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Productivity Improvement through Cycle Time Reduction and Line Balancing: A Case Study of Machine Shop

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Abstract: Competitiveness among the manufacturing industries is rapidly increasing because of industrialization. In today's era, every manufacturing industry is trying to produce low cost products with superior quality and with propriety to deliver them in stipulated time period. Every manufacturing organisation needs appropriate system to produce high quality products in minimum cycle time, which can be achieved by maintaining higher productivity. In this research study, an attempt has been made to enhance the productivity of automotive component oil pan by reducing the machining cycle time and balancing the line to avoid unwanted movement of work piece and bottlenecks. It has been found that by incorporating CBN cutters and spot facing tool in machining, cycle time has been reduced by 7.02minutes per job. U type machine layout has been suggested to balance the production line.It has been observed that, with reduction of cycle time by 7.02 minutes per job, production capacity per shift can be increased from current 28 jobs per shift to 36 jobs per shift. With machining of additional 8 jobs per shift, production capacity of oil pan can be increased from 2000 jobs per month to 2900 jobs per month.
Keywords: Productivity, Cycle Time Reduction, Line Balancing, Machine Shop

I. INTRODUCTION

The demand placed by customers especially in manufacturing industry is about mainly two things one is lead time and another one is price. In a production system, highest profit can be obtained by eliminating waste elements in the manufacturing system. In manufacturing industry, there are three primary ways to eliminate waste:

1) Establish machine performance capabilities before actually starting the manufacturing activities.
2) In process inspection.
3) Automate non value-added tasks such as tool setting and work piece set-up [1].

In a production system, productivity is the ratio of output to the input. Productivity can be improved by following ways;

a) Reducing input required for getting desirable output
b) Increasing output with provided fixed input.
c) Achieving higher output with marginal increase in input.

Cycle time can be defined as the period required for completing one cycle of operation or completing a job or task from start to finish. Various elements of cycle time are set-up time, parts movement time, inspection time and rework time. By reducing cycle time to produce a product or to finish a job or operation, waste can be eliminated and hence higher profits can be achieved.

Reduced cycle time leads to increase in production capacity which further results into higher profits due to enhanced productivity. Reduced cycle time is helpful in increasing customer satisfaction by delivering the superior quality products in stipulated time period. A good machine tool system concentrates on cycle time by eliminating the non-value-added activities.

The mathematical expression for calculating cycle time is as follow [2];

$$\text{Cycle time} = \frac{\Sigma\,(setuptime + machining\ time)}{number of components produced}$$

By minimizing the non-value-added activity (e.g. inspection, set-up, adjustments, tool breakage, etc.) we can maximize productivity and profits. Five Steps for improvement of machine capability are listed below:

- Determine the accuracy as per need.
- Establish a baseline.
- Identify and rank the sources of error.
- Eliminate or calibrate the errors.
- Re-establish a new baseline.

CNC machines tools are the most commonly used machine tools in a machine shop. Time-consuming set-up activities on CNC machines can be identified as measurement of tool geometry, identification of machine work offsets, cutting a second part, adjustment of rough and finish tools to specification, inspection of first-off parts to verify setup adjusting work offsets and repeating inspection of altered process parameters. By reducing time involved to complete these setup activities on CNC machine, cycle time can be minimized.

II. AN INDUSTRIAL CASE STUDY

In order to study and explore the productivity improvement by cycle time reduction and line balancing of machine shop, a case study has been carried out in well known machining unit at Kolhapur of Maharashtra State. This machining unit is dealing with finished machining of automotive castings. Machining component selected for study purpose is oil pan which is one of the important components of internal combustion engine.

In case study the problem stated as "To produce 3000 jobs per month, by reducing cycle time of VMC and HMC workstations and line balancing for automotive casting-oil pan".

To fulfil the above problem statement the following objectives were considered;

1) To produce 38 jobs per shift.
2) To provide minimum handling within working area.
3) To increase productivity with modified layout of machine.
4) To reduce rejection rate per month.

A. Methodology

Following steps were identified to achieve desirable outcomes as specified above.

