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Time Reduction and Analysis of Machining Process for Differential Case

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Abstract — *Differential casing is an important component of an automobile. It is first casted with sand casting and then two machining process (i.e.) milling and turning are carried out on it. In this project the machine development process is introduced. In which the milling and turning operation are combined together to form a same differential. As a result of which the production will be increased, reduce loading/unloading time, reduce lead time, increase surface finish and reduce cost per component of differential case. The main aim of this study is to reduce cost per differential case component by reducing cycle time and improving accuracy in low cost then current machining process.*

For this combined machining operation a new design of jaws of chuck is designed for the ATM machine with same operational sequence with turning and milling machining operations which results in optimum machining time. Compare the old machining cycle time with the new developed machining cycle time.

Keywords- *Accuracy, Cycle Time, Differential Case, Jaw design of chuck, Machining Operation*

I. INTRODUCTION

These are Differential Cases which house the Side Gear and Pinions. Two sizes of differential pinion and side gear are used in the cases. These are SG Iron casting procured from of the most reputed foundries in India & China and machined to extremely close tolerance. Machined from nodular cast iron and housing the vehicle differential gear assemblies, differential housings present difficulties in terms of interrupted cuts during roughing passes. Surface finishes and tolerances must be held to customer standards, and machining operations involve custom combination tooling such as turning heads, drills and reamers.

II. MACHINING PROCESS

There are mainly two types of machining process used for differential casing are given below.

i) CNC MILLING MACHINING

CNC milling uses commands or G codes to program machinery. Each alphanumeric codes has a designated functions to be performed by the machine. The drill and turn along axis to cut and shape metal and wood. X and Y axis are labeled to complete vertical movements and Z axis are labeled to perform horizontal machine movements.

ii) CNC TURNING MACHINING

CNC turning refers to the automated machining process of shaping material such as metal, wood of plastic, Using CNC machine. During the CNC process a work piece of material is rotated and a cutting tool is moved parallel to the axis of rotation to produce precise diameters and depth It can be performed on outside on W/P or the inside to produce tabular component to various geometries.

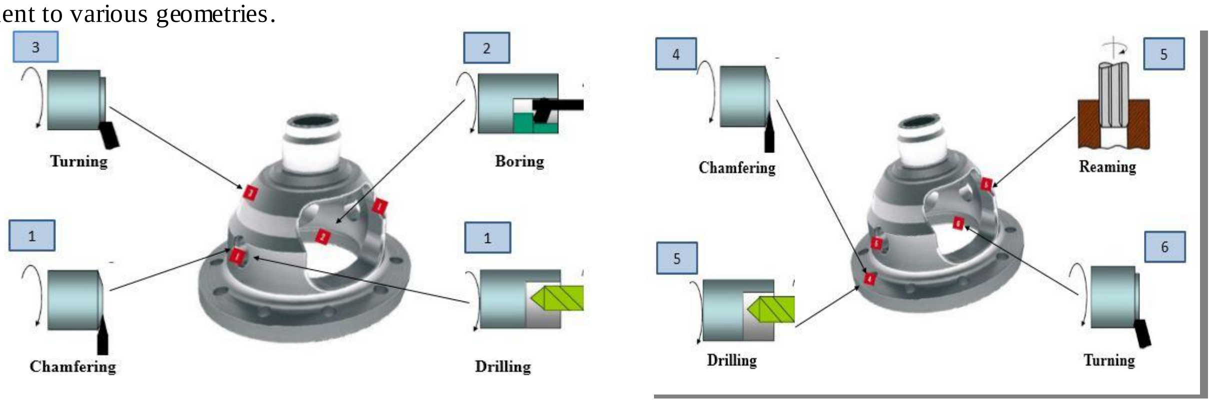


Fig. 1 Machining Processe

III. CURRENT MACHINING PROCESS

There are generally two main current process are used to manufacturing the differential case.
(1) CNC Turning Process
(2) CNC Milling Process

