EFFECT OF HIGH PRESSURE COOLANT JET (HPCJ) IN DRILLING AISI 4340 STEEL

P. SATYANARAYANA
Assistant professor, Department of mechanical engineering, Geethanjali College of engineering and technology, Telangana, India

B. ANITHA
Assistant professor, Department of mechanical engineering, Geethanjali College of engineering and technology, Telangana, India

YALAGANDALA AKSHAY KUMAR
Assistant professor, Department of mechanical engineering, CVSR College of Engineering, Hyderabad, India.

ABSTRACT
High production machining, grinding and drilling inherently generates large amount of heat leads to high cutting zone temperature for its higher cutting velocity, feed and depth of cut, Such high cutting temperature if not reduced impairs surface integrity of the product and reduce the dimensional accuracy as well as tool life. Applications of cutting fluids change the performance of machining operations because of their lubrication, cooling, and chip flushing functions. However, the conventional cutting fluids are not that effective in such high production drilling. Low boiling temperature cause vaporization of cutting fluid and prevent it to enter into the cutting interface making a barrier to flow. In addition, flowing chips through drill flute prevent the fluid to enter into the cutting zone. Further, they also deteriorate the working environment and lead to general environmental pollution.
High-pressure coolant presents itself as a viable alternative for drilling with respect to heat dissipation, roundness deviation and taper of the hole, chip formation mode and tool wear. This study compares the mechanical performance of high-pressure coolant to completely dry lubrication for the drilling of AISI-4340 steel based on experimental measurement of roundness deviation, surface roughness, chip formation mode and tool wear, Results indicated that the use of high-pressure coolant leads to lower roundness deviation and surface roughness, favorable chip-tool interaction and reduced tool wear.

KEYWORDS: Speed, Depth of cut, Cutting zone, heat dissipation, high pressure coolant, dry lubrication, AISI steel. etc…

INTRODUCTION

In the present days, production industries are concerned with high productivity and superior quality. Productivity depends on the work materials and machining processes, which are associated with many parameters like machining speed, feed rate, depth of cut, and cutting environment. Cutting environment is one of the most important parameter to increasing the product quality. Product quality and overall economy in manufacturing by machining, grinding and drilling, particularly to meet the challenges thrown by liberalization and global cost competitiveness, insists high material removal rate and high stability and long life of the cutting tools. However, high production machining, grinding and drilling with high cutting velocity, feed rate and depth of cut is inherently associated with generation of large amount of heat and high cutting temperature. Such high cutting temperature not only reduces dimensional accuracy and tool life but also impairs the surface integrity of the product and quality. Worst Quality of product is affected on customer satisfaction and reduces customer demand.
Longer cut under high cutting temperature cause thermal expansion and distortion of the job particularly if it is slender and small in size, which lead to dimensional and form in accuracy. On the other hand, high cutting temperature accelerates the growth of tool wear and enhances the chances of premature failure of the tool by plastic deformation and thermal fracturing. The changing of cutting tool within a short time is committed due to tool wear and tool fracture, for this tool cost and tool changing time increases. In both the cases, production cost is increased. The surface quality of the products also deteriorates with the increase in cutting

temperature due to built-up-edge formation, oxidation, rapid corrosion and induction of tensile residual stress and surface micro-cracks. These problems are more predominant in drilling where cutting temperature is, as such, very high due to much higher specific energy requirement and cutting velocity. Such problem becomes more acute and severe if the work materials are very hard, strong and heat resistive and when the machined or ground part is subjected to dynamic or shock loading during their functional operations.

Therefore, it is essential to reduce the cutting temperature as far as possible. In industries, the machining temperature and its detrimental effects are generally reduced by

- Proper selection of process parameters, geometry of the cutting tools and proper selection and application of cutting fluid.
- Using heat and wear resistant cutting tool materials like carbides, coated carbides and high performance ceramics.

In the metal cutting operation, temperature is the apprehensive element. If wearable to reduce or minimize the temperature, quality will also be developed. Temperature can be reduced by using cutting fluid. Cutting fluid not only reduces temperature but also provide lubrication between the tool and work interface. Temperature can be reduced in different ways like flood cooling, near dry cooling or micro lubrication, MQL cooling, cryogenic cooling and high-pressure jet cooling. Near dry cooling is based on air coolant, a little amount of temperature is reduced. MQL is same in fashion of dry. Large amount of small particles are produced which effect inhalation of the operator. Flood cooling reduces temperature to some extent by bulk cooling but is not very much effective because it cools only the top surface of the job and the tool due to its overhead application, It has some bad effects too, when cutting fluid comes in contact with the human body, it creates skin irritation, lung cancer etc. Cryogenic coolant effectively reduces temperature from the cutting zone but it is very costly and in nitrogen rich atmosphere notch wear of the tool takes place. Best performance is found in high-pressure cooling jet (HPCJ). High-pressure jet of conventional coolant has been reported to provide some reduction in cutting temperature .It reduces temperature very quickly due to high pressure jet coolant reaches very easily into the chip- tool interface. It is reported that a coolant applied at the cutting zone through a high pressure jet nozzle could reduce the contact length and coefficient of friction at chip-tool Interface and thus could reduce cutting forces and increase tool life to some extent.

