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Study on Effect of Various Cutting Fluids During Turning Operations of AISI 1016 Steel

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Abstract

High cutting temperatures affect the tool life, surface finish of the component and chip formation. In order to reduce the cutting temperature, suitable cutting fluids should be selected. In this work, water, coconut oil, compressed air, mixture of water and oil at room temperature and mixture of water and oil at 0 ^{0}C were used as cutting fluids during turning operation of AISI 1016 steel. In addition to this, dry turning was also performed. Turning operations were done using HSS cutting tool at different spindle speeds, while feed and depth of cut were kept constant. The influence of various cutting fluids on the cutting temperature, surface roughness and chip morphology were studied and compared. At minimum cutting temperature, reduced surface roughness and continuous chips were noticed when a mixture of water and oil were used as cutting fluid at 0 ^{0}C.

Keywords - Turning operation, Cutting fluids, Chip morphology, Surface roughness, AISI 1016 steel.

Introduction

Steel is extensively used for the production of shafts, axles, connecting rods, gears, bolts, rolls, etc. During turning operation, high temperatures occur because of interaction between (a) work piece and tool and (b) chip and tool. Among the two, maximum heat is generated when the chip-tool interaction occurs [1]. High cutting temperature at this zone affects the tool life and dimensional accuracy [2].

To reduce the cutting temperature, cutting fluids are used. Cutting fluids also help to improve the surface finish, increase the tool life, and to remove the chips in cutting zone [3]. Good cutting fluids should be able to (a) lubricate (b) provide cooling effect and (c) remove chips produced [3]. Lubrication helps to decrease the friction between chip and tool zone as well as work-piece and tool zone. Cooling effects ensure that the work piece is at a low temperature and thus prevent a thermal shock on the work piece [4]. The cutting fluid should have high thermal conductivity and specific heat to attain these properties. Cutting fluids are used for removing chips at the cutting zone and also protecting them from coming in contact with work-piece which may result in a reduced surface finish.

Cutting oils, water soluble fluids and gases are generally used as cutting fluids. El Baradie [3], reports that a mixture of oil and water in a ratio of 1:20 gives good cooling and lubrication properties. Shashidhara, and Jayaram [5] found that vegetable oil is good for lubrication but has very poor cooling effect.

Shaw [6] observes that water is a good cutting fluid, since it possesses good ability to transfer heat from work-piece and tool, but has very poor lubricating property and cause rusting of tool and work piece. In order to keep the cutting temperatures below room temperature, Dhar and M. Kamruzzaman [1] used liquid nitrogen (LN_2) as a cutting fluid and found that the surface roughness has reduced. The disadvantage of using liquid nitrogen as cutting fluid is the hazardous effect on environment [7].

In the present work, the effect of various cutting fluids on surface roughness, chip morphology, and temperature at tool-chip interaction zone during turning of AISI 1016 steel using HSS tool was investigated. Compressed air, water, coconut oil, mixture of water and oil are used as cutting fluids. The water and oil mixture is used at room temperature and at 0 ^{0}C.

Experimental Procedure

The experiment was carried out by turning low carbon steel (AISI 1016) specimens (Ø 20.2 × 150 mm length). The chemical composition of AISI 1016 steel is given in Table 1. Machining was carried out on a Kirloskar make Turn-Master Lathe using HSS tool. The HSS Tool was mounted on the tool post. The experimental conditions are reported in Table 2.

Various cutting fluids (water, coconut oil, compressed air, oil and water mixture at room temperature, oil and water mixture at 0 ^{0}C temperature) are continuously sprayed during turning at various spindle speeds (280, 450, 710, 1120 rpm).

A K-type thermocouple, with the range of -50 ^{0}C to 1300 ^{0}C, was attached to the tool and the cutting temperature was measured during machining. Surface roughness (average ‘Ra’ value) of the turned specimens were measured using Zeiss make surface roughness tester with resolution of 0.02 μm and probing force of 4 mN. Chips formed during the application of various cutting fluids were collected and analysed for chip morphology.

Table.1 Chemical Composition of AISI 1016 Steel

Elements	Fe	Mn	C	S	P
Percentage	98.67	0.858	0.175	0.019	0.014

Table.2 Experimental Conditions

Work-piece	AISI 1016 steel, Ø20.2 × 150 mm
Cutting tool	High speed steel (HSS)
Input parameters	Spindle speeds: 280, 450, 710, 1120 rpm Feed: 0.07 mm/rev Depth of cut: 0.5 mm
Cutting Fluids	Water Coconut oil Compressed air Mixture of oil and water at room temperature (1:20) Mixture of oil and water at 0 ^{0}C (1:20) No cutting fluid (Dry Turning)

Results and Discussion

Cutting Temperature

Table 3, shows the cutting temperature, surface roughness and average chip length for various spindle speed. It is observed that as the spindle speed increases the cutting temperature also increases. From Figure 1, it can be noted that the maximum cutting temperatures are observed during dry turning and the least cutting temperatures are found while oil and water mixture at 0 ^{o}C is used as cutting fluid.

