Design, fabrication and application of minimum quantity essay

He has worked on the project titled, “ Design, Fabrication and Application of Minimum Quantity Lubrication (MGM) Setup in Machining” at the Machine Tool and Meteorology Laboratories, Department of Mechanical Engineering, Indian Institute of Technology, Delhi He has abided by the rules of the institute and has finished all tasks assigned to him to my satisfaction. Associate Professor Department of Mechanical Engineering Indian Institute of Technology, Delhi Haze Asks, New Delhi-110016 Abstract Environmental concerns call for the reduced use of cutting fluids in metal cutting practice.

Minimum quantity lubrication (MGM) machining Is one of the rumoring solutions to the requirement for decrease in cutting fluid consumption. This paper reports the results of an experimental work to investigate the effect of a well-designed MGM set up on machining constraints like tool forces and surface finish. It was found that machining with the MGM set up produced better results In terms of lesser cutting forces and better surface finish in comparison to dry and wet machining. Acknowledgement This work has been completed under the guidance of the following members of IT Delhi: Faculty Members 1 .

Dry. Sudan Gosh (Mechanical Dept.) Email: Did. AC. In 3. Mango Sinai 2. Dines SETI Ph. D. Research Scholars 1. Bias Chi. Bearer I would also like to thank Mr.. Subtask Sandal (Tech. Superintendent, Meteorology Lab.) for his effort help in manufacturing the MGM frame stand. Contents Title 1 . Introduction 2. Principle of MGM Machining 3. Advantages of MGM Machining 4. Setup Design of MGM Machining 5. Machining using MGM Setup 6.

 1. Introduction Machining is the process of removing material in the form of chips by means of a wedge shaped tool. The need to manufacture high precision items and to machine difficult-to-cut materials economically leads to the development of improved machining processes. The feasibility of dry cutting in the manufacturing industries has received much attention due to high cost of cutting fluids, estimated at about 17% of the total manufacturing cost which is about twice the tooling cost itself [1].

Cutting fluid waste needs to be treated prior to disposal and furthermore, prolonged exposure to them is hazardous to the machine operators due to risk of skin cancer and breathing difficulties [2]. Dry cutting is desirable because not only it reduces manufacturing cost but also eliminates all the adverse negative effects associated with the usage of cutting fluids for cooling and lubricating purposes. In spite of the noble idea to implement the process of dry machining as mentioned above, the usage of cutting fluids in machining several types of materials which are difficult to machine (like super alloys, etc. Offers several important advantages, especially to increase productivity and surface quality of the machined work piece and hence processes to be carried out at much higher speed, higher feed rate and greater cutting depth [3] due to increased lubricity and cooling at the chip-tool and chip- workplace interface. When used effectively, cutting fluids not only improve surface finish and dimensional accuracy, but also decrease the amount of power consumptions [4].

Furthermore, cutting fluid also helps transport the excessive heat and chips produced during the cutting processes away from the cutting area, thus anger tool life may be achieved [5]. Cutting fluid related costs and health concerns associated with exposure to cutting fluid mist and a growing desire to achieve environmental sustainability in manufacturing have caused industry and academia to re-examine the role of these fluids and quantify their benefits. In developed countries like USA stricter legislations have been enforced to minimize the use of cutting fluids in machining [6].

Hence some of the noble approaches taken in this direction without compromising with the benefits achieved from flood application of outing fluids are mentioned below: 1) Proper selection of cutting fluids is a very important, although complicated process as it includes various aspects of machining conditions and parameters. There has been a gradual shift from straight oils to soluble oils and further to vegetable and synthetic oils due to better cooling and lubricating properties and more importantly due to much safer handling and disposal as they are CEO-friendly [7-9].) Proper application of cutting fluids is also an important aspect because in most cases, majority of the fluid applied goes east without any benefit to the machining process. Thus areas like nozzle design, its placement, supply system and other machining conditions have to be considered effectively. 3) Cutting fluids also need to be managed meticulously after use to reduce their health and environmental effect and also to cut down disposal costs. 4) Gradual reduction of cutting fluid usage by increasing the use of near-dry and dry machining is the most promising step taken in this regard.

