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Productivity Improvement of 170 Series Connecting Rod Using MAG HMC 1000 CNC Machine

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Abstract Productivity improvement is a continuous process and an important technique to achieve both individual as well as organizational growth. Connecting rod manufacturing done in BEML machine shop engine division, Mysuru consists of 28 operations in different work centres. In some of the work centres, the components have to be passed 2 to 3 times, thereby increasing the waiting time of the components in the production line. This reduces the flexibility of line leading to line imbalance thereby less output from the line. In this project, an attempt was made to avoid machine waiting and line imbalance; the operations were combined using MAG HMC 1000 using suitable fixture design and program in order to increase the productivity of the connecting rod with reduction in set-up and labour time. Twelve components were accommodated in a single set-up, which would increase productivity by 18.54%.

Keywords Connecting Rod, MAG HMC 1000, Fixture

1. Introduction

The connecting rod or conrod connects the piston to the crank or crankshaft. Together with the crank, they form a simple mechanism that converts reciprocating motion into rotating motion. Connecting rods that function in internal combustion engines are subjected to high cyclic loads comprised of dynamic tensile and compressive loads. They must be capable of transmitting axial tension and compression loads, as well as sustain bending stresses caused by the thrust and pull on the piston and by the centrifugal force of the rotating crankshaft [1].

Connecting rods are manufactured by casting, forging, and powdered (sintered) metal processes. Forged connecting rods have been used for years and have a thick parting line along the length of the rod. They are mostly used in high performance engines and are generally used in heavy-duty engines. The cost of cast rods is lower than that of forged rods, both in the initial casting and in the machining. Cast rods can be identified by a thin parting line along the length of the rod. Generally, the forging method produces lighter weight and stronger, but more expensive connecting rods.

The function of connecting rod is to transmit the thrust of the piston to the crankshaft. Connecting rods are widely used in variety of engines such as, in-line engines, V-engine, opposed cylinder engines, radial engines, and opposed-piston engines. Table 1 shows the Chemical Composition of Boron Steel used as work piece.

The manufacture of connecting rods involves a number of operations that must be routed to different machining centres. Figure 1 shows a connecting rod that consists of a rod and a cap and involves a variety of operations such as milling, boring, grinding, chamfering, drilling, reaming, honing, and assembling.

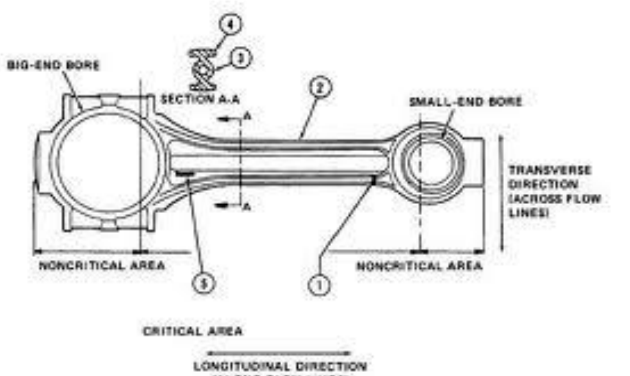

Figure 1. Connecting Rod

1.1. Problem Definition

The 170 series connecting rod is manufactured in the BEML machine shop engine division, and consists of 28 operations in different work centres. In some of these work centres, the components have to be passed 2 to 3 times, thereby increasing the waiting time of the components. This reduces the flexibility of the line leading to line imbalance, and thereby less output from the line. This also increases the waiting time, set- up time, and labour time. This results in reduction of the production of the connecting rods.

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Table 1. Chemical Composition of Boron Steel

Particulars	Carbon	Silicon	Manganese	Phosphorus	Sulphur	Aluminium	Cromium	Boron
Boron Steel	0.25-0.30	0.2-0.35	1.1-1.3	0.020max	0.005max	0.025-0.065	0.4-0.6	0.001-0.004

1.2. Objective

In order to avoid machine waiting and line imbalance, the operations should be combined and automated so that some of the operations are implemented into the latest machining centre MAG HMC 1000, with advanced features, better and consistent in- built quality by using suitable fixture design and program in order to increase the productivity of the connecting rod.

- In the same fixture, 5 operations should carried out for a single component in a single set-up.
- 12 components can accommodated for a single set-up.

