I J M S E
© Serials Publications
8(1) 2017 : January-June • pp. 23-28

ENHANCEMENT OF MACHINING PERFORMANCE WITH CRYO-TREATED HSS TOOL

Kamaljit Singh Boparai[1], Gagan Rooprai[2] and Harish Garg[3]

[1]*MRSPTU, Bathinda, Punjab, India, Email: kamaljitboparai2006@yahoo.co.in*
[2]*Chandigarh University, Gharuan Punjab, India, Email: rooprai49@gmail.com*
[3]*Email: harish_k_garg@rediffmail.com*

Abstract: This Paper highlights the potential effect of cryo-treatment on HSS single point cutting tool. Machining input parameters such as feed rate and machining length were varied and the responses (cutting force, shear plane temperature and roughness of work piece) were measured in order to realize the machining performance of single point HSS cutting tool for turning operation. The results show that cryo-treatment has significant influence on the performance of cutting tool. Hence, cryo-treatment is a good alternative for productivity enhancement and greater tool life.

Keywords: cryogenic treatment, single point cutting tool, turning process, surface roughness.

1. INTRODUCTION

The conventional heat treatment processes have an effect on the performance of various materials [1] [2] [3]. This is due to the alteration of metallurgical changes in its microstructure up to a certain extend [2] [4]. With the invention of more hard or more stable materials and with the increasing demand of making complex shapes, it is required to improve the properties of tool material more than ever [3] [5]. Due to the advancement in modern industry, the advanced treatment (such as cryogenic treatment) can be applied to tool material for improving its tool life and dimensional stability [2] [6]. The High speed steel tools are most widely used tool material in the auto parts manufacturing industries [3] [4] [6]. It is used for machining in both CNC and conventional lathe machines. The HSS tools required heat treatment before it's used in order to increase its wear resistance and hardness so that it can retains high thermal stability during the cutting operation [4] [6] [7]. Moreover, the HSS tools are easily available at reasonable costs in market [4] [5].

The present research has been focused on the comparative study of machining performance of cryo-treated tool (CRTT) and conventional treated tool (CTT) for orthogonal cutting process. The machining performance can be predicted by measuring shear plane temperature, cutting force generated during machining and surface roughness. In this work, the HSS tools were deep cryo-treated as per their respective cycle [5].

2. EXPERIMENTATION

2.1. Work piece Material and Cutting Tool Material

The work piece material was mild steel (AISI1018) which is most commonly used in auto part manufacturing industries, having diameter 38mm and length 305mm. The HSS cutting tools (Miranda tool bits M42 grade) have been used for experimentation.

2.2. Cryogenic Cycle Process

The cryogenic treatment of specimen was carried out at Institute of Auto Parts, Ludhiana. The equipment is specifically maintained to control and adjust the cycles. Deep cryogenic treatment was done by using 12-24-12 cycle. The temperature of cryogenic chamber was ramp down from atmospheric temperature to -185°C in 12 hrs. The work piece was then soaked for a period of 24hrs and again brought back to atmospheric temperature in the time period of 12hrs. The cryogenic cycle followed tempering cycle having maximum tempering temperature of 150°C. The tempering cycle is generally employed to remove the residual cold stresses developed during cryogenic cycle.

A hole is drilled in the cutting tool near to the tool tip with the help of EDM drilling machine for inserting the thermocouple probe. The drilled hole has nearby same diameter as the thermocouple diameter. In this work Nickel-Chromium K-Type thermocouple (capable of measuring temperature ranging from -200ºC to 1250ºC) was used for the measurement of temperature in shear plane.

2.3. Process Parameter

In this research work, the experiments were performed by varying machining input conditions (like: feed rate and length of cut) and measuring responses such as cutting force, shear plane temperature and roughness of work piece.

3. RESULTS AND DISCUSSIONS

3.1. Measurement of Cutting Forces

During the orthogonal cutting various types of forces such as cutting forces (which is in the direction of cutting speed), and the feed or thrust force (which is in the direction normal to cutting speed) are generated [7]. The cutting forces were measured using strain gauge based dynamometer fixed on tool holder. Three co-axial cables were connected the tool holder with the dynamometer and display indicates the numerical value of different forces (i.e. cutting force, feed force, thrust force) acted on tool during turning operation. Based on the design of experiments, the effect of cryo-treatment on single point cutting tool on cutting force with the variation of feed rate and length of cut were realized and compared with untreated tool.