1) Collecting inputs
2) Analysis of available resources
3) Calculation of existing cycle time.
4) Study of various tools used for machining and identification of new tools
5) Conduction of trials with new tools
6) Analyzing the results of trails
7) Taking preventive action if necessary
8) Implementation of suggestion
9) Documentation of the process

B. Oil Pan Machining Process

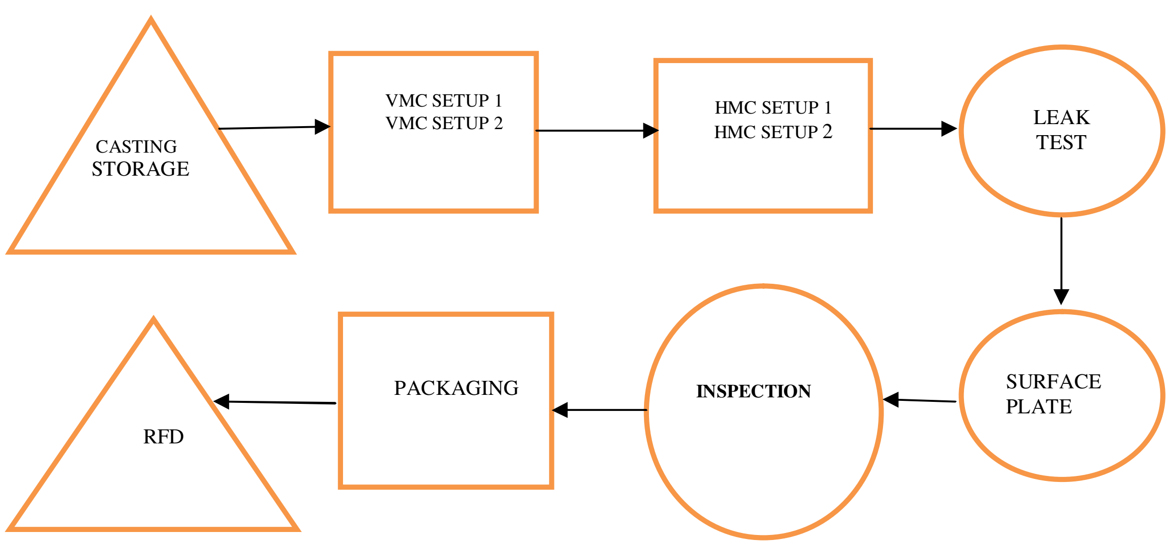

Fig. 1 Block diagram of oil pan machining process

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As shown in Fig. 1, castings of oil pan are temporarily stored in storage area. With lot size as 100 and sample size as 5, casting inspection is done to identify any rejections. Then material enters in VMC workstation for various machining operations like rough and finish milling, drilling and reaming. After VMC setup oil pan is checked for flatness on surface plate near it. Flatness of oil pan is main factor of cause of rejection of oil pan. After this, job enters in HMC workstation for further machining. After HMC workstation, leak test is carried out to check oil leakage. For inspection of a lot containing 10 work pieces, 45-50 minutes are required.

C. Calculation of Cycle Time with Existing Layout

In the process of improving productivity by reducing cycle time, at first we have to calculate cycle time for existing layout of machining an oil pan. Time study method has been adopted for determining cycle times for various operations on workstations VMC and HMC. Determined cycle times have been shown in Tables I and II below.

Table I Cycle time at VMC workstation

VMC set up 1			VMC set up 2		
Sr. No.	Operation	Time in minutes	Sr. No.	Operation	Time in minutes
1.	Rough milling	3	1.	Milling	1.7
2.	Finish milling	4	2.	Drilling	0.14
3.	Short drill	1.2	3.	Step drilling	0.15
4.	Step drill	1.09	4.	Tapping	0.6
5.	Reaming	0.13	5.	Tapping	0.9
	Total	9.42	6.	Long drilling	1.31
			7.	spot facing	1.38
				Total	6.18

Overall cycle time on VMC workstation is 16 minutes including loading and unloading of job.

