIONS

7.1 Effect on Pouring Temperature of Metal

With previous layout, 13 moulds were prepared for casting for one heat. The temperature of metal within the mould should be between 1464^{0}C to 1360^{0}C. But when pouring was done in actual, it was noticed that the temperature of liquid metal after 10th box dropped below 1360^{0}C. With new layout, 13 moulds are prepared out of which 9 moulds are queued on pouring line. The liquid metal is picked with the help of overhead gantry and poured into the moulds. It has been noticed that the temperature of liquid metal in all the moulds was between the specified temperature range.

7.2 Effect on Volume of Worker

The volume of workers engaged in casting process was also reduced which has been shown in the table 4. below:

Table 4: Volume of workers

OPERATION	NO. OF WORKERS WITH PREVIOUS LAYOUT	NO. OF WORKERS AFTER NEW LAYOUT
SAND PLANT:		
Sand mixture	2	0
Preparing mold on molding machine	4	4
Shifting molding boxes to platform	2	0
Placing cores	2	2
MOULDING PLANT:		
Raw material to furnace	3	3
Pouring metal from furnace to ladle	1	1
Pouring metal to molding boxes	8	2
Shifting molding boxes to knockout area	2	2
Helpers	4	4
TOTAL	28	18

7.3 Effect on Total Process Time

The time taken from melting metal in furnace to shifting moulds to the knock-out area was compared. It has been noticed that with old layout the total process time was 70 minutes and after implementation of new layout it came out to be 54 minutes. It has been shown in table 5. below.

Table 5. Effect on total casting process time

S. No.	Operation	Time before new layout	Time after new layout
1	Shifting raw material to furnace + heat preparation	40 min.	40 min.
2	Shifting sand and other ingredients to sand mixture	10 min.	4 min.
3	Preparing sand	10 min.	10 min.
4	Preparing cope and drag	40 min.	40 min.
5	Shifting cope and drag	40 min.	38 min.
6	Placing cores	40 min.	40 min.
7	Pouring molten metal to ladle + reaching first box	2 min.	1 min.
8	Pouring molten metal to all 13 boxes	12 min.	6 min.
9	Shifting boxes to knock-out area	16 min.	6 min.
	Total casting process time	70 min.	54 min.

8. ECONOMIC ANALYSIS

8.1 Labour Cost before Modification

The whole team was divided process wise into molding team, furnace team and helpers which are represented in table 6, 7., 8. and 9.. Their salary was calculated as per previous salary norms.

Table 6:Molding team

Number of workers	20
Number of heats	12
Average quantity of metal per heat	450 kg
Net quantity of metal per heat	450 x 12 = 5400 kg
Rate of wages (by weight)	@ Rs. 3 per kg
Salary S1	5400 x 3= **Rs. 16200**

Table 7:Furnace team

Number of workers	4
Number of heats	12
Rate of wages(per heat for team of 4)	@ Rs. 240
Salary S2	12 x 240 = **Rs. 2880**

Table 8:Helpers

Number of helpers	4
Rate of wages	@ Rs. 350
Salary S3	4 x 350 = **Rs. 1400**

Table 9: Miscellaneous

Refreshment	Rs. 15 x 28 = Rs. 420
Medical & safety (lump sum)	Rs. 500
Salary S4	**Rs. 920**

TOTAL SALARY:
S1+S2+S3+S4= Rs. 21400
LABOUR COST PER Kg.:
Total metal casted/day: 5400 Kg
So, Labour cost per Kg = Rs. 21400/ 5400
= Rs. 3.96/Kg

8.2 Labour Cost after Modification

New salary plan was discussed with workers and implemented on their approval on daily wages basis. The salaries of trained workers were fixed at Rs. 450 per 8 hours shift and those of untrained workers were fixed at Rs. 350 per 8 hours shift. The detail of it is discussed below in table 10, 11 and 12.

