International Journal of Scientific Engineering and Technology (ISSN : 2277-1581)
Volume No.3 Issue No.10, pp : 1265-1269 1 Oct 2014

Time Study to Compare Different Operation Cycles Included in Manufacturing of Components with Cylindrical Bores

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Abstract— ***While considering the manufacturing of any components of aerospace industry it is very important to reduce the time associated with its production with minimum cost and high quality. The manufacturing of Electro Hydraulic Servo Valve (EHSV) considered for this work is a two stage electrically operated hydraulic valve, in which the output flow is proportional to the input current. Here investigated on both theoretical and practical aspects of using different processes involved in the production of EHSV. The material used for EHSV is SS 440 C. This investigation gave me a complete idea about the problems related to different machining operation cycles associated with the manufacturing of EHSV, especially the problems related to the wire electric discharge machining (WEDM). The main problems associated with WEDM increased time for manufacturing cylindrical bores and high costs associated with its production can only be eliminated by replacing the existing WEDM process with suitable process which is cost effective, time saving and produce components with better quality. For this purpose TiN coated carbide reamer is the best option to overcome the above mentioned problems for the manufacturing of cylindrical bores. Time study need to be performed on both existing operation cycle and proposed operation cycle in order to get the complete idea about the total time associated with the manufacturing of cylindrical bores in EHSV valve body.***

Keywords— Cycle time, Cylindrical bores, EHSV, Normal time, Standard time, Time study

I. INTRODUCTION

The Electro Hydraulic Servo Valves (EHSV) is basically an electrically operated valve in which the output flow is proportional to input current. The EHSV is a two-stage flow control valve, in which the output flow is proportional to the input current. Different varieties of EHSV are available according to the requirements. The main difference between different EHSV is in its flow rates. The EHSV works in conjunction with an Electro Hydraulic Servo Actuator which is essentially a double acting type actuator. The actuator moves the Fin Tip [v] (controlled elements) with reference to the given command and operates in a closed loop. The material used for manufacturing EHSV is SS 440 C.

There are so many manufacturing techniques used in precision manufacturing of components. Wire EDM is most extensively use techniques in manufacturing components with intricate shapes and profile. But this process is not suitable for manufacturing components with cylindrical bores and uniformly tapered bores, as they are time consuming and costly process. Application of advanced reamers like TiN coated carbide reamer can be used to overcome the problems related to manufacturing of cylindrical and tapered bore manufacturing of components in precision manufacturing. Technological and economical comparison, surface integrity, corner error, crater, corrosion, etc. of WEDM process where studied with the help of literatures [i], [ii], [iii], [iv], [vi].

While considering the manufacturing of EHSV, the WEDM is applied for the manufacturing of cylindrical bores in the EHSV valve body. But it is a time consuming and costly process. Also WEDM has several disadvantages as seen from several journals. So advanced process such as special purpose reaming process can be used instead of WEDM process for cylindrical bore manufacturing. Reaming is common machining process for enlarging, smoothing and accurately sizing existing holes to tight tolerances [vii]. Guhring's International manual for special purpose tools gives a complete idea about the type of tools that suitable for different work materials. In that manual the type of reamer suitable for machining SS 440C is found as TiN coated carbide reamer. It was found that the most influencing parameter for reaming process are speed, feed, depth of cut and allowance. In this work, depth of cut is not considered as the variable parameter; as it can only be varied according to the length of spool bore. Reaming was retained for finishing, as a process capable of yielding required results when performed on inexpensive machine tools such as drill press with simple fixtures. Reaming is suitable for batch production typically of job shops, facing the challenges of meeting specifications at competitive costs. Better surface finish and bore geometry can be obtained with the help of reaming process. Apparently minor influences led to enhanced process control and substantially better results at no extra cost.

