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The cost comparison of hard turning and grinding processes of AISI 52100 steel

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Abstract — *The hard turning process became in the last years a serious alternative for replacing grinding at finishing machining of the parts with hardness bigger than 45 HRC. Papers present the advantages that hard turning can offer in order to perform a final finishing operation. This paper is not only brief the condition required as for hard turning to be more efficient then grinding but also to bring the calculation method at the simplest formula possible in order to use it in forthcoming cost-effective calculation.*

Keywords- *cost; manufacturing time; hard turning; grinding processes.*

I. INTRODUCTION

The motivation of this investigate is to study the effects of cutting parameters on the cutting performance of hard turned parts with PCBN (polycrystalline cubic boron nitride) tools , in wholly dry cutting. The data obtained gives a wide scope to understand the influence of cutting conditions such as the cutting speed, feed rate and depth of cut on the costing of hard turning and finish grinding. The results presented will be useful for application of AISI 52100 steel for the development of turning finishing processes. Hard turning operation involves various input variables that include cutting speed, feed rate and depth of cut. These variables have direct as well as indirect effect on the performance of hard turning process. Hardened steel is one such that has been used extensively, particularly in the automotive industry for components such as bearings,gears,shafts,cams, forgings, dies and molds etched turning offers a number of potential benefits over traditional form grinding, including lower equipment costs, shorter setup time, fewer process steps, greater part geometry flexibility, and elimination of the use of cutting fluid [1,2 and 3].Hard turning is, therefore, of a great importance to both the manufacturing industry and research community.

II. EXPERIMENTAL SETUP

Hardened 52100 bearing steel with a hardness of 48~50 Hark was chosen for experimental studies because of its wide use in both automobile industry and research fields. The chemical composition as tested is shown in Table 1.

Table 1 Chemical composition of the steel material

C	Cr	Man	Si	S	P
0.92	1.06	0.51	0.22	0.039	0.040

The uncoated CBN cutting inserts (Mitsubishi, Japan) with a negative land and a 0.8 mm nose radius were used for turning experiments. Inserts are recommended for machining hardened steel and cast iron in finish operations. The geometry and grade of insert is NP-CNMA120408G.The tool holder used for clamping the insert is PCLNR 2525 M (Make- WIDIA). It has 95º approach angle and -6º back rake angle.

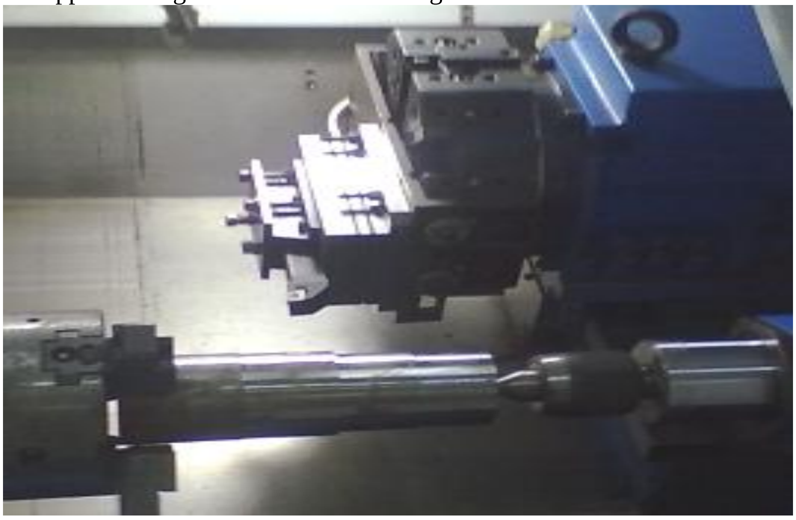

Figure 1 Experimental set-up

The experimental set-up is shown in Figure .1

III. MACHINING TIME FOR TURNING OPERATIONS

The cutting time is the time during which the tool moves at the feed rate and calculated from the following equations. To turn a cylindrical surface of length (l),feed rate (f) and number of revolutions(n) of the work piece, the operation time t_m is given by [4,5 and6]. Figure 2 shows a steel part that requires a cylindrical finish turning operation.

Table 1 Work piece and process parameters

Work piece parameters			Process parameters		
Hardness (Hark)	Initial Diameter (mm)	Final Diameter (mm)	Cutting speed (m/min)	Feed Rate (mm/rev)	Depth of cut (mm)
48~50	76.00	75.80	250	0.04	0.2

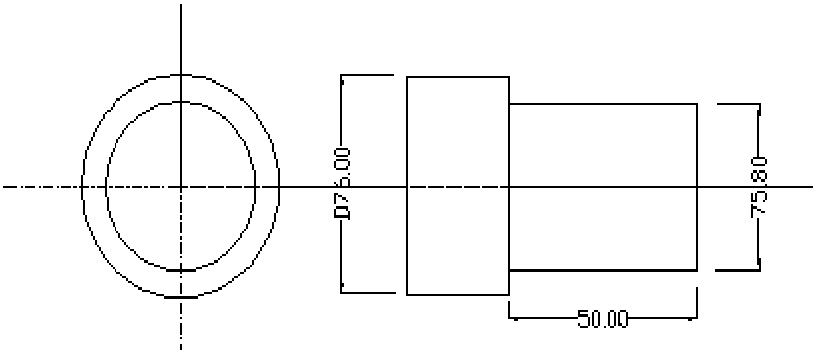

Figure 2 Steel part for cost estimating example

$$t_{m\ lathe} = \frac{l}{f \times n} \qquad (1)$$

$$= \frac{50}{0.04 \times 1038}$$

= 1.20 Min.

