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Improving Machining Productivity of Single Cylinder Engine Block – A Case Study of Manufacturing Organization

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Abstract

Purpose – This paper focuses on the concept of machining productivity enhancement for single cylinder engine block. By modifying the design of clamping unit, machining productivity of the machine shop is going to be enhanced.

Design/methodology/approach – An eight step methodology have been used to complete whole research work in prescribed time. Problem is recognized and actual causes have been shortlisted which are responsible for the problem. After the complete analysis of the data related to these causes, improvements are going to be made. After applying the improvements machining productivity of the machine shop is going to be enhanced.

Findings - After implementing the changes in the design of clamping unit, 9.0% increment in production rate per month, 32% reduction in manual time per job has been achieved. Along with the reduction in manual time, 13% increment in machining time per job and 11% decrement of cycle time per job has also been recorded. Also the machining productivity of the machine has been increased by 11.25% per month along with an increment of 4.5% in overall production rate, 5.1% increase in machining productivity of ABC machine shop has also been recorded.

Research limitations/implications - The findings of this case study are valid due to limited selection of machines only.

Originality/value - This paper depicts the true picture of implementation of modifying design of fixture for cycle time reduction to enhance productivity of an organization.

Keywords: Productivity, Production Rate, Loading and Unloading time, Cycle time.

INTRODUCTION

Gupta (2007) had defined productivity as the ratio of output viz. finished product or service to input viz. labor, material, machine etc. While according to Brynjolfsson (1998), Productivity is the amount of output produced per unit of input. While it is easy to define, it is notoriously difficult to measure, especially in the modern economy. In particular, there are two aspects of productivity that have increasingly defied precise measurement: output, and input. Properly measured, output should include not just the number of widgets coming out of a factory, or the lines of code produced by a programming team, but rather the value created for consumers. Fifty years ago, tons of steel or bushels of corn were a reasonable proxy for the value of output. In today's economy, value depends increasingly on product quality, timeliness, customization, convenience, variety and other "intangibles".

Similarly, a proper measure of inputs includes not only labor hours, but also the quantity and quality of capital equipment used, materials and other resources consumed, worker training and education, even the amount of "organizational capital" required, such as supplier relationships cultivated and investments in new business processes. The irony is that while we have more raw data today on all sorts of inputs and outputs than ever before, productivity in the information economy has proven harder to measure than it ever was in the industrial economy.

Goel (2010) had revealed three prime strategies to improve productivity. First strategy aims to maintain performance by reducing the use of resources. This strategy is applied in situations of stagnation and declining market and strives towards the reduction of work staff, i.e. the amount of material used, number of employees, which often leads to potential conflicts and loss of time. Second strategy aims at increasing output with steady input. Output maximization seems to be the only possible way to increase productivity directly depends on market cycles. But there is no improvement in internal processes of organization. A short term increment in the output by high work intensity in manufacturing leads to a considerable increase in machine down time and to a shorter durability of machines in medium run. Hence, besides working, more intelligent work is required for permanent enhancement in production. And third strategy defines increase in productivity as the attempt to continuously improve relation between input and output, irrespective of current market, by optimizing processes. Permanent improvements in business process is the key factor for market success and are so positively influence that additional demand which is created due to productivity improvement.

Prokopenko (1999) investigated that proper measure of inputs must include, not only labor hours, but also the quantity and quality of capital equipments used, materials and other resources consumed, workers training and education, organizational capital required like investment in new business processes, supplier relation cultivation etc. the researcher also investigated that there are a number of ways to classify productivity factors and among them the most general classification is as external and internal factors. The external factors are those which are not controllable by organization while internal factors are in organizations control. Both the factors have an equal impact on productivity improvement.

Purpose of the study

During last few years companies have been creating and using tools to identify and eliminate wastage of time during a process to improve the quality production time and to reduce the process cost. So, with increasing automation and mechanization, production processes are shifting from manual to machines and to succeed in this new environment, equipment must run effectively. Proper utilization maximizes the performance and availability of machinery, which leads to increased production rates. Machine performance problems are identified early on and therefore, one of the main areas for productivity improvement is the proper utilization of available resources. So, the research work presented here focuses on improvement in the machining productivity by properly utilizing the available resources i.e. work piece holder, already available with the machine from the manufacturer and by modifying the design of clamping unit, machining productivity of the machine shop is going to be enhanced. Rest of the paper is as follows:-

Section 2 reports the literature review. Section 3 explains the case study of an organization. Section 3 tells the present work done in the case organization. Finally, Section 5 concludes by narrating the contributions of the present research.

LITERATURE REVIEW

Brown et al. (1999) discussed no cost applications for assembly line manufacturing processes cycle time reduction strategies, which were applied to assembly areas of semiconductor manufacturing industries. A study was conducted using discrete event simulation models. It was used to evaluate the current production practice of a high volume semiconductor backend operation. The overall goal was to find potential areas for improvement in productivity that would collectively yield a 60% reduction in cycle time for manufacturing. Simulation analysis resulted in number of recommendations for the assembly area that require no additional capital expenditure. The model showed that cumulative impact of these assembly recommendations would be 20% reduction in average cycle time which was a significant contribution to the overall goal.