Initially, the experimentation starts with the feed rate of 0.05mm/rev and length of cut 70mm, the cutting forces generated for CRTT and CTT are 3kg and 4kg respectively (Fig. 1). It has been observed that as the length of cut increased from 70mm to 140mm, the cutting force of CRTT and CTT also increase and reached to 7kg and 8kg respectively. With further increasing the length of cut shows decrease of cutting forces and the value for CRTT and CTT decreased to 6 kg and 7 kg respectively.

Fig. 2 highlights that, with the length of cut 70 mm and feed rate 0.07 mm/rev, the cutting force remain same for both CRTT and CTT (5kg). When the length of cut increased to 140 mm, the cutting force value of CRTT and CTT increase and attains the value of 7kg and 8kg respectively. With further increase in length of cut from 140 mm to 210 mm while keeping feed rate constant, the cutting force value of CRTT and CTT also increase to the value of 8kg and 9kg respectively. It has been observed that at the constant feed rate

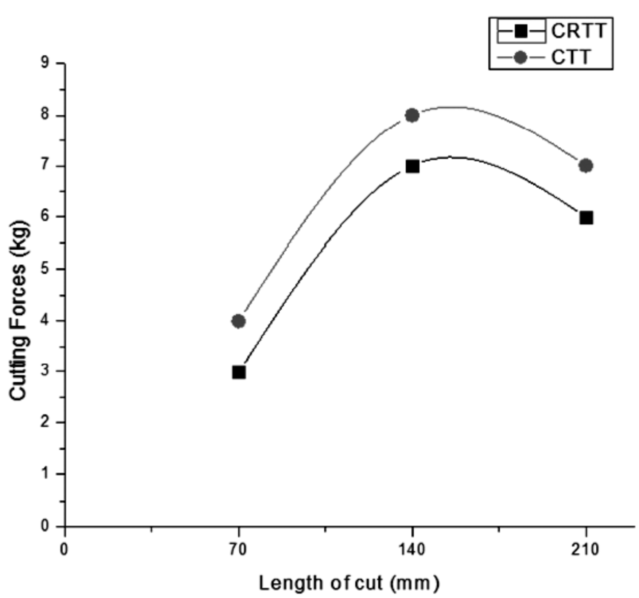

Figure 1: Cutting forces at feed rate of 0.05mm/rev.

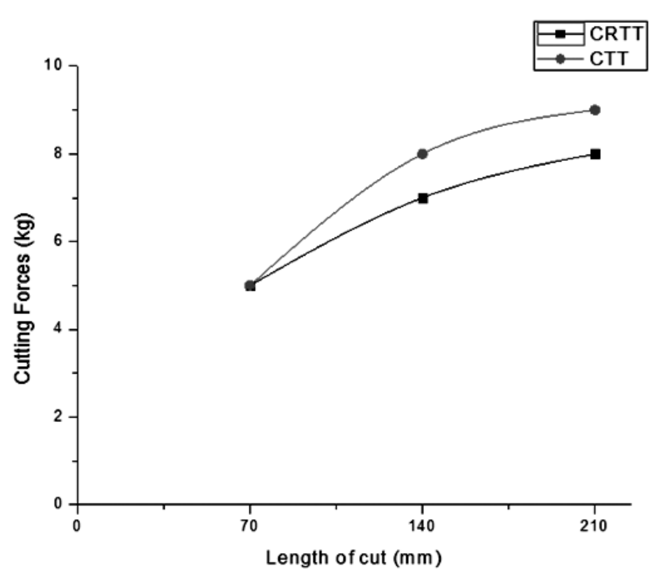

Figure 2: Cutting Forces at feed rate of 0.07mm/rev

of 0.07rev/mm, the cutting force of CRTT and CTT varied directly proportional to length of cut.

Fig. 3 illustrates the effect of length of cut on cutting force value of CRTT and CTT at the feed rate of 0.09rev/mm. It has been observed that when the length of cut was 70 mm, the cutting force value of CRTT and CTT are 8kg and 10kg respectively. When length of cut was increase from 70 mm to 140 mm, the cutting force of CRTT and CTT are 9kg and 10kg respectively. The further increase in length of cut to 210 mm, shows increase in cutting force value of CRTT and CTT and reach to highest value 10kg and 11kg respectively.