DESIGNS AND DEVELOPMENT OF HIGH PRESSURE COOLANT SYSTEM

2.1 HPC MACHINING

HPC machining has developed very quickly day by day. The idea of delivering coolant under high pressure to the cutting region in order to increase tool life during machining began in early 1950s. Mainly HPC has used in high production manufacturing industries where product quality and dimension accuracy are needed within acceptable limit and difficult-to-machine materials are processed to get the desired job. High speed machining is needed to increase productivity in manufacturing technology. High speed machining is related with high temperature, such high temperature creates lot of problems. So for reducing this high temperature HPC jet is used as a heat removing as well as lubricating agent.

Flood cooling has some problem in machining, A lot of heat is created during high speed machining, Low pressure cutting fluid of flood cooling is vaporized due to high temperature when it comes in contact with the tool-chip-work, makes a barrier(film), for this no cutting fluid reach in the tool-chip interface or cutting zone. The film boiling temperatures of conventional cutting fluids is about 350^0C .But in HPC machining coolant is supplied with high pressure. Due to high pressure coolant reach sufficiently into the tool-chip interface and break down the vapor barrier and easily enter into the cutting zone.

2.2 DESIGN AND FABRICATION OF THE HPC JET DELIVERY SYSTEM

HPC setup contains motor, pump, flow control valve, pressure gauge and filter is shown in Fig.2.1.These devices are mounted at the top of a tank that is made of mild steel sheets and angle bars. This tank contains the cutting oil that is used as a coolant. And the capacity of the coolant tank is 15 litters. A coolant indicator is mounted beside the wall of coolant tank; it is used to know the quantity of coolant present in the tank during machining. A 1.0 hp motor is used to operate the pump.

This pump pressurized the coolant to pass through the flow control. Flow control valve controls the amount of flow, the flow control valve is turned to minimize and maximize flow during machining. A pressure gauge

NOVATEUR PUBLICATIONS
INTERNATIONAL JOURNAL OF INNOVATIONS IN ENGINEERING RESEARCH AND TECHNOLOGY [IJIERT]
ISSN: 2394-3696
VOLUME 4, ISSUE 9, Sep.-2017

is also mounted to observe the pressure of coolant. A direction control valve is used for changing the direction of supply. A perfect nozzle is used to supply high pressure coolant towards the cutting zone. From the nozzle pressurized fluid impinged at the chip-tool interface and reduces the cutting temperature. A recycling pump and a filter are used to recycle the used coolant.

2.3 FIGURES

Fig 2.1

2.4 DESIGN AND FABRICATION OF THE NOZZLE

A nozzle play major role to supply coolant towards the tool-chip and tool-work interface. Better velocity of jet and higher pressure is produced by a nozzle. Nozzle has been designed for proper jet. The designed nozzle tip is composed of 1.5mm tip diameter; 4.0mm inlet inner diameter and 6.0 mm inlet outer diameter is shown in Fig.2.2 to get desirable jet so that the perfect Jet can pass through the tool-chip interface. Nozzle tip plays an important role to supply coolant very superiorly.

Nozzle tip was placed closed to the work piece and drill bit contact point so that the jet impinged at the contact zone. The nozzle was placed at a certain distance from the top surface of the specimen and maintained an approximate angle. With the axis of the drill bit so that Jet can easily enter into the hole along the drill flute to function properly.

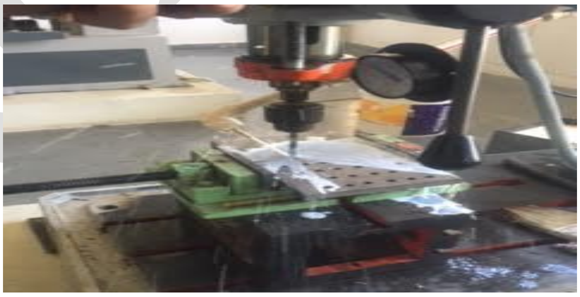


Fig 2.2

EXPERIMENTAL INVESTIGATIONS

3.1 EXPERIMENTAL PROCEDURE AND CONDITION

Machining ferrous metals by HSS is a major activity in the machining Industries. Machining of steels involves more heat generation for their ductility and production of continuous chips having more intimate and wide chip-tool contact. A gain, the cutting temperature increases further with the increase in strength and hardness of the steels for more specific energy requirement. Keeping these facts in view the commonly used steel like AISI-4340 steel has been under taken for the present investigations. Considering common interest and time constraint, only HSS drill bit have been used for the present investigation. Wide scope will remain for further study on high-pressure coolant effect in drilling steels by HSS bit and exotic materials by high performance drill bit. The drilling tests have been carried out by drilling AISI-4340 steel on a drill machine (R915L, Italy, 3.7 k w) by HSS drill bit under both dry and high-pressure coolant condition.

Drilling ferrous metals by HSS drill bit is a major activity in the machining industries. Drilling of steels involves more heat generation for their ductility and production of continuous chips having more intimate and wide chip-tool contact. Again, the cutting temperature increases further with the increase in strength and hardness of the steels for more specific energy requirement. Keeping these facts in view, the commonly used steel like AISI-4340 steel have been undertaken for the present investigations. The compositions, strength, hardness and industrial use of this steel is given in Table3.1.