Lee and Kim (2002) investigated about the reduction of manufacturing cycle time using balance control in semiconductor fabrication line. Wafer fabrication is one of the most complicated and important process, which is composed of several hundred process steps and involves a large number of machines. Productivity of this manufacturing process depends upon the controlling balance of WIP (work in progress) flow to achieve maximum output under short manufacturing cycle time. In this paper, researcher discussed the way of determining proper WIP level for operations, against which balance status was measured. Balance measurement was applied in mathematical modeling for bottleneck scheduling and operations management of the fabrication line. Performances were evaluated through computational experiments which show that balance driven management leads to 15-33% more production in 21% shorter manufacturing cycle time than production driven management.

Lodha (2003) discussed six sigma approach for cycle time reduction. Key process input variables (KPIV's) were identified by six sigma process improvement approach and the methods were implemented to reduce overall cycle time with negligible impact on factory personnel or work flow. The process improvement was achieved with no additional cost. Cycle time was reduced by 10% for initial processing stage in wafer build when daily wafer starts frequency was increased from 2 times per day to 6 times per day.

Masood and Khan (2004) investigated about the improvement of productivity through computer integrated manufacturing. A world market has been created due to efficient transportation networks in which everyone participate on daily basis. For any country to compete in this must have companies that provide timely high quality products to customers in an economical way. The importance of integrating product and process design is to find a production system which cannot be overemphasized. However, even once a design is finalized, industries must be willing to accommodate customers by allowing last minute design changes without altering product quality and delaying shipping schedules. Therefore most of the U.S. based industries have to shift from conventional to computer integrated manufacturing styles to provide this flexibility in their manufacturing system.

Kumar (2005) discussed the problem of low productivity for Indian plywood and black board industry. The whole research work was done in two stages. During first stage a pilot survey was carried out using a questionnaire, specially designed for such industries. During this stage some important factors responsible for high input cost and poor productivity were found. A case study on GMG Plywoods Pvt. Ltd. was done in second stage to have in depth picture of the working of the units especially with respect to work methods, processes, productivity and quality. The total productivity index of the unit was calculated by using Financial Ratio Model as 1.0059. It was based on the data collected for financial years 2001-02, 2002-03 and 2003-04. After implementation of energy conservation and proper wood utilization techniques, total productivity index increased up to 1.1663 along with an increment of 15.95% in overall productivity of the unit.

Gupta (2007) made an attempt to implement Kaizen practice in the process industry so that overall profit of the industry increases. The research was done at Hero Cycles Limited (C.R. Division), Ludhiana (India). A steering committee was made to monitor the overall kaizen initiation and implementation. Different projects were selected for the kaizen in the field of cost reduction by reducing fuel consumption and power consumption, reduction of quality defects and increasing the production of bottle neck production lines. By the implementation of kaizen methodology, a total reduction of 47% in gauge variation and 25% in sticker marks was achieved. Also the fuel and power consumption was reduced by 1.5% and 5.25% respectively. An increase of 7.9% in the production of annealing department is also achieved.

Sharma et al. (2008) investigated about the advances in turning process which are responsible for improvement in productivity. In machining, productivity is increased by setting high values of cutting parameters, but this also involves a risk of surface quality and tool life deterioration. Literature reveals the modification in tool geometry (like grooved/ restricted contact tools (RCTs) and chamfered/ honed edges), application of coolants, ultrasonic assisted turning (UAT), hot machining and cryogenic treatment of tool inserts which have led to efficient and economic machining of modern materials used for aerospace, steam turbine, bearing industry, nuclear and automotive applications.

Tolouei and Zolfaghari (2009) discussed about the improvement of productivity using special purpose modular machine tools. Manufacturers have no clear idea regarding utilization of widely used CNC's or less commonly used Special Purpose Modular machine tools (SPM's), when highly accurate components have to be produced in relatively large volumes. This research work helps them in deciding the most economical method by presenting basic components of SPM and how they are used, necessary steps to configure the machine and a detailed analysis of economy while presenting a real case study in which a comparison of unit cost per part was made.

Goel (2010) discussed the problem of low production in tractor manufacturing industry. Machining operation has been focused in this work. After a thorough study of existing process plan, improvements in the cycle time were made by modifying fixtures and cutting tools. The study was carried out on machining of two critical components i.e. Cylinder Head and Main Transmission Housing. About 30% reduction in cycle time had been achieved by modifying jigs and fixtures and by implementing latest cutting tools. An improvement of 41% in the machining productivity of cylinder head and 22% in main transmission housing had been achieved after implementing the modifications. Also a reduction of 20% in machining cost for cylinder head and 16% for main transmission housing machining cost had also achieved. This study was resulted in an annual saving of Rs. 6.5 lakh and Rs 5 lakh in case of cylinder head and main transmission housing respectively.

CASE STUDY

Place of Work

ABC Motors Limited was setup in the year 1988 and firstly focused on the two wheeler market solely, as automobile and automobile component industry is one of the largest growing industries in India. The mission of the company is to provide innovative, clean, functional product design incorporating latest technology with optimal utilization of resources in India. ABC motors slow key, but focused style of management has earned company plaudits amidst investors, employees, vendors and dealers as also worldwide recognition.

