ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

Effect of Coolant on Carbide Tool Life

U. Dileep Kumar
Department of Mechanical Engineering,
Sistam Engineering College,
Srikakulam, A.P - 532404, India.

G. Sireesh Kumar
Department of Mechanical Engineering,
Sistam Engineering College,
Srikakulam, A.P - 532404, India.

ABSTRACT

Any liquid or gas applied directly to machining operation to improve cutting performance two main problems addressed by cutting fluids: Heat generation at shear zone and friction zone, Friction at the tool chip and tool work interfaces. Other functions and benefits: Wash away chips (e.g., grinding and milling), Reduce temperature of work part for easier handling, Improve dimensional stability of work part. Cutting fluids are used in machining for a variety of reasons such as improving tool life, reducing work-piece thermal deformation, improving surface finish. Mota and Machado (1995) concluded that reducing cutting tool cost and increased production can be achieved through the use of appropriate cutting fluids. In this thesis soluble oil, water and palm kernel oil were used as coolants in machining operations. Tungsten carbide cutting tools are employed as cutter with different cutting speeds. The main aim of this thesis is to conduct test on milling machine by changing cooling system and finding grain structure changed inside the cutting tool in different cases. Transient thermal analysis is done on the parametric model to determine the effect of different cutting fluids on the cutters.

Parametric Modeling is done in Pro/Engineer and analysis is done in Ansys.

Key words: ***Friction, Tool cost, Cutting fluids***

1. INTRODUCTION

Milling is the process of cutting away material by feeding a work piece past a rotating multiple tooth cutter. The cutting action of the many teeth around the milling cutter provides a fast method of machining.

1.1 TYPES OF MILLING MACHINES

1.2 KNEE-TYPE MILLING MACHINE

Knee-type milling machines are characterized by a vertically adjustable worktable resting on a saddle which is supported by a knee. The knee is a massive casting that rides vertically on the milling machine column and can be clamped rigidly to the column in a position where the milling head and milling machine spindle are properly adjusted vertically for operation [1].

The plain vertical machines are characterized by a spindle located vertically, parallel to the column face, and mounted in a sliding head that can be fed up and down by hand or power. Modern vertical milling machines are designed so the entire head can also swivel to permit working on angular surfaces.

The turret and swivel head assembly is designed for making precision cuts and can be swung 360° on its base. Angular cuts to the horizontal plane may be made with precision by setting the head at any required angle within a 180” arc.

The plain horizontal milling machine’s column contains the drive motor and gearing and a fixed position horizontal milling machine spindle. An adjustable overhead arm containing one or more arbor supports projects forward from the top of the column. The arm and arbor supports are used to stabilize long arbors. Supports can be moved along the overhead arm to support the arbor where support is desired depending on the position of the milling cutter or cutters [2].

Cite this article as: U. Dileep Kumar & G. Sireesh Kumar, "Effect of Coolant on Carbide Tool Life", International Journal & Magazine of Engineering, Technology, Management and Research, Volume 5 Issue 2, 2018, Page 95-106.

ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

The milling machine's knee rides up or down the column on a rigid track. A heavy, vertical positioning screw beneath past the milling cutter. The milling machine is excellent for forming flat surfaces, cutting dovetails and keyways, forming and fluting milling cutters and reamers, cutting gears, and so forth. Many special operations can be performed with the attachments available for milling machine use. The knee is used for raising and lowering. The saddle rests upon the knee and supports the worktable. The saddle moves in and out on a dovetail to control cross feed of the worktable. The worktable traverses to the right or left upon the saddle for feeding the work piece past the milling cutter. The table may be manually controlled or power fed.

1.3 UNIVERSAL HORIZONTAL MILLING MACHINE

The basic difference between a universal horizontal milling machine and a plain horizontal milling machine is the addition of a table swivel housing between the table and the saddle of the universal machine. This permits the table to swing up to 45° in either direction for angular and helical milling operations. The universal machine can be fitted with various attachments such as the indexing fixture, rotary table, slotting and rack cutting attachments, and various special fixtures [3].

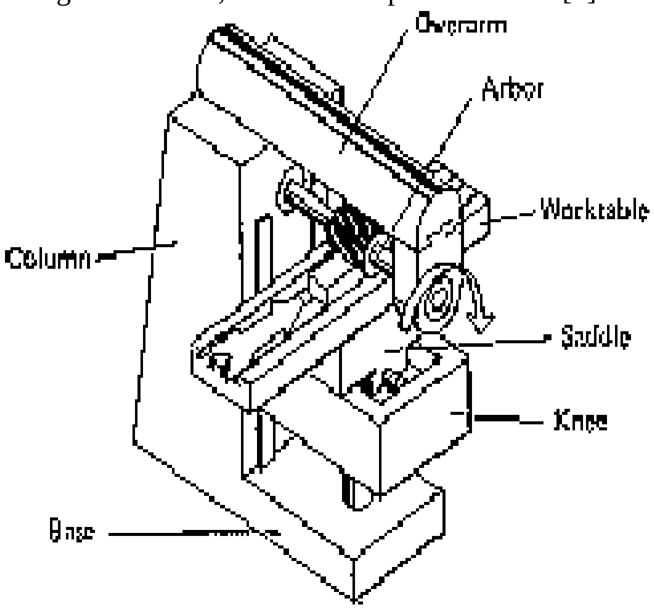

Fig: 1.1

1.4 RAM-TYPE MILLING MACHINE

The ram-type milling machine is characterized by a spindle mounted to a movable housing on the column to permit positioning the milling cutter forward or rearward in ahorizontal plane. Two popular ram-type milling machines are the universal milling machine and the swivel cutter head ram-type milling machine.

1.5 UNIVERSAL RAM-TYPE MILLING MACHINE

The universal ram-type milling machine is similar to the universal horizontal milling machine, the difference being, as its name implies, the spindle is mounted on a ram ormovable housing.