II. MATERIALS AND METHODOLOGY

The main objective of this project work is to find out how various reaming parameters such as speed, feed and allowance influence various output characteristics such as surface finish and cylindricity while considering the manufacturing of cylindrical bores in the EHSV valve body. The valve body is the main component of EHSV. Figure 2 shows the EHSV valve body. When consider the valve body, the spool bore is the most important part of valve body. The spool bore is the only port where spool movement takes place. So while considering the valve body manufacturing, the manufacturing of spool bore was considered specifically and the manufacturing of other ports of valve body generally considered.

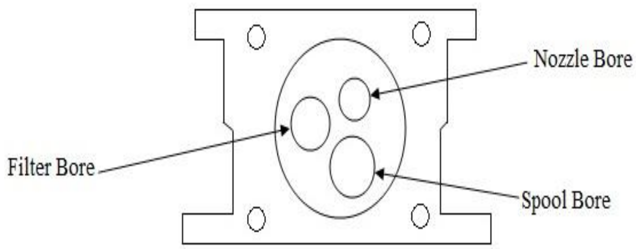

Figure 1. Bores in EHSV valve body

A. Existing Wire EDM Process

Wire Electrical Discharge Machining (WEDM) is a widely accepted non-traditional material removal process used to manufacture components with intricate shapes and profile. It is a specialized thermal machining process capable of accurately machining parts with varying hardness or complex shapes that are very difficult to machine by the main stream machining process. The basic features of WEDM are shown in figure 4. The principle of the WEDM process is based on the conventional EDM sparking phenomenon utilizing the widely accepted non – contact technique of material removal. However, WEDM utilizes a continuously travelling thin wire electrode made of copper, brass, or tungsten of diameter 0.03-0.30 mm, which is capable of achieving very small corner radii. The wire and there is no direct contact between the work piece and the wire, eliminating the mechanical stresses during machining. In addition, WEDM process is able to machine exotic and high strength and temperature resistive (HSTR) materials and eliminate the geometrical changes occurring in the machining of heat-treated steels.
Since the introduction of the process, WEDM has evolved from a simple means of making tools and dies to the best alternative of producing micro-scale parts with the highest degree of dimensional accuracy. WEDM has greatly altered the tooling and manufacturing industry, resulting in dramatic improvements in accuracy, quality, productivity and profit. Over the years, the WEDM process has remained as a competitive machining option fulfilling the demanding machining requirements imposed by the short product development cycles and the growing cost pressures. However, the risk of wire breakage and bending has undermined the full potential of the process drastically reducing the efficiency and accuracy of the WEDM operation. A significant amount of research has explored the different methodologies of achieving the ultimate WEDM goals of optimizing the numerous process parameters analytically with the total elimination of the wire breakages and improving the overall machining reliability which are explained in the literature survey.

B. Experimental details for proposed reaming process

The experiment was conducted on vertical milling machine. The machine has speed settings up to 15,000 RPM, feed settings up to 30,000 mm/min. The experiments are conducted on stainless steel 440C.

Output responses

Surface Finish and cylindricity are the output responses needed to be considered. But since this paper is related to time stuy, only time study details are considered.

C. Time Study

Time study need to be performed in order to compare the total cycle time for manufacturing valve body by using both the WEDM process and reaming process. The time study is considered to be one of the most-widely used means of work-measurement. Basically, by using time study, an analyst will be taking a small sample of a single worker's activity and using it to derive a standard for tasks of that nature.
The steps of time study are as follows:
Step 1: First select the job to be studied. Breakdown the work content of the job into smallest possible elements.
Step 2: Observe the time for appropriate number of cycles.
Step 3: Determine the average cycle time (CT).
CT = (ΣTimes)/(No. of cycles)
Step 4: Determine the normal time (NT).
NT = CT x PR
Where, PR is the performance rating
Step 5: Determine the standard time using the following formula.
ST = NT x AF
Where AF =1 / (1-% Allowance), AF is the allowance factor.
Compare the standard time for existing process and proposed process, then find out which process is time saving.
A brief overall cost analysis is also done to find which process is economical.

III. RESULTS AND TABLES

The time study is considered to be one of the most widely used means of work measurement. In this work, time study is conducted to study the time for manufacturing of bores in EHSV valve body.