ABC Machine Shop is equipped with most advanced and sophisticated CNC's running throughout the day and throughout the work. ABC produces the key component for Hero Honda i.e. Single Cylinder Engine Block. ABC is equipped with world class machines like:

- Tong Tai
- Arrow
- Robodrill
- Sabre
- Nagal

Problem Statement

These days, survival of any company is strictly dependent on its competitiveness in the market. The competition may be at the national or international level. As technology grows fast, management system becomes more complex. To sustain in the highly globalized world, production rate of an organization becomes very important.

A thorough study of existing process revealed that ABC Motors Limited (ABC), a leading manufacturer of Single Cylinder Engine Blocks is experiencing the problem of low production rate. The actual production coming out from ABC is 35,550 units per month, while the target is of 40,000 units per month. This is a big difference, which results in a considerable loss to the organization. And production of the ABC depends solely on the machine TONG TAI, as most of the primary operations have to be done on it and only after that job proceeds for further machining. So, the main focus of present research work is on improving machining productivity of these machines so that overall machining productivity and production rate of ABC shall improve.

The objective of this research work is to enhance the machining productivity of the ABC machine shop.

Methodology

The whole research work presented here, is divided into eight basic steps, which shall be completed well in time to achieve the goal of the research work. The complete methodology in form of a line diagram is shown in figure 1 below:

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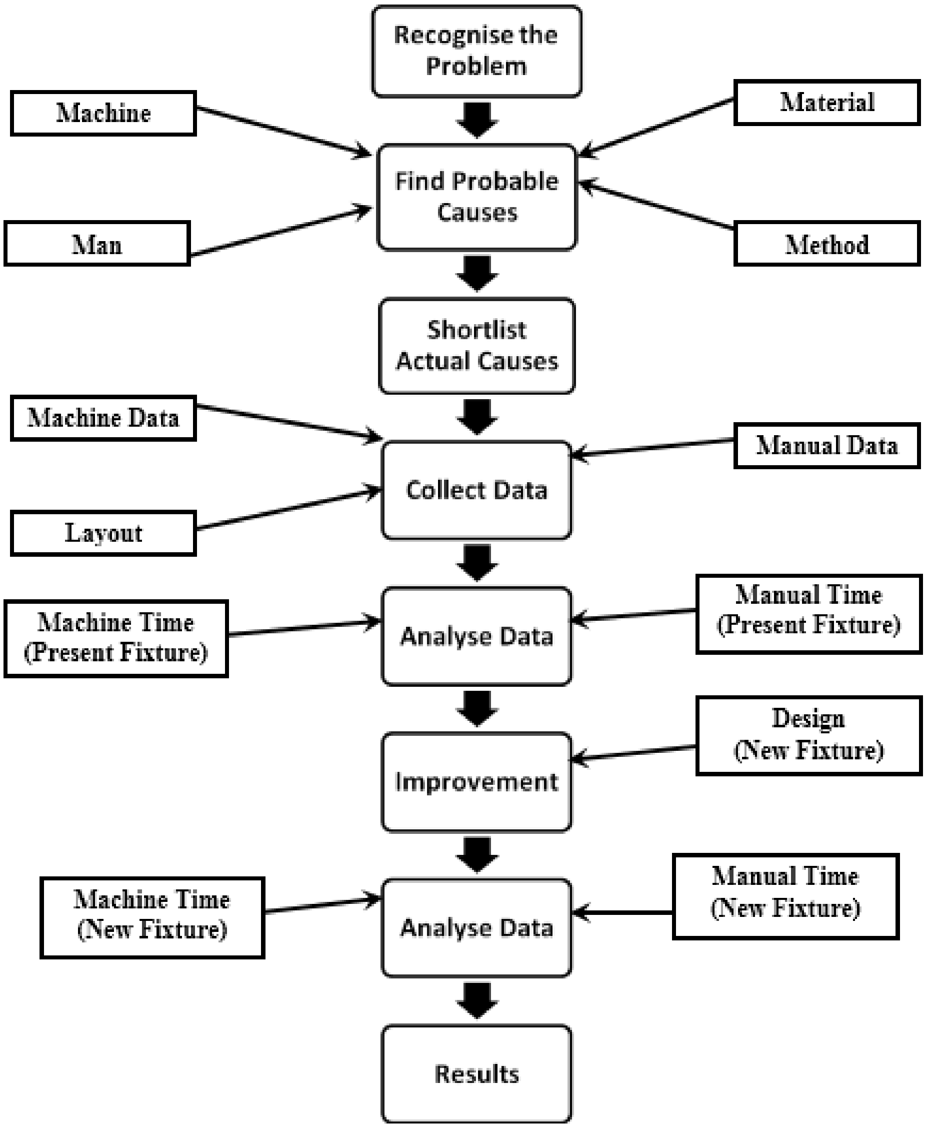


Figure 1: Methodology (Line Diagram)