Table 3.1: Characteristics of the used steel

Work Material	BHN	UTS (kgf/mm^2)	Chemical Composition (Wt %)	Applications
AISI-4340 Steel	275	110	C – 0.360 Mn - 0.920 Ni – 2.850 Cr – 1.410 Mo - 0.520 V - 0.200	1.Crank shafts 2.Differential shafts 3.Heavy duty gears 4.Turbine discs 5.High strength studs and bolts

- Firstly, we people gathered all the material required for carrying out the experiment.
- Coming to the work piece material, we chosen AISI 4340 grade and high speed steel with 8mm diameter is selected as tool.
- A electric motor with 1.0 hp, flow control valve, pressure gauge, pipe and a nozzle are also purchased to arrange a high pressure coolant jet set up for radial drilling machine in machine tools lab.
- The positioning of the nozzle tip with respect to the HSS drill has been settled after a number of trials. The photographic view of the experimental set-up is shown in Fig.3.1 and the conditions under which the machining tests have been carried out are briefly given in Table-3.2.

Fig 3.1

3.2 EXPERIMENTAL CONDITIONS

Machine tool : RADIAL DRILLING MACHINE 1440 RPM
Work Material : AISI 4340 STEEL
Cutting tool : HIGH SPEED STEEL (DIA 8MM)
Cutting oil : SOLUBLE OIL
Process Parameters :
CUTTING VELOCITY : 40ft/min
FEED RATE : 0.002 in./rev
DEPTH OF CUT : 17mm
HPC Supply : 1 liter/min
Environment : DRY AND HIGH PRESSURE COLLANT CONDITION

The cooling capacity of the cutting oil (Soluble oil) at different pressure and flow rate used in this experiment is important. They were found out using an electric furnace. The maximum temperature measured in the middle of the work piece was 400^0C, obtained after keeping it inside the furnace for a period of 8 minutes. After heating, the work pieces were submitted to cooling condition similar to the

NOVATEUR PUBLICATIONS
INTERNATIONAL JOURNAL OF INNOVATIONS IN ENGINEERING RESEARCH AND TECHNOLOGY [IJIERT]
ISSN: 2394-3696
VOLUME 4, ISSUE 9, Sep.-2017

experiments i.e. High pressure coolant (HPC) condition at different pressure.
The temperature was measured by a K-type (cromel-alumel) thermo couple for 8 minutes. This thermo-sensor was connected to the work piece through a hole that allowed it to reach the center of the work piece. The house of fluid was in a distance of 15mm from the upper part of the work piece. After completing first process coolant was kept on the open air to reduce the temperature of the coolant that came from the hot specimen and coolant temperature were reduced up to room temperature.

3.3 EXPERIMENTAL RESULTS

3.3.1. NUMBER OF HOLES

The specimen is shaped by turning and facing in traditional lathe machine. The surface is finished by using surface grinding machine; Punching has been done on the top surface of the specimen in right way in order to locate the drill bit at right place. Punching was done on the specimen maintaining equal distances in between centers.
Work piece was placed on the table of the drill machine and clamped very rigidly. A hollow cylinder was placed keeping the work piece at its centre, whose purpose was to control chips and coolant flow is shown in Fig.3.1. Drill bit was placed on the top surface of the located work piece and holes were drilled sequentially (like 1, 2, 3, 4) on both two parts of the divided specimen, one for dry condition and another for HPC condition.AISI-4340 steel was drilled by 8mm HSS drill bit.AISI-4340 steel is drilled under HPC jet condition at 1 bar pressure with coolant supply at 1 liter/min because of high cooling capacity. The photographic views of the holes are shown in Fig.3.2.

Holes drilled under Dry Condition

.

Holes drilled under HPCJ Condition

Fig 3.2

3.3.2.CHIP FORMATION

Chips must be small enough to move up the tool's flutes and out of the way. Long, stringy chips can damage surface finish and cause premature tool wear or breakage. Coolant has to get to the tool tip to keep the tool and work piece cool, as well as force chips out of the hole. A rigid machine tool with good damping characteristics and low spindle run out is required to hit targets for accuracy, repeatability and surface finish. Of course, the right drill geometry will make deep-hole drilling operations much more efficient.
Chips were collected after the completion of every drilling operation. Drilled chips were allowed for some time to become clean from coolant and cool down. Collected chips were washed out with acetone, dried and preserved in a desecrator packing with aluminum foil. The photographic view of chip is shown in Fig.3.2.

Chip Formation in Dry Condition

Chip Formation in HPCJ Condition
Fig 3.3

3.3.3. ROUNDNESS DEVIATION

The deviation in diameter and roundness of the holes were measured by a precision digital slide caliper having least count 0.01mm. At least 16 measurements with same alignment were taken for each hole. Dial Indicator caliper is used while measuring the roundness.Table3.3 and Table 3.4 show the average, maximum and minimum diameters measured randomly of the hole length under both dry and HPC conditions, It can be seen in the table that the standard deviation of average diameter obtained under HPC conditions is lower than that obtained using dry condition, which means that the HPC presented a better quality. Fig.3.4 and Fig.3.5 shows the roundness of the holes close to the entrance respectively. Fig.3.6 and Fig.3.7 shows the roundness of the holes close to the end of the holes obtained during drilling the steel.