Fig 2: PX10 CNC milling machine

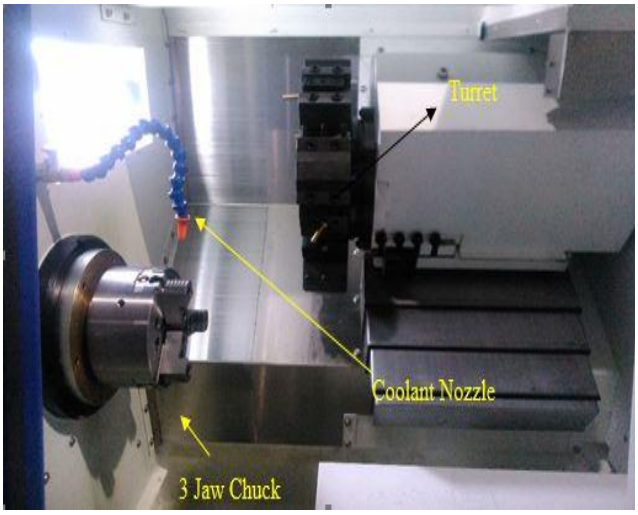


Fig 3: DX 200 CNC turning machine

A. Cycle Time Calculation:

Table 1: Total machining cycle time

Sr. No	Operations	Cutting time (sec)	Tool change (sec)	Slide travel (sec)	Total time (sec)
1	Rough internal sphere turning	96	3	6	105
2	Finish internal sphere turning	57	2	4	63
3	Cross bore drilling	44	1	2	47
4	Cross bore chamfering	24	1	2	27
5	Cross bore boring	26	2	4	32
6	Cross bore reaming	26	2	4	32
7	Cross bore circlip grove milling	51	1	2	54
			TOTAL TIME		360

- **TOTAL MACHINING TIME**

DIFFERENTIAL CASE= Rough internal turning + finish internal turning + milling operations
= 1 min 45 sec + 1 min 3 sec + 3 min 12 sec
= 6 min

- **TOTAL UNLOADING / LOADING TIME**

DIFFERENTIAL CASE = Rough internal turning + finish internal turning + milling operations
= 30 sec + 30 sec + 2 min 20 sec
= 3 min 20 sec

- **TOTAL TIME**

DIFFERENTIAL CASE = 6 MIN + 3 MIN 20 SEC
= 9 MIN 20 SEC

IV. DEVELOPED MACHINING PROCESS

There are various seven types of machining process to manufacture differential case. All the machining processes are described below in the Auto turn mill (ATM) Machine.