PRESENT WORK

Recognition of the problem

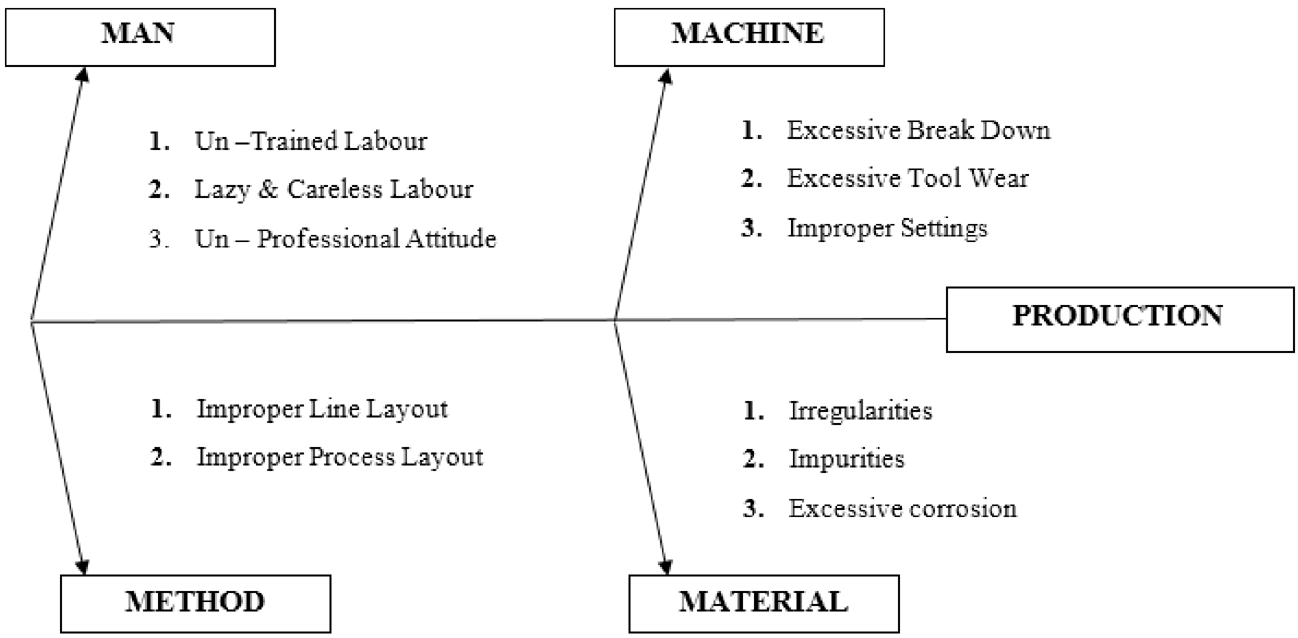
The aim of this research work is to enhance the machining productivity of machine Tong Tai so that overall productivity of the ABC machine shop will increase.

With respect to ABC, productivity can be defined as the capacity of doing work in given span of time or it is the theoretical value, which is usually higher than the actual value of production. While production is the actual number of products, which are being processed in the same span of time in which productivity for the same is specified. Thus the value of production is always lower than productivity. Thus another aim of the research work is to decrease the difference in the value of production and productivity of ABC machine shop.

Probable causes responsible for the problem

The first view reasons or topmost reasons or general reasons, which are considered initially to solve the problem, are the probable causes. Thus while starting the research work one has to refer these reasons in order to reach the exact cause.

After a rigorous brain storming session with production authorities and fellow workers few of these reasons are elaborated as under with the help of Ishikawa Diagram for ABC machine shop as shown in figure 2.



Actual causes responsible for the problem

The total number of products manufactured per day depends on two things:

- Machining Time
- Manual Time (Loading and Unloading Time)

Machine time is the time which machine requires in completing the job with full satisfaction. Machine time generally depends on:

- The material to be machined
- Tools used
- Quality of job desired
- Machining conditions

All above mentioned factors are interconnected with each other. Therefore machining time is subjected to a very little change or no change. Hence, Loading and Unloading is our last option left, which can be dealt in order to increase production.

It was discovered that manual operations almost consume 28% of the total production cycle time.

Total Working Minutes per shift

(Excluding Tea Break and Meals)

Shift A (6:00 AM to 2:00 PM)	**:**	**450**
Shift B (2:00 PM to 10:00 PM)	**:**	**450**
Shift C (10:30 PM to 5:00 AM)	**:**	**360**
Total Working Minutes per day	**:**	**1260 (21 Hour)**

Out of Total time, 28% is Manual handling time. So:

Manual Handling Time : 1260 X 0.28

: 352.8

= 353 Minute (about 6 Hour)

Collection of data related to the problem

In ABC machine shop, engine block shown in figure 3 has to pass through various processes.