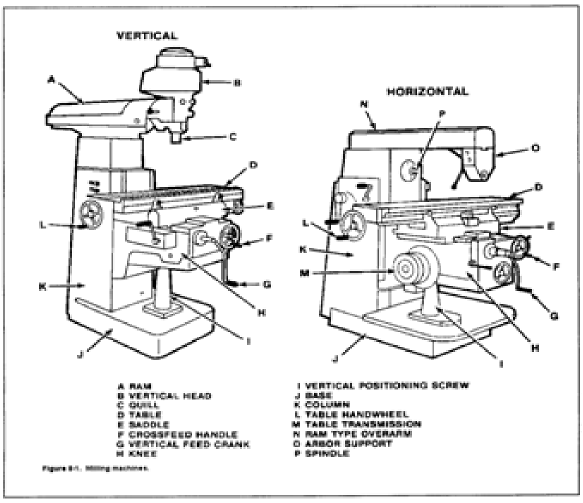

Fig:1.2

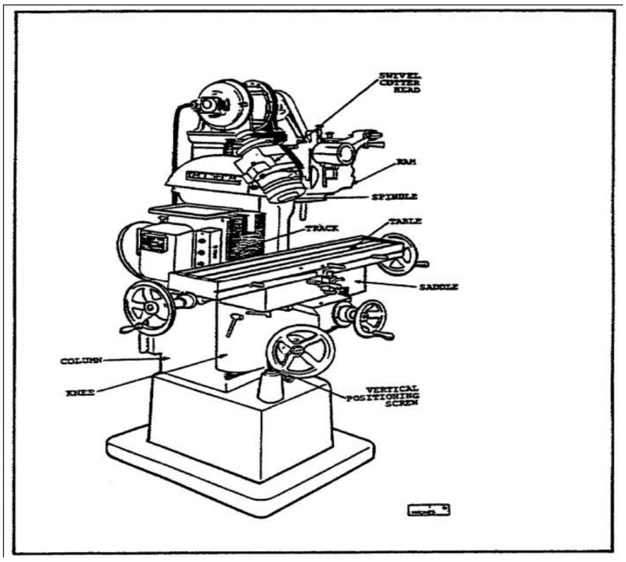

Fig:1.3

ISSN No: 2348-4845
International Journal & Magazine of Engineering,
Technology, Management and Research
A Peer Reviewed Open Access International Journal

1.6 SWIVEL CUTTER HEAD RAM-TYPE MILLING MACHINE

The cutter head containing the milling machine spindle is attached to the ram. The cutter head can be swiveled from a vertical spindle position to a horizontal spindle position or can be fixed at any desired angular position between vertical and horizontal [4]. The saddle and knee are hand driven for vertical and cross feed adjustment while the worktable can be either hand or power driven at the operator’s choice.

1.7 SAFETY RULES FOR MILLING MACHINES

Milling machines require special safety precautions while being used.

- Do not make contact with the revolving cutter.
- Place a wooden pad or suitable cover over the table surface to protect it from possible damage.
- Use the buddy system when moving heavy attachments.
- Do not attempt to tighten arbor nuts using machine power.
- When installing or removing milling cutters, always hold them with a rag to prevent cutting your hands.
- While setting up work, install the cutter last to avoid being cut.
- Never adjust the work piece or work mounting devices when the machine is operating.
- Chips should be removed from the work piece with anappropriate rake and a brush.
- Shut the machine off before making any adjustments or measurements.
- When using cutting oil, prevent splashing by using appropriate splash guards. Cutting oil on the floor can cause a slippery condition that could result in operator Injury.

1.8 TOOLS AND EQUIPMENT

MILLING CUTTERS

1.9 Classification of Milling Cutters

Milling cutters are usually made of high-speed steel and are available in a great variety of shapes and sizes for various purposes. You should know the names of the most common classifications of cutters, their uses, and, in a general way, the sizes best suited to the work at hand [5].

1.10 Milling Cutter Nomenclature

Figure 8-3 shows two views of a common milling cutter with its parts and angles identified. These parts and angles in some form are common to all cutter types.

- The pitch refers to the angular distance between like or adjacent teeth.
- The pitch is determined by the number of teeth. The tooth face is the forwardforms the cutting edge.
- The cutting edge is the angle on each tooth that performs the cutting.
- The land is the narrow surface behind the cutting edge on each tooth.
- The rake angle is the angle formed between the face of the tooth and the centerline of the cutter. The rake angle defines the cutting edge and provides a path for chips
  that are cut from the work piece.
- The primary clearance angle is the angle of the land of each tooth measured from a line tangent to the centerline of the cutter at the cutting edge. This angle prevents each tooth from rubbing against the work piece after it makes its cut.
- This angle defines the land of each tooth and provides additional clearance for passage of cutting oil and chips.

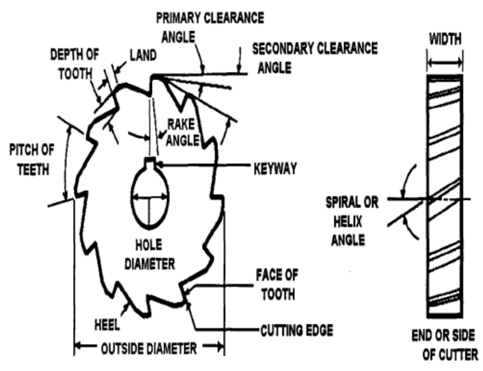

Figure 8-3. Milling cutter nomenclature.

. Fig:1.4

ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

- The hole diameter determines the size of the arbor necessary to mount the milling cutter.
- Plain milling cutters that are more than 3/4 inch in width are usually made with spiral or helical teeth. A plain spiral-tooth milling cutter produces a better and smoother finish and requires less power to operate. A plain helical tooth milling cutter is especially desirable when milling an uneven surface or one with holes in it.

