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An inclusive discussion about chip shape during turning of the Nimax steel

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Abstract **–**In this study, Taguchi method was used to determine the cutting parameters for pre-hardened mold steel Nimax turning process. After completing the experiments which carried out with three different cutting speed, feed rate and depth of cut values, chips were collected for further analysis. As known, chips reflect the machining characteristics about the cutting material and give information about the cutting tool condition and its wear situation in some way. Therefore, analysis of the chips is an important issue in machining operations. It is aimed in this approach to put light for chip formation and its basic mechanisms during turning of the mold steels. This kind of study may be helpful for academic studies and industrial applications.

Keywords –Chip shape, Nimax, Turning, Taguchi,

I. INTRODUCTION

In recent years, depending on the use of plastic products, importance of mold steels has increased gradually. Pre-hardened mould steels stand out among mold steels with their high strength and machinability properties. Nimax is a mold steel which commercially available in the pre-hardened condition of about 40 HRC [1]. Nimax has high toughness, shock resistance and weldability based on low-carbon content [2]. Determination of optimum cutting conditions of high strength pre-hardened mold steels is important for surface quality and dimensional sharpness [3, 4]. Cutting conditions generally are evaluated with cutting force, tool wear, power consumption, surface finish and tool life parameters. Taguchi developed a statistical optimization approach to improve the quality [5-7]. Taguchi method provides to determine the optimum cutting parameters more efficiency and economically [8]. Turning is a common machining method of pre-hardened mold steels. Feed rate, depth of cut, insert radius and cutting speed are generally accepted as decisive parameters in the turning operation. Surface finish is a criterion to evaluate the turning skills too. Since surface finish is strictly related with cutting parameters and chip formations. Feed rate was determined as primarily parameter for surface finish in turning Inconel 718 by Ramanujam et al. [9]. Gupta et al. investigated the turning of AISI P-20 tool steel with TiN coated tungsten carbide tool by using hybrid Taguchi-fuzzy method. Optimal cutting results was obtained in middle level of cutting speed of turning under cryogenic environment [10]. Large amount of heat generate at the chip -tool and workpiece interface in turning of high strength pre-hardened mold steels [11]. This high temperature gradient zone deform the tools cutting edge and resulted in high tool wear [12, 13]. Cutting fluids are used to decrease the detrimental effects of high temperature gradient. However, the environmental harmful effects of cutting fluids are a phenomenon [14, 15]. Minimum quantity lubrication (MQL) method can improve the turning performance alternatively [16-18]. Dry machining can also improve the surface finish. Devillez et al. evaluated the surface quality and cutting force with the coated carbide tool in turning Inconel 718 under dry and wet conditions. Dry machining with coated carbide tool performed well surface roughness [19]. Debnath et al. investigated the influence of cutting fluids on cutting parameters in turning by using Taguchi method. It was reported that the feed rate influential parameter on surface

roughness [20]. Chip morphology plays major role on the surface finish and tool wear in turning operation. Continuous chip formation leads to deformation of the surface finish and increase in the temperature of the cutting tool in hard condition. The control of high temperature zone at chip-tool-workpiece interface and chip shape provides to improve the machinability [21]. The chip shape turns from continuous to segmentation with increasing cutting speed [22]. Serrated chip formation generally occurs when cutting in dry turning of pre-hardened steels [23]. The serrated chip formation was increased up to fragment with the cutting speed increasing in high speed cutting of Ti6Al4V [24].The crack formation occurs due to strain in the chip goes beyond the materials limit strain. It was observed that the crack started at the chipless surface and progresses with during turning[25].

Investigation of chip formation mechanism is important to improve the turning process of hardened steels. The main objective of the study is to investigate the influence of the chip formation on the turning process. Chip shapes were analyzed with different cutting and lubricating condition in turning pre-hardened Nimax mold steel.

II. Materials and Methods

Pre-hardened Nimax mold steel specimens were used in tests that chemical composition is seen in Table 1. The dimensions of the workpiece were 50x50x100 mm dimension and 40HRC hardness. Cutting tools with TiC coated were used in accordance with ISO 3685 that specifications are given in Table 2. Cutting tools were renewed after every try. Tests were conducted with a lathe machine with different cutting parameters as specified in Table 2. Turning experiment carried out for three different cutting depths of (0.05-0.1-0.15 mm), three different feed rates per tooth of (0.15-0.3-0.45 mm/tooth) and three cutting speeds (30-40-60 m/min). Chips were evaluated based on different cutting conditions. Chip shape is discussed in this study. The Taguchi L9 method was used in designing the tests. In this paper, L9 orthogonal array was used instead of making complete 27 experiments.