[Insert Figure 3]

Various processes through which an engine block has to pass through in ABC machine shop are:

- Facing
- Boring
- Drilling
- Reaming
- Tapping
- Fine Boring
- Honing
- Washing and Cleaning

The process layout of ABC machine shop is shown in figure 4 below:

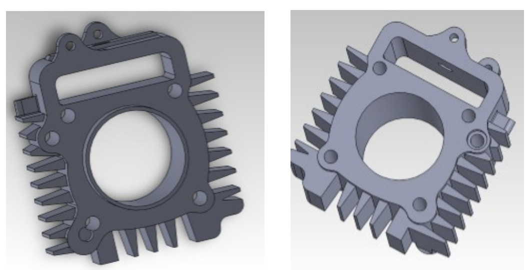


Figure 3: Engine Block

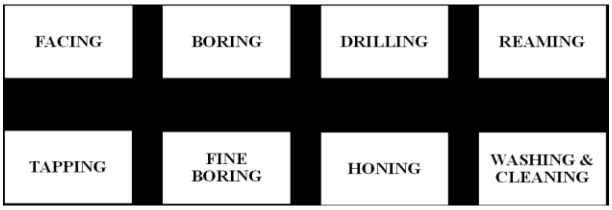


Figure 4: Various operations done on engine block

After studying process layout and line layout of ABC machine shop, it was found that four machines lie under bottle neck area, i.e. the machines on which real production depends and if problem occurs in any one of them the production is hurt. These machines are:

- Tong Tai-1
- Tong Tai-2
- Tong Tai-3
- Tong Tai-4

Among all these machines Ton Tai-2 and Tong Tai-4 is using manual loading and unloading. While on all other machines hydraulic loading and unloading systems are used. Therefore the prime concern of this research work is Tong Tai – 2 and Tong Tai - 4 machines.

Loading and Unloading data for present fixture

Present fixture as shown in figure 5 is a combination of several smaller units. These units are:

- Fixture Bed
- Clamps
- Supporting Rods
- Limiting Rods

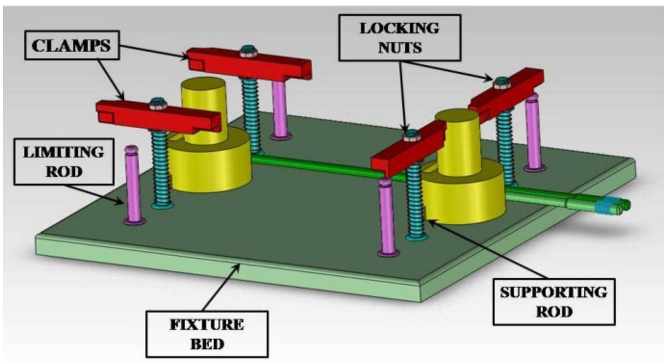


Figure 5: 3D view of present fixture

The whole loading and unloading process on the present fixture occurs in three basic steps, which are:

a) Unloading the Job
b) Air cleaning the fixture
c) Loading the job

These three steps have been divided into a series of smaller steps further. The values in the Table 1 below are the values for various steps during the whole loading and unloading process and are the average values of 5 readings taken continuously on the same machine and for the same operator at 11:00 AM (general shift). The values are taken with the help of a stop watch and are subjected to change with the machine and operator as well.

Table 1: Detailed working time with present fixture

S. No.	Basic Step	Operation	Time (Sec.)
1	Unloading of job	Pickup Spanner	4
2		Loosening of Locking Nut	9
3		Drop Spanner	5
4		Turn Clamp to OUT position	6
5		Pickup Old Job	5
6		Air Clean the Fixture	10
7	Loading of job	Place New Job	9
8		Turn Clamp to IN position	6
9		Pickup Spanner	5
10		Tightening of Locking Nut	9
11		Drop Spanner	4
Total Time Taken			**72**

Problems with the present fixture

Some general problems an operator faces with present fixture during loading and unloading of the job on the fixture are mentioned below:

- Present fixture totally depends on manual work i.e. each and every operation needs manual work which increases cycle time of clamping. After few hours operator working speed decreases due to fatigue.

- In order to pick and drop spanner a worker has to devote about 15-20 Sec per job, therefore calculating further :

Time spent on spanner per job	:	18sec
No. of processed jobs per day	:	Total Working Time per day / Cycle Time per job
	:	(1260 X 60) / 280 = 270 Jobs
Total time spent on spanner	:	18 X 270 = 4860 Sec (81 Min or 1.35 hour)
No. of jobs produced in 4860 sec	:	4860 / 280 = 17.35 = Approx. 17 jobs.

- There are times when operator somehow misses the spanner or he forgets it somewhere which usually happens during shift change and present fixture can't work without it. Hence there was a considerable loss of time in searching the spanner which leads to increase in cycle time or decrease in production.

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Improvement in clamping unit

The new fixture given as a solution to the problem is yet a manually operated unit but is semi automatic in operation. It is designed in order to eliminate all kinds of drawbacks with the present fixture. The new design of the fixture which is the solution to present problem is designed with following special features:

- Reduction of 50% of operations than present fixture.
- Reduction of excessive manual labor.
- Pressurizes the job accurately and evenly.
- Requires no special or formed tool like spanner for its operation.
- Can be made by modifying the present fixture.
- Simple and easy in construction.

Hence figure 6 shown below represents the 3D view of the new fixture which has all above mentioned features.