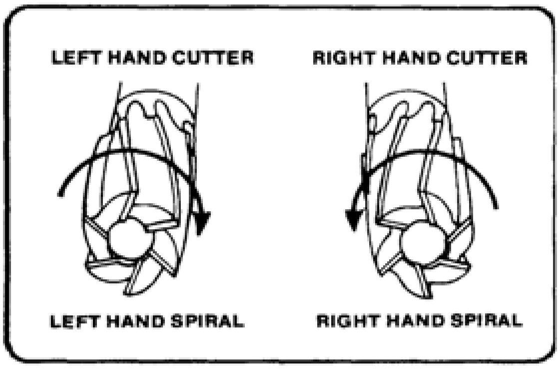

Figure 8-4. Left and right cutters

Fig:1.5 Types of Teeth

The teeth of milling cutters may be made for right-hand or left-hand rotation, and with either right-hand or left-hand helix. Determine the hand of the cutter by looking at the face of the cutter when mounted on the spindle. A right-hand cutter must rotate counterclockwise; a left-hand cutter must rotate clockwise. The right-hand helix is shown by the flutes leading to the right; a left-hand helix is shown by the flutes leading to the left. The direction of the helix does not affect the cutting ability of the cutter, but take care to see that the direction of rotation is correct for the hand of the cutter

Saw teeth similar to those shown in Figure 8-3 are either straight or helical in the smaller sizes of plain milling cutters, metal slitting saw milling cutters, and end milling cutters.

The cutting edge is usually given about 5 degrees primary clearance [6]. Sometimes the teeth are provided with off-set nicks which break up chips and make coarser feeds possible.

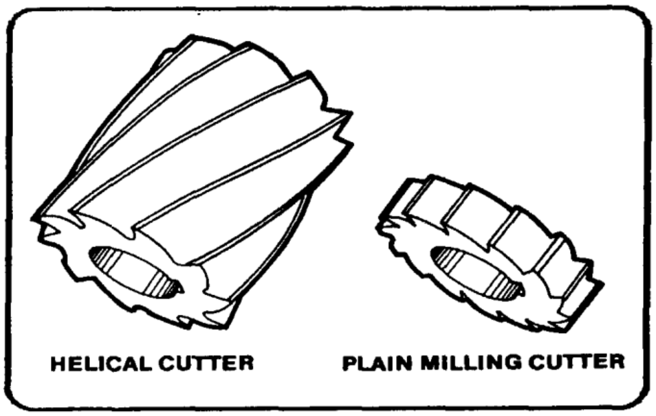

Figure 8-5. Plain and helical milling cutters.

Fig:1.6

1.11Helical Milling Cutters

The helical milling cutter is similar, to the plain milling cutter, but the teeth have a helix angle of 45° to 60°. The steep helix produces a shearing action that results in smooth, vibration-free cuts. They are available for arbor mounting, or with an integral shank with or without a pilot. This type of helical cutter is particularly useful for milling elongated slots and for light cuts on soft metal. See Figure 8-5.

1.12 Metal Slitting Saw Milling Cutter

The metal slitting saw milling cutter is essentially a very thin plain milling cutter. It is ground slightly thinner toward the center to provide side clearance. These cutters are used for cutoff operations and for milling deep, narrow slots, and are made in widths from 1/32 to 3/16 inch.

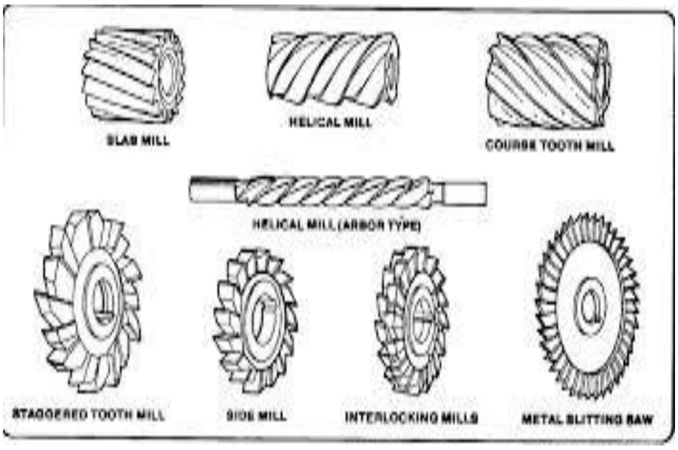

Fig:1.7

ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

1.13 Side Milling Cutters

Side milling cutters are essentially plain milling cutters with the addition of teeth on one or both sides. A plain side milling cutter has teeth on both sides and on the periphery [7].

When teeth are added to one side only, the cutter is called a half-side milling cutter and is identified as being either a right-hand or left-hand cutter. Side milling cutters are generally used for slotting and straddle milling.

Interlocking tooth side milling cutters and staggered tooth side milling cutters are used for cutting relatively wide slots with accuracy (Figure 8-6). Interlocking tooth side milling cutters can be repeatedly sharpened without changing the width of the slot they will machine [8].

After sharpening, a washer is placed between the two cutters to compensate for the ground off metal. The staggered tooth cutter is the most washer is placed between the two cutters to compensate for efficient type for milling slots where the depth exceeds the width.

1.14 End Milling Cutters

The end milling cutter, also called an end mill, has teeth on the end as well as the periphery. The smaller end milling cutters have shanks for chuck mounting or direct spindle mounting. End milling cutters may have straight or spiral flutes. Spiral flute end milling cutters are classified as left hand or right-hand cutters depending on the direction of rotation of the flutes. If they are small cutters, they may have either a straight or tapered shank.