Since past few decades many efforts are being undertaken to develop advanced machining processes using less or no cutting fluid. Although machining without the use of cutting fluids has become a popular avenue for eliminating the problems associated with their management and other advantages, but it has its associated drawbacks. The advantages of dry machining are obvious: cleaner parts, no waste generation, reduced cost of machining, reduced cost of chip recycling (no residual oil), etc. However, these advantages do come at a cost.

The most prohibitive part of switching to dry machining is the large capital expenditure required to start a dry machining operation. Machines and tools designed for cutting fluids cannot be readily adapted or dry cutting [10]. New, more powerful machines must be purchased, and special tooling is often needed to withstand the high temperatures generated in dry cutting. The quality of machined parts may be affected significantly as the properties of the machined surface are significantly altered by dry machining in terms of its metallurgical properties and residual machining stresses.

High cutting forces and temperatures in dry machining may cause the distortion of parts during machining. Moreover, parts are often rather hot after dry machining so their handling, inspection gauging, etc. May present a number of problems. Near-dry machining (AND), also development to provide at least partial solutions to the listed problems with dry 2. Principle of MGM Machining In MGM machining, very small quantity of cutting fluid (CUFF) is supplied to the machining zone in very small (atomized) droplet size with high velocity.

The amount of oil used is generally in the range of 10-100 ml/her, which is about 1000 times smaller than that used in conventional flood application of oil. It was developed as an alternative to flood and internal high pressure coolant supply to reduce the CUFF consumption. The media is supplied as a mixture of air and oil in the form of an aerosol (often referred to as mist) with precise control over amount of oil and direction of spray to the cutting zone. 3.

Advantages of MGM Machining The reason for the shifting trend towards MGM machining is that it is supposed to give the combined advantages of dry and conventional flood machining in an CEO- friendly manner. The amount of oil used is so less that parts engaged in metal removal are practically dry, although the high velocity air Jet carries the small but sufficient amount of oil precisely to the machining zone so as to provide the accessory cooling and lubrication, besides removal of the chips by the compressed air.

Many research papers have been published which goes to show that MGM application involves much better machining parameters than dry machining which are also on a par or in some cases better than flood application of oil.

Deed et al. [1 1] found that temperature reduction in MGM turning is approximately 5%, while in MGM end milling it is 10-15% and in MGM drilling it is 20-25% compared to the temperature in dry cutting. Khan and Dharma [12] found that MGM with vegetable oil educed the cutting forces by about 5-15% from that in dry cutting.

The axial force decreased more predominantly than the power force. They attributed this reduction as well as the improved tool life and finish of the machined surface to reduction of the cutting zone temperature as the major reason for the improved performance of machining operations. Similar results were obtained in machining 1040 steel [13]. Lie and Liana [14] found cutting forces in machining 1045 steel lower in MGM compared with dry cutting. They also attributed this reduction to the cutting temperature difference. Other groups of researches have compared MGM with wet machining. Dharma et al. Tidied the effect of MGM in tuning of 4340 steel using external nozzle and aerosol supply to the tool [15]. They found that the temperature at the tool-chip interface reduced by 5-10% (depending upon the particular combination of the cutting speed and feed) in MGM compared to wet machining. As a result, tool life and finish of the machined surface improved by 15-20%. Philippic and Stephenson [16] found similarity in tool life in gun-drilling and cross-hole drilling of crankshafts between wet machining and MGM. Using MGM ND a diamond-coated tool in the drilling of aluminum-silicon alloys, Brag et al. 17]showed that the performance of the MGM process (in terms of forces, tool wear amount of water-soluble oil, with both coated and uncoated drills. Studying turning of brasses, David et al. [18]concluded that, with proper selection of the MGM system, results similar to flood lubricant condition can be achieved. Although many research papers have attempted to give explanation for the distinctive results of MGM machining no direct conclusive evidence of most are provided due to the topic analysis being extremely difficult onto it.

