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INVESTIGATION OF MACHINABILITY IMPROVEMENT DURING TURNING OPERATION OF HEAT TREATED MILD STEEL

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ABSTRACT

The main objective of this paper is to investigate the effect of heat treatment on machinability improvement of mild steel during turning operation. In the experimental investigations heat treated mild steel under full annealing conditions and normal mild steel has been considered as two work materials. Tool life, surface roughness and chip morphology were investigated during the experiments for both the work materials. Turning operation tests were conducted for mild steel machining using lathe machine with automatic feed. Machining was performed at room temperature in dry cutting conditions for both annealed and non annealed mild steel. Softening of materials during heat treatment helps in substantially increasing tool life as tool wear is delayed. It has been observed that surface quality has been improved and different chip type has also been observed during the machining of annealed compare to machining of non annealed mild steel. From the experimental findings, the obtained improvement reflects the feasibility of using this technique as a cost effective machining process.

Keywords: Mild Steel, Annealing, Machinability, Tool Wear, Surface Roughness

1. INTRODUCTION

Turning is one of the principle machining operations in which rotating the work piece against the cutting tool is the primary method of removing metal in a machine tool called lathe. Mild steel is a very popular alloy in industrial manufacturing process of metals.The cutting tool wear function is an important factor in turning operation which leads to tool failure as an associated part of all machining process. High speed machining uses high cutting speed and feed rate and ultimately generates high cutting temperature which not only reduces tool life but also impairs the product quality. The most important surface quality requirement in turning is surface roughness. Therefore, it is important to address the factors affecting surface quality and tool wear mechanism in turning [1-5]. For continuous turning up to the maximum allowable tool wear land width (V_B) shows a near linear increase with cutting distance after initial rapid wear [6]. The productivity of a machining process is not only determined by the use of low cost-high performance alloys, but also by the capability to transform a specific steel alloy to the required surface finish and geometry by machining at sufficiently high speed [7]. Machining productivity is limited by tool wear which indirectly represents a significant portion of the machining costs. However, by properly selecting the tool material and cutting conditions an acceptable rate of tool wear may be achieved and thus lowering the total machining cost [8]. The performance of a cutting tool is normally assessed in terms of its life. Wear criteria are usually used in assessing tool life. Mostly, flank wear is considered, since it largely affects the stability of the cutting edge and consequently the dimensional tolerance of the machined work surface [9].

The annealing of mild steel leads to an increase in ductility and impact energy, but decrease in hardness that results in shorter the tool life and worse machinability. On the other hand, normalizing heat treatment increases hardness, ductility and impact energy; but the tool life is shortened more and more. The minimum surface roughness was observed on the hot rolled specimen at final cutting speeds. A significant correlation between the machinability and the hardness of specimens could not be determined [10].This paper contains the results from machining of mild steel after annealing using lathe machine and comparison with results for non heat treated mild steel. Cutting parameters were constant feed rate, constant depth of cut in each operation, using no coolant. Two samples of mild steel shaft were taken, one annealed and the other non-heat treated. Hardness was measured for both samples before machining. Tool wear was measured after certain intervals for both the cases until tool wear reached around 0.3 mm. Finally it was found that a relevancy of machinability improvement with heat treatment of mild steel by considering surface roughness, tool wear reduction and chip characteristics during lathe machining.

2. EXPERIMENTAL PROCESS

Heat treated sample was produced using full annealing heat treatment on the mild steel sample containing 0.25% carbon having hardness 84 in Rockwell B scale. Each sample had a length of 170 mm and diameter of 25 mm. Then again hardness of the heat treated sample was measured 77 in Rockwell B scale. The process flow diagram for both the conditions are shown in Fig. 1(a) & hardness tester and heat treatment furnace is shown Fig. 1(b). The turning operation for both heat treated and non heat treated mild steel was conducted on a precision lathe (Gate INC. Model- L-1/180) under dry cutting condition. Fig. 2 shows the experimental setup. The cutting tool or insert used was Coated Tungsten Carbide Insert. The tool holder is shown in Fig. 3 along with the insert dimensions. The cutting parameters were selected as feed 1mm/second (automatic feed), Depth of cut 0.5mm/per operation and rotational cutting speed 530 rpm.