Table 1. Chemical composition of Nimax steel (wt%)

Material	C	Si	Mn	Cr	Ni	Mo
Nimax	0.1	0.3	2.5	3	1	0.3

Table 2. Machining parameters used in this study.

Cutting speed (m/min)	Feed Rate (mm/tooth)	Cutting depth (mm)
30	0.15	0.05
40	0.15	0.1
60	0.15	0.15
40	0.3	0.05
60	0.3	0.1
30	0.3	0.15
60	0.45	0.05
30	0.45	0.1
40	0.45	0.15

III. Results

Turning is a widely applied process to machine cylindrical parts used in the industry. Therefore, there is huge amount of material is produced thanks to this process and this newly generated metallic parts are called as chips. These samples can reflect the signs of machining mechanism which is important to arrange the cutting conditions. Because the lubricating conditions, level of the basic cutting parameters have significance on determining the shape and length of the chips. The need for the monitoring and classification of the chip shape and type comes from the some aspects of the chips such as; i) chips are the most important source in machining environment to eliminate the excessive heat, ii) chip breakability is highly important issue due to its mission is about to reduce the high levels of temperatures, iii) if the chips are not broken easily, they can crash or tangle around the workpiece or cutting tool and destructive results can emerge. Therefore, keeping the chip shape in certain range can guarantee some results to reach better quality in machining such as lower thermal effects, longer tool life, better tool wear results, improved surface quality etc. Therefore, in this study, the chips were collected after the turning operations during machining of the Nimax mould steel. Figure 1 represents the collected chip shapes under different cutting conditions. The figure was created as considering the cutting parameters are kept in same values in same columns and lines. Therefore, it is much easier to make comments and understand the impact of the fundamental turning parameters. As seen, with the increase of the cutting speed, chip thickness show decreasing behavior. Also, untidy chip formation can be seen with applying lower cutting speeds where short and log chips can be observed simultaneously. Increasing of the depth of

cut have a complex impact on the chip shape seemingly which can be explained by its unimportant influence on the chips. It should also be noted that chip tangling is an important problem in turning of the Nimax mould steel. However, with further investigation by using SEM observation, detailed analysis can be done.

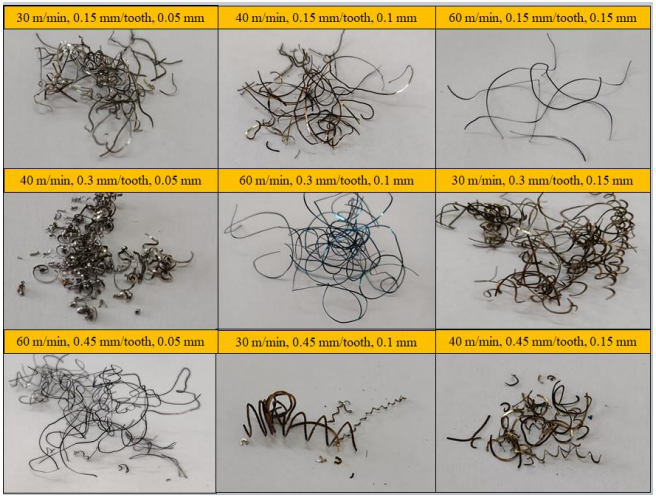

Figure 1. Collected chips after turning operations.

IV. CONCLUSION

After making some experiments for Nimax mold steel under turning operations, the following observations can be done:

- Cutting speed is the most important parameter on determining the chip shape.
- Seemingly, no big difference among the chips while applying different levels of cutting depth and feed rate.
- Also, there is little difference between color of chips while using basic turning parameters.
- Nimax mold steel produces long chips which can be a problem in some aspects in terms of tangling and crashing during machining operations.

