Experimental Investigation of Effective Lubrication on Turning Hardened Steel

[1]R.Naveen Kumar [2]M.Naresh Babu
[1]ME-CAD/CAM,
[2]Associate Professor,
[12]Dept of Mechanical Engineering, Saveetha Engineering College, Chennai, Tamilnadu, India.
[1]navenrja@gmail.com [2]nareshbabu@saveetha.ac.in

***Abstract*— Turning is an important material removal process used in most manufacturing process. Wear of tool and poor surface finish are the main factors to be considered in turning process. The application of high-pressure coolant (HPC) in cutting processes can strongly influence the wear on the cutting tools providing a longer tool life. Presently, single nozzle is used for the application of high pressure cutting fluid for the machining process. This experimental work paves a way for a new concept. In this High pressure coolant (HPC) nozzles are used for effective lubrication. The material used for turning process is AISI 410 steel. The input parameters considered were cutting speed, Inserts and coolants. Experiments were performed by using Taguchi L_{18} orthogonal array method. The responses measured are, surface roughness (R_a), tool wear and Chip morphology.**

Keywords— High pressure coolant (HPC), Nozzle, Surface roughness, Tool wears

I. Introduction

The aim of the machining is to manufacture the product with less cost of high dimensional accuracy& surface finish. The benefits of hard turning are reduction of cost per product and good surface finish. In turning (R_a) average surface roughness & tool wear are the two important aspects which are needed in research and industries. Titanium Nitride (TiN), silicon carbide (Sic), and Tungsten carbide (Tic) are the most widely cutting inserts which is used for machining the hardened steel. Surface roughness and tool wear plays important role of the turning process.

The water and oil based lubricants are used in machining operation in order to reduced friction of the tool - chip & tool – work piece interface and the coolant which cools both chips and the tool. The high pressure coolant allows a better penetrating between tool &work piece and its providing a better cooling effect and decreasing the tool wear. This process undergoes on effective lubrication technique.

Nomenclature:
HPC – High pressure coolant [bar]
R_a – Average surface roughness [μm]
DOC – Depth of cut [mm]
Ø – bar diameter [mm]
V_c – cutting speed [m/min]
TiN – Titanium Nitride
Wc – Tungsten Carbide
OA – Orthogonal Array

II. Literature Review

V.T.G.Naves et. al: The application of high pressure coolant (HPC) in cutting processes can strongly influence the wear on the cutting tools providing a longer tool life .This is possible due to better penetration of the fluid into the tool work piece and tool chip contact region, providing a better cooling effect and decreasing tool wear through lubrication of the contact areas. Based on the investigation it was found that high pressure coolant obtain the lowest flank wear and rake face. The lowest flank wear was obtained when the fluid was applied with 10% concentration of fluid and 10MPa of pressure, and also it increases the tool life of cutting inserts.

Pigott et. al discussed the use of high pressure cutting fluid in steel turning with high speed steel tool. They injected the fluid in the form of a jet at very high speed in to the clearance face of the tool. They observed a significant increase in tool life compared to conventional methods of applying low- pressure fluid with a large flow rate. In addition, they observed about a

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twenty to hundredfold increase in tool life and low velocity of penetration does not allow the lubricant to reach the cutting edge and this situation favors the formation of built – up – edges.

Kaminski et.al investigated the effects of the conventional cooling methods and compared them with high and ultra-high pressure water jets directed at the tool chip interface. The effect on tool temperature, cutting force, chip shape and surface roughness in turning operation was investigated. They showed that conventional methods of fluid application are not very effective because of low pressure jet hinder penetration at the interface, increasing friction and, hence, raising the cutting zone temperature.

Anselmo Eduardo Diniz et.al the main objective of this work is to understand the tool wear mechanisms are influenced by fluid pressure, flow rate and direction of application in finish turning of AISI 1045 steel using coated carbide tools. It was revealed for the turning process of the steel, the longest tool life were obtained when fluid was applied either simultaneously on the rake and flank face with high pressure and high flow rate, or solely and the flank face with high pressure and low flow rate.

Machado carried out several experiment to check the influence of high – pressure fluid injection directed towards the tool rake face in the turning of Ti-6Al-4V and Inconel 901 with uncoated tool. He concluded that machining titanium alloy with a high – pressure cooling system, the tool life increased significantly in all cutting conditions. However when machining nickel alloy the high pressure system generally adhered chip was removed from the tool by the coolant flow resulting in a greater crater wear.