A marginal decrease in temperature is identified when the other cutting fluids such as compressed air, water, coconut oil, oil and water mixture at room temperature are used for machining. The cutting temperatures vary between 30 ^{0}C and 50 ^{0}C when coconut oil, compressed air and water are used. The decrease in temperature is due to the lubrication and cooling effect of the cutting fluid [8].

At 0 ^{0}C, the cooling effect is faster than room temperature. Therefore the oil and water mixture at 0 ^{0}C gives the lowest cutting temperatures compared to other cutting fluids

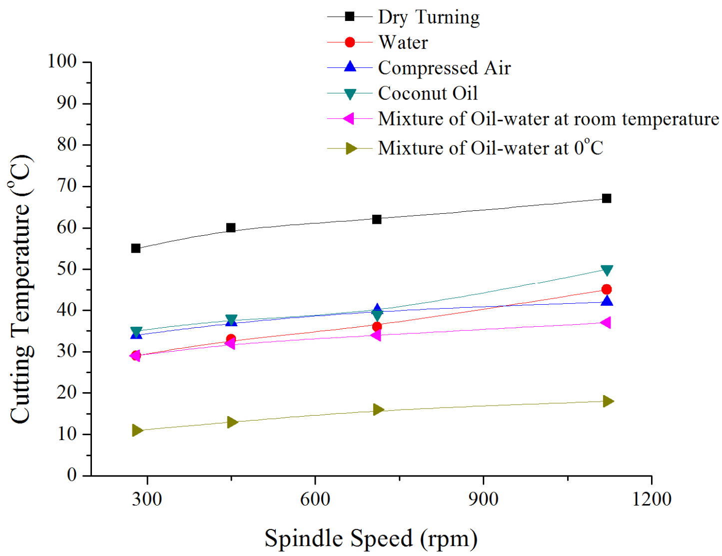


Figure.1 Effect of Cutting Fluid on Cutting Temperature with Various Spindle Speeds

Chip Morphology

Figure 2 shows the average chip length with various cutting fluids and spindle speeds. The photographic images of the chip formed during use of various cutting fluids are shown in Figure 3. From Figure 3, it can be also noted that, as the spindle speed increases, continuous chips are formed for all types of cutting fluids.

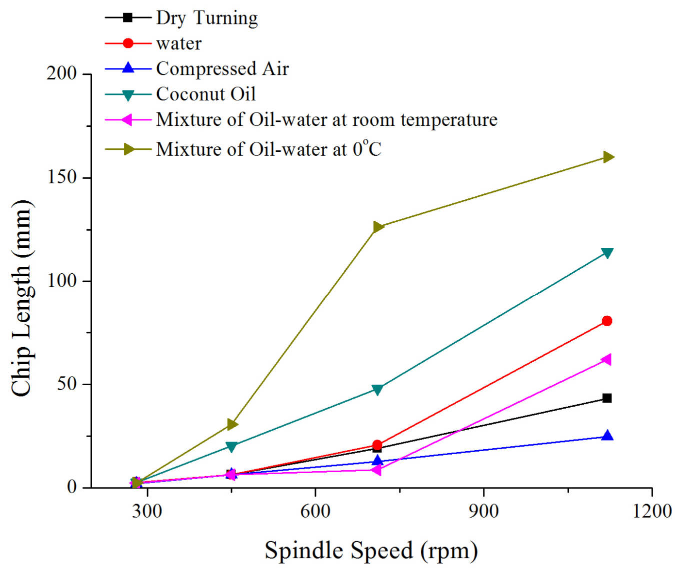


Figure.2 Chip Lengths for Various Cutting Fluids and Spindle Speeds

When compared to other cutting fluids, long continuous chips with an average length of 160 mm are formed at 1120 rpm when oil and water at 0 ^{0}C is used. At high spindle speed, the rate of deformation at shear plane will be higher resulting in increased temperatures at shear zone, due to which thermal softening of work piece occurs [9]. As resistance to plastic deformation decreases, continuous chips are formed confirming with results of H.Suhulz, E.Abele, A.Sahm and Warren R. Devries [10,11]. It is also found that good surface finish is obtained while continuous chips are produced, agreeing with M.C Shaw and V.Vyas [12,13].

Surface Roughness

The average surface roughness “Ra” values are obtained from finished work pieces using surface roughness tester.