A. Time Study for Bore Manufacturing for Existing Operation Cycle

Table 1: Data collection for pilot hole drilling process

Component ID No.	Operation name	Drilling setting time (minutes)	Time for drilling (minutes)
A1	Pilot Hole Drilling	6.44	2.53
A2	Pilot Hole Drilling	7.23	2.34
A3	Pilot Hole Drilling	6.47	1.52
A4	Pilot Hole Drilling	6.51	2.49
A5	Pilot Hole Drilling	7.49	1.57

Table 2: Data collection for WEDM process

Co mpt . ID No.	Operat ion Name	WEDM Setting Time (minutes)	Time for Rough Cut (minutes)	Time for Fine Cut (minutes)	Re-setting time due to Wire Cut time loss (Minutes)
A1	Wire EDM	9.11	17.51	13.43	
A2	Wire EDM	7.19	15.59	13.23	
A3	Wire EDM	10.58	19.34	12.21	
A4	Wire EDM	10.52	18.57	14.54	5.52
A5	Wire EDM	8.49	19.43	12.57	

Data collected for the production of bores of EHSV valve body by considering the time included for the pilot drilling, Wire EDM, honing and lapping processes. Data collected for the time study that involved in the spool bore production while following the operation cycle given below.

Drilling → Wire EDM → Bore Honing → Lapping

The time was taken with the help of stop watch. The data collection for the time study for the above mentioned operation cycle are tabulated in the table 1, table 2, table 3 and table 4. From the above tables, time for each processes involved in the existing operation cycle are analysed separately. The total cycle time for each operation cycle are tabulated on table 4.25. Idle time is not considered for this study as idle times between different processes are different from person to person.

Table 3: Data collection for honing process

Compt. ID No.	Operation name	Honing setting time (minutes)	Honing with roughing stone (minutes)	Honing with fine stone (minutes)
A1	Honing	7.54	8.53	4.43
A2	Honing	7.33	9.57	6.37
A3	Honing	6.21	8.49	4.52
A4	Honing	6.44	7.52	5.33
A5	Honing	8.47	9.51	4.47

Table 4: Data collection for lapping process

Component ID No.	Operation name	Lapping setting time (minutes)	Time for lapping with fine diamond abrasive (minutes)	
			Trial 1	Trial 2
A1	Lapping	9.58	24.43	11.39
A2	Lapping	8.47	21.37	13.23
A3	Lapping	9.52	23.57	9.57
A4	Lapping	8.43	27.45	10.34
A5	Lapping	8.58	25.36	11.54

Table 5: Cycle time for existing operation cycle

Compone nt ID No.	Total time for different processes (minutes)				Cycle time for existing operation cycle (minutes)
	Dril ling	WEDM	Honing	Lappin g	
A1	9.37	40.45	21.30	46.20	118.12
A2	9.57	36.41	24.07	43.47	114.32
A3	8.39	42.53	20.02	43.46	115.20
A4	9.40	50.35	20.09	47.02	127.26
A5	9.46	41.29	23.25	46.28	121.08

Average Cycle Time (CT)

CT = (118.12 + 114.32 + 115.20 + 127.26+ 121.08)/5
= 119.28 minutes

Normal Time (NT) = CT x PR

Where PR is the performance rating and is assumed to be 100 %
NT = 119.28 x 100 % = 119.28 minutes

Standard Time (ST) = NT x AF

Where AF being the allowance factor, AF =1/(1-%A)

%A is the allowance, it is assumed to be 10 % = 0.10

ST = 119.28/(1 - 0.10) = 132.53 minutes ≈ 133 minutes = 2 hour 13 minutes

B. Time Study for Bore Manufacturing for Proposed Operation Cycle

Table 6: Data collection for drilling and reaming process

Bore No.	Operation Name	Setting Time (minutes)	Time for pilot drilling (minutes)	Time for reaming (minutes)	Total time for drilling and reaming (minutes)
1	Drilling/ Reaming	7.21	2.08	1.09	10.38
2	Drilling/ Reaming	7.16	1.11	1.15	9.42
3	Drilling/ Reaming	5.19	2.20	1.06	8.45
4	Drilling/ Reaming	6.31	1.12	1.10	8.53
5	Drilling/ Reaming	8.09	1.15	1.03	10.27

Data collected for the production of bores of EHSV valve body by considering the time included for the pilot drilling, reaming and lapping processes. Data collected for the time study that involved in the spool bore production while following the proposed operation cycle given below.