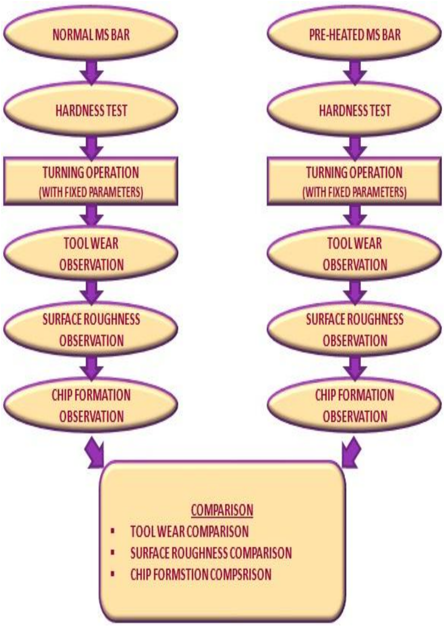


Fig 1(a). Process flow diagram for experiment and result analysis

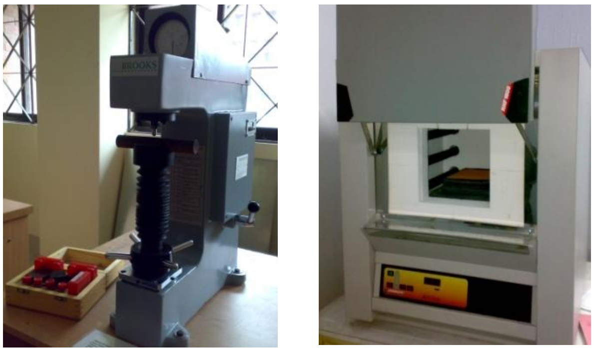


Fig 1(b). Rockwell hardness tester and Heat treatment Furnace

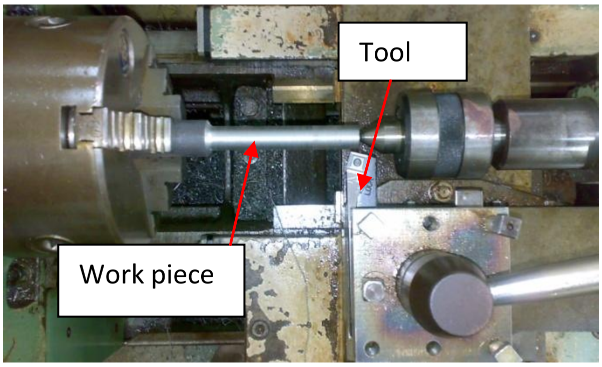


Fig 2. Lathe machine setup for turning operation

Fig 3. Tool holder and insert with geometry

Tool wear was observed after each 200 mm cutting using the metallurgical microscope shown in Fig. 4 and pictures of surface was taken by using a built in camera of the microscope. For measuring surface roughness an image processing technique developed by Anayet U. Patwari and M. D. Arif [11-12] has been used.

Fig 4. KRUSS Metallurgical microscope used for measuring tool wears

The process flow diagram of the steps to determine a linear regression calibration curve for measuring surface roughness using digital image processing, is shown in Figure 5(a).

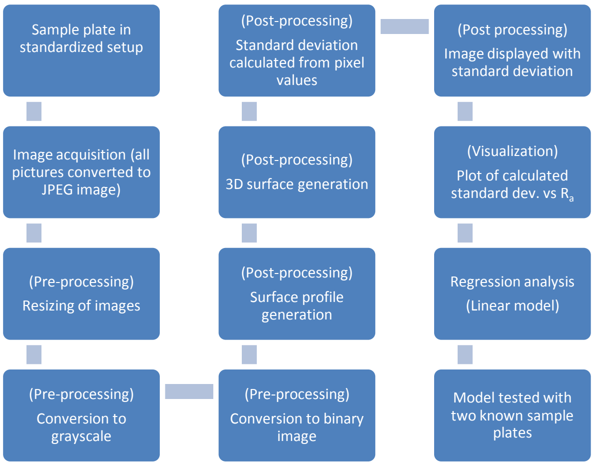


Fig 5(a). Flow diagram of the steps to determine a linear regression calibration curve

The flow diagram of the process used by Anayet U. Patwari et al. [11-12] in order to generate the 3-D contours and to determine the Ra of machined surfaces is as follows in Fig.5 (b):