The results presented in Fig. 1 to Fig. 3 concluded that the evolution of cutting forces with the variation of length of cut and feed rate. If the feed rate increases, the section of the sheared chip increases because the metal resists the rupture more and requires larger efforts for chip removal. Hence the cutting force increases as the feed rate increases. Further, for all experiments, CRTT experiences less cutting force as compared to CTT [8] [9].

3.2. Measurement of cutting temperature

An infrared thermometer is used to measure the temperature at tool- work piece interface. The variation of cutting tool rake face temperature with respect to length of cut at constant feed rate of 0.05 mm/rev is shown in Fig. 4. With a feed

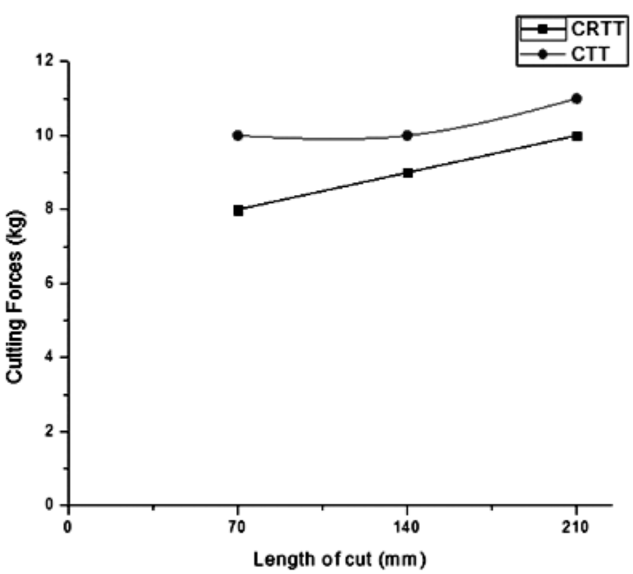

Figure 3: Cutting Forces comparison at feed rate of 0.09mm/rev

rate of 0.05 mm/rev and length of cut 70 mm, the tool rake face temperature for CRTT and CTT was found to be 85°C and 90.32°C respectively. The increase in length of cut from 70 mm to 140 mm, the cutting temperature also rises to 90.4 °C for CRTT whereas temperature for CTT attains a value of 90.39°C which is closer to previous one. For CRTT the cutting temperature decreased to 87.8 °C with the increase of length of cut to 210 mm and in case of CTT, the cutting temperature remains same. It was observed that with the variation in length of cuts there is very less variations in cutting temperature for CTT whereas for CRTT the cutting temperature first increases then decreases.

The trend of cutting tool rake face temperature with respect to length of cut for a constant feed rate of 0.07 mm/rev is shown in Fig. 5. For 70mm length of cut, the tool rake face temperatures for CTT and CRTT were found to be 101.3 °C and 92.7 °C respectively. When length of cut was increased to 140 mm the cutting temperatures raised to 114.6°C and 95.6°C for CTT and CRTT respectively.

The cutting temperature decreases to a value of 112.7 °C for CTT when length of cut was further increased to 210 mm whereas the temperature increased to 97°C for CRTT. It was observed that for all length of cuts, the tool rake face temperature increases for CRTT whereas for CTT it increases up to 140 mm length of cut and then decreases for 210 mm length of cut. The variation of cutting tool rake face temperature with respect to length of cut for the feed rate of 0.09 mm/rev is shown in Figure 6. With a length of cut of 70 mm, the tool rake face temperature for CRTT and CTT were found to be 93°C and 101.3oC respectively. As the length of cut increased to 140 mm, the cutting temperature rises to 97.6°C for CRTT whereas for CTT it decreases to a value of 99.4°C. For CRTT the cutting temperature reaches to 98°C for the length of cut to 210 mm and it becomes 99.8 °C for CTT. It was observed that the cutting temperature is highly influenced with the variation in machining length and feed rate [7]. The CRTT shows small variation as compared to CTT. The reason is due to cryogenic treatment the structure of HSS becomes dense and heat generated during machining process is continuously dissipated which is not appeared in the case of CTT [8] [9].