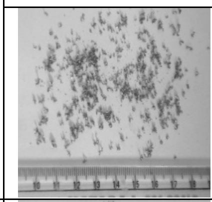
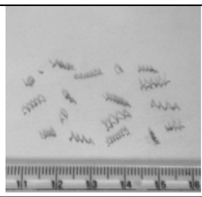
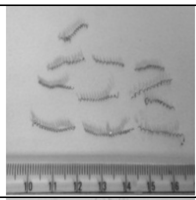
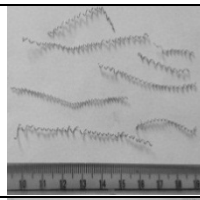
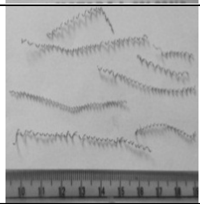
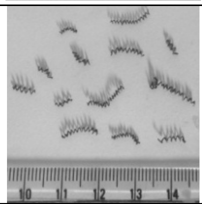
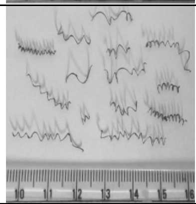
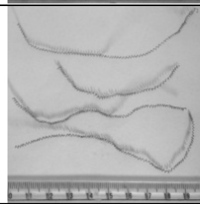
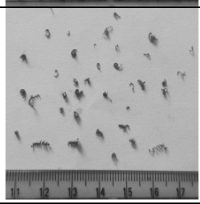
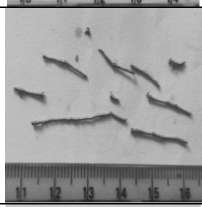
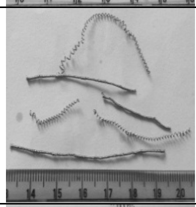
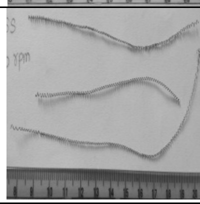
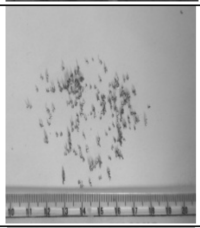
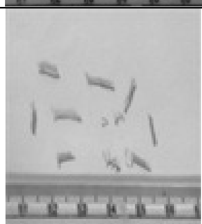
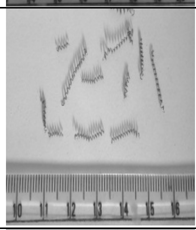
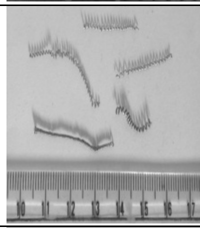
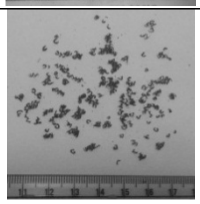
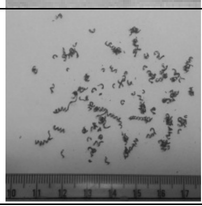
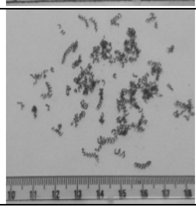
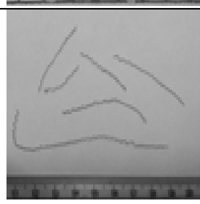
Table 3 shows the surface roughness of the work pieces after turning operation for various spindle speeds and cutting fluids and the results are plotted in Figure 4. It can be noted that the surface roughness value ‘Ra’ drops as the spindle speed increases.

Low surface roughness values at high spindle speeds are due to low built up edge formation [14].This is because, as the chip moves away from the tool at a faster rate, the contact time between the chip and tool is very low [15].This is insufficient for seizure of the material on to the tool. The results show that the minimum surface roughness value is obtained when the turning is done at high spindle speed with oil and water mixture at 0 ^{0}C as cutting fluid. This is because heat is removed at the chip-tool interface more effectively compared to other cutting fluids [16].

Table.3 Cutting Temperature and Surface Roughness of Work Piece and Average Chip Length for Various Cutting Fluids and Spindle Speeds

Cutting Fluid	Spindle Speed	Cutting Temperature	Surface Roughness (Ra)	Average Chip Length
	(rpm)	(^{o}C)	(µm)	(mm)
Dry Turning (no cutting fluid)	280	55	3.95	2
	450	60	3.81	6.33
	710	62	3.49	19
	1120	67	2.84	43.22
Water	280	29	3.93	2.66
	450	33	3.55	6.33
	710	36	3.43	20.66
	1120	45	2.36	80.66
Compressed Air	280	34	3.83	2
	450	37	3.44	6.33
	710	40	3.31	12.66
	1120	42	2.35	24.66