One of the most feasible and sound explanation is provided by V. P. Astrakhan in one of his literatures [19] which accredits the reason to the embitterment action of the cutting fluid, which reduces the strain at factual of the work material. This action is based on the Rebind effect, directly concerned with the metal cutting process. He suggests that atomized oil possesses greater ability to enhance the embitterment of the layer being removed and thus to reduce the work of plastic deformation done in the transformation of the layer being removed into the chip. 4.

Set up Design of MGM Machining Aerosols used in MGM are generated using a process called atomization, which is the conversion of bulk liquid into a spray or mist (I. E. , collection of tiny droplets), by passing the oil carried by pressurized air through a nozzle. The design of the atomized is critical in MGM as it determines the concentration of the aerosol and the size of droplets. A distinction is drawn in the MGM technique between external supply via nozzles fitted separately in the machine area and internal supply of the medium via channels built into the tool.

Each of these systems has specialized individual areas of application. In applications involving external supply, which is the aim of the current work in CNN turning, the aerosol is sprayed onto the tool from outside via a nozzle fitted close to the machining zone. This technique is used in sawing, end and face milling, and turning operations. Besides a well-designed nozzle, which is the primary inspiration for the current work and will be addressed soon, other equipments needed for the MGM set up in CNN turning are listed below: I.

A compressor for sending pressurized air. A pressure gauge fitted close to the nozzle for measuring pressure of incoming air to he nozzle. A pump and oil reservoir for sending oil continuously to the nozzle in minute quantity. A stopper for checking and measuring oil flow rate. A frame stand for supporting all the above in a convenient manner. Accomplish in the current application: ; ; It should provide proper mixing of oil with air so that so that the oil gets atomized into fine droplets by the action of compressed air.

The transition of oil through the nozzle to its outlet should be smooth and continuous and also with a high enough velocity to properly penetrate the machining interfaces. Keeping the above points in mind, an internally mixed air assisted atomized has been designed as shown in fig. L and 2. It basically consists of an internal nozzle for introducing a very high velocity Jet of air at its exit which is fitted into an external nozzle having a fine orifice for oil inlet very close to the exit point of internal nozzle. The internal and external nozzles are fitted together with the help of a cap tightened by screwed bolts.

Some of the design parameters which are not so important in the current field of study have been kept in consistency with locally available designs which are easier to fabricate. Figure 1: Sectional view of the nozzle Figure 2: Solid view of the nozzle 4. 1. 1 . Internal Nozzle The inspiration for design of internal nozzle has been taken from a few fundamental books and other materials on fluid mechanics It has been stated in a few papers [23] that higher the air Jet velocity higher will be its penetration capacity in the difficult-to-reach plastic area of contact between chip and tool which is the most challenging task in metal machining.

Hence equipped with this knowledge, the design criterion of nozzle was studied thoroughly with an aim to achieve a very high velocity of air Jet, comparable to or greater than the speed of a pressure wave (like sound) in air. It was observed that a simple converging nozzle could increase the velocity of the air Jet at most to a value equal to speed of sound under the prevailing temperature condition, which is also referred to as a speed of Mach 1. Even if the mass flow rate of air is kept on increasing, the speed at the outlet does not increase further, which is referred to as choked condition.

But a nozzle having an initial converging section followed by a diverging section and separated by minimum cross-section throat (also referred to as converging-diverging nozzle) has the capacity to increase the air Jet velocity at exit to a value way above Mach . Depending on the inlet pressure and temperature conditions, mass flow rate of air and certifications area at the throat and exit, the air Jet takes a speed of Mach 1 at the throat and further increases to higher values which give rise to a shock wave (due to an abrupt change in pressure and temperature conditions) at any particular cross section of the diverging section.