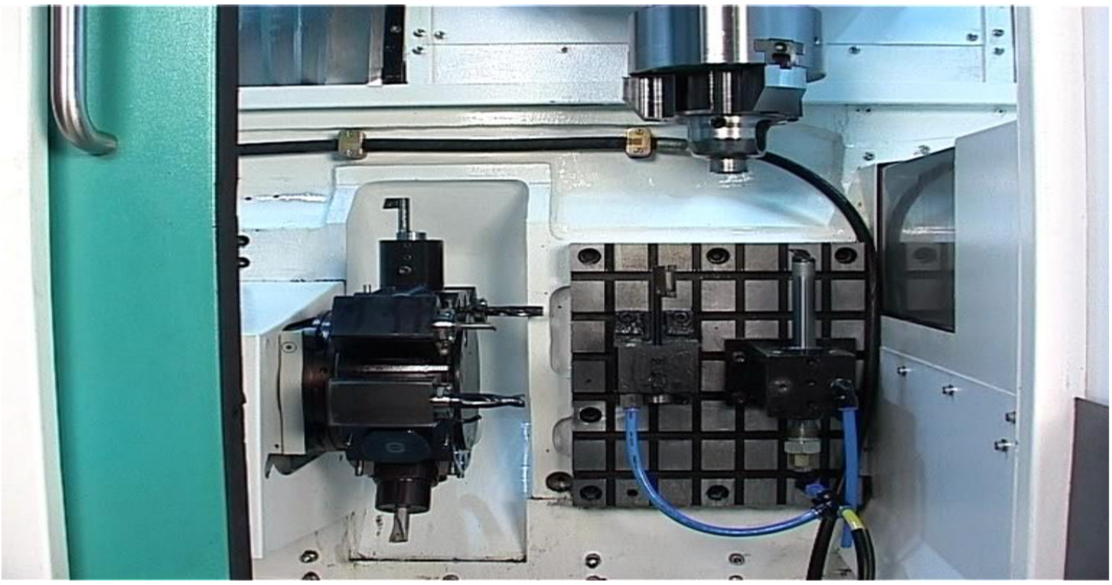
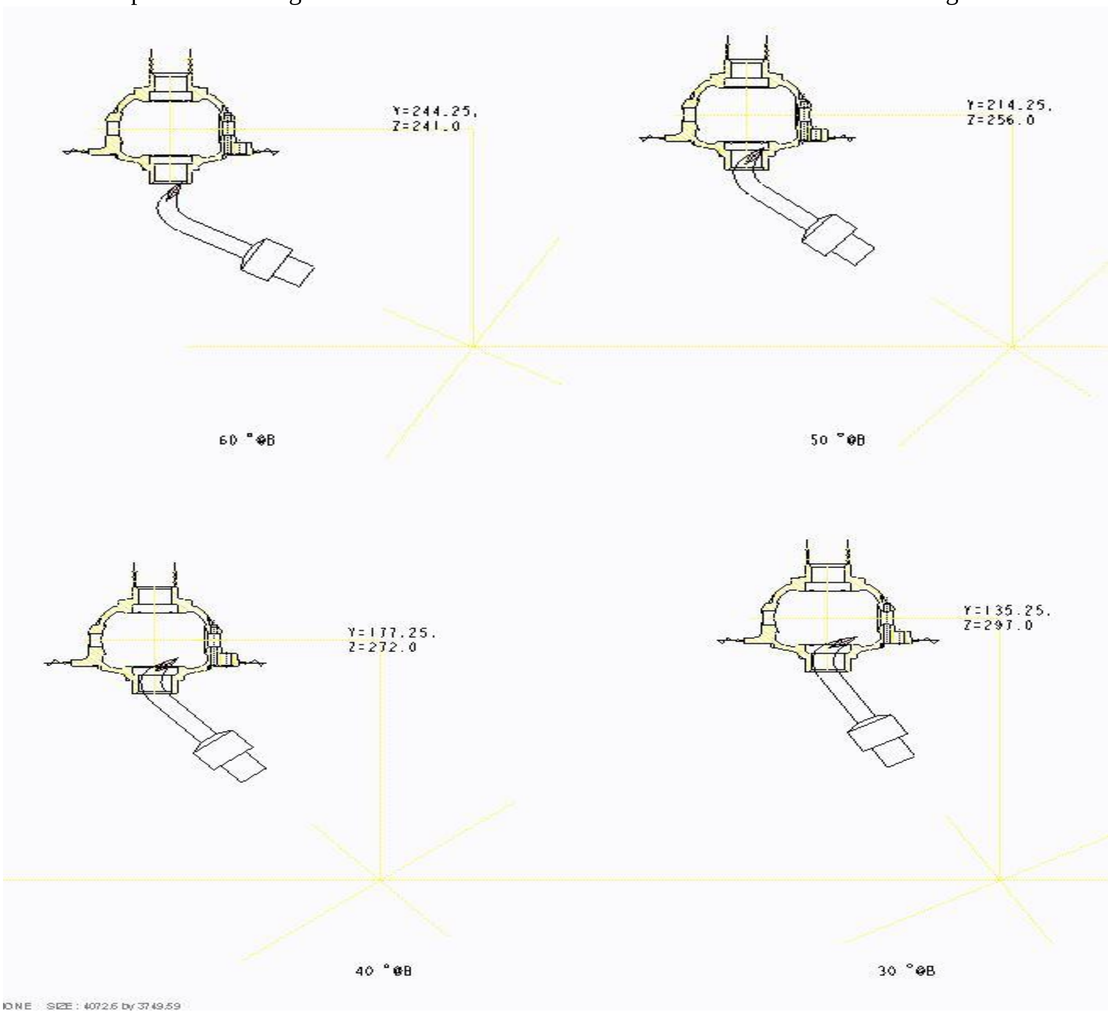


Fig.4 Set up of Auto turn mill

A. Guzneck Tool Entry Sequence

There are various steps of enter the guzneck tool in auto turn mill machine for differential case is given below