Table 3.2
Diameter of the holes at the Entrance and close in Dry Machining

S.no	D_{max}	D_{min}	D_{avg}
1.	8.0	7.98	7.99
2.	8.1	7.95	8.025
3.	8.3	7.95	8.125
4.	8.1	7.9	8.0
5.	8.2	7.91	8.055
6.	8.12	7.9	8.01

Table 3.3
Diameter of the holes at the Entrance and close in HPCJ Machining

S.no	D_{max}	D_{min}	D_{avg}
1.	8.01	7.9	7.955
2.	7.85	7.4	7.5
3.	8.1	8.0	8.05
4.	8.15	8.02	8.08
5.	8.1	8.0	8.05
6.	8.1	8.0	8.05

Dry Condition(Roundness of the holes close to the entrance)
Fig:3.4

HPCJ Condition (Roundness of the holes close to the entrance)
Fig:3.5

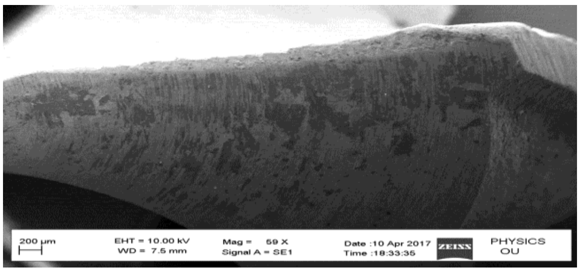
Dry condition (Roundness of the holes close to the end)
Fig:3.6

HPCJ condition (Roundness of the holes close to the end)
Fig:3.7

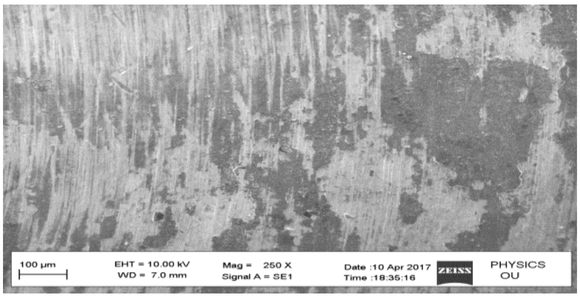
3.3.3.TOOL WEAR

Wear not only affects the surface roughness of the hole but also influences the life of the drill bit. Wear in drill bit is characterized as flank wear, chisel wear, corner wear, crater and margin wear. Since wear on drill bit indicates the hole quality and tool life of the drill bit. Worn drills produce poor quality holes and in extreme cases, a broken drill can destroy almost all finished parts. A drill begins to wear as soon as it is placed into operation. A sit wears, cutting forces increases, the temperature rises and this accelerates the physical and chemical processes associated with drill wear and therefore drill wears faster. Thrust and torque depend upon drill wear, drill size, feed rate and spindle speed.

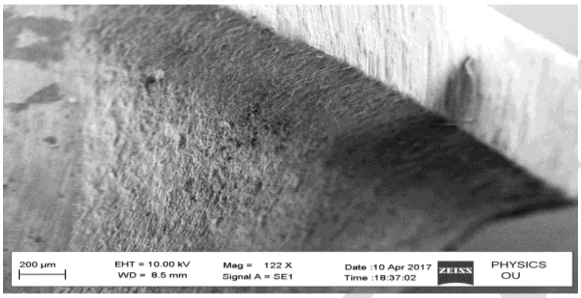
Tool wear play important role in drilling operation. Tool wear caused to poor quality of hole surface, irregularity of roundness and unacceptable diameter deviation. Then drill bits used in both the machining are scanned under SEM for knowing the tool wear. The SEM views of tool wear are shown in Fig.3.7 and Fig.3.8.



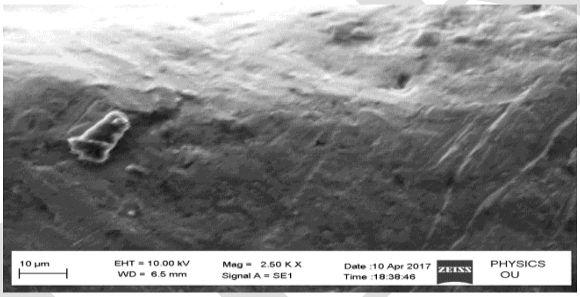
In the above figure the micro structure of work piece is analyzed under magnification of 59X, electron high tension of 10.00 k v, and working distance of 7.5mm



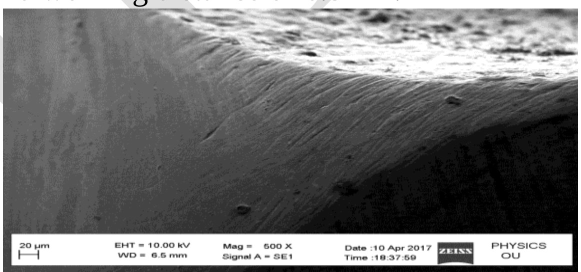
In the above figure the micro structure of work piece is analyzed under magnification of 250X, electron high tension of 10.00 k v, and working distance of 7.0mm



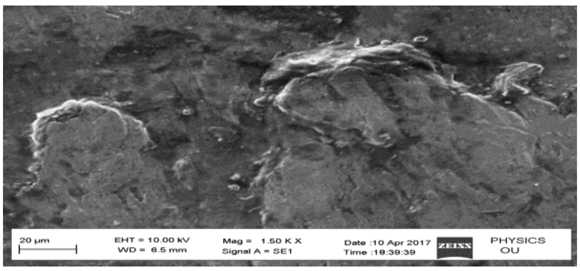
In the above figure the micro structure of work piece is analyzed under magnification of 122X,electron high tension of 10.00 k v, and working distance of 8.5mm



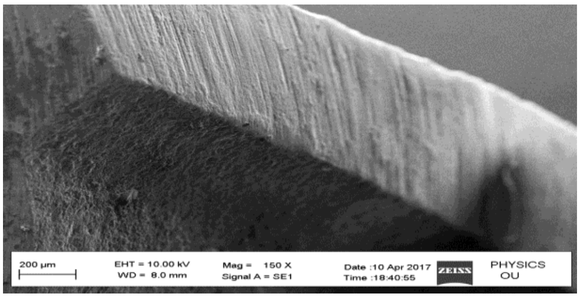
In the above figure the micro structure of work piece is analyzed under magnification of 2.50 KX, electron high tension of 10.00 k v, and working distance of 6.5mm.