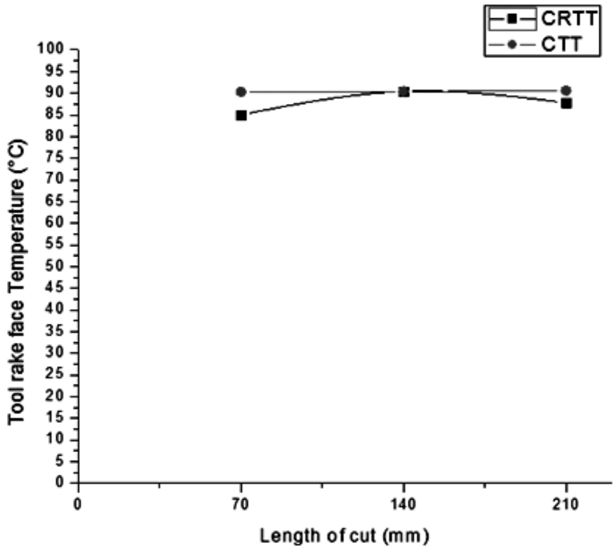

Figure 4: Tool face temperature at feed rate of 0.05 mm/rev

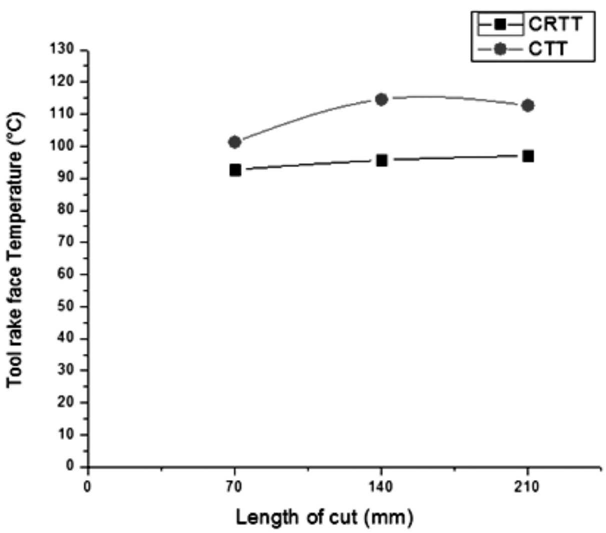

Figure 5: Tool face temperature at feed rate of 0.07 mm/rev

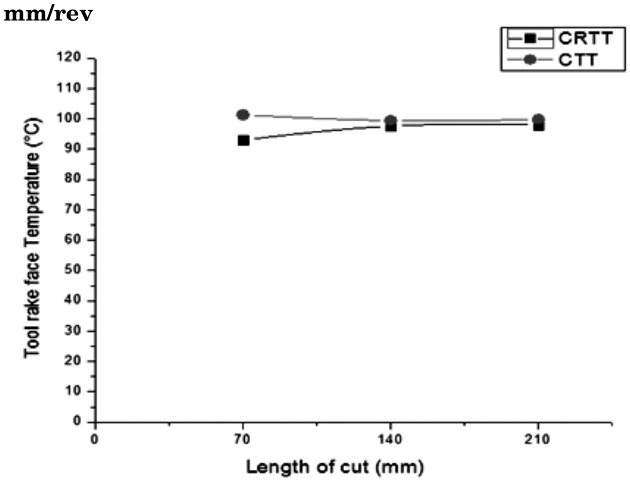

Figure 6: Tool face temperature at feed rate of 0.09 mm/rev

3.3. Measurement of surface roughness

Most commonly surface roughness is defined by arithmetic average (AA) value usually known as Ra. The 'AA' value is obtained by measuring the height and depth of the valleys on a surface with respect to an average centre line. In this work, "RT-10" surface roughness tester was used to measure the surface roughness of the work piece.

