Process Parameter Optimization On Micro-Machining(Engraving)-A Review

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ABSTRACT

Day by day increasing demand of production, Industrialist increase the speed, feed so produces high temperature, which reduce tool life. There have been continues efforts in developing metal working fluids to replace the conventional mineral oil based MWF. This paper reviews recent developments in Cutting fluids performance and tribological studies of different MWF formulation including the application of dry machining, wet machining, MQL Process and Cryogenic cooling process. In this paper, a comprehensive and in-depth review on optimization of different process parameters were carried out using different optimization tools. Engraving machine is superior to other machine as regards accuracy and better surface finish. Every manufacturing industry is trying to achieve the high quality products in a very short period of time with less input. In engraving machine, there are many process parameters like spindle speed, feed rate, depth of cut, coolant, tool geometry which affected on required quality parameters. So, selections of process parameters are the important phenomena. It is first optimizing for required quality parameters while selection. By using different Software we can evaluate the process parameter. Taguchi methodology is widely used for single optimization. But, sometime multi objective quality parameters are required to be optimized. For multi objective optimization Utility concept, Grey relation analysis, PCA etc. are widely used. ANOVA analysis is also used to determine which parameters is the most significant effect on the selected quality parameters.

Keyword: *- ANOVA, Grey relation analysis, Milling Machine, Multi optimization, Process parameters, Taguchi.*

1. INTRODUCTION

CNC Engraving machine is one of the most commonly used in industry and machine shops today for machining parts to putting design on to hard flat surface by engraving on to it, result may be decorated piece in itself. Decorated piece like jewellery, coining punch, Punching die, weaponry, banknotes, illustration for books, magazines, Printmaking and different decorative part which is used in automobile. So all this process required surface finish. Among different types of engraving processes of the most vital and common metal cutting operations used for machining parts because of its capability to remove materials at faster rate with a reasonably good surface quality (Yuma faujii et al. 2016) Also, it is capable of producing a variety of shapes using Engraving cutter. In recent times, computer numerically controlled (CNC) machine tools have been used to make the engraving process fully automated. It delivers greater enhancements in productivity, increases the quality of the machined parts and minimizes the production cost. For these reasons, CNC Engraving process has been recently proved to be very versatile and useful machining operation in most of the modern manufacturing industries. Only the implementation of automation in Engraving process is not the last achievement. It is also necessary to optimize the process parameters for required quality (Alborz Shokrania et al. 2012) the surface roughness, material removal rate, machining time, power consumption, tool life, chips flushing are some of the quality parameters which required optimizing for the selected process parameters. For the Engraving machine, the different process parameters are spindle speed, feed rate, depth of cut, coolant, tool geometry etc. The optimization objective may be single or multiple. For single optimization Taguchi, RSM, GA, etc. are used while for multi objective optimization utility concept, Grey relation analysis, Principle component analysis, etc are used.

2. EXPERIMENTAL METHOD

Surface finish and material removal rate are one of the most important quality characteristics in manufacturing industries which influences the performance of mechanical parts as well as cost. In recent times, modern industries are trying to achieve the high quality products in a very short period of time with less input. For that purpose, the computer numerically controlled (CNC) machine tools with automated and flexible manufacturing systems have been implemented. In the manufacturing industries, various machine tools are used to remove the material from the work piece. Out of these, milling machine is the first most common method for metal cutting because of its ability to remove materials faster with a reasonable good surface quality as well as Engraving machine is used to engrave material and make decorative design on the surface. In actual practice, there are many factors which affect responding parameters, like cutting conditions, tool variables, work piece variables and cooling process. Cutting conditions include spindle speed, feed rate and depth of cut, tool variables include tool material, flute angle, helix angle, rake angle, peripheral 2nd relief angle whereas in work piece variable include material hardness and other mechanical properties and in cooling process include dry, wet and MQL Machining etc. However, it is very difficult to control all the parameters at a time. All author used different experimental method in which MQL cooling method gives best performance. In a Engraving machine, it is a vital task to select the control parameters properly to achieve the high quality performance as well as decorative design etc. While desigining the experiment select machine, process parameter and any one cooling method find out result.

3. LITERATURE REVIEW

Sachin Agrawal et al. (2018) had taken process parameters like spindle speed, depth of cut, feed rate to investigate to reveal their Impact on surface finish using Taguchi Methodology. Main objective of this paper he take experiment on. on aloe vera oil as MQL and using Taguchi method and analysis various parameters such as speed, feed and depth of cut. They had taken 3-Level design with 3 independent factors L9 to perform experiments. They found the optimal setting for selected process parameters and optimal value of surface finish which is lower by 6.7% Surface roughness using aloe vera oil as compared to conventional cutting fluid. Tool wear using aloe vera oil is lower by 0.14% as compared to conventional cutting fluid.