2. MAG HMC 1000 CNC Machine

Figure 2. MAG HMC 1000 CNC Machine

Table 2. Specification of the MAG HMC CNC Machine

Machine Make	MAG Huller Hille
X axis travel	2700mm
Y axis travel	1100mm
Z axis travel	1100mm
Table size	1500x1000mm
T-slots	18x5x100mm
Max. Table load	900kg
Spindle speed	7000rpm
Spindle Taper	BT-40
Rapid traverse(X,Z)	20m/min
Rapid Traverse(Y)	15m/min
Feed rate(X,Y,Z)	1-6000mm/min
Tool change mechanism	Arm type ATC
Max. Tool diameter	ø75 mm
Max. Tool weight	7kg
Max. Tool	200mm

The MAG HMC 1000 adopts an impressionable casting with scrapping skill, high rigidity structure, and precision axial feed rates to assure high precision machining capacity. It uses a box way mechanism with a worktable of dimension 1500x1000mm and the X, Y, Z axes travel 2700x1100x1100mm.

It is a multi- pallet system with a tool magazine capacity of 190 tools and costs < 19.89 crores.

3. Literature Survey

Improving Productivity of Manufacturing Division by using Lean Concepts and Development of Material Gravity Feeder- A Case Study

K. Hemanand et al. carried out as a case study in an automotive industry. They made efforts to reduce motion waste in the shop floor. The problems were identified and analyzed in the current layout through simulation and the results were compared, which resulted in productivity improvement of 11.95%. Motion waste was decreased by developing a new material handling system.

Implementation of Productivity Improvement Strategies in a Small Scale Company

A. Gunasekaran et al. presented a few of their experiences in implementing the latest productivity development strategies in a small company. The objective of the project was to improve productivity in the 2 cells of the manufacture of the head lamp cleaning systems through three aspects to be implemented.

Improving Productivity of Connecting Rods by Doe Method

Vashim I. Kureshi et al. carried out their work in reducing the rejection rate of connecting rods. The rejection of the connecting rod was taking place due to the assembly of rod and cap tight bolts Using DESIGN OF EXPERIMENTS as tool and by considering four different types of control parameters there was a reduction in the rejection rate by 3%.

Improving Productivity for Engine Crank Case Machining Line Using TPS Techniques and Simulation

V. N. Borikar et al. used the Toyota Production System (TPS) techniques to optimize the machining line of the Engine Crankcase, where multiple machines were operated by a single operator. It used simulation modelling using ARENA software to verify the on- hand as well as the proposed results.

To Improve Productivity for Casting Technology by Reducing Weight of the Gating System

Shashank V. Gulhane et al. tried to discover the problem related with the gating system for the production of ginning dead weight. Casting defects were recognized with % of defect and rejection of around 25-30%.

4. Fixture Details

Fixture is a work holding device that positions the work, but does not guide the tool or position the cutting tool. A fixture can be used for any operation that requires precise relationship in the positioning of a tool to a work piece.

4.1. Fixture Requirements for Connecting Rod

The proper holding of a connecting rod in a particular machine requires a special designed fixture. Here the proposed fixture designed for the MAG HMC 1000 is presented. The advantage of the proposed fixture is that it can hold 12 components at a time and perform 6 different operations. The material for the fixture should have enough strength to allow the 12 component to be placed in the fixture and also the supporting pads, which rest on the connecting rod.

4.2. Selection of Fixture

4.2.1. Fixture Material

Mild steel is used for making fixtures such as base plate, big end boring plate, and front and rear end plates, while C-45 is used for supporting the fixture plates.

Table 3. Composition of Mild Steel

Sl. No.	Particulars	% of composition
1	Carbon (C)	0.16-0.18
2	Silicon (Si)	0.40 Max
3	Manganese (Mn)	0.70-0.90
4	Sulphur (S)	0.040 Max
5	Phosphorus (P)	0.040 Max

Table 4. Composition of C-45

Sl. No.	Particulars	% of composition
1	Carbon (C)	0.42-0.50
2	Silicon (Si)	0.40 Max
3	Manganese (Mn)	0.50-0.80
4	Sulphur (S)	0.035
5	Phosphorus (P)	0.030
6	Chromium (Cr)	0.40 Max
7	Nickel (Ni)	0.40 Max

4.2.2. Fixture Design

The designing of a suitable fixture for the production of connecting rod consists of 3 plates, viz,

- Base plate
- Big end boring plate
- Front and rear end plate

Base Plate

The base plate is the main plate, which is connected to a work table of length 1000mm, width 1000mm, and thickness 63mm. Fig. 3 shows the base plate.

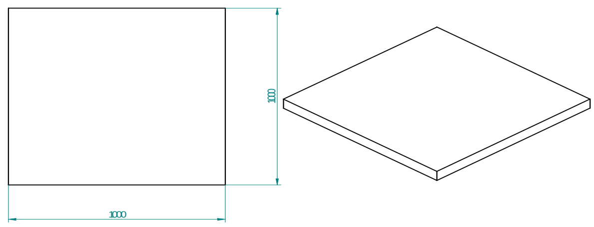

Figure 3. Base Plate

Big End Boring Plate

The big end boring plate is placed between the front and rear end plate. This plate is of length 250mm, width 800mm, and thickness 36mm. It is made to accommodate 12 components to carry out the operation of big end boring. Fig. 4 shows the big end boring plate.