Coconut Oil	280	35	3.7	2.5
	450	38	3.1	20.33
	710	39	2.82	48
	1120	50	2.01	114.33
Mixture of Oil-water at room temperature	280	29	2.86	2.33
	450	32	2.84	6.33
	710	34	2.55	8.66
	1120	37	1.53	62
Mixture of Oil-Water at 0^oC	280	11	3.68	2.33
	450	13	3.19	30.6
	710	16	2.47	126.33
	1120	18	1.42	160

	280 rpm	450 rpm	710 rpm	1120 rpm
Without Cutting fluids				
Water				
Coconut oil				
Compressed air				
Mixer of oil-water at room temperature				

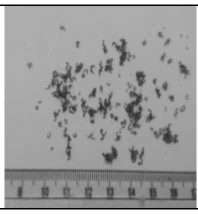
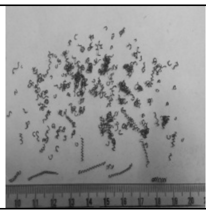
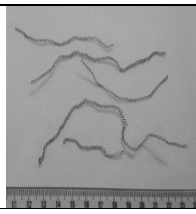
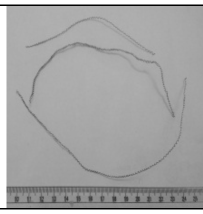
Mixer of oil-water at 0 ^{0}C temperature				

Figure.3 Chip Images for Various Cutting Fluids and Spindle Speeds

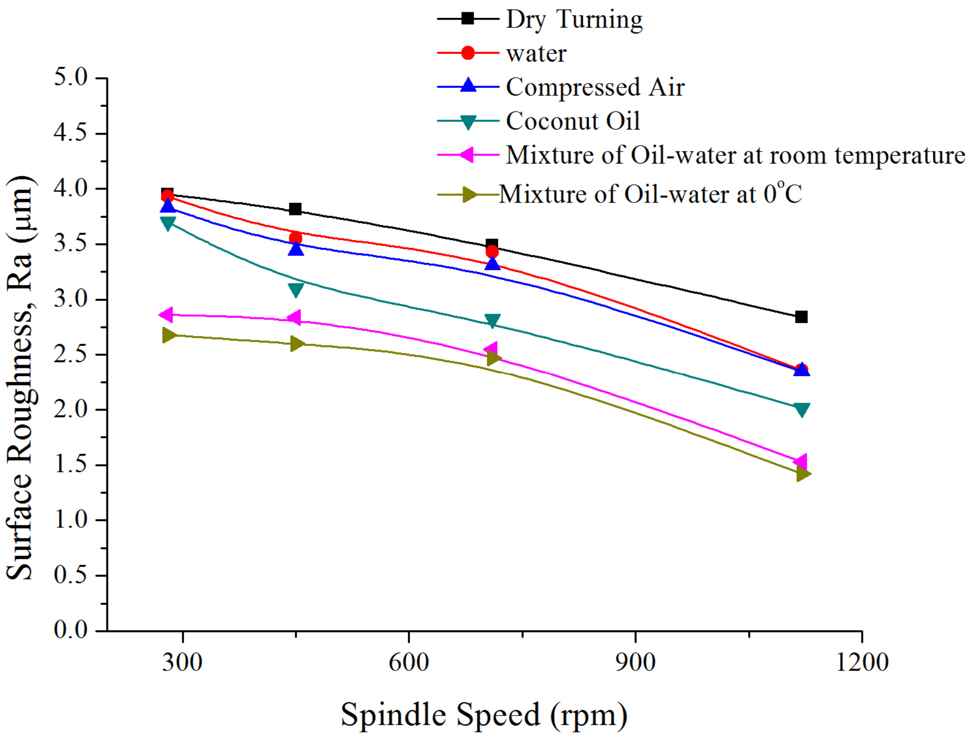


Figure.4 Effect of Cutting fluid on Surface Roughness with different spindle speeds.

CONCLUSIONS

Based on the above investigation of turning AISI 1016 steel with various cutting fluids and spindle speeds, the following conclusions can be drawn:

- Cutting temperature on tool is reduced drastically when mixture of oil and water at 0 ^{0}C is used as cutting fluid at higher spindle speed. This will result in increased tool life and reduced interactions between tool and chip.
- Minimum surface roughness (Ra) is obtained at high spindle speed when mixture of oil and water at 0 ^{0}C is used as cutting fluid compared to other cutting fluids.
- Continuous chips are formed when the cutting fluids are used at higher spindle speeds.
- When mixture of oil and water at 0 ^{0}C is used as a cutting fluid, the average length of chip obtained is more compared to other cutting fluids.

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