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# Cycle Time Reduction for Bearing House Assembly

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**Abstract:** This study deals with Reduction of cycle time which is very important element considered in successful manufacturing now-a-days. Clearly, long cycle times cause high inventory, high cost and very poor customer service. Cycle time reduction has a good predictable role in operation of CNC and Non-Conventional machining processes. Reducing cycle time requires eliminating non-value added activities which does not add value to the product manufactured. Examples of non-value added activity includes machine set-up, inspection and scheduled delays. The parameters considered in this context are speed, feed, depth of cut, hand-offs etc., these parameters should not violate any of the constraints that may apply on the process and satisfy the objective function such as reducing cycle time, maximizing the production rate, reduction in costs, increase throughput, streamline process, improved communications, process variability reduction or combinations of the above functions. In this study, a major component is considered with turning, facing, grooving, threading, boring and drilling operations. Non-Value added activities not only the processes but also the unnecessary hand-offs of the operators which will increase the time to produce a component. The various operations performed on the component will be reduced to reduce the time required to produce the component. Now-a-days customers are asking for short span delivery time to satisfy their needs with good quality products which will be helpful for the organization keeping the old customers and increasing the new customers number. Cycle time of this component can be reduced by varying speed, feed and depth of cut. The objective of the study is obtained by changing the process/production type, pre machining the components and also by implementing new tool called form tool.

**Key words:** Cycle time, speed, feed, depth of cut, drilling, pre-machining

## INTRODUCTION

Reduction of cycle time is one of the very important elements considered in successful manufacturing now-a-days. More number of customers are demanding that manufacturers should quickly respond to their wants and needs and delivering perfect quality products on time. This trend which will continue, has led companies to focus more attention on their order-to-delivery cycle time. Reduction of cycle times has many advantages on the manufacturing process from reducing Work In Process inventory (WIP) to increasing throughput without increasing the resources required to produce the product. Although, Computer Numerical Control (CNC) machine do not automatically guarantee high productivity, reducing the cycle time is critical, particularly in high volume production like in auto parts:

- Investment in finished goods, WIP (work in process) inventory and financing of receivables decreases
- New market opportunities based upon order fulfillment speed and flexibility are enabled, pricing can be strengthened and customer loyalty enhanced in existing segments through improved service capabilities
- Hand-offs on raw materials, WIP or finished goods inventories are reduced, as there is less damage during storage and less risk of obsolescence

The goal of this study was to provide specific solutions of how to reduce cycle time and its inventory component for the part under study.

Various literatures has been studied and proposed in which best methods for minimizing the cycle time followed in present scenario by the various organizations are http://www.vorne.com/solutions/improvement/reduce-cycle-times.htm:

- Line pacing
- Reduce load time of component
- Increase capacity of machines/operators

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**Line pacing of machines:** It creates good exposure of real-time efficiency and reveals all key performance indicators to the operators. Line pacing will reduce the cycle time.

**Reduce load time of component:** It creates operator awareness of how loading time will affect the efficiency of the process and divides the cycle time into load and in-process times with very clear visual distinction. Reducing load time improves cycle time.

**Increase capacity of machines/operators:** It increases equipment effectiveness and output by monitoring the Overall Equipment Efficiency (OEE). It focuses on cycle time reduction and overall equipment effectiveness by tracking OEE of the machine. It increases the capacity and reduces cycle time.

Kakir and Garuda (2000) formulated a procedure to calculate the machining conditions for milling operations according to minimum production cost as the objective function.

Saravanan by using boundary search procedure, genetic algorithm, Nelder mead simplex method and simulated annealing based optimization procedures for solving CNC turning problem and found the optimum operating parameters such as cutting speed and feed rate (Saravanan *et al*., 2001).

Saravanan and Janakiraman (2008) by using optimization techniques they made a Study on reducing machining time in CNC Turning centre which optimizes the parameters such as speed, feed, depth of cut.