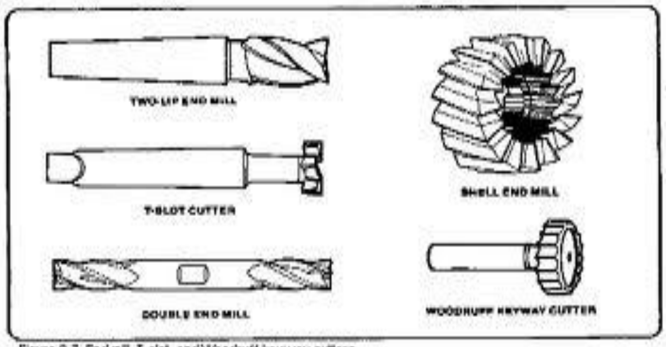

Figure 8-7. End mill, T-slot, and Woodruff keyway cutters.

Fig:1.8

The most common end milling cutter is the spiral flute cutter containing four flutes. Two-flute end milling cutters, sometimes referred to as two-lip end mill cutters, are used for milling slots and keyways where no drilled hole is providedfor starting the cut. These cutters drill their own starting holes.Straight flute end milling cutters are generally used for milling both soft or tough materials, while spiral flute cutters are used mostly for cutting steel.

Large end milling cutters (normally over 2 inches in diameter) (Figure 8-10) are called shell end mills and are recessed on the face to receive a screw or nut for mounting on a separate shank or mounting on an arbor, like plain milling cutters. The teeth are usually helical and the cutter is used particularly for face milling operations requiring the facing of two surfaces at right angles to each other.

4. INTRODUCTION TO PRO/ENGINEER

Pro/ENGINEER Wildfire is the standard in 3D product design, featuring industry-leading productivity tools that promote best practices in design while ensuring compliance with your industry and company standards. Integrated Pro/ENGINEER CAD/CAM/CAE solutions allow you to design faster than ever, while maximizing innovation and quality to ultimately create exceptional products [9].

Customer requirements may change and time pressures may continue to mount, but your product design needs remain the same - regardless of your project's scope, you need the powerful, easy-to-use, affordable solution that Pro/ENGINEER provides.

LITERATURE SURVEY

PAPER 1 - Optimization of Machining Parameters of Titanium Alloy for Tool Life by *Dinesh Kumar Chauhan, Kapil Kumar Chauhan*

High speed machining of highly reactive material like titanium and its alloys is still far away uncertain. For this reason, it is wiser to study the optimization of Machining parameters under transient cutting speed before

ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

advancing to high speed machining.This paper presents the influence of machining parameters like coolant flow rate, cutting speed on Tool life of Titanium alloy during machining. Machining process is carried out in dry or nearly dry condition using Physical Vapor Disposition (PVD) coated cemented carbide tools. For near dry machining, two levels of coolant flow rate of 50 and 100 mL/H were investigated.A plan of experiments based on Taguchi technique has been used to acquire the data. An Orthogonal array and signal to noise (S/N) ratio are employed to investigate the machining characteristics of titanium alloy & optimize the machining parameters. In optimization technique, Taguchi method is used for optimization for Variable parameters coolant flow rate (0, 50& 100mL/Hr), cutting speed (120, 135 & 150m/min), feed rate (0.1, 0.125, 0.25mm/tooth) and depth of cut (2, 2.25 & 2.5 mm). Finally Minitab 15, a comprehensive DOE tool is used for multilevel factorial screening designs to help you find the critical factors that lead to breakthrough improvements

PAPER 2 - Surface Roughness and Tool Wear Study on Milling of AISI 304 Stainless SteelUsing Different Cooling Conditions by P. Chockalingam, Lee Hong Wee

This research deals with the effect of different coolant conditions on milling of AISI 304 stainless steel. Cooling methods used in this investigation were flooding of synthetic oil, water-based emulsion, and compressed cold air. Cutting forces and the surface roughness were studied and tool flank wears observed. In this study, the comparison between different coolants' effect to the milling of AISI 304 stainless steel is done and the results from the study can provide very useful information in manufacturing field. The experiment results showed that water-based emulsion gave better surface finish and lower cutting force followed by synthetic oil and compressed cold air. Different cooling condition required different parameters in order to obtain lower surface roughness and cutting force. Chipping was the initial wear mode in the milling of AISI 304 stainless steel.

4.1 Pro/ENGINEER Wildfire Benefits:

- Unsurpassed geometry creation capabilities allow superior product differentiation and manufacturability
- Fully integrated applications allow you to develop everything from concept to manufacturing within one application
- Automatic propagation of design changes to all downstream deliverables allows you to design with confidence
- Complete virtual simulation capabilities enable you to improve product performance and exceed product quality goals
- Automated generation of associative tooling design, assembly instructions, and machine code allow for maximum production efficiency

Pro ENGINEER can be packaged in different versions to suit your needs, from Pro/ENGINEER Foundation XE, to Advanced XE Package and Enterprise XE Package, Pro/ENGINEER Foundation XE Package brings together a broad base of functionality. From robust part modelling to advanced surfacing, powerful assembly modelling and simulation, your needs will be met with this scaleable solution. Flex3C and Flex Advantage Build on this base offering extended functionality of ourchoosing.