Alborz Shokrania et al. (2018) had studied effect of different process parameters on surface roughness. Main objective of paper is compare lubrication system MQL , Cryogenic and MQL+Cryogenic(Hybrid cooling) system. Each tool was inspected prior to experimentation using a tool makers' microscope and the tool overhang was kept constant at 50mm for all experiments and Furthermore, the surface roughness of the work pieces was measured using a Taylor Hobson S100 contact profilometer using 5 cut offs of 0.8mm sampling lengths. Finally check performance of cutting process, best performance obtain by using MQL+Cryogenic system like Better surface quality, Tool life increased and Ra value reduced by 5%.

Alborz Shokrania et al. (2012) had studied effect of different process parameters on surface roughness. This paper presented one of the very first studies on the cryogenic CNC milling of Inconel 718 nickel based alloy. In addition to surface roughness, power consumption and tool wear have also been monitored in this study. In order to compensate the effect of tool wear on the surface roughness of the machined test parts, initially the investigations was limited to the very first section of the machined path. The surface roughness measurements revealed that the average arithmetic surface roughness (Ra) has been reduced from 0.21μm to 0.14μm resulting in more than 33% reduction in surface roughness. A similar trend has been observed for ISO Rz value of the surface roughness where the introduction of cryogenic cooling has reduced the ISO Rz value from 2.25μm to 1.34μm resulting in 40% reduction.

Narinder Gupta et al. (2014) studied the comparisons of machining properties of three different types of machines like dry, near dry and wet machining. The machining will be done on EN-9 Steel. The CNMG120408 tool is used for turning, widely used in industry because of the cheaper cost. The input parameters are selected according to the recommendation of tool manufacturer for achieving best machining performance. The surface roughness, cutting temperature and cutting forces studied and in near dry machining technique could reduce many cutting problems coming from high consumptions of petroleum based lubricants, like high machining costs or environmental and worker health problems.

E. Uhlmanna et al. (2017) had optimized the process parameters levels on conventional Milling of Cast Iron using internally cooled mill. Main objective is use the closed internally cooled milling tool which can increase productivity and cost, waste can be reduced. Machining test between the dry cutting and an internally cooled process temperature differences of 15% is present and increase in productivity as well as increase in tool life of 50% is feasible as well as Better surface finish, tool life increase, and increase lubrication characteristic. The closed internally cooled milling tool leads to a decrease of the monetary costs in the production process, to a productivity increase up to 25 % as well as a waste reduction by avoiding the use of cooling lubricants. Furthermore the adverse health effect of the worker is also reduced by the substitution of cooling lubricants.

Yuma Fujii a et al. (2016) had optimized cutting resistance and surface roughness simultaneously on AL, CU, and Brass material. In this study, droplet-free ta-C films were prepared on WC-Co cutters using a T-shape filtered arc deposition method. He compared the wet Machining with dry Machining. Dry machining was best method, by using this method and the ta-C films were deposited onto WC-Co cutters reduced cutting resistance, suppressed metal adhesion, and prevented damage to the cutting edge.

S. Minl I. et al. (2005) had optimized study, the adsorption characteristics of MQL media during orthogonal cutting was investigated using two experimental setups; one in a high vacuum chamber with a mass spectrometer to observe mass changes of MQL media during cutting, and another setup in an atmospheric chamber where the supply of MQL media can be controlled on alloy steel (S45C). Main Objective of paper is used MQL Lubrication system and compare with conventional flood supply machine. Performance is almost same but by using MQL system to achieve both environmental and ecological benefits. Result was obtained Better surface finish, tool life increse, Increase lubrication characteristic.

Domnita Fratila et al. (2010) had optimized study of comparison of dry and wet machining using different types flood as coolant. A macro-level assessment of the comparative life cycle environmental performance of the near-dry machining (NDM) using TiN-coated carbide tools and the flood machining (FM) is performed by a case study referring to the gear milling alloy steel material. The assessment, using the SimaPro 7.1.5 software and the ecoinvent1.5 database, includes combined Life Cycle Assessment (LCA) of the work piece material, the scrap processing, the use of lubrication, and the energy consumption improved. Result was NDM gear Milling machine power(0.52 kwh) consumption less compare to FM gear Milling machine power(0.67 kwh) on same process parameter.