It was observed from Fig. 7 that with the feed rate of 0.05mm/rev and the length of cut of 70mm, the surface roughness of work piece machined with CRTT and CTT have values 3.09 µm and 3.15

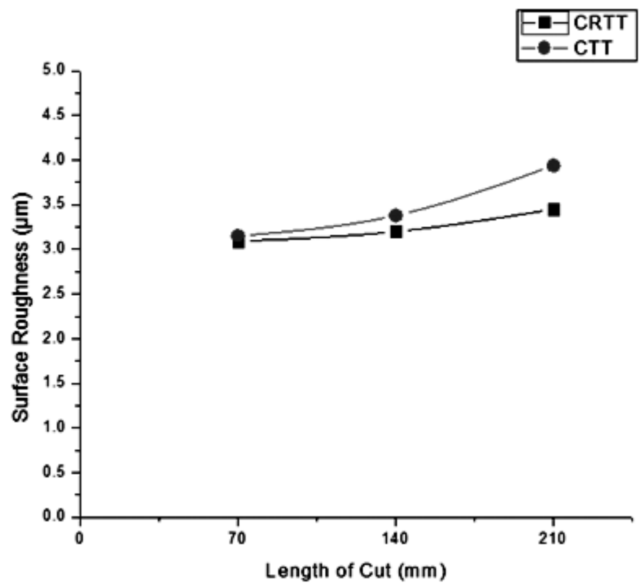

Figure 7: Surface roughness of work piece at feed rate of 0.05mm/rev

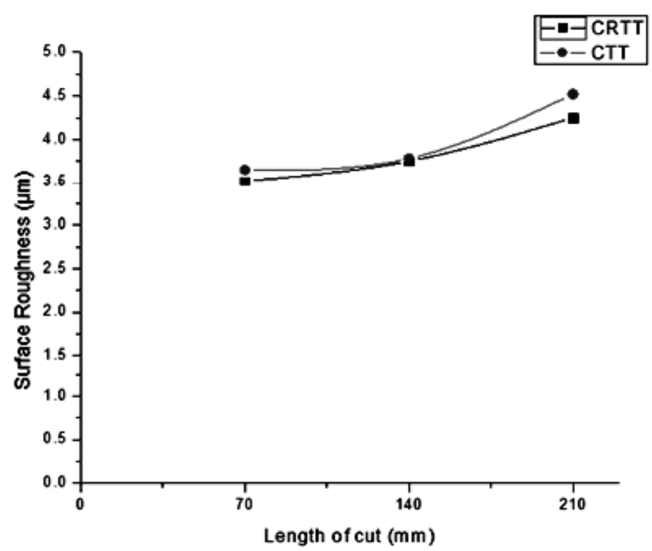

Figure 8: Surface roughness of work piece at feed rate of 0.07mm/rev.

µm respectively. With the increase of length of cut, their value increases and reached to 3.2 µm and 3.38 µm respectively. Further increase of machining length increases surface roughness and reached to 3.45 µm and 3.94 µm.

The value of surface roughness increases with the increase the feed rate from 0.05mm/rev to 0.07mm/rev. The surface roughness for CRTT 3.52 µm and for CTT 3.65µm when the length of cut was 70mm. As the value of length of cut increase from 70mm to 140mm the value of surface roughness was observed for CRTT 3.75 µm and for CTT 3.78 µm as shown in the Fig. 8. Furthermore increase in length of cut from 140mm to 210mm their value again shifted to higher side and becomes 4.25 µm for CRTT and 4.52 µm for CTT. With the increase in feed rate of 0.09mm/rev, the material removal rate increases, due to which more heat is developed and the roughness of the cut increases. The value of roughness for CRTT was 5.42 µm and 5.47 µm for CTT at 70mm length of cut, 5.52 µm and 5.548 µm for CRTT and CTT at length of cut 140mm. Further the value of roughness of surface again increases at 210mm length of cut for CRTT 5.54 µm and for CTT 5.74 µm. as shown in Fig. 9. The poor surface finish is due to the generation of heat during work piece and tool interaction which in turns adversely affect the tool life. As already mentioned above that CRTT has more dense and stable structure than CTT [8] [10] [11].