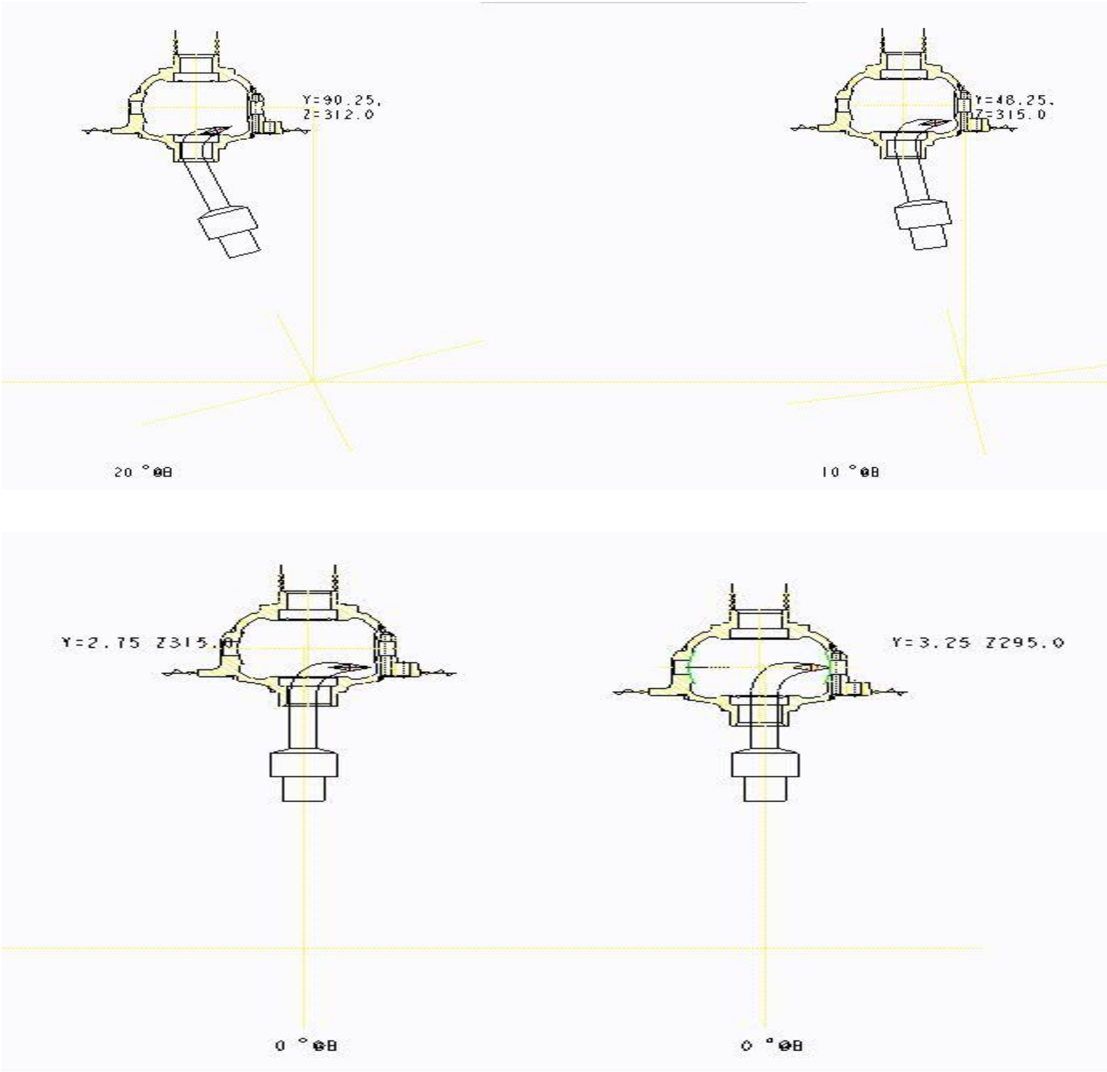


Fig.5 Guzneck Tool Entry Sequence

B. Design of chuck

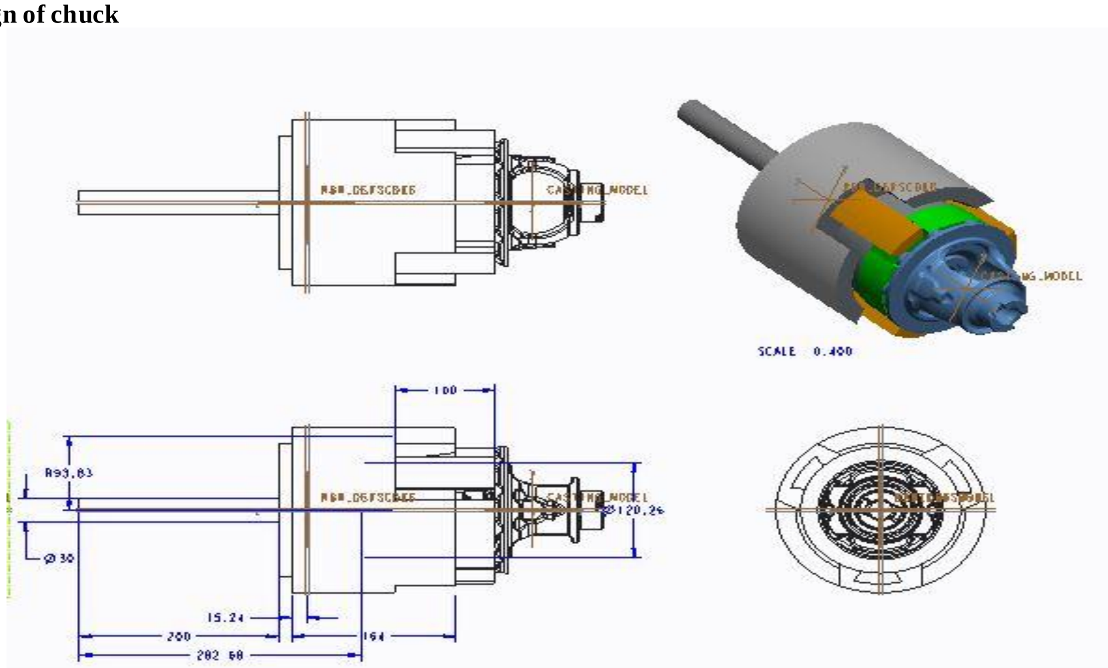


Fig.6 Design of chuck

Three-jaw pull loch style power chuck are ideal for finishing machine application. The redial and pull back features allow high gripping force, component length control and high repeatability. Open center pull loch chuck (PUB), grip the work piece from the outside, and then pull it back.

- **Special Features**

1) High accuracy for finish machining
2) Through hale model
3) Length control for efficient operation
4) Pull back feature is ideal for second operation requiring the highest precision
5) Maintains more grip force at high RPMs compared to conventional chucks

C. VDI Type turret

VDI holders (Verein Deutscher Ingenieure) have a serrated shaft that is inserted into an opening on the face of the turret. The tool is held in place by a mating part with teeth that is housed inside the turret.