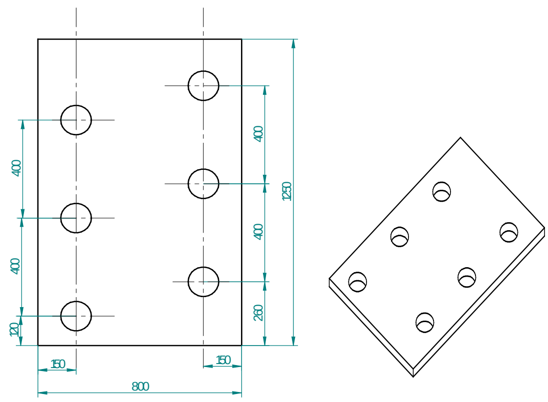

Figure 4. Big End Boring Plate

Front and Rear End Plate

The front and rear end plate is mounted on the base plate and connected to the big end boring plate in inverted c shape. This plate is of length 1250mm, width 800mm, and thickness 36mm. It is used to carry out operations such as top and rough milling, top and bottom rough grinding, small end rough boring, small end chamfering and boring, and side end bolt seat milling. Fig. 5 shows the front and rear end plate.

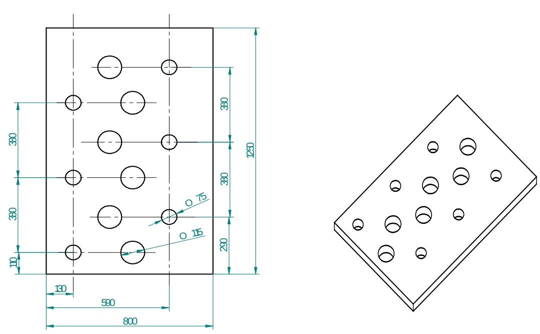

Figure 5. Front and Rear End Plate

4.2.3. Fixture Processing

The processing starts with the selection of raw material for the fixture plates. A base plate of 70mm is taken and its thickness is reduced to 63mm by the milling operation. Then, mild steel for the big end boring and front and rear end plate is taken. It is also milled to the desired dimensions and certain operations are carried out on that plate such as

- Marking
- Drilling
- Tapping

The resting pads required for supporting the fixture plates are made of C-45 material and are milled to respective dimensions, and marking, drilling, and tapping operations are carried out. The resting pads are connected to the main fixture plates through permanent fasteners.

4.2.4. Hardening

Hardening is a metallurgical and metalworking process used to increase the hardness of a metal. The hardness of a metal is directly proportional to the uniaxial yield stress at the location of the imposed strain. Quenching and tempering are heat-treatment methods used for high-quality heavy plates.

4.2.5. Assembly

The big end boring plate and the front and rear plate is connecting to the base plate by welding in inverted c shape. The welding is done at four points on the fixture plate and carried out in 2 layers. Fig. 6 shows the assembly of the fixture plates from different perspectives.

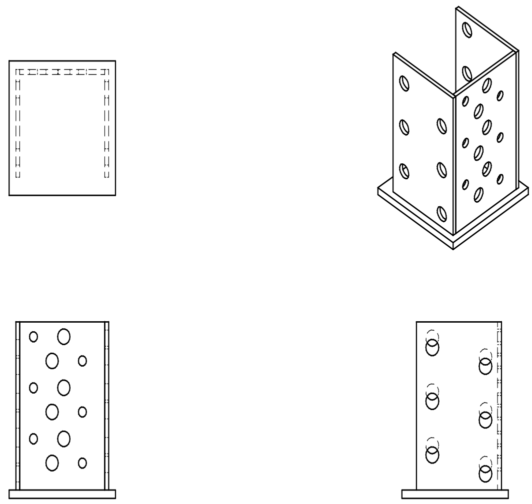

Figure 6. Different Views of the Assembly of Fixture Plates

5. Theoretical Analysis

The manufacture of connecting rods done in the Machine Shop Engine Division of BEML Limited, Mysuru. BEML produces 4 series of connecting rods that are used for various applications. They are

- 170 series
- 145 series
- 125 series
- 105 series

This project is mainly concerned with the manufacture of the 170 series connecting rod used in large trucks and earth movers. The operations carried out in the respective machines for the conventional production of connecting rods are shown in Table 5.