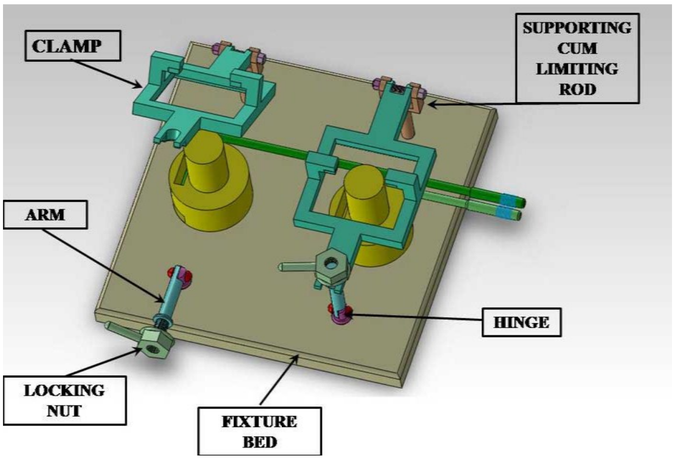

Figure 6: 3D view of new fixture

New fixture is also a combination of several units like the old fixture, explained in following paragraphs. These units are:

1. Fixture Bed
2. Clamp
3. Supporting cum Limiting rods
4. Locking Mechanism

a) Locking Nut
b) Arm
c) Hinge
d) Locking Rivet
e) Rivet Cap

Fixture bed for new fixture

Purpose of the bed is exactly the same as it is in existing fixture. The bed has the same dimensions i.e. 400mm X 400mm X 25mm and is also made up of same material i.e. cast iron. The 3D view and detailed drawing of bed is shown below in figure 7.

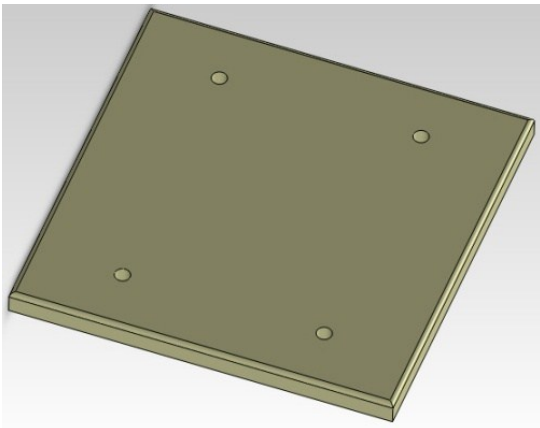

Figure 7: 3D view of fixture bed (new fixture)

Clamps for new fixture

The purpose of the clamp is exactly same as in present fixture but the design is a bit different. Clamp is designed for the new fixture keeping in mind the dimensions of the job. The inner dimensions of the clamp are equal to the maximum outer dimensions of the work piece. The 3D views of new clamp are shown in figure 8

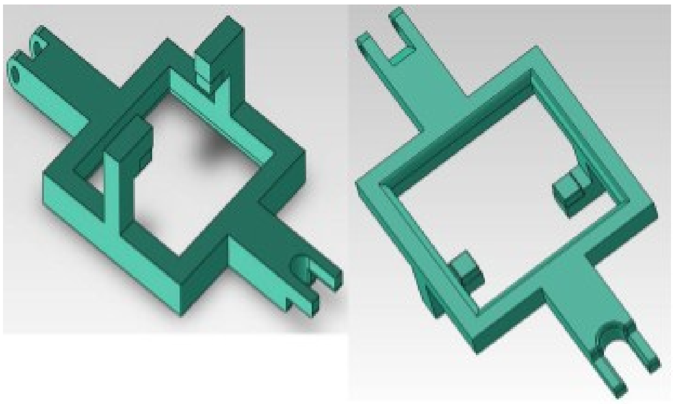

Figure 8: 3D views of new clamp

Supporting cum limiting rod for new fixture

Supporting cum limiting rod is a new unit in new fixture. It performs the functions of both limiting rod and supporting rod in case of present fixture. The material for the rod is same as in case of present fixture i.e. mild steel. Overall height of the rod is equal to the height of the work piece. The 3D view and detailed drawing of supporting cum limiting rod is shown in figure 9.

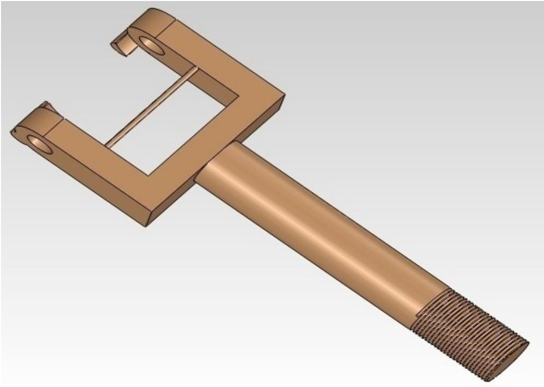

Figure 9: 3D views of supporting cum limiting rod (new fixture)

Locking mechanism in new fixture

It is a new part in the new fixture. The work of locking mechanism is similar to that of clamps in existing fixture. It moves in two positions which are:

- IN position for loading the job
- OUT position for unloading the job

The mechanism is divided into two parts. The lower part is fixed rigidly to the bed while upper part can move angularly about 180 degree with vertical plane. Locking mechanism is a combination of several parts which are mentioned and explained below:

a) Locking Nut

b) Arm

c) Hinge

The detailed drawing and 3d views of the main parts of locking mechanism are shown in various figures as below.

a) Locking nut for new fixture

Locking nut is same as in present fixture with only difference that a small rod is attached on it for loosening and tightening of nut. Figure 10 shows the 3D view of locking nut.