4.2 DIFFERENT MODULES IN PRO/ENGINEER

- PART DESIGN
- ASSEMBLY
- DRAWING
- SHEETMETAL
- MANUFACTURING

MODEL OF CUTTER

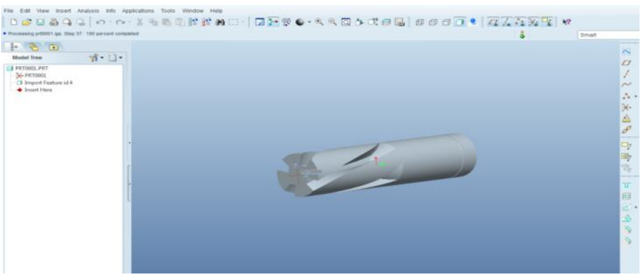

Fig:4.1 Designed model of milling cutter

ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

4.3 2-D DRAWING

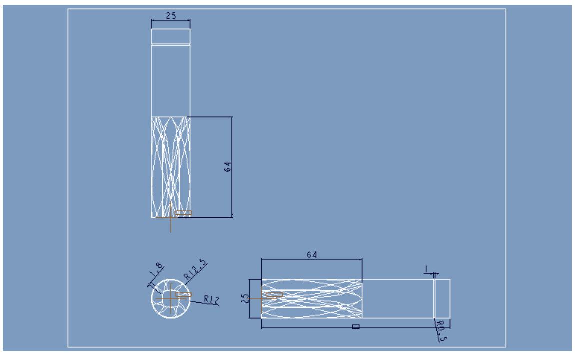

Fig:4.2 Wire frame model of milling cutter

4.3 2-D DRAWING

THERMAL ANALYSIS OF MILLING CUTTER - TUNGSTEN CARBIDE COOLANT - WATER

Element Type: Solid 20 node 90

Material Properties: Thermal Conductivity – 70w/mk

Specific Heat – 320 j/kg k

Density - 0.00000149 kg/mm^3

Imported model

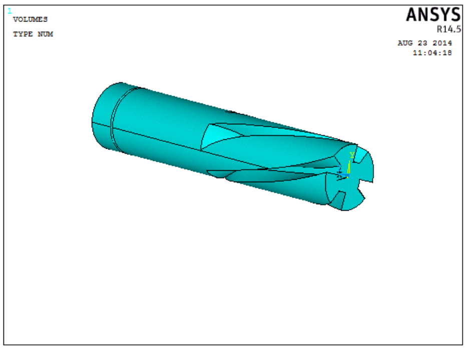

Fig:4.3 Imported model of cutter

Meshed model

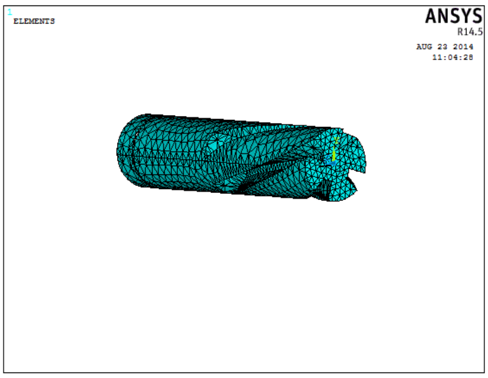

Fig:4.4 Meshed model of cutter

Apply Loads

Loads – Define Loads – Apply – Thermal – Temperature

Temperature – 393k

Loads – define Loads – Apply – Thermal – Heat flow – On nodes

Heat flow – 2kj/sec

Loads – define Loads – Apply – Thermal – Convection – on areas

Bulk Temperature – 313k

Film coefficient of water = 0.005W/mm^2 K

Solution

Solution – Solve – Current LS – ok

Post Processor

General Post Processor – Plot Results – Contour Plot - Nodal Solution – DOF Solution – Nodal Temperature Vector sum

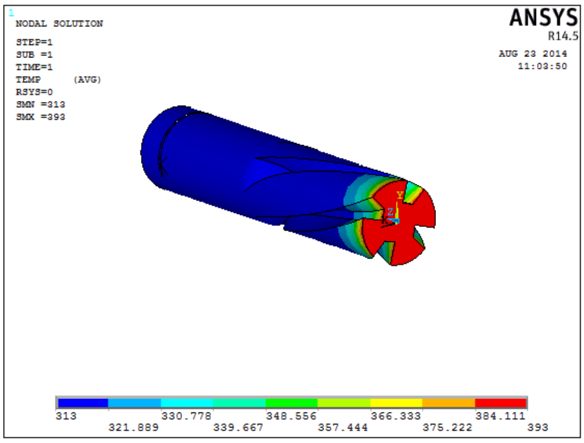

Fig::4.5 Stress variations

General Post Processor – Plot Results – Contour Plot - Nodal Solution – Thermal Gradient Vector sum

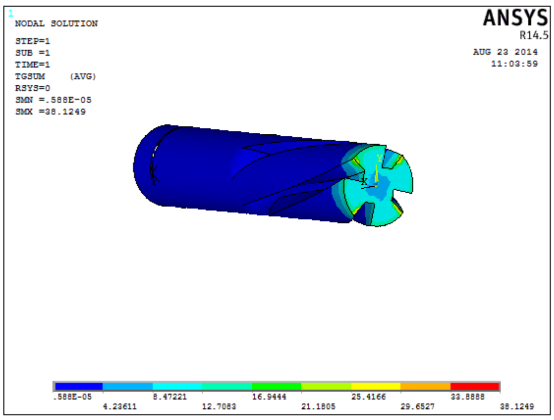

Fig:4.6 Stress induced

ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

General Post Processor – Plot Results – Contour Plot - Nodal Solution – Thermal flux vector sum

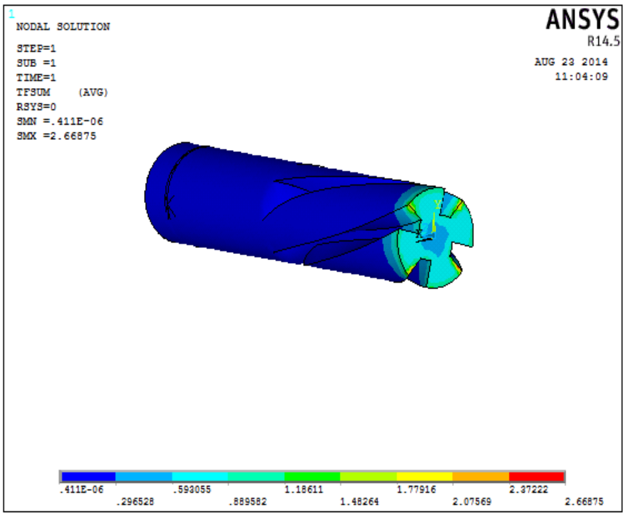

Fig:4.7 Principal stress distributed

COOLANT - SOLUBLE OIL

Film coefficient of soluble oil =0.0025 W/mm^2 K

General Post Processor – Plot Results – Contour Plot - Nodal Solution – DOF Solution – Nodal Temperature Vector sum