Table 5. Operations on Respective Conventional Machines

Sl. No.	Operations	Machines
1	Top & Bottom Rough Milling	Milling Machine
2	Top & Bottom Rough Grinding	Grinding Machine
3	Small End Rough Boring	Lathe
4	Small End Rough Boring & Chamfering	Boring & Slitting Machine
5	Side End Bolt Seat Milling	Milling Machine
6	Big End Slitting	Boring & Slitting Machine
7	Joint Face Grinding Rod & Cap	Grinding Machine
8	Big End Rough Boring	Boring & Slitting Machine
9	Drill & Ream Bolt Hole	Drilling Machine
10	Tapping of Bolt hole	Tapping Machine
11	Dowel Drilling & Reaming Rod & Cap	Drilling Machine
12	Notch Milling of Rod & Cap	Notch Milling
13	Gun Drilling of Oil Hole in Rod	Gun drilling Machine
14	Lapping of Joint Faces in Rod & Cap	Lapping machine
15	Assembly of Rod & Cap	Manual
16	Top & Bottom Surface Grinding Finish	Grinding Machine
17	Small End Key Stone Milling	Key Stone Milling Machine
18	Finish Boring of Big & Small Ends	Boring & Slitting Machine
19	Weighing & Balancing of Rod & Cap	Weighing Machine
20	Honing of Big End Bore	Honing Machine

The total time taken by conventional machines to complete the operations to produce the connecting rod is 8hrs and the set- up time required to produce the 170 series connecting rod is 13hrs.

5.1. Comparison between Conventional and Proposed Methods

The comparison of conventional and proposed method is presented in Table 6.

Table 6. Comparison between Conventional and Proposed Methods

Sl. No.	Conventional Method	Proposed Method
1.	Individual operations are carried out in an individual machining centre.	Six operations are carried on a MAG HMC 1000 CNC Machine.
2.	Individual set-up is required at respective machining centres.	Six operations can be carried out in two set-ups.
3.	Waiting time is increased since the components have to be passed 2 or 3 times in the same work centre.	Waiting time is reduced since the 12 components are produced at the same time in a single work centre.
4.	Only one operation can be carried out on one component.	More than one operation can be carried out on one or more components.
5.	Labour time is increased	Labour time is greatly reduced.
6.	This method creates inflexibility, thereby creating line imbalance and reduced output.	This method avoid machine imbalance and increases output.

6. Results and Discussions

The first six main operations are implemented into the MAG HMC 1000 machine. The operations that are implemented and their respective set-up time and labour time in conventional machine are shown in Table 7.

Table 7. Operations with their Set-up and Labour Times in Conventional Machines

Operation	Set-up Time	Labour Time
Top and Bottom Rough Milling	60 min	30 min
Top and Bottom Rough Grinding	120 min	18 min
Small End Rough Boring	31 min	14 min
Small End Chamfering and Boring	76 min	9 min
Side End Bolt Seat Milling	122 min	29 min
Big End Boring	51 min	13 min
TOTAL	460 min	113 min

The results obtained after the trail run of the component on the MAG HMC 1000 CNC Machine is shown in Table 8.

The first five operations were carried out in a single set- up, which required fixture set-up time of 1hr. And another operation, the big end boring was carried out in another set –up, which required fixture set-up time of 1hr.

With this new fixture design and programming capability, the time taken by the MAG HMC1000 CNC Machine for the operations is reduced. The time taken by respective machining centres to carry out these six operations is 113min per component, whereas the time taken by this new fixture design is about 24min for a single component. This new fixture design can perform machining operations for 12 components at a time. It takes around 290min to complete the machining operations for 12 components in this fixture design, whereas it takes 3 shifts by employees to complete these machining operations in respective convention machines.

Table 8. Operations conducted on MAG HMC 1000

Operation	Tool Used	Set-up Time	Time Consumption
Top and Bottom Rough Milling	Face Milling Cutter	15min	4min for one component
Top and Bottom Rough Grinding	Finish Face Milling Cutter	In same set-up, top and bottom rough milling	4min
Small End Rough Boring	Rough Boring Bar Deo Slide	15min	3.5min
Small End Chamfering and Boring	Finish Boring Bar	In same set-up, small end rough boring	3.5min
Side End Bolt Seat Milling	Insert End Mill	20min	7min
Big End Boring	Rough Boring Bar	15min	2min
TOTAL		65min	24min

In the same fixture, slots are made to accommodate three different positions of the component. More than one operation can be carried out or two components can be accommodated in a single operation.

7. Conclusions

In this project, an attempt has been made to present the implementation process of productivity improvement method in a company.

By the implementation of this new fixture design and program, the productivity is increased to around 30%. The overtime allocated to workers for the completion of orders gets reduced. The waiting period of machines for the arrival of the components at the different machining centres is reduced. Better quality of connecting rods can be produced. The set-up time and cycle time for production is also reduced.

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