PROCESS ANALYSIS AND OPTIMIZATION OF CONVENTIONAL SAUCEPAN MANUFACTURING INDUSTRY VIA TIME STUDY

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ABSTRACT: This study was carried out at the Jayantha saucepan industry to improve and enhance the productivity by reducing the idle time and enhance the bottleneck by different methods such as changing the layouts, changing the number of work stations and changing the process flow. During the study, it investigated and searched for possible solutions and alternatives aimed at achieving the objective by Pareto analysis for time study, allocating the work stations in an effective way, changing the layout for a better productivity, and analysing skill matrix to allocate the works for the current labourers, and train the labourers and need of hiring more labourers for the particular work stations in an efficient way to enhance the bottleneck manually. Further improvements such as adapting into new techniques and using better alternatives for some processes were also discussed to enhance the productivity of the local saucepan manufacturing industry. Overall, suggested alternatives yielded an expected improvement of 20% in the production capacity.

Keywords: Productivity, Time Study, Facility Layout, Standard Time, Bottleneck

1. INTRODUCTION

There are several methods to manufacture an aluminium (Al) saucepan such as die-casting, spinning, non- stick cookware making. Developing countries like Sri Lanka uses the sand casting method which is one of the simplest and cheapest way to produce aluminium cookware. It doesn't contain any complicated processes; first they melt al, then cast it and polish it for a better surface finish. Even though this method is widely used in Sri Lanka unfortunately there are no any standards in operation to specify and improve the process. There are many problems associated with the current local saucepan making industry such as improper layout, inefficient use of labours, lack of technology usage, and idle time of the work stations. The proper process optimization is needed to enhance the productivity of the process.. Many researchers have worked on the quality improvement of the casting and the finishing operation, but not on process optimization. Therefore one of the major saucepan production companies in Sri Lanka, "Jayantha aluminium industry (JAI)" was selected as a case study to investigate issues prevailing in the saucepan manufacturing industry. This paperpresents the findings of the case study. The paper is organized as follows. Next section describes the saucepan manufacturing process of jai. In the section iii problem definition and research aim is described. Section IV of the paper described the followed methodology for time study. Section v describe the factors consider when improvements are made. Section VI and vii discussed the conclusion of the research.

Process Description

Saucepan manufacturing is done with several different operations in a sequence. These operations are listed down below.

1. Al is melted in a furnace.
2. Sand mould is made
3. Pour melted Al into the mould and make casting
4. Break the mould and removing the casting
5. Removing burr and smoothen the sharp edges

6. Polishing inner surface
7. Remove sprue
8. Polishing outer surface
9. Making and fixing handle

No standard time for activities -Therefore workers cannot be evaluated according to their performance.

Bottlenecks in the production process - More time has been taken by the mould preparation and polishing inner surface. Apart from that, to polish the outer surface, remove sharp edges and making the handle takes considerable amount of time compared to other operation. Because of these time differences between each operation, more bottleneck points could be found.

Quality Variation ofthe Product - Most of the production processes are being done manually by the workers. Among these processes, polishing inner surface, polishing outer surface and mould preparation are required high skill level, because the skill level directly affect the production rate and the product quality.

2. METHODOLOGY

Time study is conducted to eliminate bottlenecks and standardised process time. Following steps were employed to conduct a time study.

1. Normal time for each operation was measured and the standard time was calculated for each operation.
2. Bottleneck points were investigated and checked.
3. The required number of observations to predict the true time within ±10% precision and 95% confidence level was obtained using the following formula: [1]-[3]

SD= $\sqrt{(x- \bar{x})^2/n}$ $\quad E = z_{\alpha/2}\frac{\sigma}{\sqrt{n}}$ $\quad n = \left(\frac{Z\sigma}{E}\right)^2$

Where,

X= each stop watch reading or individual observation
Σ= sum of individual readings
n= required number of observations/sample size
E = margin of error

4. The standard time for each inspection point was calculated by using the following formula [4]

Standard time= Normal time*100/ (100-allowance in percent)

5. Analysis charts were used to understand the bottleneck points.
6. The bottleneck points were subdivided into more elements and the normal time was measured for each element. Steps 2 and 3 were repeated for each element.
7. Further investigation and analysis were done for the most time demanding elements inthe bottleneck
8. Possible solutions and alternatives were searched and evaluated by using principles of motion economy and appropriate tools from motion and time study and ergonomics.