If all the parameters are controlled carefully then the hock wave occurs Just at the exit of the nozzle. This will favorably cause turbulence in that region, where the cutting fluid will also enter from the orifice in the exterior nozzle and this turbulent high speed air Jet will have better capacity to finely atomize the oil particles. Following is a summary of the equations used in the determination of the throat and exit cross-sectional areas of idealized adiabatic condition.

This approximation is quite valid because the fluid flow speed is considerably high. The inlet air stream is considered to be stagnant, I. E. With zero velocity. Let the inlet or stagnation properties be defined by the subscript zero, the throat properties by subscript', and exit properties by subscript' and other symbols have usual meanings. ; h h t + (v/2) Steady Flow Energy Equation (SAFE) Treating air as a perfect gas, we may also write, C p T O = C p T t + (v t 2/2) But, C p = hence (T O IT t) = 1+ ((y-1)/2)*M t 2, where M t = Mach No. T throat – v t /(YURT t)0. 5 ; ; (P 0/ P t) = (T o and (P 0/ p t) = (T o adiabatic relations For air, y = 1. 4, hence for achieving Mach 1 at the throat, we have 1. 2 (P 0/ 1. 893 (P 0/ 1. 577 ; Mass flow rate of given by m t A t v t where A t is the cross-sectional area at the throat or m = (y/ART O)0. 5 * (P O A t 0/+1)/20/-1))) ; Using SAFE and adiabatic relations between throat and exit similarly, we have (T e IT (T O IT e V e = (yurt e)0. * M e m = peeve where A e is the cross-sectional area at the throat Calculation It is desired that at exit of internal nozzle a Mach. No. Of 1. 5 is achieved. Hence, the throat will invariably have air speed equal to Mach 1 . Considering inlet conditions as follows: P O = 6 bar, T O = ICC = KICK and Diameter at the throat, d t = 1 mm (for convenience of fabricating), we have m = 1. G/s v e = 432. 5 m/s and, diameter at the throat, d e = 1. Mm approximately Due to unavoidable factors of irreversibility the flow will not be perfectly adiabatic and there will be some energy loss from air flowing through the nozzle which is expected to show up as a loss in the kinetic energy, thereby decreasing the velocity at the exit than the desired one. Considering this factor and also the ease of fabrication, the diameter at the nozzle exit has been slightly increased from the one calculated above. The new adopted value is, d e = 2 mm All the other dimensions as shown in fig. And table. Are noninsured from the viewpoints of strength of material used, ease of fabrication and the locally available standards. Figure 3: Sectional view of internal nozzle Figure 4: Solid View of internal nozzle Table 1 : Geometric dimensions of internal nozzle Internal did (ID) at inlet ID at throat ID at exit Length of converging part Length of diverging part Thickness of the nozzle mm 1 mm mm L= mm L= mm t= mm 4. 1. 2. External Nozzle Basically the design concept of the external nozzle has been taken from the standard ones available in the market with some modifications to meet the requirements of the current work.

It has the following important tasks to perform: ; ; ; It should properly enclose the internal nozzle from the ambient to have a well-designed orifice for inlet of oil near the exit mouth of the internal nozzle. It should provide a proper mixing section of oil with the supersonic air followed by a near streamline converging flow towards its exit. With the above considerations, the external nozzle was designed as shown in fig. Sand 6. Figure 5: Solid view of external nozzle Figure 6: Sectional view of external nozzle Table 2: Geometric dimensions of external nozzle Internal did (ID) at inlet ID at exit