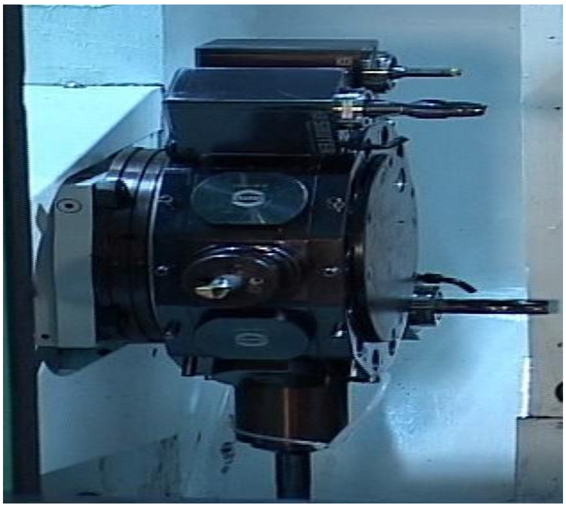


Fig.7 VDI Type turret

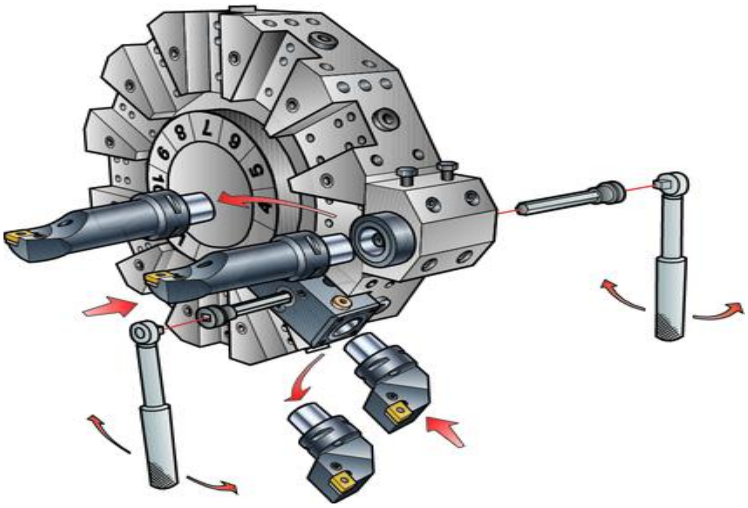


Fig.8 Tool mounting on turret with tool holder

Because of its design, and due to the likelihood that the tool will rotate out of position (around the centerline of the mounting shaft) when being mounted, most VDI holders have been equipped with a dial mechanism to assist the operator when installing the tool holder on the machine.

It is worth pointing out that, although this additional step of indicating the holder straight will not only insure that drills and taps are on the same plane when entering the work piece, but it also provides an additional level of accuracy and peace of mind that is not capable with BMT holders. With the BMT system, once the tool holder has been installed, and located securely by the alignment keys, the tool cannot be "tweaked-in" for increased accuracy if necessary.

D. Cycle Time Calculation

- **TOTAL TIME**

DIFFERENTIAL CASE = **Total machining time + loading unload time + Guzneck entry/Exit time.**
= 168 SEC + 12 SEC + 60 SEC
= 4 MIN

Table. 2 : Machining Parameter

SR.NO	OPERATION	CUT. SPEED (M/MIN)	SPN. SPEED (RPM)	FEED (MM/REV)	FEED (MM/MIN)
1.1	ROUGH INTERNAL SPHERE TURNING	150	597	0.18	107.48
1.2	FINISH INTERNAL SPHERE TURNING	160	637	0.18	114.65
1.3	CROSS BORE DRILLING	100	1990	0.10	199.04
1.4	CROSS BORE CHAMFERING	100	1274	0.10	127.39
1.5	CROSS BORE BORING	130	2464	0.12	295.72
1.6	CROSS BORE REAMING	100	1873	0.15	281
1.7	CROSS BORE CIRCLIP GROVE MILLING	80	1592	0.10	169.24

Table.3 Cycle Time Calculation

Sr. no	Operations	Cutting time (sec)	Tool change (sec)	Slide travel (sec)	Total time (sec)
1	ROUGH INTERNAL SPHERE TURNING	52	1.5	2.0	55.5
2	FINISH INTERNAL SPHERE TURNING	24	1.5	1.5	27
3	CROSS BORE DRILLING	16	1.5	2.0	19.5
4	CROSS BORE CHAMFERING	10	1.5	2.0	13.5
5	CROSS BORE BORING	12	1.5	2.0	15.5
6	CROSS BORE REAMING	12	1.5	2.0	15.5
7	CROSS BORE CIRCLIP GROVE MILLING	18	1.5	2.0	21.5
			Total time		168

E. Accuracy

Accuracy is the degree to which information on a map or in a digital database matches true or acceptable value. Reflection of how close a measurement represents the actual quality measured and of the number and severity of errors in a dataset.

There are two types of accuracy in machining

- Dimensional accuracy
- Geometrical accuracy

Dimensional Accuracy

Dimensional accuracy is achieved when the final product falls within the tolerances bands for each dimension specifies in the drawings. Dimensional accuracy measured by a gantry type CMM machine.

Geometrical Accuracy

It is a drawing which consider the functions of the part and how this part functions with related part. This allows a drawing to contain a more defined feature more accurate without increasing tolerances. It is system that use standard symbol to indicate tolerances that are based on the feature geometry. It is sometime known as feature based dimensioning or true position dimensioning.