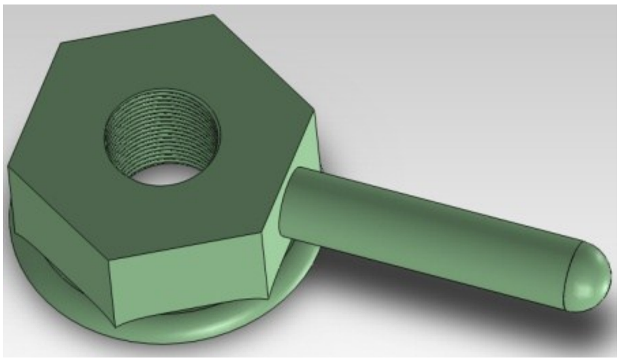

Figure 10: 3D view of locking nut (new fixture)

b) Arm and Hinge for new fixture

The function of the arm in new fixture is similar to that of limiting rod in present fixture. The clamp is being tightened in this. Height of the arm and hinge together is equal to the height of limiting rod in present fixture while diameter of both is same as limiting rod in present fixture. 3D view and detailed drawing of arm is shown in figure 11.

Figure 11: 3D view of arm (new fixture)

Arm is fixed on the hinge with the help of a rivet and it is made free to move along an angle of 180^0 with the axis of hinge. 3D view of hinge is shown in figure 12 below:

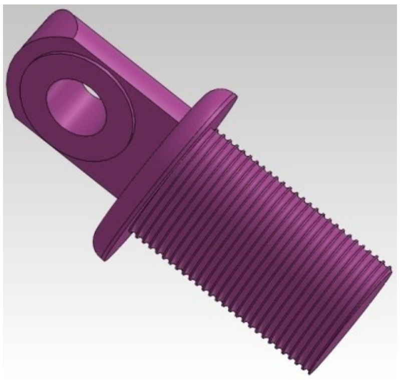

Figure 12: 3D view of hinge (new fixture)

Loading and unloading data on new fixture

The basic working procedure of new fixture is exactly the same as the present fixture. The whole working process is divided in following steps.

1. Unloading the job
2. Air cleaning the fixture
3. Loading the new job

The values in the Table 2 below are the average values of 5 readings taken continuously on the same machine and for the same operator at 11:00 AM (general shift). The values are taken with the help of a stop watch and are subjected to change with the machine and operator as well. Table 2 also shows the comparison of time for same operations with present fixture:

Table 2: Detailed working time of new fixture and comparison of time with present fixture

S. No.	Basic Step	Operation	Time (Sec.) (Present Fixture)	Time (Sec.) (New Fixture)
1	Unloading of job	Pickup Spanner	4	-
2		Loosening of Locking Nut	9	4
3		Drop Spanner	5	-
4		Turn Clamp to OUT position	6	3
5		Turn Locking Arm to IN position	-	3
6		Pickup Old Job	5	5
7		Air Clean the Fixture	10	10
8	Loading of job	Place New Job	9	9
9		Turn Clamp to IN position	6	3
10		Turn Locking Arm to IN position	-	3
11		Pickup Spanner	5	-
12		Tightening of Locking Nut	9	4
13		Drop Spanner	4	-
Total Time Taken			**72**	**44**

Detailed machine time for Tong Tai – 4 using present fixture and new fixture is given in Table 3 below:

Table 3: Tong Tai-4 machine time data with present fixture and new fixture

S. No.	Operation	Tool No.	Time (Sec.) (Present Fixture)	Time (Sec.) (New Fixture)
1	Loading/ Unloading (LUL)		72	44
2	Drill Φ 7.6 (4 Holes)	13	63	63
3	Ream Φ 8 (4 Holes)	6	32	32
4	Drill Φ 8.1	17	27	27
5	Centre Drill (4 Holes)	1	24	24
6	Chamfer 0.5 X 45" (6 Places)	5	20	20
7	9.1 Slot Drill	9	13	13
8	Drill Φ 5	4	9	9
9	M6 Tap	7	8	8
10	Spot Face Φ 19	10	6	6
11	Miscllaneous		6	6
Total Cycle Time			**280**	**252**

Detailed working time per day using the new fixture is calculated below:

Total Working Minutes per shift

(Excluding Tea Break and Meals)

Shift A (6:00 AM to 2:00 PM) : 450

Shift B (2:00 PM to 10:00 PM) : 450

Shift C (10:00 PM to 5:00 AM) : 360

Total Working Minutes per day : 1260 (21 Hour)

Out of Total time 19% is Manual handling time with New Fixture, as calculated above in Table 3, hence:

Manual Handling Time : 1260 X 0.19

: 239.4

= 239 Minute (about 4 Hour)