Table II Cycle time at HMC workstation

HMC set up 1			HMC set up 2		
Sr. No.	Operation	Time in minutes	Sr. No.	Operation	Time in minutes
1.	Milling	2.22	1.	Milling	0.28
2.	Rough end milling	1.28	2.	Drilling	0.19
3.	End milling	0.40	3.	Step drilling	0.12
4.	Step drilling	1.23	4.	Tapping	0.16
5.	Drilling	1.27	5.	Spot facing	3.1
6.	End milling	0.29	6.	End milling	1.07
7.	Tapping	2.15		Total	5.32
8.	Milling	0.40			
	Total	9.24			

Overall cycle time on HMC workstation is 15 minutes including loading and unloading of job. It has been observed that, for carrying out leak test 4 minutes are required per job. It needs 4 minutes for final inspection and 3 minutes for packaging per job.

In order to minimize the cycle time, 5W and 1H technique has been used for new tool selection. In this analysis technique, for selecting new tool, various questions asked were;

1) What type of tool is used instead of existing tool?
2) What properties of tool we required to get output?
3) What speed and feed it should adhere?
4) Why to use specifically this tool?
5) When does it give required output?
6) How does we can effectively use the life of given tool?
7) Who is responsible for given finish?

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From the above analysis and in order to perform high speed machining, CBN cutting inserts were identified as new cutting tools for machining. Following trials were performed in the machine shop to reduce the cycle time;

a) CBN cutter is used for the 1st setup of VMC workstation.
b) The rough milling and finish milling were the operations performed during this trails.
c) Using the same cutter on HMC workstation, rough milling operation trails were done.
d) Rough milling operation was done by using carbide coated inserts.
e) The carbide plus some additional material is used for spot face operation.
f) Spot facing tool has been used for machining on HMC workstation.

D. Line Balancing

Line balancing is production strategy that involves balancing operator and machine time to match the production rate. Line balancing is levelling the workload across all processes in a cell or value stream to remove bottlenecks and excess capacity. In the present study, an attempt has been made to balance the production line for machining of oil pan to achieve the target of machining 3000 jobs per month. Fig. 3 shows existing layout for machining of oil pan on VMC and HMC workstations.

The material is in warded and stored in storage for 15 to 20 min. Then the parts are moved to VMC workstation for machining. As shown in layout (fig. 2), there exists a leak test set up between VMC and HMC. There is also an arrangement of crane for one workstation which makes working area of machines more congested. Due to this, workers need to force extra effort to lift that load. In daily shift they carry up to 1 ton of load by lifting oil pan. The inspection table is placed at extreme right corner of workplace which adds extra travel time of the work piece. Here the traditional packaging system is used which add extra time to produce oil pan. Dispatch area is also so far from inlet and outlet shutter which consumes more travel time and human effort.

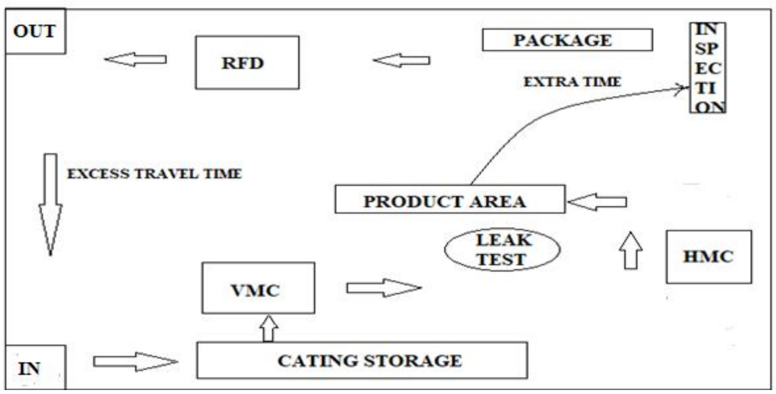

Fig. 2 Existing layout of oil pan machining

After studying the existing layout, for reducing the cycle time by avoiding unwanted movement of the job, new U type machine layout has been formed and suggested as shown in fig. 3 below.