Workers preparing mold on molding machine	4
Workers placing cores	2
Workers pouring metal to boxes /furnace	3
Total	9
Salary for 8 hours shift	Rs. 450 x 9 = Rs. 4050
Salary for 14 hours (S1)	**Rs. 7087**

Table 11 Workers with salary @ Rs. 350

Workers shifting raw material to furnace	3
Workers shifting boxes to knock-out area	2
Helpers	4
Total	9
Salary for 8 hours shift	Rs. 350 x 9 = Rs. 3150
Salary for 14 hours (S2)	**Rs. 5512**

Table 12: Miscellaneous

Refreshment	Rs. 18 x 18 = Rs. 324
Medical & safety (lump sum)	Rs. 500
Salary S3	**Rs. 824**

NEW SALARY:

S1 + S2 + S3 = Rs. 7087 + Rs.5512 + Rs. 824

= Rs. 13423

NEW LABOUR COST PER Kg.:

Total metal casted per day: 5400 kg

So new labour cost per kg = Rs. 13423/ 540

Rs. 2.48/kg

8.3 Savings in Labour Cost

Labour cost per kg before upgradation: Rs. 3.96

Labour cost per kg after upgradation: Rs. 2.48

Difference: Rs 3.96 – Rs. 2.48 = Rs. 1.48

Amount of metal casted per day: 5,400 kg

Amount of metal casted per month (25 working days): 1, 35,000 kg

Monthly savings in labour cost per kg = Rs 1.48 x 1, 35, 00

= Rs. 1, 99, 800

Annual savings in labour cost per kg = Rs. 1, 99, 800 x 12

= Rs. 23, 97, 600

8.4 Rejection Analysis

3900 housings were casted in the month of May 2016 and rejection was noticed which has been shown in table.13

Table 13: Rejection after modification

S. No.	CASTING DEFECT	REJECTION	REJECTION %
A	Pin hole	32	0.82%
B	Sand crush	39	1%
C	Mold broken	33	0.84%
D	Slag inclusion	48	1.2%
E	Shrinkage	29	0.74%
F	Cold shut	22	0.56%
		203/3900	**5.2%**

Reduction in rejection: 11.73% - 5.2% = 6.53%

Increase in output capacity: 255 pc per month

Cost of one piece: Rs. 1575

Cost of 195 pcs. = Rs. 1575 x 255

Rs. 4, 01,625.

Net Benefit in the Month of May 2016

Savings in labour cost: Rs. 1, 99,800

Savings by reduction in rejection: Rs. 4, 01,625

Total benefit: Rs. 1, 99,800 + Rs. 4, 01,625

= **Rs. 6, 01, 425.**

Cost involved in setting the layout = Rs 12,000(approx.)

Net Profit = **6, 01, 425 – 12,000 = 589425 rupees**

8.5 Alternatives for layout modification

The alternatives for layout modification includes theory of constraints and root case analysis in which constraints coming in the path of producing high quality product are identified and eliminated by root cause analysis. Small incremental changes can done in the process of manufacturing the product. Kaizen, 5S, Poka-Yoke, TPM and TQM approach can also be applied to enhance the performance of current manufacturing system processes.

9. CONCLUSION, LIMITATIONS AN FUTURE SCOPE

The results of investigation demonstrated that Layout Planning plays a significant role in improving the performance of manufacturing system processes. Total outcomes notices after implementation of new layout has been studied and shown in the below:

- Total process time has been reduced by 22% from 70 minutes to 54 minutes.
- Labour cost per kg has been reduced by 37% from Rs. 3.96 to Rs. 2.48
- Volume of workers involved in casting process has been reduced by 35% from 28 to 18.
- Pouring time of molten metal has been reduced by 45% from 11 minutes to 6 minutes.
- Rejection rate of housing has been reduced by 55% from 11.73% to 5.2%
- Production output has been increased by 7% from 3510 components per month to 3765 components per month in the month of May 2016.

The selection of manufacturing Industry is done on convenient sampling technique. Work can be extended to full automation of casting unit and safety measures to be taken in a casting unit.

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