P.Vamsi Krishna et.al.. The present work features a specific study on the application of Nano solid lubricants suspension in lubricating oil in turning of AISI 1040 steel with carbide tool. SAE – 40 and coconut oil are taken as base lubricants and boric acid solid lubricants of 50 nm particle size. Variation of cutting tool temperatures, average tool flank wear and the surface roughness of the machined surface with cutting speed and feed are studied with Nano solid lubricants suspensions in lubricating oil. However, all the parameters were decreased, by comparing both the lubricants SAE – 40 based lubricants shows better performance in terms of cutting temperatures, tool wear and surface roughness at 0.5% nanoboric acid.

S.Paul et.al .The present work deals with experimental investigation in the role of cryogenic cooling by liquid nitrogen jet on tool wear and surface finish and tool life. The result has been compared with dry machining and machining with soluble oil as coolant. Comparing these two the cryogenic cooling by liquid nitrogen jet provided to reduced tool wear, improved tool life and surface finish as compared to dry and wet machining of AISI 1060 steel.

The aim of the present work is to evaluate the performance finish in turning AISI 410 steel using both conventional coolant and high pressure coolant (HPC) directed at the interface between chip and the cutting tool inserts. The trials were carried out a different cutting speed, depth of cut & cutting inserts. By using the taguchi method the result has to be optimized.

III. EXPERIMENTAL DETAILS

The experimental work is carried out by turning AISI 410 steel in the form of round bar. The dimensions of work piece considered are (Ø32 × 90 mm). Machining were performed in a conventional lathe. A tool holder PDJNR 2020 K 15 is used to hold the cutting inserts. The cutting parameter with their levels are shown in Table 1 . Four factors varied at 3 levels and As the orthogonal array is assorted level Taguchi L_{18} Orthogonal Array is selected. The three types of insert used were Titanium Nitride, silicon carbide, and Tungsten carbide for machining the work piece. High pressure coolant (HPC water based) is supplied from the coolant tank through the three different nozzles pressure at 10 bar with outlet tip having Ø2mm. In the machining on water based conventional coolant as supplied in normal coolant pipe whose outlet tip is Ø6mm. A coolant pump with the coolant tank setup is used for this purpose.

Table.1 Levels and Factors

Parameters	**Notation**	**Levels of factors**		
		1	**2**	**3**
Types of coolant (bar)	-	Conventional coolant	HPC	-
Depth of cut	d	0.4	0.6	0.8

(mm)				
Cutting speed (m/min)	v	37	55	75
Cutting inserts	-	Wc	TiN	Sic

A. Experimental conditions

Work specimen: AISI 410 stainless steel (Ø32 × 90 mm)
Cutting inserts: titanium nitride, cemented carbide, tungsten carbide.
Cutting angle: 55˚
Process parameters
Cutting speed: 37.20, 55.80, 75.40 m/min
Depth of cut: 0.4, 0.6, 0.8 mm
Machining environments: Wet and High pressure coolant (10bar).

Nozzle diameter: 2mm (HPC coolant) fluid pressure 10bar, 6mm (conventional coolant)

Table.2 Experimental Table of Orthogonal array L_{18}

Run	Types of coolants	Cutting speed(m/min)	Depth of cut (mm)	Tool and inserts	Surface roughness (R_a)
1	Conventional coolant	37.20	0.4	Tic	3.48
2	Conventional coolant	37.20	0.6	TiN	3.28
3	Conventional coolant	37.20	0.8	Sic	1.22
4	Conventional coolant	55.80	0.4	Tic	1.15
5	Conventional coolant	55.80	0.6	TiN	1.38
6	Conventional coolant	55.80	0.8	Sic	7.92
7	Conventional coolant	75.40	0.4	TiN	5.05
8	Conventional coolant	75.40	0.6	Sic	0.39
9	Conventional coolant	75.40	0.8	Tic	4.01
10	HPC	37.20	0.4	Sic	1.27
11	HPC	37.20	0.6	Tic	1.99
12	HPC	37.20	0.8	TiN	1.38
13	HPC	55.80	0.4	TiN	2.14
14	HPC	55.80	0.6	Sic	1.26
15	HPC	55.80	0.8	Tic	2.01
16	HPC	75.40	0.4	Sic	2.26
17	HPC	75.40	0.6	Tic	0.61
18	HPC	75.40	0.8	TiN	2.38

Fig .1 surface roughness instrumentation setup

IV. RESULT AND DISCUSSION

The average surface roughness value (R_a) is measured by using a contact type surfcorder SE3500 as shown in fig 1. The variation of surface roughness values with different cutting speed and depth of cut is shown in Fig 2&3. By using conventional coolant the maximum Roughness value 7.92µm for cutting speed of 55.80 m/min and depth of cut =0.8mm &minimum Roughness value at the condition of 0.39µm at the condition of cutting speed 75.80 m/min and depth of cut =0.6mm. By using high pressure coolant maximum roughness value = 2.38µm at the conditions of cutting speed =37.20m/min and depth of cut =0.8mm & minimum Roughness value 0.61µm at the condition of cutting speed =75.80m/min and depth of cut=0.6mm.