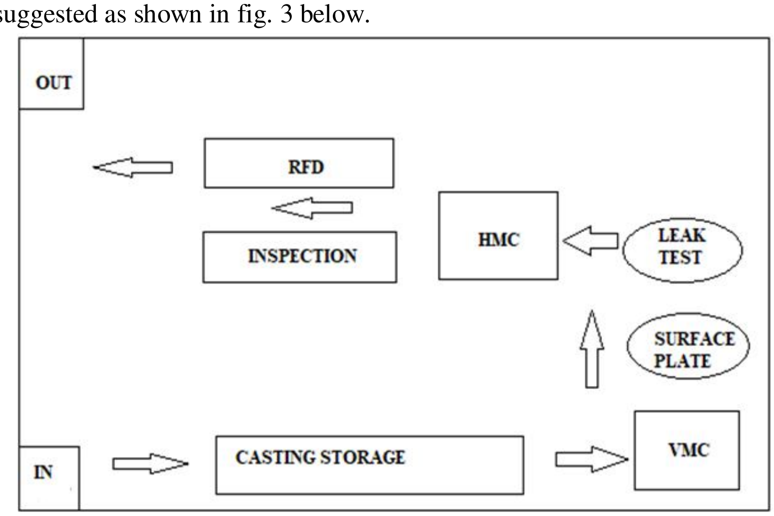

Fig. 3 Suggested U type machine layout for machining of oil pan

III. RESULTS AND DISCUSSIONS

By studying the existing layout, for reducing the cycle time by avoiding unwanted movement of the job, new U type machine layout has been formed and suggested. But in this we need to adjust some machines which is quite difficult task and also it hampers the one day production of oil pan. So by trial and error method we have drawn many layouts to balance the process of oil pan. In this layout for machining of oil pan, as shifting of VMC workstation to corner of layout and adjusting inspection table near to inlet which get closer to the dispatch line of outlet .This layout uses zero gravity crane which is used for 2-3 machines at a time. This arrangement is helpful in reducing cycle time by avoiding unwanted movement of job. By implementing u type layout, flexibility is obtained in working zone. Also the excess travel time for inspection and dispatch is reduced. It helps to increase production also. The 5s system is also followed by this layout which is helpful in 5s audit. It has been observed that, factors such as dispatch time, human efforts and rejection rate is reduced. Handling of job is improved. By improving handling the chances of damage and dent is reduced.

Following are the results of trails performed with CBN cutter:
1) Use of CBN cutter on VMC workstation gives good impact on machining of oil pan.
2) By using this cutter on 1stset up of VMC, 36 jobs have been machined.
3) As the strength of tool is too high for this operation the tool damage the edge of total lot of 1st shift.
4) The spot face tool is beneficiary as it is available at low cost and it reduces cycle time of machines

After taking the preventive actions, some improvements have been observed in machining of the oil pan. The 5W 1H technique helps us to suggest new tools and choose their appropriate properties. Here we can see that for VMC workstation cycle time of rough milling is reduced from 3 min to 1.30min. Also, the cycle time of finish milling is reduced from 4 min to 2 min. The cycle time on HMC workstation for spot face is also reduced up to 1.30 min. And for milling it comes to 1.10 min.
So finally implementing the suggested tools, reduction in cycle time has been found as shown in table below.

Table III Comparison of earlier and new cycle time

Workstation	Earlier cycle time(min)	New cycle time (min)	Reduction in cycle time (min)
VMC	15.6	11.9	3.7
HMC	14.56	11.24	3.32

The overall reduction in cycle time for machining of oil pan is 7.02 minutes per job. With reduction of cycle time by 7.02 minutes per job, production capacity per shift can be increased from 28 to 36 jobs per shift. With excess machining of 8 jobs per shift, production capacity of oil pan can be increased from 2000 jobs per month to 2900 jobs per month.

IV. CONCLUSIONS

In this research study, an attempt has been made to improve the productivity by increasing production which is achieved by reducing cycle time of job and with line balancing. By using CBN cutter to rough and finish milling operation the targeted production per month for VMC machine has been achieved. Also output of HMC is increased up to 36 jobs per shift. By implementing U type layout minimum travel within working area is possible, which reduce overall time to produce oil pan. With reduction of cycle time by 7.02 minutes per job, production capacity per shift can be increased from 28 to 36 jobs per shift. With improved machining of 8 jobs per shift, production capacity of oil pan can be increased from 2000 jobs per month to 2900 jobs per month.

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