Ravikumar Kudaravalli et al. (2018) had optimized study of cryogenic machining method to improve the surface roughness and tool life and optimized cryogenic cooling system. Cryogenic machining, which uses liquid nitrogen as the cooling media, is considered a sustainable alternative to conventional flood cooling application used in the machining process. A brief review of the potential benefits and drawbacks of cryogenic machining is presented in this paper. Using factors as a guideline, an optimized cryogenic cooling system and tooling has been developed. The cooling system is optimized for flow quality, thermal insulation, controllability and safety. The innovative cryogenic cutting tool design utilizes built-in coolant channels to achieve the optimal process performance. This solution incorporates outstanding cooling capability for optimal performance, while minimizing or eliminating the adverse effects.

N. I. Galanis et al. (2008) studied the machining parameters, including cutting speed, feed and depth-of-cut for dry and wet machining on lathe CNC machine by using AISI 422 Stainless Steel. The main outputs monitored were the cutting tool temperature and the surface roughness. dry machining can be achieved the appropriate surface quality, choosing the accurate cutting conditions, which needs to be higher cutting speed and less feed rate speed. In comparison with the dry one, wet cutting results 5-10% lower surface roughness values, for the same conditions. But when we apply dry machining can achieve the same or better surface quality for high cutting speeds, over up to 270m/min, and for low cutting depths and feed rates, approximately 0.2-1mm cutting depth and feed rate depending upon the geometry of the cutting tool insert.

Lutfi Taner Tunca et al. (2016) in this paper, the effects of MQL conditions on surface integrity in robotic milling of austenitic stainless steel are discussed. The surface integrity is assessed in terms of surface residual stress (XRD) and surface roughness (optical metallography), where MQL conditions for improved tool life is also investigated. The surface residual stresses can be decreased by well controlled MQL oil flow. The oil flow rate significantly affected the surface residual stress. The tool condition, i.e. flank wear and cutting heat affected zone, is significantly affected by lubrication settings. The most significant parameter was observed to be the duty cycle, which controls the oil flow rate. It was seen that increasing number of strokes per minute, i.e. increasing the oil flow rate, decreases the width of the cutting heat affected zone on the flank face. This can be associated with the heat barrier effect of thickened oil film, so that the heat transfer to the flank face decreases.

F. Itoigawa a et al. (2006) in this paper effects and mechanisms in minimal quantity lubrication are investigated by use of an intermittent turning process. Especially a difference between minimal quantity lubrication (MQL) and MQL with water is inspected. In order to obtain a good cutting performance by MQL it is considered that two things are needed: first is appropriate lubricant, such as a synthetic ester, to form a strong boundary film and second is a chilling effect to sustain strength of the boundary film. MQL with rapeseed oil has only a small lubricating effect and in light loaded machining conditions. The boundary film developed with rapeseed on a tool surface is not strong enough to sustain low friction and to avoid adhesion of work material. MQL with water droplets, namely OoW, gives good lubrication performance if the appropriate lubricant synthetic ester is used.

E. A. Rahim et al. (2016) this paper using MQL based synthetic ester as the cutting fluid used. Experiment were conducted using orthogonal cutting process in which the efficiency of MQL technique was compared to dry technique with respect to cutting temperature, cutting force, tool-chip contact length and chip thickness. The experimental results showed that the application of MQL based synthetic ester as the cutting fluid was more efficient for the machining process as it reduced the cutting temperature, cutting force, tool-chip contact length and produced better chip thickness compared to dry machining technique. The cutting temperature was reduced 10% to 30% for the MQL condition compared to dry condition. The reduction of temperature improved the tool life thus contributes to the sustainable manufacturing. Cutting force was reduced by 5% to 28% for the MQL condition compared to dry condition.

Sana Werda et al. (2016) this paper explain identification the evolution of tool temperature, tool wear, surface roughness and cutting forces in milling process. The influence of two oils (synthetic ester and fatty alcohol) is investigated and compared with dry machining. Among the MQL lubricants, machining results showed that the PX5130 synthetic ester oil was best correlated with good Surface integrity. It maintaining a high flash point (here >300°C) which gives better results under load and then a better surface roughness. The PX5131 fatty alcohol oil led to a better lifetime.

Balinder Singh et al. (2016) this study discusses an investigation into the use of Taguchi Parameter Design methodology for Parametric Study of CNC milling operation for Surface Roughness and Material Removal Rate as a response variable. A 27 experimental runs were conducted and find out surface roughness (Ra) & material removal rate (MRR). The result showed that the feed rate contributed 87.79%, cutting speed contributed only 1.58% and depth of cut contributed was least with 0.003% for surface roughness (Ra).