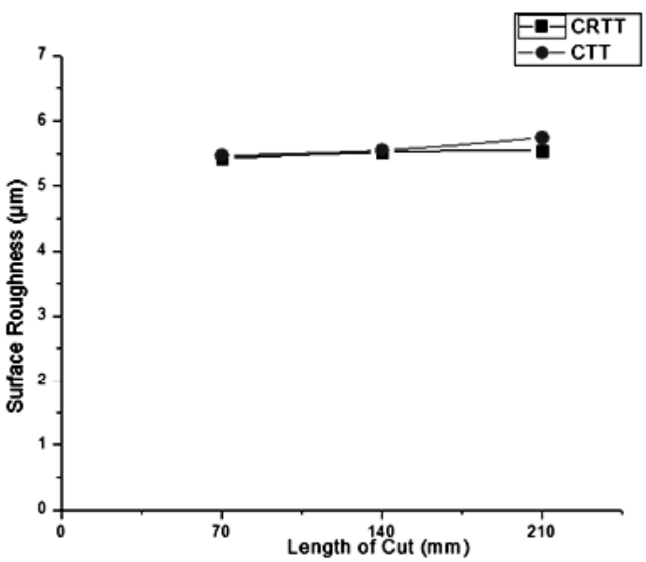

Figure 9: Surface roughness of work piece at feed rate of 0.09mm/rev

4. CONCLUSIONS

The response such as cutting force, work piece tool interface temperature and surface roughness have been measured with the variation in feed rate from 0.05mm/rev to 0.09mm/rev and length of cut. The following conclusions and observations can be drawn from the investigations:

1. From the study it is observed that the cryogenic treatment improves the machining performance of the HSS single point cutting tool used for turning operation.
2. The cutting forces increased with the increase of feed rates and it is realized that with the increase in length of cut, the cryo-treated tools shows maximum decrease of cutting force.
3. The cutting temperature is highly influenced with the variation in machining length and feed rate. The CRTT shows very small variation as compared to CTT. The minimum surface roughness is observed with low feed rate.
4. The turning operation by cryogenic treated tool bit shows less surface roughness as compared to conventional treated tool.
5. Finally, cryo processing has significant favorable influence on the performance of cutting tool. Hence, cryo processing is a good alternative for productivity enhancement and better tool life.

ACKNOWLEDGMENT

The authors are highly thankful to Institute of Auto Parts Ludhiana and CTR Ludhiana for providing research facilities for this research work.

REFERENCES

[1] Y. Dong, X.P. Lin & H.S. Xiao, “Deep cryogenic treatment of high-speed steel and its mechanism”, Heat Treatment of Metals.Vol. 3, 1998, pp. 55–59.

[2] Z.Y. Wang, & K.P. Rajurkar, “Cryogenic machining of hard-to-cut materials”, Wear, Vol. 239, 2002, pp. 168-175

[3] H.A. Stewart, “Cryogenic treatment of tungsten carbide reduces tool wear when machining medium density fibreboard”, Forest Products Journal, Vol. 2, 2004, pp. 53–56.

[4] V. Leskovsek, M. Kalin & J. Vizintin, “Infuence of deep cryogenic treatment on wear resistance of vacuum heat treated HSS”, Vacuum, Vol. 80, 2006, pp. 507–518.

[5] K. Singh, “Effect of cryogenic treatment on various tools for machining cost reduction: A case study”, M.Tech Thesis, Punjab Technical University Jalandhar, 2009.

[6] N.R. Dhar, S. Islam, M. Kamruzzaman & S. Paul, “Wear behavior of uncoated carbide insert under dry , wet and cryogenic cooling condition in turning c- 60 steel”, J. Braz. Soc. Mech. Sci. & Engg., Vol. 28, 2006, pp.146-152.

[7] H.S. Yang, W. Jun, S.B. Luo, L.H. Huai, G.S. Ji & H.S. Jiu, “Effect of cryogenic treatment on the matrix structure and abrasion resistance of white cast iron subjected to destabilization treatment”, Wear, Vol. 261, 2006, pp. 1150–1154.

[8] P.S. Babu, P. Rajendran & K.N. Rao, “Cryogenic Treatment of M1, EN19 and H13 Tool Steels to Improve Wear Resistance”, Journal of Metallurgy & Material Science, The Institution of Engineers (India), Vol. 86, 2006, pp. 64-66.

[9] J.D. Silva, S.D. Franco, A.R. Machado, E.O. Ezugwe & A.M. Souza, “Performance of cryogenically treated HSS tools”, Wear, Vol. 261, 2006, pp. 674–685.

[10] A.A. Khan & M.I. Ahmed, “Improving tool life using cryogenic cooling”, Journal of Materials Processing Technology, Vol. 196, 2008, pp. 149–154.

[11] M. Pellizzari, “Influence of deep cryogenic treatment on the properties of conventional and PM high speed steel”, Trattamenti Termici, 2008, pp. 17-22.