## PROBLEM DEFINITION

The cycle time to manufacture the components in CNC turning are found to be high than the necessary. Eight different parts are studied and bearing house assembly is identified for the case study based on the requirement demanded to eliminate unnecessary operations and movement of components. The parts are produced as per the sequence of operations in conventional and CNC turning section. Many processes, not just the manufacturing process, contribute to long cycle times, where all the delay for manufacturing of a product appears on the factory floor in the form of waiting (more than 95% of the order-to-delivery cycle time is occupied by waiting), the causes for those waiting from various processes both internal and external to manufacturing. The major time is wasted in inventory, raw material purchase, tool setup for various operations, transport between various sections, etc. and almost 15 min is lost in loading and transporting them from the conventional section to the turning centre and vice versa. This can be minimized by altering the plant layout or by altering the tools used for manufacturing or the process sequence if possible.

## PROBABLE CAUSES FOR THE PROBLEM

- Milling the square bars after first cutting will consume more time because filing should be performed after each side milling operation which consumes same time of milling for filing also. Proper utilization of manpower is not there
- Converting square to circle will take more time in turning. So, cost will be more as we know that the CNC is costlier than the conventional lathes. The drill hole diameter is also small
- Grooving tool using for this is of 3 mm grooving tool for rough operation which consumes more time in two turning operations

This is followed by two VMC operations which performs drilling four holes on the corners of the square on one VMC and performing end milling operation for fillets at 4 corners.

## BEARING HOUSE ASSEMBLY-1318895

**Material:** Aluminum (Fig. 1).

- Components of these products are machined on 2 Jobber machines and 2 vertical machining centres
- It consists of totally 130 operations performed on each component for dispatching product where operations 70, 80, 90, 100 are performed in turning centre
- 300 pieces are targeted for every month
- 3 months stock are available in store

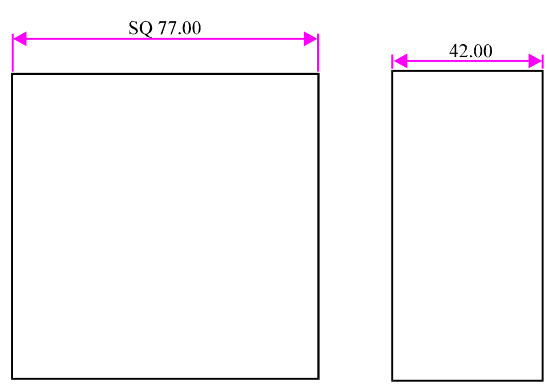


Fig. 1: Input material for the component

**Operations performed:**

- **70th operation:** Square with a through hole is the input and it is converted to circular on one side with one groove on the outer diameter. It takes 330 sec to complete this operation (Fig. 2)
- **80th operation:** Circular diameter is held on the chuck and remaining portion is machined with boring, chamfering, facing and 2 inner diameter grooves. It takes 563 sec to complete this operation (Fig. 3)
- **90th operation:** Component will be sent to drill 4 holes on the square billet which takes 205 sec to complete the operations (Fig. 4)
- **100th operation:** Component is subjected to milling by radius cutting for smooth surface finish and burrs are removed. It takes 103 sec to complete this operation (Fig. 5)

**Hand-offs on the component:** It is the various sections that a product will undergo machining to obtain the required output. The different hand-offs on this component are as follows:

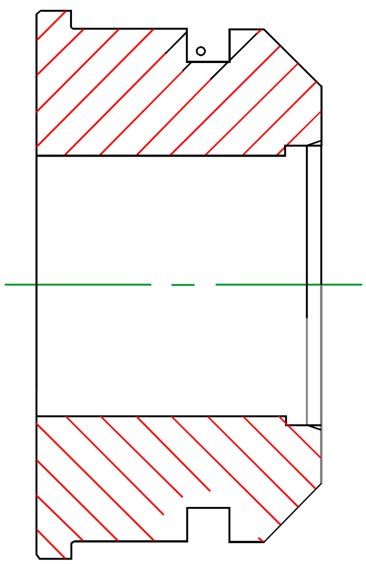

Fig. 2: 70th operation

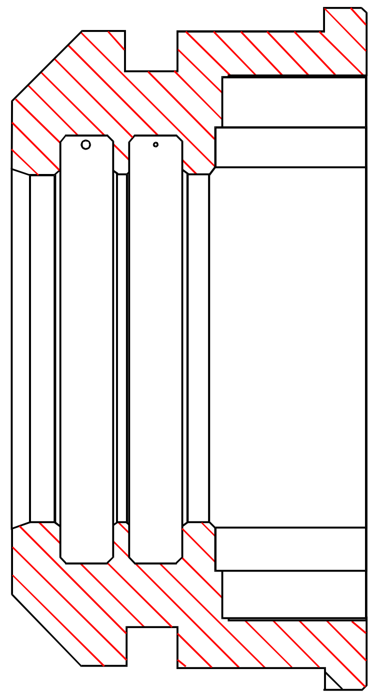

Fig. 3: 80th operation

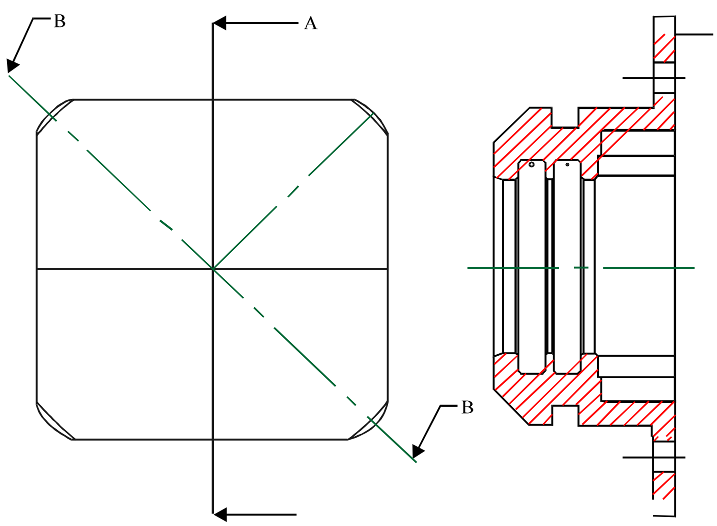


Fig. 4: 90th operation

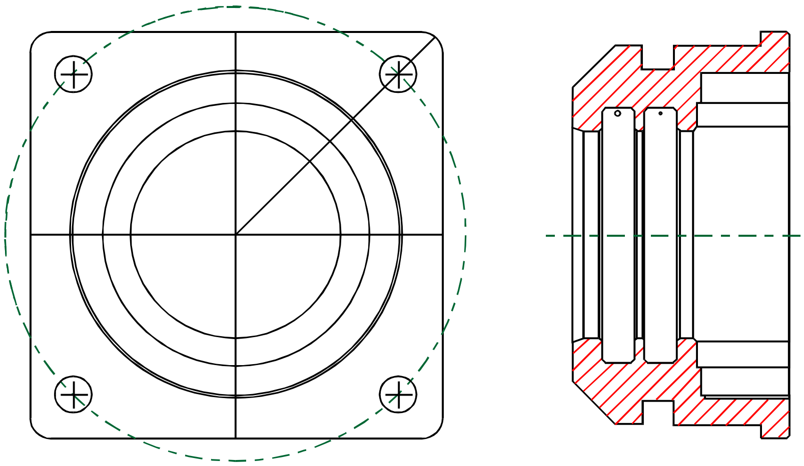

Fig. 5: 100th operation

Table 1: Cycle time for 1318895/70

| Process | Time (min) | Time (sec) |
|---|---|---|
| OD turning | 02:16 | 136 |
| ID roughing | 02:45 | 29 |
| OD rough groove | 03:23 | 38 |
| OD finishing | 03:49 | 26 |
| OD super finish | 04:24 | 35 |
| OD groove finish | 05:15 | 51 |
| ID bore finish | 05:30 | 15 |
| Total | 05:30 | 330 |

Table 2: Cycle time for 1318895/80

| Process | Time (min) | Time (sec) |
|---|---|---|
| OD roughing | 00:55 | 55 |
| Bore roughing | 02:01 | 70 |
| OD finishing | 02:45 | 44 |
| Bore finishing | 03:22 | 37 |
| ID groove rough | 08:31 | 309 |
| ID groove finish | | |
| Bore finish | 09:23 | 52 |
| Total | 09:23 | 563 |

- Cutting 3000 mm bars
- Milling 300 mm bars
- Cutting 77×77 sq.
- Conventional drilling 30 mm
- Turning-1
- Turning-2
- VMC-1
- VMC-2
- Deburring
- Inspection and packaging

**Cycle times for components in turning:** Cycle time for component is mainly based on the machining time of the component to be produced in turning centre. Data is collected for various components and the component selected is bearing house assembly (part number 1318895). At present scenario, short cycle time delivery and responsiveness can have an opportunity in increasing the number of customers and keeping old ones and also If we reduce the machining time of the components, cycle time will be automatically reduced and this will result in increasing production, reducing the cost, reducing the labor cost etc. (Table 1 and 2).