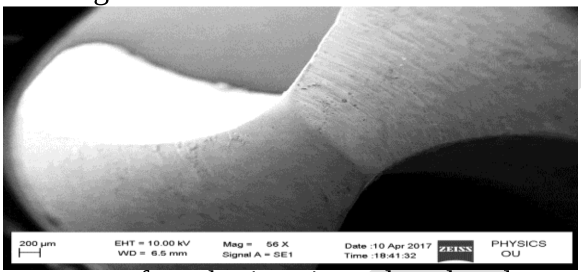
In the above figure the micro structure of work piece is analyzed under magnification of 500X, electron high tension of 10.00 k v, and working distance of 6.5mm



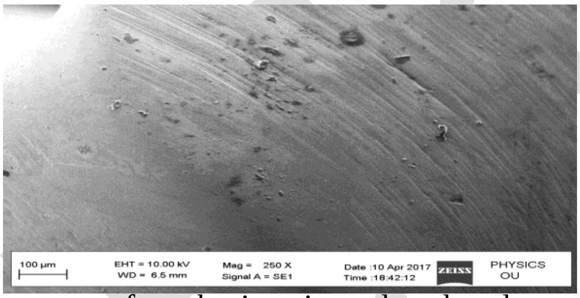
In the above figure the micro structure of work piece is analyzed under magnification of 1.50 KX, electron high tension of 10.00 k v, and working distance of 6.5mm



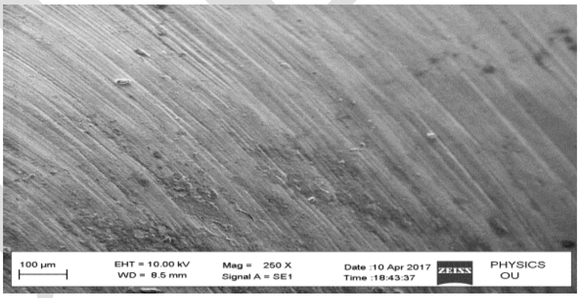
In the above figure the micro structure of work piece is analyzed under magnification of 150 X, electron high tension of 10.00 k v, and working distance of 8.0mm



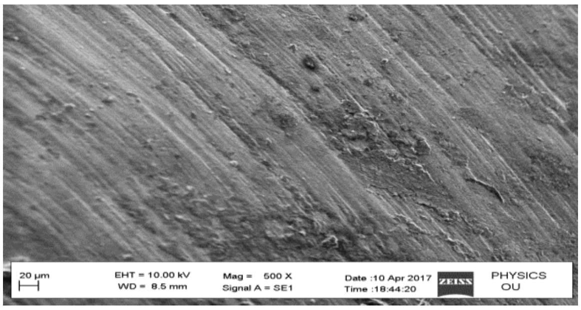
In the above figure the micro structure of work piece is analyzed under magnification of 56X, electron high tension of 10.00 k v, and working distance of 6.5mm



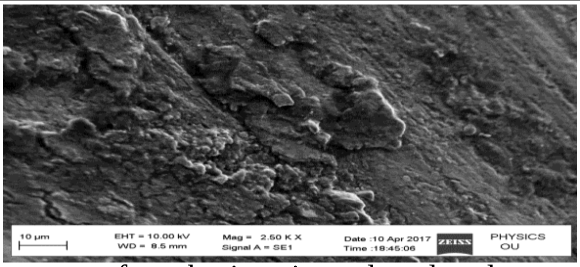
In the above figure the micro structure of work piece is analyzed under magnification of 250X, electron high tension of 10.00 k v, and working distance of 6.5mm



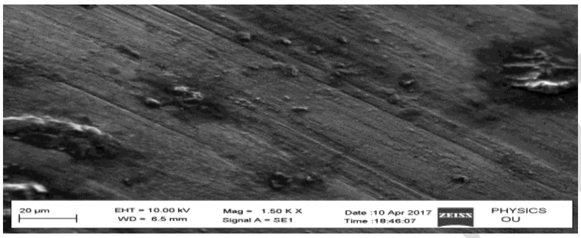
In the above figure the micro structure of work piece is analyzed under magnification of 250X, electron high tension of 10.00 k v, and working distance of 8.5mm



In the above figure the micro structure of work piece is analyzed under magnification of 500X, electron high tension of 10.00 k v, and working distance of 8.5mm



In the above figure the micro structure of work piece is analyzed under magnification of 2.50KX, electron high tension of 10.00 k v, and working distance of 8.5mm



In the above figure the micro structure of work piece is analyzed under magnification of 1.50KX, electron high tension of 10.00 k v, and working distance of 8.5mm