3. RESULTS AND DISCUSSION

a. Sample Size, Normal Time and Standard Time.

In this study, manufacturing process is divided into sub processes and mean time taken to each process is measured. Mean time is measured to 95% percentile confidence. Initially a sample of 40 observations is used to calculate the required sample size to meet the above condition. It was found that, 79 observations should be done in order to find mean time for mould preparation with 95 percentile confidence. Same method is used to estimate the sample size for all sub process and mean time for each process is measured. Mean time does not contain allowances. It is the actual time taken for each process if average worker work at normal tempo. However it is not expected for a worker to work in the same tempo throughout the day. The operator may take time out for personal needs, which is beyond the control of them. For working 8h/day, moderate workers might have 5% - 8% unorganized time for their rest [4]. Since in this cookware manufacturing industry, workers has to work hard, 7% allowances is allocated. Accordingly, the standard time for each process is found. These standard times are mention in table 1. More time is taken for mould preparation, polishing inner surface, remove sharp edges, handle making, polishing outer surface respectively. There is a possibility to reduce time taken for these processes. All though Al melting process takes more time, it was not analysed since melting procedure and melting time were fixed by the manufacture.

Table I. Standard Time Measurement

Steps	Normal Time (Sec)	Standard Time (7% Allowance)
MeltingAl	1.5 hrs.	-
Sand Preparation	25.0	27
Mould Preparation	140.0	151
Poring Al	3.7	4
Break the Mould	4.2	5
Collecting castings	1.4	2
Removing Sharp edges	29.0	31
Polishing inner surface	73.1	79
Polishing outer surface	25.4	27
Sprue Cutting	8.4	9
Handle Making	4.8	5

b. *The Process Flow Diagram*

Actually melting is done at the beginning of each working day while other processes are continuing .process flow diagram of current process is illustrated in Figure1. The whole process is divided into two main categories. That are finishing and casting.

Process times for each process in finishing area and casting area are mentioned in Table 2 and Table 4 respectively. In this time study casting and finishing processes are considered as two separated batch processes. Therefore a time study analysing has been done separately for these two processes.

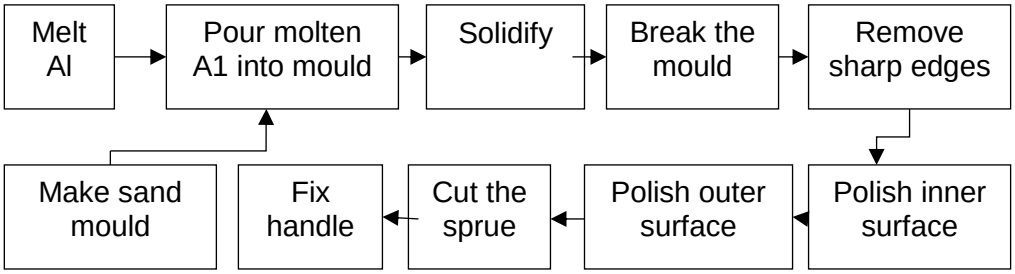

Figure 1. Process Flow Diagram

c. ***The Allocation Work Station***

The production is a batch process, where initially the casting will be done and after that the finishing operation is done batch wise. Therefore, analysing the time of whole process in a single view is not possible. Hence it was decided to analyse in two different parts. In the current flow there is a huge bottleneck at the inner surface polishing. In order to avoid the idle time of the each work station, re arrangement of the process flow and parallel allocation of workstations were needed.