The various benefits through reducing cycle time are:

- Reduced costs
- Increased throughput
- Streamlined processes
- Improved communications
- Reduced process variability
- Schedule integrity
- Improved on-time delivery

## ANALYSIS OF COMPONENTS

**Approach method-I:**

- In this approach we have an idea to forge the component to reduce the cost and time taken to machine the component
- For this we need to change the shape of the input material
- In present method we are using square bars as the input but in the proposed method circular bar to be used as input
- The different calculations and the requirements for the proposed methods are listed below and comparison of costs is calculated
- The material to achieve the final product in a very short span is through change in the shape of the material and the process incurred in producing the component

Table 3: Cost on hand-offs for present process

| Present method | Cost (Rs.) |
|---|---|
| Cutting | |
| Milling | 6.00 |
| Cutting | 2.00 |
| Conventional drilling | 2.00 |
| Turning-1 | 16.50 |
| Turning-2 | 27.75 |
| VMC-1 | 13.00 |
| VMC-2 | 6.00 |
| Deburring | 1.00 |
| Inspection and packaging | - |
| Total | 74.25 |

Table 4: Cost on hand-offs for forging process

| Proposing method-forging | Cost (Rs.) |
|---|---|
| Cutting | 2.00 |
| Forging | 10.00 |
| Heat treatment | 12.31 |
| Pre-machining-drilling | 0.50 |
| Turning-1 | 11.50 |
| Turning-2 | 21.75 |
| VMC-1 | 13.00 |
| VMC-2 | 6.00 |
| Deburring | 1.00 |
| Inspection | |
| Packaging | - |
| Total | 78.05 |

- The weight of the material is reduced as such the cost of the material is reduced to half of its initial requirement
- The whole process is changed to reduce the total machining time of the component

**Bar route (present method):**

Input weight = 0.694 kg
Output weight = 0.178 kg
@Rs. 210 per kg
Raw material cost = 0.694×210 = 145.74
Scrap cost = 0.516×80% = 0.4128
Scrap @ Rs.60 per kg = 0.4128 * 60 = Rs. 24.26.
Total material cost = Rs. 145.74 - Rs. 24.26 = 120.98.
Total machining cost = Rs. 74.25.
Present Total cost = Rs. 120.98 + Rs. 74.25 = Rs. 195.23.
Comparison is shown in Table 3:
2% rejections = 195.23+(0.02×195.23)
= Rs. 199.1346

**FORGE route (proposed method):**

Input weight = 0.378 kg
Output weight = 0.178 kg
@Rs. 210 per kg
Raw material cost = 0.378×210 = 79.38
Scrap cost = 0.200×80% = 0.16
Scrap @ Rs. 60 per kg = 0.16 * 60 = Rs. 9.6.
Total material cost = Rs. 79.38 - Rs. 9.6 = Rs. 69.78.
Total machining cost = Rs. 78.05.
Proposing total cost = Rs. 69.78 + Rs. 78.05 = Rs. 147.846.
Comparison is shown in Table 4:
5% rejections (Rs.) = 147.846 + (0.05×147.846)
= 155.2383

Savings on each component (Rs. per piece) is = Rs. 199.134-Rs. 155.238
= Rs. 43.8966

Table 5: Comparison of machines for two processes

| Machines using | Machines proposed |
|---|---|
| Conventional drilling | Conventional drilling |
| Jobber-1 | Conventional lathe |
| Jobber-2 | Jobber-1 |
| VMC-1 | Jobber-2 |
| VMC-2 | VMC-1 |
| | VMC-2 |

**Die requirements:** The following are the different requirements of the die to forge the component:

- Die = 200 dia×130 length-1 No.
- Punch = 170 dia×130 length-1 No.
- Pin = 70 dia×100 length-1 No.
- Trimming die = 200 dia×50 length-1 No.
- Mild steel = 100 sq.×100 length-1 No.