IV. MACHINING TIME FOR CYLINDRICAL GRINDING OPERATIONS

The work piece diameter d_w of a AISI 52100 Steel bar is 76 mm, traverse ground for a length l_w of 50 mm.,and the grinding wheel width is 12.70 mm. The recommended metal removal rate per unit width of wheel Z_w / w_t is 17.27 mm^2/min. for cylindrical grinding [4,5and 6].

For rough grinding, the volume of metal to be removed *Vm* expressed by ,

$$Vm = \pi \times d_w \times \text{depth of cut} \times \text{length} \qquad (2)$$
$$= \pi \times 76 \times 0.175 \times 50$$
$$= 2089\ mm^3$$

The rough grinding time $t_{(g)}$ is given by

$$t_{(g)} = 60Vm / Zw \qquad (3)$$
= 460.86 Sec.
= 7.69 Min.

For finish grinding, the volume of metal to be removed *Vm* expressed by ,

$$Vm = \pi \times d_w \times \text{depth of cut} \times \text{length}$$
$$= \pi \times 75.82 \times 0.025 \times 50$$
$$= 297.75\ mm^3$$

The finish grinding time $t_{(g)}$ is given by

=60x298.45/1.24x17.27x12.70
= 65.62 Sec.
= 1.10 Min.

Total grinding time = Rough grinding time + Finish grinding time
= 8.79 Min.

V. TIME COMPARISON

Assumed that the plant works on the single shift basis per day of 8 hours each. The total time required for the processing the components is given by [7]

The total time t_m is given by,

Total time required = Setup time + operation time (4)

For CNC Lathe

Total time required = Setup time + operation time
= 7.45 hrs.

For CNC grinder

Total time required = Setup time + operation time
= 31.30 hrs.

The process time in hard turning is 7.45 hrs. and in grinding it shows 31.30 hrs. In result the cycle time is reduced up to 66 %.in turning.Table 2 shows the Time Comparison between CNC lathe and Cylindrical Grinder with available equations.

Table ***2 Time Comparison between CNC lathe and Cylindrical Grinder***

Variables	**CNC Lathe**	**CNC Grinder**
Setup time per batch	10 min.	10 min.
Operation time (min/piece)	1.20 min.	8.79 min.
Production per month (No.)	100	100
Total time	7.45 Hrs.	31.30 Hrs.

V. COST COMPARISON

The machining cost per unit time depends on the manufacturing facility, machining centre, and labour costs. The cost function in this case , C(x), is provided in equation (5),

$$C(x) = C_f + x\, C_m \qquad (5)$$

Where C_f = Fixed cost
= Interest per hrs x operating hrs.

x = No. of units

C_m = The machining cost per part
= Hourly charge x operating hrs

Investment in machine and interest on capital invested are the assumption with available data [8].The various cost comparison entries are shown in Table 3 and Table 4.

Table 3 Cost comparison of hard turning with grinding process

Particulars	**Hard turning** (CNC Lathe)	**Grinding** (CNC Grinder)
Fixed cost (C_f) (Rs.)	19 x 7.45 =142	28 x 31.30 = 877
i) Investment in Machine@(Rs.).	16,67,000	24,50,000
ii) Interest on capital invested (%)	10	10
iii) Interest per year (Fixed cost)	1,66,700	2,45,000
iv) Interest per day(Rs.)	456	671
iv) Interest per hrs. (Rs.)	19	28
Variable cost (C_V) (Rs.)	400 x 7.45 = 2,980	475 x 31.30 =14,867
i) Machining cost/hour (Rs.)	400	475
ii) Operating hours (hrs.)	7.45	31.30
iii) Variable cost (Rs.)	2980	14,867

Table 4 Summary of comparison of hard turning with grinding process

Particulars	**Hard turning** (CNC Lathe)	**Grinding** (CNC Grinder)
Total time (hrs.)	7.45	31.30
Fixed cost (Rs.)	142	877
Variable cost (Rs.)	2,980	14,867
Total cost for 100 Units (Rs.)	3,122	15,744
Unit cost (Rs.)	31.20	157.45

Formulated a cost-based objective function which considered both fixed cost and machining cost. Based on test data from the experimental data and literature, it was shown that significant cost reduction compare to grinding.

VII. CONCLUSION

A research application showed that using hard turning instead of grinding can cut the machining time. The process time in hard turning is less than in grinding. In result the cycle time is reduced up to 66.00 %. Also using hard turning instead of grinding can decrease the machining cost per unit time. The process cost in hard turning is smaller amount than in grinding. In result the cost is condensed up to 72.00 %.

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