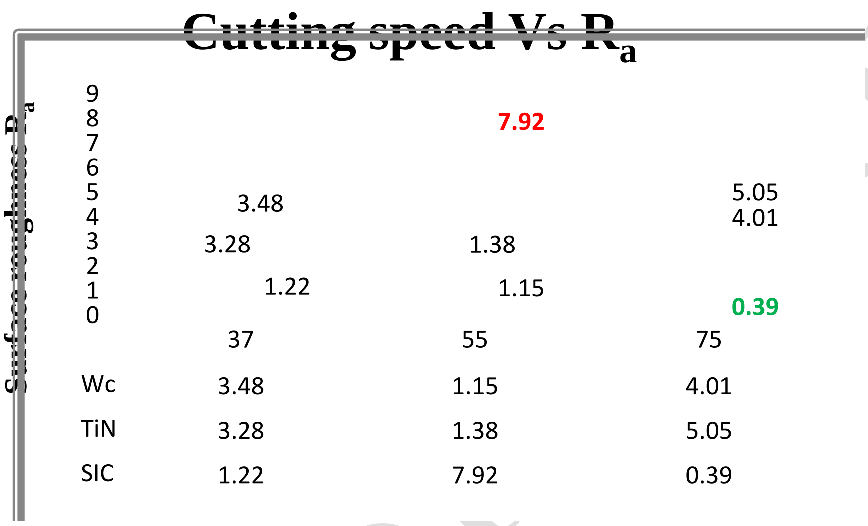

Fig.2 conventional coolant results of depth of cut, cutting speed & R_a

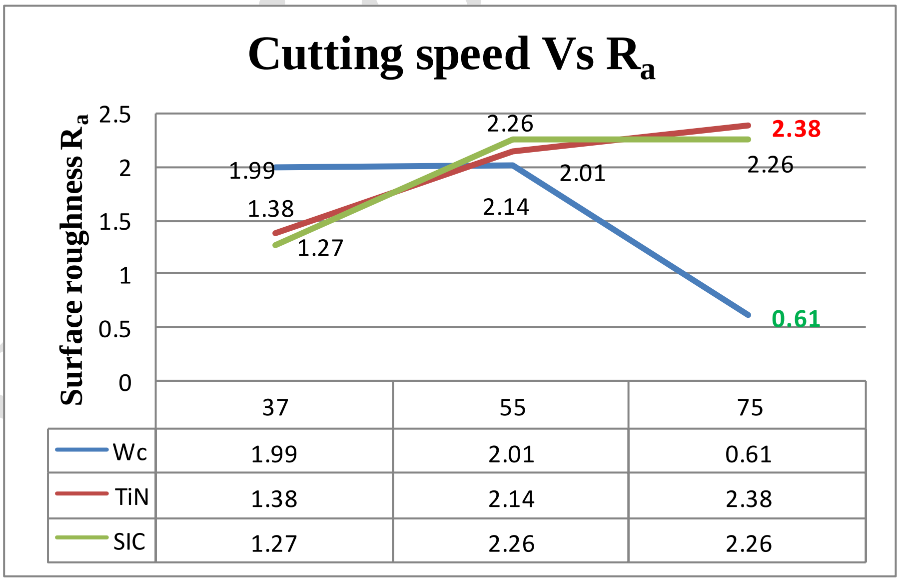

Fig. 3 HPC (high pressure coolant) results of depth of cut, cutting speed & R_a

V. CONCLUSION

The High pressure coolant (HPC) is used as the cutting fluid for turning AISI 410 stainless steel and the conclusion are summarized as follows. Average surface roughness (R_a) value has to be decreased in the high pressure coolant (2.38 max) when compared to the conventional coolant (7.92 max) at the condition of high cutting speed and depth of cut. When HPC was injected on the tool - chip and tool – work piece the friction is reduced so the roughness value has been decreased when compared with the conventional coolant High pressure coolant is found to give the better surface finish on high cutting speed and depth of cut.

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Authors Short Profile:

R.Naveen Kumar received his Bachelor's degree in Mechanical Engineering from Sri Nandhanam College of Engineering and Technology, Anna University, Chennai in 2013, and currently he is on the verge of completing Master's Degree program (2013-2015) in CAD/CAM Engineering from Saveetha Engineering College, Anna University in 2015. His area of interest includes, Design, Optimization Technology, Material science.

M. Naresh Babu is working with Saveetha Engineering College since 2006. He received his M.Tech degree in Production Engineering from M.S. University, Tirunelveli in 2002. He has 10 years of experience in teaching. His research interests include Abrasive machining technology, optimization and metaheuristics techniques. He has 3 international publications to his credit.