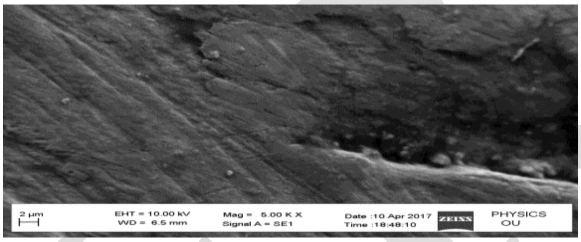


Fig.3.9: SEM Views of the Drill Bit under HPCJ Condition

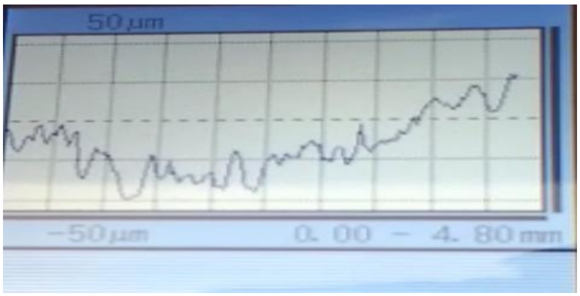
In the above figure the micro structure of work piece is analyzed under magnification of 1.50KX, electron high tension of 10.00 k v, and working distance of 8.5mm

3.2.6 SURFACE FINISH

In dry condition due to drilling number of holes without using coolant a certain amount of heat is produced, the heat produced results in the tool wear, due to the tool wear the surface roughness of hole will change from first hole to the last hole.

Where as in high pressure coolant condition the tool wear in very less amount compared to in dry condition, the following Fig.3.10 and 3.11 shows the surface roughness in both dry and high pressure coolant jet conditions.

Fig.3.10. Surface roughness of a hole in dry condition



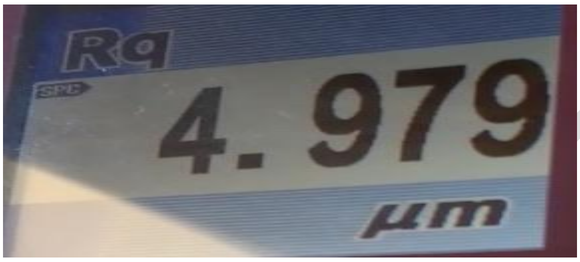


Fig 3.11. Surface roughness of a hole in HPCJ condition

RESULTS AND DISCUSSIONS

4.1 NUMBER OF HOLES

Number of holes in drilling operation is a major concern. Small number of holes are drilled one by one. Drill bit increases the manufacturing cost due to tooling cost and cost for replacement of the tool. Maximum possible numbers of drilled holes with a single piece of bit are the prime necessity for high production manufacturing. During drilling huge amount of heat is produced due to shearing of metal, friction between chips and flute and rubbing the flank with newly cleaved surface.

Machining with higher speed flank of drill bit wears out, drill bit tip burns and melts by higher temperature produced in the cutting zone. Found that in dry condition.

AISI-4340 steel is drilled under dry and HPC condition by 8 mm HSS drill bits is shown in Fig 3.3(a). In dry condition drill bit becomes burnt blue in color after completing 16 holes on AISI-4340 steel and creates very rough surface with changed roundness. Very small chips are found on the surface of the hole as wielded matter due to accumulation of huge heat while cutting. On the other hand in HPC condition drill bit remains its original color and without any burning 16 holes are drilled on AISI-4340 with metallic color chips is shown in Fig.3.3 (b). Holes dimension are very close to acceptable limit having proper shape and no wielded chip is found in the HPC drill. High pressure coolant washout all the chips and cools tool chip and work piece rapidly. High-pressure coolant jet results effective outcome at pressure bar at a flow rate 1 lit/min.

4.2 CHIP FORMATION.

Chips play significant role in the manufacturing technology as maximum heat is carried out from the cutting zone through the chip that commits maximum tool wear while passing over the tool. In drilling, the material is removed in the form of chip and evacuated through the drill flutes. High-pressure coolant (HPC) played very effective role for cooling and provided lubrication between drill bit and chip interface. Fig.3.3(a) and Fig.3.3(b) shows the shape of chips during drilling steels by HSS drill bit under both dry and high-pressure coolant (HPC) conditions. The shape of the chip produced under both dry and high-pressure coolant condition become spiral when drilling AISI-4340 steel. The color of the chips have also become much lighter i.e. metallic from burnt blue due to reduction in drilling temperature by high-pressure coolant condition.

It is evident from the figure of drilled chip. Fig.3.3 (b), that chips produced in high-pressure coolant (HPC) condition is smooth due to proper cooling and lubrication in drilling both the steel which creates a lubricant film that protects the tool face from rubbing with the work material and pretend sharp edge of the drill bit. On the other hand saw toothed chips are produced in dry condition due absence of lubrication and separation of chips.

4.3 ROUNDNESS DEVIATION

Before the analysis of the quality parameters of the holes, it is important to note that neither diameter nor any other quality parameter of the hole was influenced by tool wear. In other words, these parameters presented no tendency as feed length increased. Table 3.3 and 3.4 shows the average, maximum and minimum diameters measured randomly of the holes length in the both dry and HPC lubrication systems. It can be seen in the table 3.4 that the average diameter obtained under HPC condition is lower than that obtained using dry condition, which means that the HPC presented a batter quality with presence of adequate cooling and lubrication at the chip-tool interface.

Fig.3.4 and Fig.3.5 show the roundness of the holes close to the entrance respectively Fig. 3.6 and Fig.3.7 show the roundness of the holes close to the end of the holes obtained during drilling AISI-4340 steel and it can be seen from these figures that the roundness deviation has a little change from the beginning to the end of the holes under HPC condition in compare to dry condition, this result can be attributed to the lower cutting force and smaller roundness deviation due to effective cooling and efficient lubrication. Even with the drill penetrating further into the hole, the forces were not be able to deviate the drill more than in the entrance of the hole, and the roundness deviation was kept almost constant. The roundness deviation was smaller at both the entrance and end of the holes under HPC condition in compare to dry condition for AISI 4340 steel, because of high lubricant capacity.