III. RESULT AND DISCUSSION

A. Comparison of machining cycle time

Table 5.1 Comparison of Machining Cycle Time

Sr. no	Machining operation	Total Cycle Time (second)	
		Current process	Developed process
1	Rough internal sphere turning	105	55.5
2	Finish internal sphere turning	63	27
3	Cross bore drilling	47	19.5
4	Cross bore chamfering	27	13.5
5	Cross bore boring	32	15.5
6	Cross bore riming	32	15.5
7	Cross bore circlip groove milling	54	21.5
Total time		**360**	**168**

B. Graphical Comparison

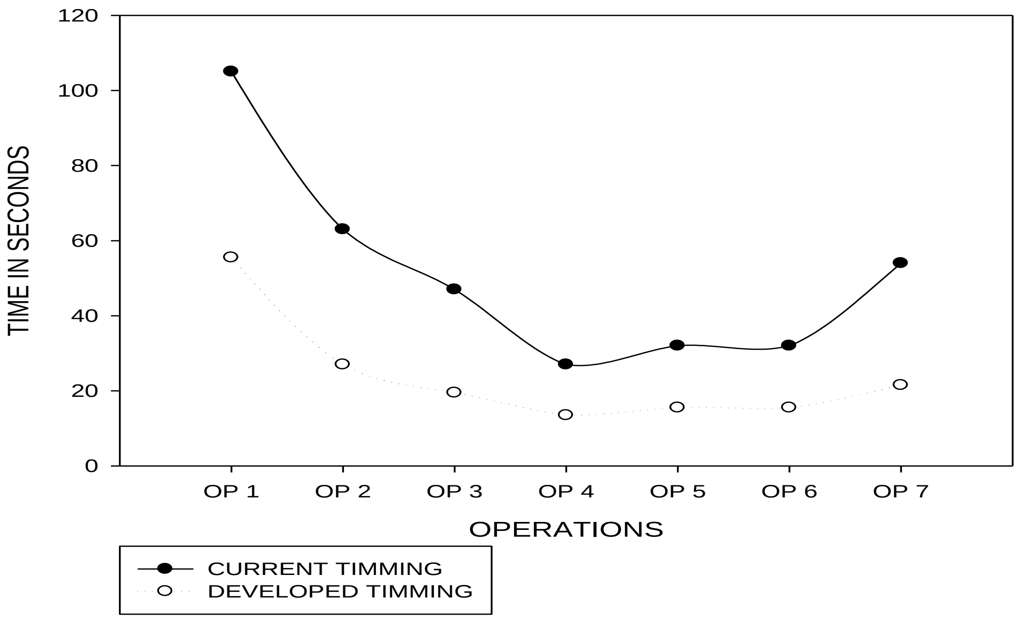


Fig.9 Graphical comparison current vs developed timing

C. Accuracy Comparison

Table 5.2 Comparison of accuracy

Sr. no	Machining operation	Dimensional accuracy (Tolerance zone)	
		Current process	**Developed process**
1	Finish internal sphere turning	38 micron	20 micron
2	Cross bore drilling	0.07 mm	0.05 mm
3	Cross bore chamfering	0.07 mm	0.05 mm
4	Cross bore boring	0.048 mm	0.03 mm
5	Cross bore riming	30 micron	15 micron
6	Cross bore circlip groove milling	0.2 mm	0.1 mm