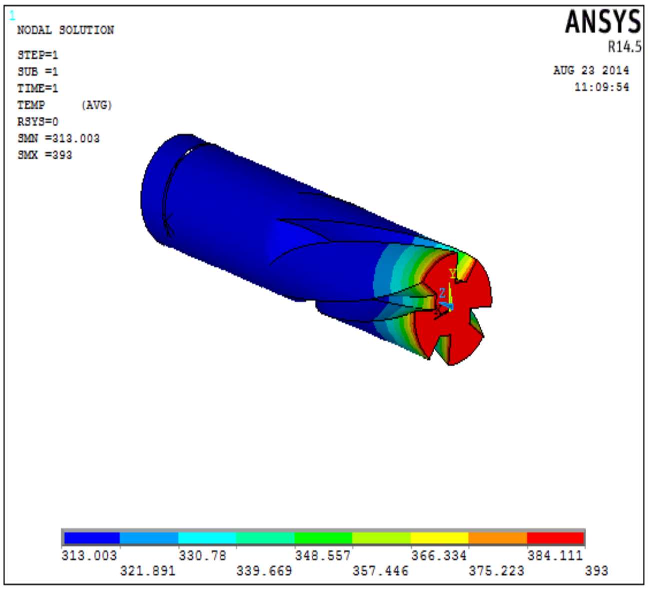

Fig:4.8 Coolant applied

General Post Processor – Plot Results – Contour Plot - Nodal Solution – Thermal Gradient Vector sum

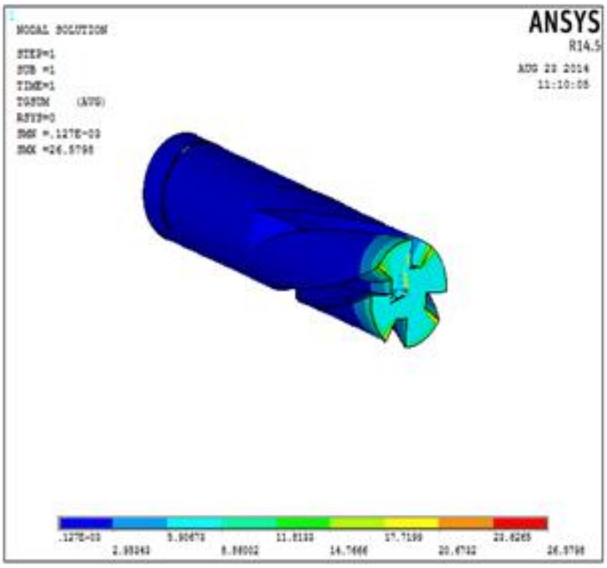

Fig:4.9 Strain diagrams

General Post Processor – Plot Results – Contour Plot - Nodal Solution – Thermal flux vector sum

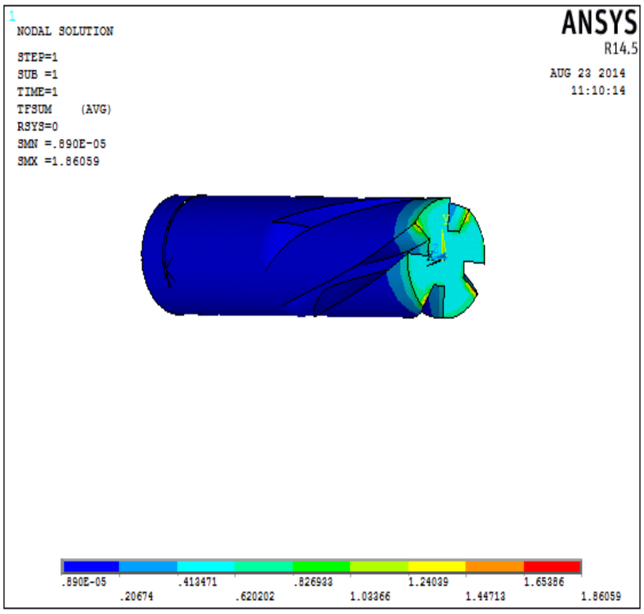

Fig:4.10 Normal temperature variation

PALM KERNEL OIL

Film coefficient of palm kernel oil =0.007 W/mm^2 K

General Post Processor – Plot Results – Contour Plot - Nodal Solution – DOF Solution – Nodal Temperature Vector sum

ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

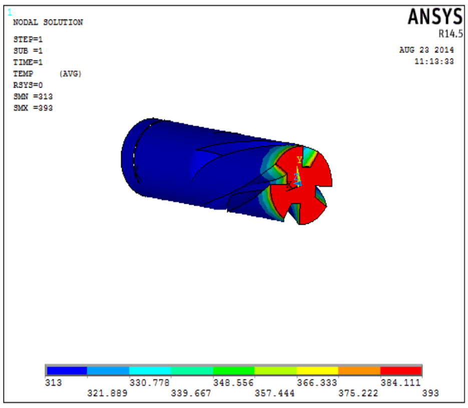

Fig:4.11 At 0.007W/mm

General Post Processor – Plot Results – Contour Plot - Nodal Solution – Thermal Gradient Vector sum

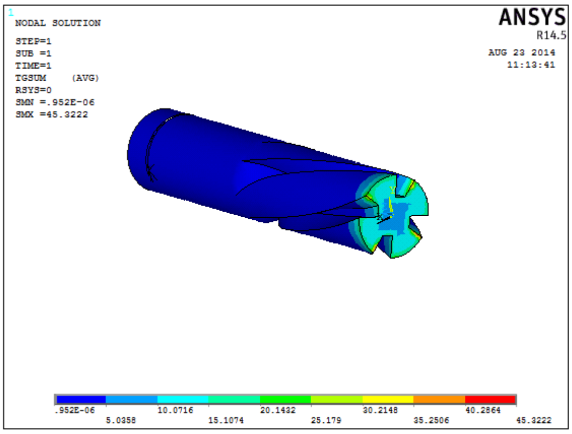

Fig:4.12

General Post Processor – Plot Results – Contour Plot - Nodal Solution – Thermal flux vector sum