**Material required for die:** The material required and the quantity needed is calculated below and listed:

| Hard die steel which is used for making | | |
|---|---|---|
| For die | (0.785×200×200×130×7.87)/1000 | 33 kg |
| For punch | (0.785×170×170130×7.87)/1000 | 23.21 kg |
| For pin | (0.785×70×70×100×7.87)/1000 | 3.027 kg |
| For Trimming die | (0.785×200×200×50×7.87)/1000 | 12.355 kg |
| 72 kg @ Rs.310 per kg | | |

| Mild steel which is used for making |
|---|
| For mild steel = (100×100×100×7.87)/1000 = 8 kg @ Rs.100/kg. |

**Process cost for die making:** The different processes and the cost incurred for manufacturing of the die is listed below:

| | | |
|---|---|---|
| Die and punch rough turning | 40 h×75 | Rs. 3000 |
| Die and punch finish turning | 40 h×75 | Rs. 3000 |
| Hardening | 72 kg @ Rs.100/kg | Rs.7200 |
| Electrode | 20 h×75 | Rs.1500 |
| EDM | 16 h×75 | Rs.1200 |
| Trimming die | 40 h×75 | Rs.3000 |
| Die polishing | 16 h×50 | Rs.800 |
| Sampling | | Rs.5000 |
| | Rs. 24,700+Rs.24, 000 = Rs. 48,700. | |

Each die can produce 2500 components.

As per the calculations Rs.43 is saving per piece during machining.

Total profit-2500×43 = Rs. 1,07,500
Die cost = Rs. 48,700
Rs. 58,800 on a lot per die

- Excluding die cost Rs.23.52 is saving per piece
- 200 tonnes capacity machine is to be used
- Comparison of machines is shown in Table 5

**Approach method-II:** Pre-machining the work piece:

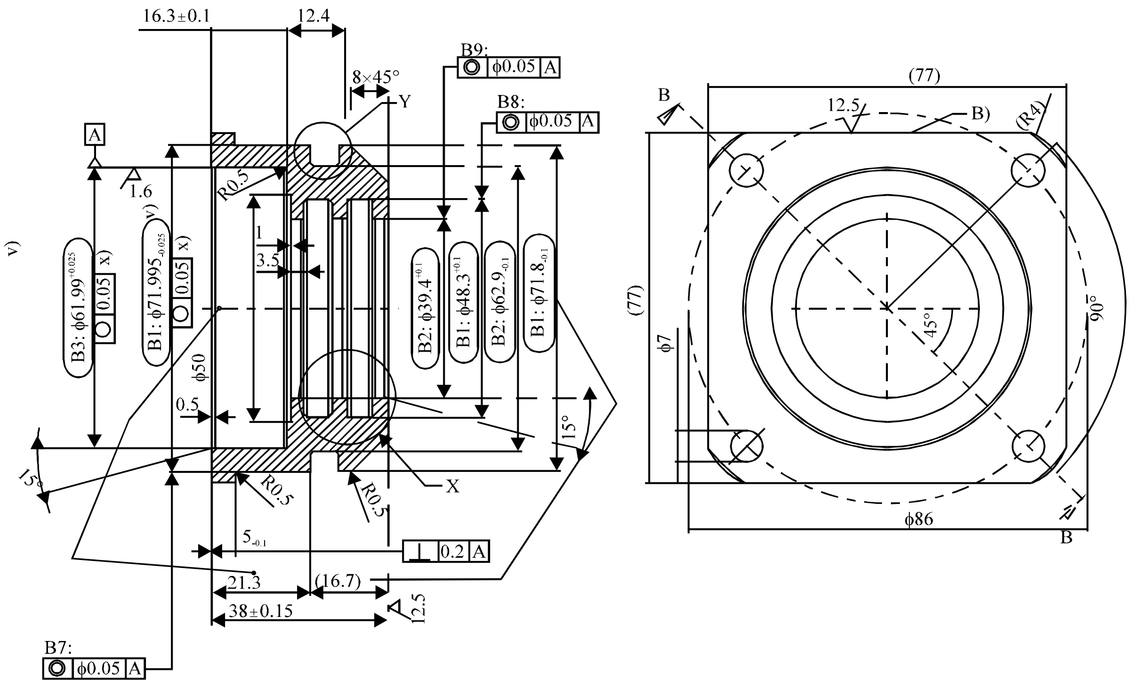

Fig. 6: Final product to dispatch

- Input material inside the turning centre can be reduced to minimize cycle time
- Cost will vary if the component is pre machined
- Material can be pre-machined using conventional machines

If the component is pre-machined, cost will be reduced because of conventional machines cheaper than the CNC Machines.