P.S. Sreejith et al. (2008) this paper reports on the effect of different lubricant environments when 6061 aluminium alloy is machined with diamond-coated carbide tools. The effect of dry machining, minimum quantity of lubricant (MQL), and flooded coolant conditions was analyzed. It is found that MQL condition will be a very good alternative to flooded coolant/lubricant conditions. MQL improving the quality of the work-piece surface and this process has got economic advantage.

Bruce L. et al. (2016) this paper summarizes the advancements and challenges of minimum quantity lubrication (MQL) technology in automotive powertrain machining from both industrial and academic perspectives. MQL refers to applying a small amount of cutting fluid in the form of mist to the cutting zone rather than flooding the work piece. Two major challenges during MQL machining are limited cooling and chip-evacuation ability. The ultimate goal is to create a clean, sustainable, and high-efficient production environment, Cost saving, environment friendly.

4. RESEARCH FINDINGS AND GAP

A Considering the above efforts by researchers, the concentration is to optimize the single response of surface roughness as the desired quality of the customer. Out of overall production cost 15% cost required for cuttting fluid, it can be minimize 5 to 10% by using vegetable oil and MQL process. Acccording to European union report only Europe consumed 3,20,000 tonns cutting fluids per year. According to Health report one litre of cutting fluids can pollute one million of drinking water. Also it is reported that 80% skin desease of operator due to skin contact of metal working fluids. MWF may cause irritation or allergy perticularly so need of new generation environmental and operator friendly cutting fluid like vegetable oils. All the government agency forcing industrialist to reduce the use of harmful cutting fluids because this fluid damage the ecosystem. Vegetable oil is a Non-edible categories like Jatropha oil etc. This oil can reduce cutting temperature 10 to 30% by using MQL process compared to Dry machining process. It also reduce cutting force 5 to 28% compared to dry machining process. All this researchers studied the concept about dry, wet, MQL, cryogenic cooling system over the different materials. The objectives of this research papers is to review, which are used for the quality and productivity improvement using the CNC machining. Detailed research is required to reduce losses to improve the productivity of the operation. The plan is to obtain better surface finish by while increasing the material removal rate and productivity choosing right values for input parameters. All companies require better quality of surface finish with better utilization of the capacity to improve the productivity. In order to have best results, it is required the development of new materials, in wet machining MQL cooling process and new coatings for the cutting tools for dry process. MQL is one of the best cooling method to obtained better surface finish. But industry has no information about MQL process and it is require to educate to all about cooling process. But by using such process we have not getting best possible results. Hence, it is planned in the study to give proper result while selection of best process parameters. Following are the all cooling method reviewed given in the table.

Table 1: Effectiveness of various cooling and lubricating strategies.

Effect of the cooling and lubricant strategy	Flood (emulsion/oil)	Dry (compressed air)	MQL (oil)	Cryogenic (LN2)	Hybrid (LN2 + MQL)
Cooling	good	poor	marginal	excellent	excellent
Lubrication	excellent	poor	excellent	marginal	excellent
Chip Removal	good	good	marginal	good	good
Machine Cooling	good	poor	poor	marginal	marginal
Work piece Cooling	good	poor	poor	good	good
Dust/Particle Control	good	poor	marginal	marginal	good
Product Quality (Surface Integrity)	good	poor	marginal	excellent	excellent

5. CONCLUSION

This paper summarize the effect of the cutting parameters on the surface roughness. Cutting and cooling applications play a major role in manufacturing operations. The process parameter and the final work piece can be improved through the application of lubricants. Dry machining cooling capacity is limited to achive best result but tool required special coating material which is costly process, therefore wet machining was seen as a good alternative. Cryogenic machining is superior in many regards, but cost is higher. By using different material researcher obtained best result using MQL processs with vegetable oil. Every industry shift to use vegetable oil for cutting fluids. Vegetable oil like Jatropha oil can reduce cutting temperature 10 to 30% by using MQL process and reduce cutting force 5 to 28% compared to dry machining process.By using MQL cutting chip can flush easily and chip size 3 to 9%thinner than dry machining. MQL performance is better as well as achieve both environmental and ecological benefit. On the other hand, wet machining though expensive but have good lubricating properties and pose less threat to the environment. Based on the literature reviewed, It was found that MQL machining provided better results than dry and wet lubricants with average cost.

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