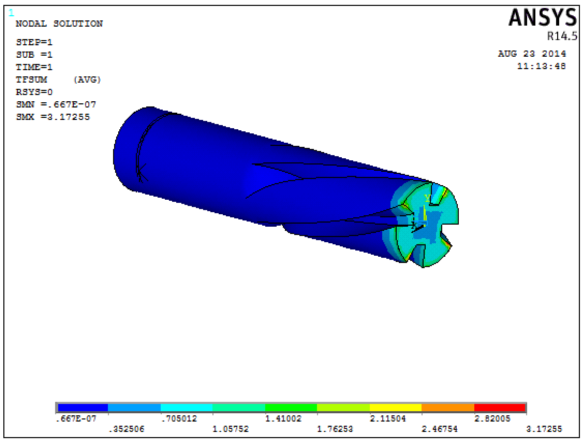

Fig:4.13

RESULTS TABLE

	Nodal temperature	Thermal gradient (K/mm)	Thermal flux (W/mm^2)
WATER	393	38.1249	2.66875
SOLUBLE OIL	393	26.5798	1.86059
PALM KERNEL OIL	393	45.3222	3.17255

5 TOOL LIFE CALCULATIONS

ROUGHING OPERATION

The **Taylor's Equation for Tool Life Expectancy** provides a good approximation.

$$V_cT^n = C$$

where

- V_c=Cutting Speed = 2500rpm = 94.246m/min
- T=tool life
- n and C are constants found by experimentation or published data; they are properties of tool material, workpiece and feed rate.

For Tool Material of Carbide and Machining of Steel,

n = 0.25

C = 500m/min

Carbide Cutter – 50R6

$V_cT^n = C$

$94.246\ T^{0.25} = 500$

$T^{0.25} = 5.305$

$T = 5.305^{1/0.25}$

T = 792.188min = 13.2hrs

FINISHING OPERATION

Carbide Cutter – 50R0.8

Cutting Speed = 3500rpm = 44m/min

$V_cT^n = C$

$44\ T^{0.25} = 500$

$T^{0.25} = 11.3636$

$T = 11.3636^{1/0.25}$

T = 16675.13319 min = 277.91hrs four tips this type of cutter is having four corner radius for each insert.

For each corner= 277/4= 69 hours

ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

6 EXPERIMENTAL INVESTIGATION

A machining process is performed using carbide cutter with cutting parameters of spindle speed 2300rpm, feed rate 1000mm/min and depth of cut 0.3mm. The machining process is done for 6 hrs for roughing [10].

The cutter used is

Solid carbide end mill

This type of end mill cutters is used for roughing and sharp corner finishing. Cutter material is solid carbide.

Fig:6.1 Cutter

Fig 6.3 Failed milling cutter

6.1 TYPES OF MILLING CUTTERS

1.METRIC SLOT DRILLS

Flute center cutting type

This cutter is used to drill blind and through holes. Its material is HSS.