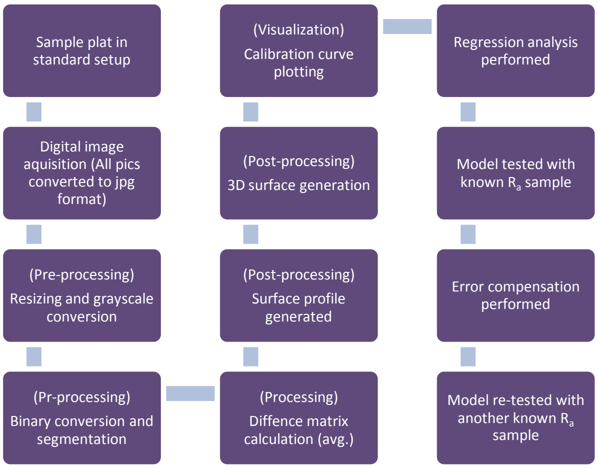


Fig 5(b). Flow diagram of the steps to develop 3-D contours

The mathematical definition of average surface roughness R_a was utilized. R_a is equivalent to half of the mean difference in heights between the asperities and troughs of a rough surface. The equation is as follows:

$$R_a = \frac{y_a + y_b + \dots + y_n}{n} = \frac{1}{n}\sum_{i=1}^{n} y_i = \frac{1}{l}\int_0^l |y|\, dx$$

3.1 RESULT DISCUSSION

Tool wear was measured by using metallurgical microscope (company-KRUSS, model MMB 2300) shown in Figure 4. The pictures of the wear surface were taken by using a built-in camera in the microscope. One sample set of the pictures is shown in Figure 6 (a). The pictures were then processed by associated software with the microscope. The wear length (V_B) was measured in millimeter for each of the picture using the software. In the observation it was found that the tool wear was relatively less in case of heat treated mild steel compared to non heat treated one. The comparison of tool wear at different length of cutting is shown in Table 1 and Figure 6(b).

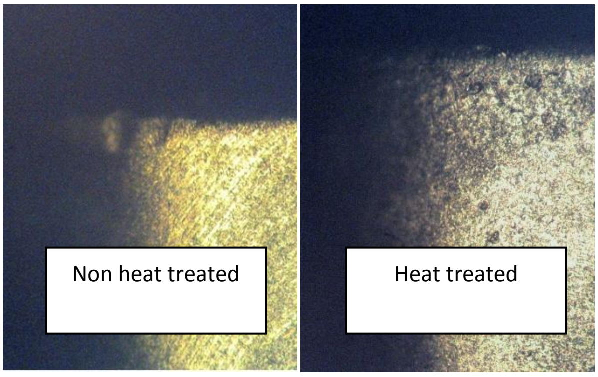


Fig. 6(a): Tool nose wear for cutting Non heat treated and Heat treated mild steel respectively.

Table 1: Tool wears at different cutting length

Length of cut (mm)	Tool wear of non heat treated mild steel bar (mm)	Tool wear of heat treated mild steel bar (mm)
0	0	0
200	0	0
400	0.1373	0
600	0.3102	0
800	0.3873	0.0229
1000	0.4431	0.0828
1200		0.1219
1400	Crossed the maximum allowable V_B limit	0.1706
1600		0.2005
1800		0.2441
2000		0.2897

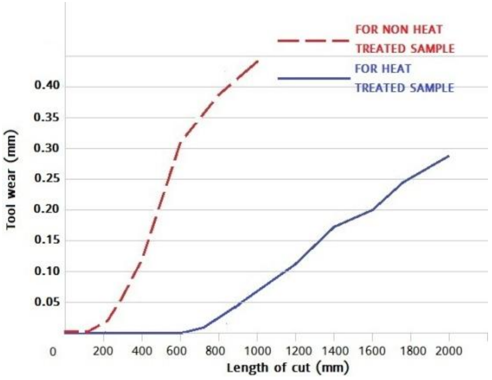


Fig 6(b). Graph showing the tool wears along with the increase of length of cut for non heat treated bar and Heat treated bar.

The tool wear reaches the 0.3 mm at 550 mm length of cut during machining non heat treated mild steel whereas the length of cut is more than 2000 mm for machining of heat treated mild steel to reach the same tool wear. Also the curve for non heat treated bar is steeper than the curve for heat treated bar. This indicates for cutting of heat treated bar not only wear happens lately but also rate of wearing slows down. The pictures of the finished surfaces of both heat treated and non heat treated work pieces were taken by the microscope. Samples of these pictures are given in Figure 7.