Total Reduction in Manual Time : 353 – 239

= 114 Minute (about 2 Hours)

Results

Decrement in cycle time per job

Total Cycle time per job with present fixture = 280

Total Cycle time per job with new fixture = 252

Decrement in Cycle time per job = 28sec/job

Comparison of production

As the fixture is yet to be installed on the machine hence the approximate increase in production is estimated and shown as below in figure 13.

$$\text{No. of processed jobs per day} : \frac{\text{Total Working Time per day}}{\text{Cycle Time per job}}$$

With Present Fixture = (1260 X 60) / 280 = 270 jobs

With New Fixture = (1260 X 60) / 252 = 300 Jobs

Increase in Production: 300 – 270 = 30 Jobs/day

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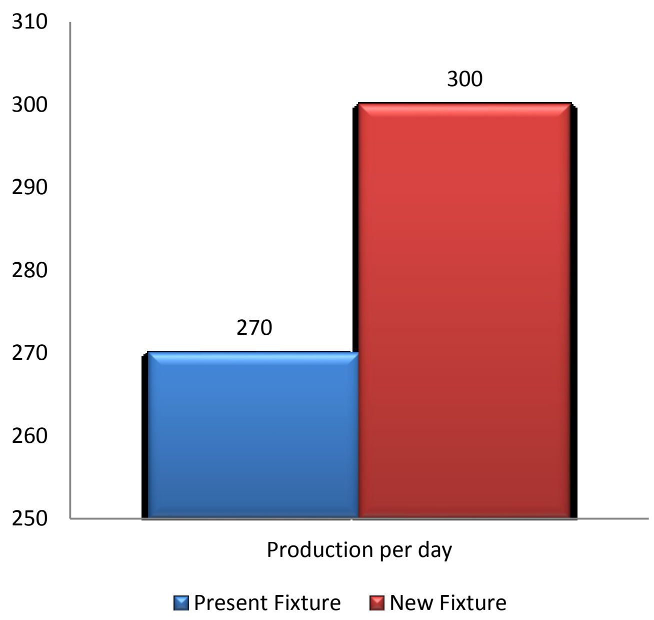

Figure 13: Increment in production

Increment in production rate and productivity per machine

As it is known that monthly target from Tong Tai – 4 =10,000 jobs

Approximate increase in production with new fixture = 30 jobs/day

Hence increase in production per month = 30 X 30

= 900 jobs/ month

Percentage increment in production rate per month = (900/10000) X 100

= 9.0 %

$$\text{Productivity} = \frac{\text{Increase in production}}{\text{Actual Production}} \times 100$$

= (900/8000) X 100 = 11.25%

Increment in production rate and productivity of ABC machine shop

Monthly target of ABC machine shop = 40,000 jobs

Production increment with new fixture = 30 + 30

= 60 jobs/day

Hence increase in production per month = 60 X 30

= 1800 jobs/ month

%age increment in production rate per month

= (1800/40000) X 100

= 4.5 %

Actual Production = (322 + 270) X 2 X 30

= 35520

%age Machining Productivity Improvement per month =

$$\frac{\text{Increase in production}}{\text{Actual Production}} \times 100$$

= (1800/35520) X 100

= 5.1%

4.9.5 Increment in working time per day for various machines in ABC machine shop

As the fixture is yet to be installed on the machine hence the approximate increase in working time per day for various machines present in ABC Machine Shop is estimated and shown in Table 4 below:

Percentage Increment in working time per day =

$$\frac{\text{Increase in Time per day}}{\text{Total working time per day}} \times 100$$

Table 4: Increment in working time per day for various machines

Sr. No.	Machine	Total working time with present fixture (minutes)	Total working time with new fixture (minutes)	Increment in working time per day (minutes)	Percentage Increment
1	CL-1	1218	1218	0	0
2	CL-2	1021	1136	115	9.13
3	CL-3	1218	1218	0	0
4	CL-4	1021	1136	115	9.13
5	TT-1	1260	1260	0	0
6	TT-2	1260	1260	0	0
7	TT-3	1260	1260	0	0
8	TT-4	1260	1260	0	0
9	FHD	1184	1244	60	4.76
10	FB-1	1136	1193	57	4.52
11	FB-2	1136	1193	57	4.52
12	GDT	1184	1244	60	4.76
13	HM - 1	1136	1193	57	4.52
14	HM - 2	1136	1193	57	4.52
15	WM	1184	1244	60	4.76

Financial increment per month for ABC

Increase in production per month	=	60 X 30
	=	1800 jobs/ month
Cost of one engine block	=	Rs. 395/-
Increment in Profit	=	1800 X 395
	=	Rs. 7, 11, 000/- ($13,912)

CONCLUSIONS

After implementing the changes in the design of clamping unit, 9.0% increment in production rate per month, 32% reduction in manual time per job has been achieved by changing the design of fixture. Along with the reduction in manual time, 13% increment in machining time per job and 11% decrement of cycle time per job has also been recorded. Also the productivity of the machine has been increased by 11.25% per month along with an increment of 4.5% in overall production rate, 5.1% increase in productivity of ABC machine shop has also been recorded.

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