Table 2. Average Time Consumption of the PolishingProcess

Process	Time (sec)
Remove sharp edges	26.9
Polish inner surface	73.1
Polish outer surface	25.4
Sprue remove	8.3
Handle making	29

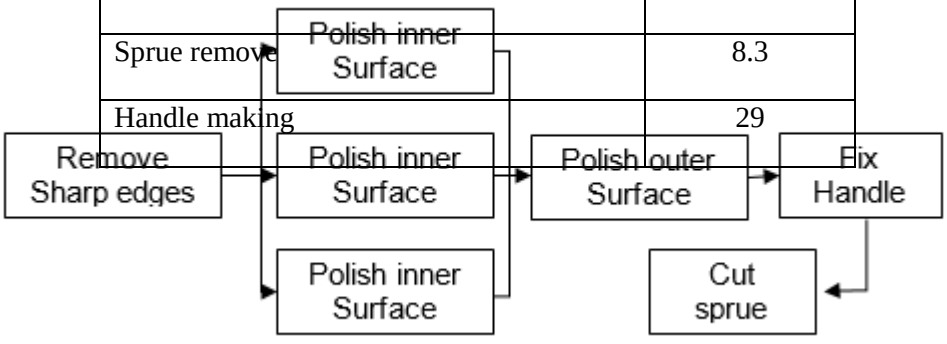

Figure 2: Work station allocation

In order to avoid the idle of the sprue cutting, the number of inner polishing work stations should be increased to 9, which is not possible because of the insufficient floor area and the labour force. With the existing floor area and the labour, the arrangement of the workstation could be liked in Figure 2.

From this arrangement, the number of inner polishing stations have been increased to reduce the idle of the all workstations. Table 3, demonstrate the variation of ideal time with respect to number of inner surface finishing stations.

Possibilities of the above arrangement – in order to allocate the workstations, the number of labourers and the skills of them were considered. Allocating three workers for inner surface polishing has reduced the idle time of other workers drastically.There is enough space to allocate 3 inner polishing stations and company has some facilities to install if 9 inner polishing stations are installed the idle times of other working stations are reduced significantly. But there are not sufficient facilities and labourers to allocate aforementioned amount of resources. The production rate is not affected with the above processes when compared with the polishing processes. Therefore the only improvement that can be done to increase the productivity with the above processes is increasing the number of workers involved with pouring and breaking the moulds. Also the current time taken to polish the saucepan in significantly larger than the above processes where, there are more moulds left to be polished for the polisher after a casting process.

Table 3. Average Time Consumption ofthe CastingProcess

Process	Time (Sec)
Al melting	1.5 hour
Mould preparation	36
Pouring	3.7
Breaking the mould and take out cast	2.6

d. ***Pareto Analysis for Time Study***

Since finishing process has a sequence of operations, Pareto analysis was done in order to identify the most critical processes which takes longer production time. From this analysis it was found that polishing inner surface, removing sharp edges, handle joining and polishing outer surface take89% time from the total production time. Therefore improvements for the production process has been done for these process. In the casting process, mould preparation takes 83% of time from the casting process. Therefore improvements for the casting process is only been done in the mould preparation.

e. ***Flow Chart***

Material flow chart can be used to reduce the material handling in the factory by the analysing it. Plan layout with the material flow is sketched in the below figure

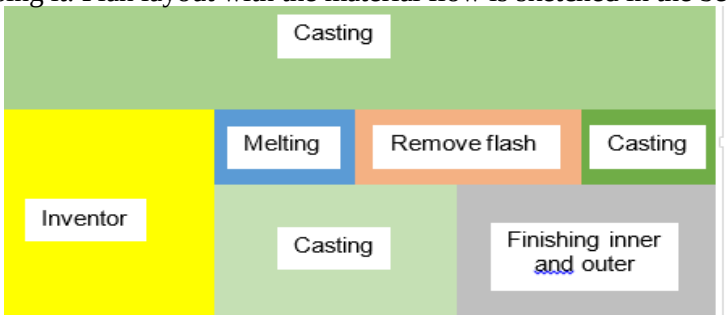

Figure 3: Existing Facility Layout

Lines drawn on the sketch to demonstrate the material movement in the factory. High amount of material handling is leading to increase the production cost and lower the production rate [5]. Therefore new layout is introduced in order to minimize the material handling.