4.4 TOOL WEAR

Tool wear causes poor quality of holes surface, irregularity of roundness and unacceptable diameter deviation. Insufficient cooling, blocking of flowing chips within the drill flute and rubbing of blocked chip with newly cleaved surface increase temperature further. This increment in temperature increase tool wears. Fig.3.8 and 3.9 show that drilling under dry condition tool wear is evident for the steel but no significant wear is found under HPC condition. High pressure coolant condition reduces cutting temperature and provides lubrication entering into chip-tool interface making a lubrication film at high pressure, thus reduces tool wear as a result tool life is increased.

4.5 SURFACE ROUGHNESS

In dry condition due to drilling number of holes without using coolant a certain amount of heat is produced, the heat produced results in the tool wear, due to the tool wear the surface roughness of hole will change from first hole to the last hole.

Where as in high pressure coolant condition the tool wears in very less amount compared to in dry condition.

CONCLUSION

Based on the experimental results the following conclusions can be drawn:

- The quality of the holes obtained using HPCJ is much better than that obtained in dry cutting. Roundness deviation was very small both at the entrance and end of the holes under HPCJ condition in compare to dry condition, because of high cooling capacity of lubricant.
- In HPCJ the chips were long in shape and continuous, so it was not stocked in the holes. This indicates that lubrication effects under HPCJ in compare to dry condition is much better, because the cutting fluid effectively works here in lubrication and cooling. On the other hand in dry condition the chips were short in size and not continuous, so it stocked in the holes.
- The beneficial effects of HPCJ may be attributed to effective and efficient lubrication action, which prevents the chip sticking on the tool and makes the operation easier. To carry out the operation with dry cutting is very much difficult, because the chip sticks to the spiral channels of the drill.
- HPC improves tool wear and results smaller diameter deviation.

LIMITATIONS:

In the above experiment less number of holes are drilled under both dry and HPCJ conditions and a motor with less horse power (1 HP) is used to supply coolant in HPCJ

BIBLIOGRAPHY

I. Ackroyd B., Compton W.D and Chandrasekhar S, "*Reducing the need For cutting fluids in drilling by means of modulation-assisted drilling"*, Proceedings of the International Mechanical Engineering Congress and Exposition, vol. 8, pp. 405-411 (1998).

II. Beaubien S. J. and Cattaneo A. G, "*A study of the Role of Cutting Fluid in Machining Operating"*, Lubrication Engineering, Vol 10, pp. 74-79 (1964).

III. Cassin C. and Boolhroyed G, "*Lubrication Action of Cutting Fluid*", J. of Mechanical Engineering Science, Vol. 7(1), pp.67-81 (1965).

IV. Davies M. A., Chou Y. and Evans C. J., "On Chip Morphology, Tool Wear and Cutting Mechanics Hardened Steels", Annals of CIRP, Vol 45/1, pp. 77-82 (1996).

V. Derflinger V., H. *Bra'"ndle, H. Zimmermann, New hard/lubricant coating for dry machining"*, Surface Coaling Technology, Vol. 113, pp. 286-292 (1999).

VI. Dhar N. R , Rahman K. M Islam S. and Hossain M ," Using a minimum quantity of lubricant (MOL) and a carbide tool in the drilling of AISI-1060 steel", Journal of Mechanical Engineering, IEB Vol. ME 33, pp. 22- 31(June & Dec. 2004).

VII. Durval U. Braga, Anselmo E. Diniz,Gilberto WA. Mirand, Nivaldo l. Coppini, "*Using a minimum quantity of lubricant (MOL) and a diamond Coated tool in the drilling of aluminum-silicon alloys*", Journal of Materials Processing Technology. Vol. 122; pp, 127-138 (2002).

VIII. Ezugwu E. 0., *"High speed machining of aero-engine alloys*", Journal of the Brazil Society of Mechanical Science & Engineering. Vol. XXVI, No. 1/11 (January-March 2004).

IX. Ezugwu E. 0 and Bonney J*: Effect of High-pressure Coolant Supplies when Machining Nickel-base*, Inconel 718, Alloy with Ceramic Tools," STLE (2003).

X. Ezugwu E. O. and Lai C. J., "*Failure Modes and Wear Mechanisms of M35 High Speed Steel Drills when Machining Inconel 901"*, Journal of materials Processing Technology, Vol. 49, pp 295-312 (1995).

XI. Eyup Ba9-ci and Babur Ozcelik, *"Investigation of the effect of drilling conditions on the twist drill temperature during step-by-step and continuous dry drilling"*, Materials and Design, vol. 27; pp. 446-454 (2006).

XII. F. Klocke, G. *Eisenbla"tter, In Proceedings of the Opening Session of the Dry Cutting, Annals of CIRP*, Vol. 46 (2), pp. 519-526 (1997).

XIII. Eyup Bagci and Babur Ozcelik: *Finite element and experimental investigation of temperature changes on a twist drill in sequential dry drilling"*, international Journal Advance Manufacturing Technology, Vo1.28, pp. 68G-687 (2006).

XIV. Frederick Mason. "*Benefits of high-pressure coolant*", Machine Shop Guide Web Archive (October 2001).

XV. Gregory S. Antoun," *The pressure's on to improve Drilling"*, Volume 51/Number 1 (February 1999).

XVI. Jeff A Degenhardt, Richard E. DeVor and Shiv G. Kapoors," *Generalized groove-type chip breaker effects on drilling for different drill diameters and flute shapes*", international Journal of Machine Tools & Manufacture. Vol. 45, pp.1588-1597 (2005).