D Graphical accuracy comparison

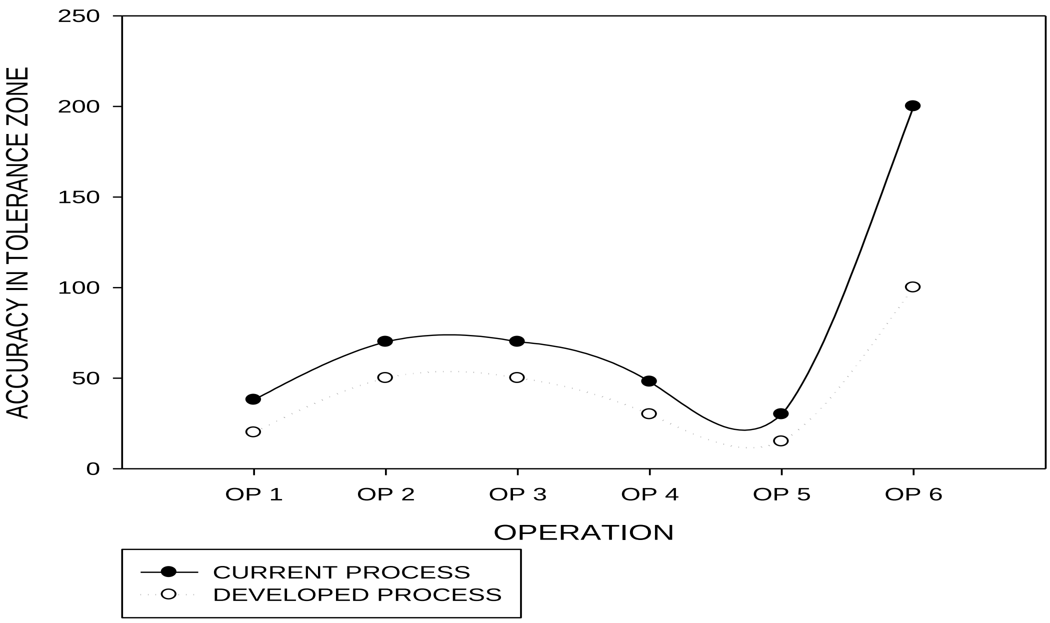


Fig:5.2 Graphical comparison current vs developed accuracy

E. Difference between current and developed process

Sr. no	Current process	Developed process
1	This process use three setup of turning machine and milling machine	This process use one setup of ATM machine.
2	Loading/Unloading time is 3 minutes and 20 sec.	Loading/Unloading time is 1 minute and 12 sec.
3	Total machining time of this process is 360 sec.	Total machining time of this process is 168 sec.
4	This process needs more space requirement	This process needs less space requirement
5	Human interference is required, because of loading and unloading is manually.	No human interference is required, because loading and unloading is automatically.
6	**Accuracy**	
•	Geometrical accuracy is less compared to developed process	Geometrical accuracy is better than current process.
•	Less dimensional accuracy than developed process	Better Dimensional accuracy due to fixed job position.

7	Cost	
•	Capital cost is higher than developed process	Capital cost is lower than current process.
•	The cost of tuning and milling machine is 56 lakhs.	The cost of ATM is 50 lakhs.
•	The prize of chuck is Rs. 3,20,000	The prize of special profile jaw chuck (PUB) is 3,80,000.
•	The cost of tooling is 3 lakhs and PX10 fixture cost 3.5 lakhs.	The cost of tooling is 2 lakhs for live tool and 80,000 for static tool.
8	This process carried out at vertical job positioning so possibilities of deflection.	This process carried out at horizontal job positioning so no possibilities of deflection
9	In this process difficulty of guzneck tool entry compared to developed process	Easy guzneck tool entry.

F. Cost Estimation Comparison

Sr.no	Current machining process (Turning and Milling)	R.S	Developed machining process (Auto turn mill)	R.S
1.	Turning machine DX200 Milling machine PX10	38,00,000 18,00,000	Auto turn mill machine	50,00,000
2.	Chuck	3,00,000	PUB Chuck	2,80,000
3.	Jaws	20,000	Special Profile jaws	30,000
	Total	**59,20,000**	**Total**	**53,10,000**

There are the above cost estimation shows that the cost reduction of the machine is reduced by the new developed machining process which reduce the cost per component of differential case.

IV. CONCLUSION

The main aim of this study is to reduce cost of component using developed process, one set up machine from the current two machine process turning and milling. The new developed machining process ATM machine reduce the cost per component by reducing the machining cycle time and reduce loading/unloading time.

The cycle time is reduced by using the modified special profile jaw chuck, VDI type turret and easy entry of guzneck tool in the ATM machine and loading/unloading time is reduced by automatic gantry type loading/unloading of ATM machine.

This study is concludes that the reduction of cost with the improvement of the dimensional and geometrical accuracy then the current machining process.

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