All the production processes are currently done in 2646ft2 (42ft × 63ft) area (figure 4) excluding handle making and handle fitting processes. Since the factory area is limited all the modifications had to be done in this 2046ft2 area. The modifications are done in the way of minimize the weight into distance. At the same time, new lay out has been introduced to reduce work in- progress inventory and throughput time, improve the work satisfaction by increasing the safety of material handling and minimizing the material handling path intersections. Optimized facility layout is obtained through the systematic layout planning (SLP) [6]. It derives from information such as flow of material between the different workstations their adjacency requirements and the corresponding reasons. From the relationship chart (Figure 4), relationship diagram and facility layout (Figure 5) were developed respectively. Activity relationship chart is developed considering the material movements across the workstations. In this chart, denotation "A" used if material movement is absolutely necessary between those two workstations and denotation "E", "I", "O" and "U" used if material movement between workstations are especially important, important, ordinary, unimportant and undesirable respectively.

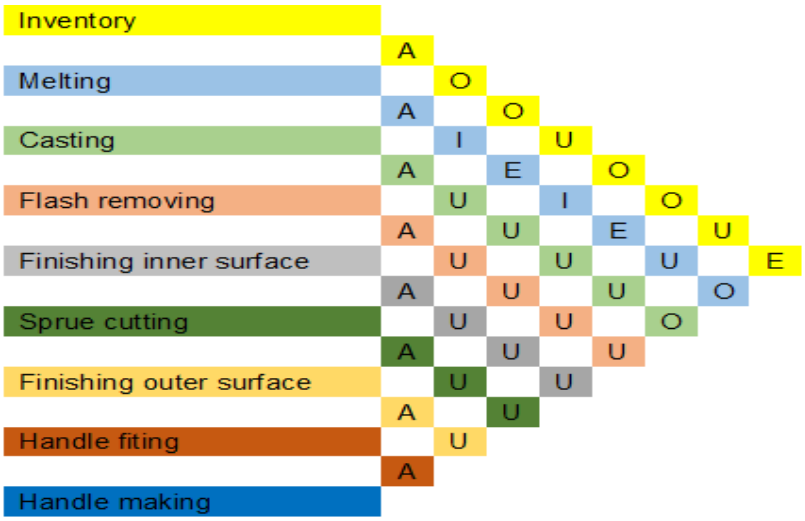

Figure 4. Activity Relationship Chart

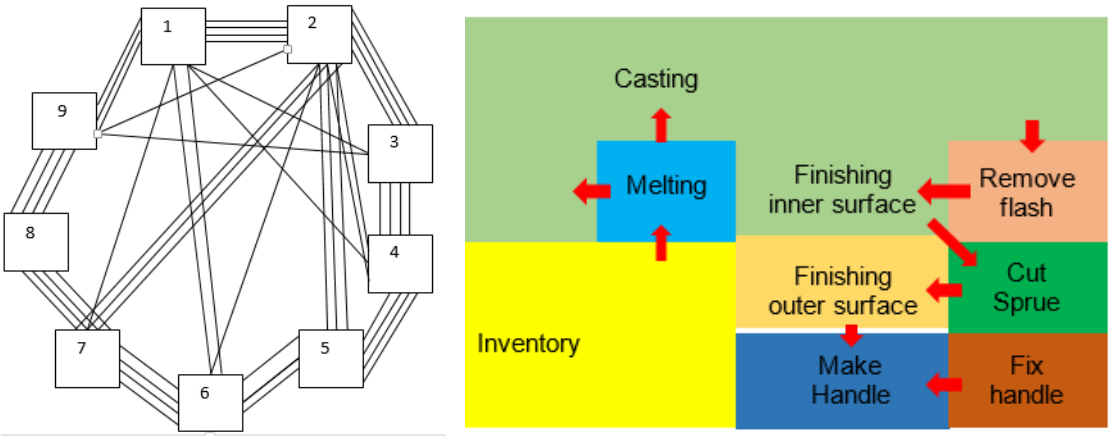

Figure 5. Relationship Diagram and Proposed Layout

From the proposed layout, workstations which are having more material movements were place closely. Large size saucepan moulds are required more molten Al than the small sizes. Therefore pouring cups have to be refilled frequently. Therefore workers have to go to the furnace more frequently when filling bigger saucepan moulds. In order to reduce the traveling distance of the workers, large moulds are suggested to place near the furnace.
In this research, workers travelling with material and traveling without material were compared separately.