REFERENCES

1. Hoseiny, H., et al., *Comparison of the microstructures in continuous-cooled and quench-tempered pre-hardened mould steels.* Materials & Design, 2011. 32(1): p. 21-28.
2. Hemmilä, M., et al., *Technological properties of direct-quenched structural steels with yield strength 900-960 MPa as cut length and hollow sections.* Rautaruukki Oyj, Ruukki Metals, Finland, 2010. 1(8).
3. Juiña, L.C., et al., *Analysis of the surface quality of a convex machining for a martensitic steel AISI P20.* Materials Today: Proceedings, 2022. 49: p. 100-106.
4. Rüstem, B., et al. *An Investigation of Factors Affecting Machinability of Milling Toolox 44 Hot Work Tool Steel by Taguchi Method*. in *International Conference on Engineering Technologies (ICENTE'20)*. 2020.
5. Taguchi, G., *Introduction to quality engineering: designing quality into products and processes*. 1986.
6. Binali, R., M. Coşkun, and S. Neşeli, *An investigation of power consumption in milling AISI P20 plastic mold steel by finite elements method.* Avrupa Bilim ve Teknoloji Dergisi, 2022(34): p. 513-518.
7. Rüstem, B., Y. Süleyman, and N. Süleyman. *Optimization of Machinability Parameters of S960QL Structural Steel by Finite Elements and Taguchi Method*. in *Proceedings of the International Conference on Engineering Technologies (ICENTE'21)(Tam Metin Bildiri/Sözlü Sunum)(Yayın No: 7301857), Konya, Turkey*. 2021.
8. Aggarwal, A., et al., *Multicharacteristic optimisation of CNC turned parts using principal component analysis.* International Journal of Machining and machinability of materials, 2008. 3(1-2): p. 208-223.
9. Ramanujam, R., et al., *Modeling and optimization of cutting parameters in dry turning of Inconel 718 using coated carbide inserts.* Procedia Materials Science, 2014. 5: p. 2550-2559.
10. Gupta, A., H. Singh, and A. Aggarwal, *Taguchi-fuzzy multi output optimization (MOO) in high speed CNC turning of AISI P-20 tool steel.* Expert Systems with Applications, 2011. 38(6): p. 6822-6828.
11. Dewes, R., et al., *Temperature measurement when high speed machining hardened mould/die steel.* Journal of Materials Processing Technology, 1999. 92: p. 293-301.
12. Ventura, C., J. Köhler, and B. Denkena, *Influence of cutting edge geometry on tool wear performance in interrupted hard turning.* Journal of Manufacturing Processes, 2015. 19: p. 129-134.
13. Aslan, A., *Optimization and analysis of process parameters for flank wear, cutting forces and vibration in turning of AISI 5140: A comprehensive study.* Measurement, 2020. 163: p. 107959.
14. Singh, R., et al., *Influence of graphene-enriched nanofluids and textured tool on machining behavior of Ti-6Al-4V alloy.* The International Journal of Advanced Manufacturing Technology, 2019. 105: p. 1685-1697.
15. Usca, Ü.A., et al., *Determination of machinability metrics of AISI 5140 steel for gear manufacturing using different cooling/lubrication conditions.* journal of materials research and technology, 2022. 21: p. 893-904.
16. Singh, R., et al., *Wear behavior of textured tools under graphene-assisted minimum quantity lubrication system in machining Ti-6Al-4V alloy.* Tribology International, 2020. 145: p. 106183.
17. Binali, R., et al., *Energy Saving by Parametric Optimization and Advanced Lubri-Cooling Techniques in the Machining of Composites and Superalloys: A Systematic Review.* Energies, 2022. 15(21): p. 8313.

18. Salur, E., *Understandings the tribological mechanism of Inconel 718 alloy machined under different cooling/lubrication conditions.* Tribology International, 2022. 174: p. 107677.
19. Devillez, A., et al., *Dry machining of Inconel 718, workpiece surface integrity.* Journal of Materials Processing Technology, 2011. 211(10): p. 1590-1598.
20. Debnath, S., M.M. Reddy, and Q.S. Yi, *Influence of cutting fluid conditions and cutting parameters on surface roughness and tool wear in turning process using Taguchi method.* Measurement, 2016. 78: p. 111-119.
21. Joshi, S., A. Tewari, and S. Joshi, *Influence of preheating on chip segmentation and microstructure in orthogonal machining of Ti6Al4V.* Journal of Manufacturing Science and Engineering, 2013. 135(6).
22. Molinari, A., C. Musquar, and G. Sutter, *Adiabatic shear banding in high speed machining of Ti–6Al–4V: experiments and modeling.* International journal of Plasticity, 2002. 18(4): p. 443-459.
23. Wan, L., D. Wang, and Y. Gao, *The investigation of mechanism of serrated chip formation under different cutting speeds.* The International Journal of Advanced Manufacturing Technology, 2016. 82: p. 951-959.
24. Chen, G., et al., *Finite element simulation of high-speed machining of titanium alloy (Ti–6Al–4V) based on ductile failure model.* The International Journal of Advanced Manufacturing Technology, 2011. 56: p. 1027-1038.
25. Zhang, X., R. Shivpuri, and A.K. Srivastava, *Chip fracture behavior in the high speed machining of titanium alloys.* Journal of Manufacturing science and Engineering, 2016. 138(8).