**Using conventional lathe:**

- Time taken to convert the square of 77×77 mm to dia of 71 mm:

$$T = \frac{L}{F \times N}$$

where, L is length of the component to be machined (mm).

F is the feed rate of the machine (mm per rev). N is speed of the machine (rpm):

$$\text{Time for 1 cut} = 32/(750\times0.1) = 0.426 \text{ min}$$
$$\text{For total length, we need 12 cuts} = 12\times0.426 = 5 \text{ min}$$
$$\text{Cost} = 5\times1.25 = \text{Rs. } 6.25$$

- Time taken for OD roughing and boring in turning can be reduced
- Comparison of hand-offs is shown in Table 6

**Approach method-III:** Changing the groove tool:

Table 6: Comparison of hand-offs

| Present Method | Proposing method |
|---|---|
| Cutting | Cutting |
| Milling | Milling |
| Cutting | Cutting |
| Conventional drilling | Conventional (drilling and turning) |
| Turning-1 | Turning-1 |
| Turning-2 | Turning-2 |
| VMC-1 | VMC-1 |
| VMC-2 | VMC-2 |
| Deburring | Deburring |
| Inspection | Inspection |
| Packaging | Packaging |

- New groove tool can be implemented to complete the work in short period of time
- Presently 3 mm groove tool is used to produce the component. It is proposed to use some other new tool which is effective
- As per the component drawing (Fig. 6) is concerned DM-5 carbide grooving insert can be used

Thin bit NEW FORM-A-GROOVE form tool system could be used for approach method-III. It generates complex profiles in a single plunge, simplifies the programming, increases productivity and accuracy and free tool locations for other tools. FORM-A-GROOVE inserts are designed to our exact specifications from stacking individual inserts and spacers or from a single block of carbide up to 50 mm wide. Tool holders are available in 25 mm round and 12.5, 18.75 and 25 mm square versions. Inserts can be coated with TiN, TiCN, TiAIN, or Diamond film coatings.

**Properties of the tool:** DM-5 carbide insert:

- 0.232” grooving width
- 0.020” corner radius, both sides
- At depth of cut, both sides
- 0.155” depth of cut to chamfer, both sides
- To centre of 0.020”radius, both sides
- 0.020”×45.0 chamfer, both sides

## CONCLUSIONS

- In approach method-I, the new process which will reduce the cost of the component as well as reducing the machining time of the component
- In approach method-II, the pre-machining the component using conventional machines will definitely reduce the machining time in turning centres
- Cost incurred for the product is also reduced
- In approach method-III, the thin bit 5.89 mm grooving tool which is preferred, can perform the whole groove at single pass leaving material for only finishing cut
- Using grooving tool, the machining time of this component can be saved nearly more than 150 sec
- Implementation of the pull production system pulls the products from the CNC end so that unnecessary queuing in the upstream operations are avoided
- The batch size suggested should be useful in reducing the idle time of the products and reduces the fatigue of the operator, for the deburring before loading in the CNC for the turning operations
- To have a safety stock in the inventory to avoid the depletion of the stock and delay due to the raw material purchase
- 5S implementation is to be made in the die store to avoid unnecessary delay in searching of the die and other accessories
- SMED (Single Minute Exchange of Die) is to be implemented in all the machining and forging areas to reduce the setup time
- Proper speed and feed rate is to be checked from the previous projects undertaken to avoid undue delay in the same
- Plant layout change with minor changes is to be incorporated to avoid the transportation waste
- The overall cycle time is reduced further by eliminating the non value adding activities and removing the unnecessary motion of the employees and the part by implementing the above suggestions and the modifications made in the method of manufacturing

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