XVII. Heisel, U., Lutz, M.,"*Pesquisa de fluido de refrigera~o e de lubrifica9l'io, Maquinas e Metais*", Vol. 388, ppA0--.49(1998).

XVIII. Heisel, U., Lutz, M., Spath, D., Wassmer, R and Walter, U., "*A te'cnica da quantidade my'nima de f1uido e sua aplicac.a-o nos processos de corte, Ma'quinas e Metais"*, SP Brazil fevereiro, pp 22-38, (1998).

XIX. Hong S. Y., Ding Y, and Jeong W.," *Friction and cutting forces in cryogenic machining of Ti-6AI-4V*', International Journal of Machine Tools & Manufacture, Yol. 41, pp, 2271-2285 (2001).

XX. Kitagawa T., Kubo A. and Maekawa K., "*Temperature and Wear of Cutting Tools in High Speed Machining of Inconel 718 and T,-6Y-2Sn"*, Wear, Vo1.202, pp, 142-148 (1997).

XXI. Kubota H. and Tabel H.,*" Drilling of a small and deep hole using a twist drill*". Transactions of the Japan Society of Mechanical Engineers, Part C 62 (601), pp. 3691-3697 (1999).

XXII. Kovacevic R, Cherukuthota C. and Mohan R., *"Improving the surface quality by high pressure water jet cooling assistance"*, Geomechanics, Vol. 93, pp. 305---310,Rakowski Balkema, Rotterdam (1994),

XXIII. Litvinov L.P" "*Vibration-assisted drilling of deep holes*", Soviet Engineering Research, Yol. 10 (5). pp. 5-8 (1990).

XXIV. Lindeke R, Schoeing F. Khan Jr A. and Haddad J., "Cool your jets", Cutting Tool Engineering, pp. 31-37 (October 1991).

XXV. Lindeke R R. , Schoening Jr F C., Khan A K. and Haddad J., "*Machining of titanium with ultra-high pressure through insert lubrication/cooling*", Transactions of NAMRI/SME, pp. 154-161 (1991).

XXVI. Mazurkiewicz, Z. Kubala, J. Chow, *"Metal Machining with High-Pressure Water-Jet Cooling Assistance - A New Possibility"*, Journal of Engineering for Industry, Vol. 111, pp. 7-12 (1989).

XXVII. Matthew Bono and Jun Ni, "*The location of the maximum temperature on the cutting edges of a drill"*, international Journal of Machine Tools & Manufacture, vol. 46: pp. 901-907 (2006).

XXVIII. Machado A. R and Wallbank J. : *The effect of extremely low lubricant Volumes in machining*", Wear, Vol. 210, pp 76-82 (1997).

XXIX. Narutaki N. and Yamane Y, *Tool Wear and Cutting Temperatures of CBN Tools in Machining Hardened Steels"*, Annals of CIRP, VoL28/1, pp.23-27 (1979).

XXX. Panda S.S., Singh A.K , Chakraborty D. and Pal S.K. "*Drill wear monitoring using back propagation neural network"*, Journal of Materials Processing Technology, vol. 172; pp. 283-290 (2006).

XXXI. Pigott R J. S. and Colwel A. T., *"i-Jet System for Increasing tool life"*SAE Quarterly Transactions, Vol. 6, NO.3, pp. 547-566 (July 1952).

XXXII. Rahman, K. M., "*Effect of Minimum Quantity lubrication (Mal) in Commercially Used Steels"*, M. Eng. Dissertation SUET Bangladesh, (2004).

XXXIII. Drilling Dhaka, Robert B. Aronson, "*Using High-Pressure Fluids, Cooling and Chip Removal are Critical"*, Manufacturing Engineering, Vol.132 (6) (June 2004).

XXXIV. Rothman, M. F., "*High Temperature Property Data: Ferrous Alloy"*, Metal Park, OH 44073 USA (1988).

XXXV. Sanjay C" Neemab M,l andChin C.W., "*Modeling of tool wear in drilling by statistical analysis and artificial neural network"*, Journal of Materials Processing Technology. VoL170; pp. 494-500 (2005).

XXXVI. Sahu S K, DeVor R.E., Kapoor S.G. and Ozdoganlar O.B. " *Effect of groovetype chip breakers on twist drill performance"*, International Journal of Machine Tools and Manufacture, Vol. 43, pp. 617-827 (2003).

XXXVII. Senthil Kumar A., Rahman M,and Ng S. l" *"Effect of High-Pressure Coolant on Machining Performance"*, International Journal of Advance Manufacturing Technology. Vo1.20,pp.83-91 (2002).

XXXVIII. Sokovic M. and MijanovlC K., *"Ecological Aspects of the Cutting Fluid and its Influence on Quantifiable Parameters of the Cutting Processes*", Journal of Material Processing Technology, Vol. 109 (1-2), pp.181-189 (2001).

XXXIX. Wrethin R., Rotberg J. and Ber A., "*Influence of High Pressure Flushing, Through the Rake Face Culling Tool"*, Annals of CIRP, Vol. 41/1, pp.101- 106 (1992).

XL. Weinert K., *Trockenbearbeitun9 und Mini malmengenkuehlschmierung*, Springer, Berlin (1999).Wang Z. Yand K. P," *Cryogenic machining of hard-la-cui materials"*, Wear, Vol. 239, pp. 168-175 (2000).