Length of converging section mm mm L= mm Length of straight section at exit Length of straight section at inlet Thickness of the nozzle ID of oil inlet orifice Distance between exit of internal nozzle and start of converging section L= mm L= mm t= mm 1 mm L= mm Calculations for the velocity of the aerosol at the exit of the external nozzle To find the velocity with which the aerosol is expected to come out from the exit of the external nozzle, we consider the following criteria with some suitable approximations: ; ; ; ; Mass flow rate of oil, m o = ml/her = Mil/min= l g/min, as the onsite of the water soluble oil used is almost equal to that of water. Earlier it was calculated that mass flow rate of air, m= 1. 1 g/s Hence, total mass flow rate, m t = m+ m o = 1. 116 g/s Now, at the exit, atmospheric condition prevails, hence pressure and temperature are P= 1 bar and T= ICC = KICK and hence the density is calculated to be p = (P/ART) = 1. Keg/mm. ; ; The diameter at the exit of the nozzle has been taken as = mm. Hence, using the continuity equation, m t = PAP at the nozzle exit, it is found that Fame/s This is a pretty high enough velocity, comparable to a speed of Mach 1. 4. 1. Cap The cap has been designed such that it precisely connects the external and internal nozzles and convenient enough for engaging and disengaging the two as and when required. The internal nozzle is made to tight fit within the cap which is further fitted into the external nozzle with the help of threaded nuts. Its design is shown in fig. 7 and 8. 023. 95 23. 95 Figure 7: Sectional view of the cap Table 3: Geometric dimensions of the cap External did Internal did No. Of bolts used Size of bolts used mm q) mm 3 MM 4. 2 Selection of Material for the nozzle The reliability, durability, performance and ear life of the nozzle depends on proper material selection. Hence this is a very important aspect that should be considered with proper attention.

Among other factors the most important in determining the selection of the material are corrosion and erosion resistance, apart from being economical too. It should also have good strength to weight ratio and have the ability to handle low temperature fluid without any shape distortion, because the temperature of the air stream inside the nozzle can go as low as -ICC. With the above considerations, it was found that Brass has a ere good combination of the desirable properties. It has good strength and ductility combined with excellent corrosion resistance and superb incapability. It is also available in a very wide variety of product forms and sizes to allow minimum machining to finished dimensions. 4. Measurement of Strength of Nozzle The yield strength of brass varies within a wide range, although for safety purpose we can consider the minimum value which is around 124 Amp. The nozzle may be considered to be of cylindrical shape with insignificant deviation for the calculation of hoop stress, which is the most important specs in the consideration of its strength against failure. The Circumferential stress (or hoop stress) in the nozzle is given by o h = PDP/at where p is the air pressure, D is the internal diameter of the nozzle and t is the thickness of the nozzle. The maximum pressure expected by the nozzle to encounter, p= bar = 8*105 Pa. After air expands in the internal nozzle, pressure will decrease in the annular space of external nozzle.

So it is sufficient to check the material strength of the interior nozzle at the section having maximum external diameter, D= mm. The thickness is same throughout, t= mm. Hence, the maximum hoop stress inside the nozzle is determined to be o h = 1. 6 Amp As the hoop stress is much lesser than the yield stress of brass, hence the design is in safe mode from the viewpoint of failure against tensile stress. 4. 4 Manufacturing of the Nozzle Assembly The entire parts of the nozzle were manufactured by an industry in New Delhi, equipped with many modern sophisticated machines. The accuracy of the dimensions could be achieved up to the micron scale. 4. Set up of MGM system As discussed earlier, several components make up the complete MGM system. For a convenient simple setup the following have been hoses: ; Fluid supply system – a burette for oil storage, a small pump for continuously supplying oil from the burette and an IV set for maintaining oil level in pressure from the oil inlet to the nozzle by means of gravitational head. This ensures continuous oil supply to the nozzle at the desired small quantity which is also simultaneously measured by a control valve. ; Air supply system – a compressor of maximum capacity of 8 bar and a pressure gauge fitted close to the air inlet to the nozzle to measure the delivery pressure to the nozzle connected by hose pipes.