Fig:6.2 Milling Cutter

MCROSTRUCTURAL ANALYSIS BEFORE MACHINING

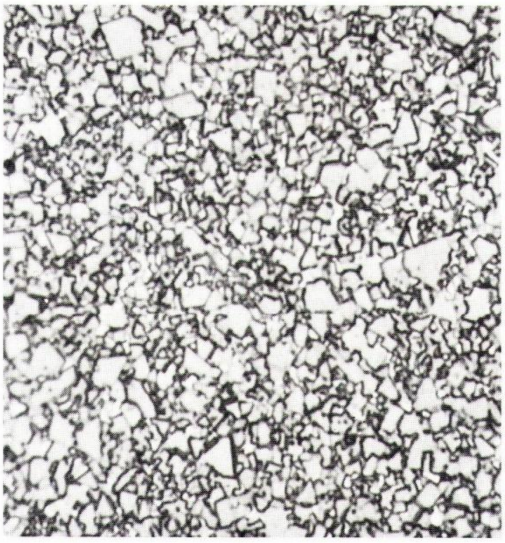

Fig:6.15 Micro structure

ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

COLOANT – WATER

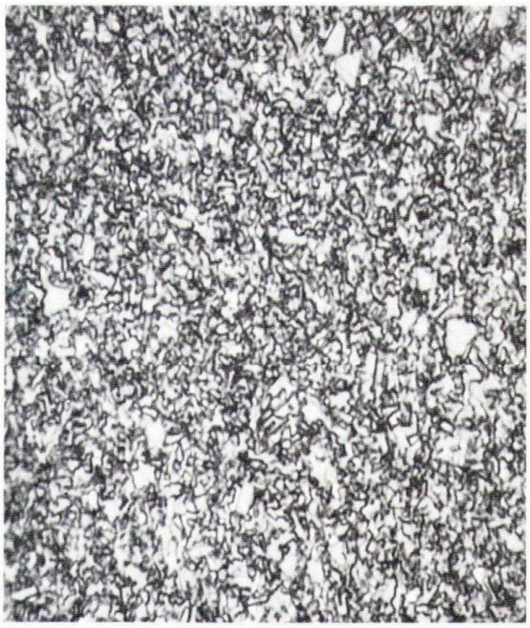

Fig:6.16 Water as Coolant

COOLANT – SOLUABLE OIL

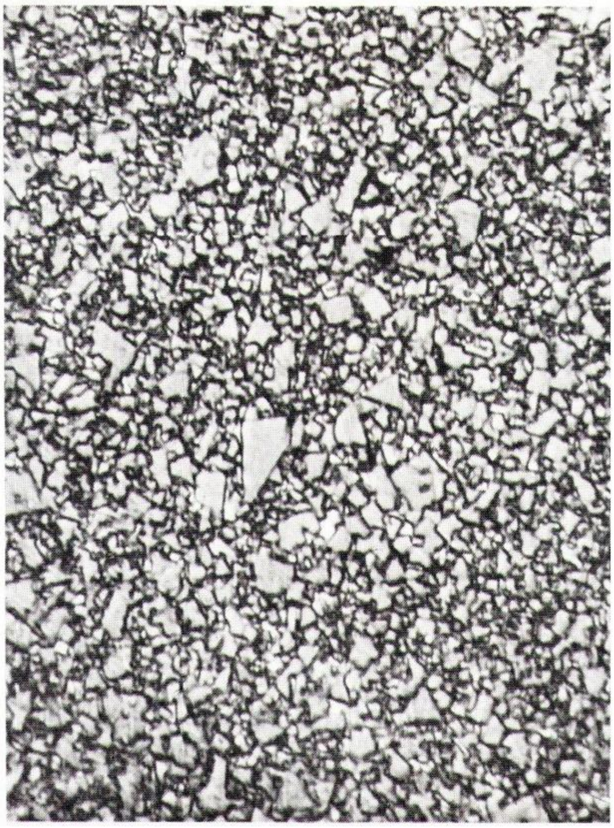

Fig:6.17 COOLANT – SOLUABLE OIL

COOLANT – PALM KERNAL OIL

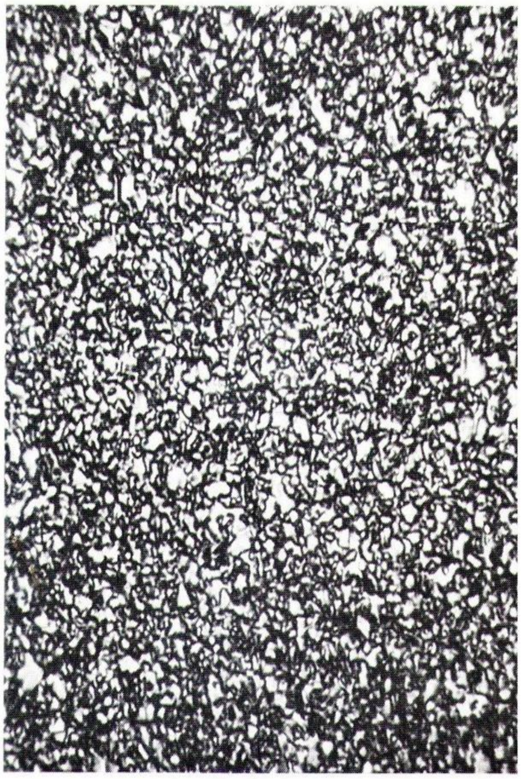

Fig:6.18 PALM KERNAL OIL

6.3 HARDNESS TEST

BEFORE MACHINING	ROCKWELL HARDNESS
	92

	AFTER MACHINING
WATER	97
SOLUABLE OIL	103
PALM KERNEL OIL	95

CONCLUSION

In this thesis soluble oil, water and palm kernel oil were used as coolants in machining operations. Tungsten carbide cutting tool is employed as cutter for a machining process is performed using carbide cutter with cutting parameters of spindle speed 2300rpm, feed rate 1000mm/min and depth of cut 0.3mm. The machining process is done for 6 hrs for roughing.

Microstructure test and hardness test are performed on the cutter before machining and after machining. By observing the microstructure test, there is not much difference in the microstructure before machining and after machining.

By observing the hardness test, the hardness is increasing after machining and it is more for soluble oil. So when soluble oil is used the cutter fails fast than by using water and palm kernel oil.

Thermal analysis is done on the cutter to determine the heat transfer rate when the coolants are used. By observing the analysis results, the heat transfer rate is more for palm kernel oil since thermal flux is more. Water is also good coolant which is easily available.

REFERENCES

[1]. Optimization of Machining Parameters of Titanium Alloy for Tool Life by Dinesh Kumar Chauhan, Kapil Kumar Chauhan

[2]. Surface Roughness and Tool Wear Study on Milling of AISI 304 Stainless Steel Using Different Cooling Conditions by P. Chockalingam, Lee Hong Wee

[3]. The Effects of a High-Pressure Coolant Jet on Machining by A R Machado, J Wallbank

[4]. Effect of high pressure coolant on surface finish in turning operation by Mr. R. A. Patil, Prof. V. D. Shinde, Prof. H. V. Shete, Prof. S. P. Nevagi

[5]. Effects of Cryogenic Cooling on the Surface Quality and Tool Wearin End-Milling 6061-T6 Aluminium

[6]. López de Lacalle, L.N., et al., Experimental and numerical investigation of the effect of spray cutting fluids in high speed milling. Journal of Materials Processing Technology, 2006. 172(1): p. 11-15.

[7]. Li, K.-M. and S.Y. Liang, Modeling of Cutting Temperature in Near Dry Machining. Journal of Manufacturing Science and Engineering, 2006. 128(2): p. 416.

[8]. Li, K.-M. and S.Y. Liang, Modeling of cutting forces in near dry machining under tool wear effect. International Journal of Machine Tools and Manufacture, 2007. 47(7-8): p. 1292-1301.

[9]. Su, Y., et al., Refrigerated cooling air cutting of difficult-to-cut materials. International Journal of Machine Tools and Manufacture, 2007. 47(6): p. 927-933.

[10]. Hong, S.Y., I. Markus, and W. Jeong, New cooling approach and tool life improvement in cryogenic machining of titaniumalloy Ti-6Al-4V. International Journal of Machine Tools and Manufacture, 2001. 41(15): p. 2245-2260.