These were processed by an image processing technique developed by Anayet U Patwari [11-12] for further evaluation to generate contour plot and roughness profile of the surfaces of the job pieces. The average value of the roughness was obtained directly from this analysis. The contour plots obtained in the analysis are shown in Figure 8.

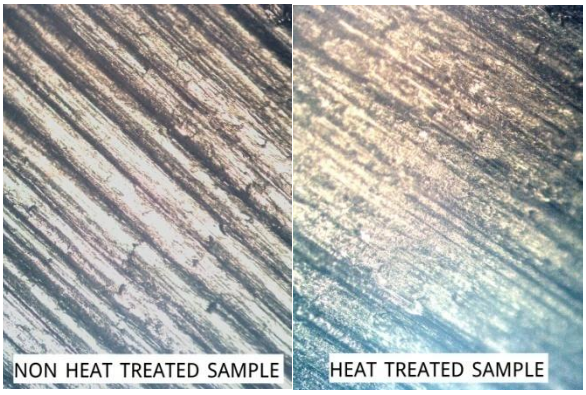


Fig 7. Pictures of the machined surfaces

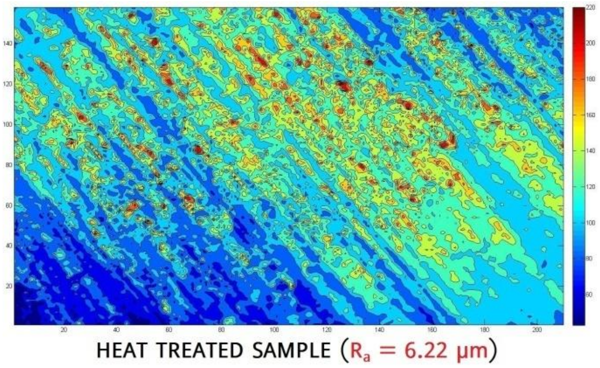
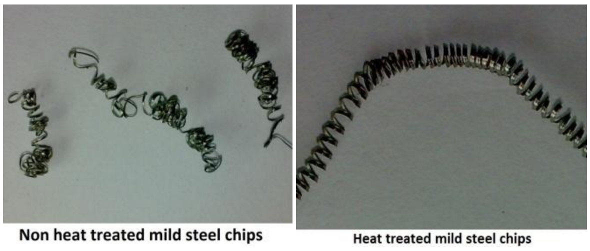


Fig 8. Contour plot of surface roughness by DIP (Patwari et.al)

It is observed that the contour plot of the surface of the heat treated machined work piece is more polished than that of the non heat treated one. The surface profile is more uniformed in case of the annealed work piece. Chips produced from non heat treated mild steel were discontinuous and much serrated. On the other hand chips from heat treated mild steel were more continuous and less serrated. This comparison is shown in Figure 9.



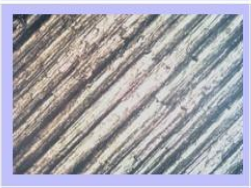
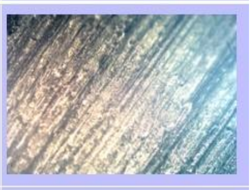
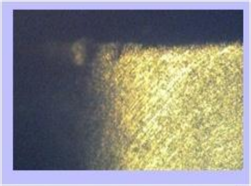
Non heat treated mild steel chips

Heat treated mild steel chips

Fig 9. Chip samples from machining

The comparison of the obtained results is shown in Table2.

Table 2: Obtained results comparison

	NORMAL MS BAR	PRE-HEATED MS BAR
SURFACE ROUGHNESS:		
TOOL WEAR:		
CHIP FORMATION:		

4. CONCLUSIONS

Based on the study it can be concluded that annealing heat treatment process softens the mild steel by releasing grain stresses, increases it's ductility by transforming large stressed grains into finer smaller grains, at the same time reduces hardness at a considerable amount. As a result improved machinability is observed and increased tool life is obtained. Same cutting tool can be used for longer cutting distances, same surface smoothness can be obtained with reduced rpm of lathe and increased depth of cut. Thus the total machining cost of mild steel can be reduced significantly.

5. REFERENCES

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6. NOMENCLATURE

Symbol	Meaning	Unit
V_B	Tool wear length	(mm)
R_a	Average surface roughness	(mm)