Drilling → Reaming → Lapping

Table 7: Data collection for lapping process for proposed cycle

Bore No.	Operation Name	Lapping Setting Time (minutes)	Time for Lapping with fine diamond abrasive (minutes)	
			Trial 1	Trial 2
1	Lapping	7.19	21.08	10.11
2	Lapping	8.21	23.13	11.07
3	Lapping	8.07	22.17	9.23
4	Lapping	9.11	24.03	12.09
5	Lapping	7.19	21.10	12.15

While considering the proposed operation cycle for the manufacturing of bores in EHSV, the confirmation block with five bores in which drilling is performed first for pilot hole. TiN coated carbide reamer is used for reaming process. Allowance is the difference between the size of reamer and drill bit. Time for lapping process is tabulated on table 5.

Since the surface roughness and cylindricity obtained by reaming process is very low value compared to WEDM, honing process can be avoided.

Table 8: Cycle time for proposed operation cycle

Bore No.	Total time for different processes (minutes)		Cycle time for existing operation cycle (minutes)
	Drilling and reaming	Lapping	
1	10.38	38.38	49.16
2	9.42	42.41	52.23
3	8.45	39.47	48.32
4	8.53	45.23	54.16
5	10.27	40.44	51.11

Average Cycle Time (CT) = (49.16 + 52.23 + 48.32 + 54.16+ 51.11)/5 = 51minutes
Normal Time (NT) = CT x PR
Where PR is the performance rating and is assumed to be 100 %
NT = 51 x 100 % = 51 minutes
Standard Time (ST) = NT x AF
Where AF being the allowance factor, AF =1/(1-%A)
%A is the allowance, it is assumed to be 10 % = 0.10
ST = 51/(1 - 0.10) = 57 minutes

IV. CONCLUSION

Standard time for existing operation cycle and proposed operation cycle were calculated. The standard time for existing operation cycle is obtained as 2 hours and 13 minutes. At the same time the standard time for proposed operation cycle is obtained as 57 minutes. By comparing existing cycle and proposed cycle, it is found that by implementing proposed reaming process instead of WEDM we can save up to 1 hour 16 minutes for one bore. Similarly 2 more bores are there in the EHSV valve body. That is by implementing the proposed reaming process; we can save more than 3 hours per EHSV valve body.

ACKNOWLEDGEMENT

First and the foremost, I thank God, the Almighty who gave me the inner strength, resource and ability to complete the work successfully without which all the efforts would have been in vain. I express my heartfelt thanks to the Head and Professor, Department of Mechanical Engineering and my internal guide, Prof. Dr. Josephkunju Paul C from Mar Athanasius College of Engineering, Kothamangalam, Kerala, India for his support, valuable advice and helpful feedback for the successful completion of my work. I express my thanks to Reji Mathew, Professor, Department of Mechanical Engineering from Mar Athanasius College of Engineering, Kothamangalam, Kerala, India. I express my sincere gratitude and I am highly grateful to my external guide Dr. S. Karunanidhi, Scientist G and Deputy Director, Control Systems Laboratory, Research Centre Imarat, Defense Research and Development Organization (RCI DRDO), Hyderabad for giving me this golden opportunity to be a part of the organization, encouraging supervision, valuable discussions, never failing kindness and inspiring guidance throughout the work. I am immeasurably thankful to all the scientists and staffs of RCI DRDO for their kind support, valuable encouragement and friendly behaviour throughout my project work.

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