f. Detailed Process Study for Bottlenecks

Time study results have exposed the bottleneck in the mould preparation. It is the most time taken process in the cast saucepan manufacturing process. Therefore detail analysis has been done to optimise the production process. From the detailed time study, possible improvements were identified. They were listed down below. These improvements would increase the productivity and workers satisfaction.

g. Further Improvements and Possible Solution to Improve the Productivity.

- Introduce electrical wrench to tighten wise and chuck.
- Proposed new layout to reduce material handling.
- Specialisation of workers in their respective operations
- Introduce parallel work stations to minimize bottlenecks
- Place two patterns once instead of placing preparation introduce finishing machine to enhance the quality of the product and the safety of the workers.

h. Tightening Chuck And Wise

At present chuck and mechanical wise are used to clamp the pasted saucepan. Each and every saucepan is needed to clamp three times in its production process. In the process of smoothing sharp edges, it takes 55% (6.2 out of 11.2) of time duration to loosing and tightening. In polishing outer surface and inner surface, it is 30% (8.1 out of 25.4) and 18% (14.3 out of 81.2) respectively. The tightening torque is also not consistent since the tightening is done manually by the workers. Sometimes workers have to retighten the wise and chuck if they were not tight enough to bare external forces. If it is over tightening, extra time and effort be put to lose it. These difficulties can be eliminated by introducing electric chuck and pneumatic clamps. It can be used to clamp and unclamp the wise and chucks quickly. In other hand, it always gives a constant torque which is useful to eliminate the problem associate with over tightening and under tightening. However, high capital is required to replace existing clamps and chucks. Since this analysis were done for the small scale saucepan manufacturing industry, mostly focus on low cost solutions. Instead of replacing existing wises and chucks, electric wrench or pneumatic wrench can be used to tighten and loosed the existing wises and chucks. Though this is a low cost solution, it gives the same advantages as electric chucks. Therefore it is more suitable to use electric wrench.

i. Separate The Finishing Inner And Outer Finishing Process For Two Sections [7].

Finishing inner and outer surface is currently done by a single worker. Its take much time to setting up the same polishing machine from inner polishing to outer polishing. These setting up time could be reduce by using separate stations for inner and outer finishing process. On other hand, letting a people to do a one work would be increased the productivity due to specialization. Both specialization and reducing setting up time would be lead to increase the productivity of the factory.

4. CONCLUSION

The time study was carried out in Jayantha aluminium industry with more than eighty samples.

The time samples were taken in different times during a week with a 0.01 seconds significant stop watch. Measurements were taken in morning, evening and throughout a week. The experimental value of time samples were analysed and bottleneck point was investigated and checked. The required number of observations to predict the true time within ±10% precision and 95% confidence level was obtained using the following formula:

Standard time= Normal time*100/ (100-allowance in percent)

From this method it was found the major time consuming are and proposed some techniques to reduce the cycle time such as use proper tool to fill sand into the mould, place two pattern once instead of placing patterns one by one and improving the tightening the chuck. From those methods it is expected to have a 5-10% of time reduction. There are some specific ways to improve the productivity. The better layout selection with elimination of waste material movement and time. Also a better flow method to reduce the idle time and avoid the bottleneck in each working stations were also suggested. This investigation found the best work station allocation from this the total idle time was reduced from 203 seconds to 31.1 seconds. There was a huge wastage of time in manual polishing method and to avoid that it was suggested to design and fabricate a simple polishing machine to reduce the cycle time.

5. REFERENCES

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