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POWER RATING AND TOOLS WEAR IN MILLING OF HARDENED SAE 4340 STEEL WITH TECHNICAL MINIMUM QUANTITY OF FLUID (MQF)

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Abstract: *This project proposes the implementation of a data acquisition system to be used in the study of SAE 4340 steel milling process using minimal amount of fluid (MQF) at different flow rates compared to conventional lubrication in the concordant and discordant for machining tools carbide with coating. The project is being developed in the Machining Laboratory Studies at UNESP-Guaratingueta, using a CNC Machining Center DMG brand model series DMU50ECO DMG Ecoline which was equipped with thesystem acquisition is capable of performing real-time data capture of power cut. The steel used in this research is the SAE 4340, it has a large industrial use in mechanical components that receive dynamic forces. For the acquisition of consumed motor power machining center were used a Hall effect sensors brand LEM model AT 100 B10. The tool wear was measured with the stereoscopic Brand Mahr, MarVision MM200 model. It was applied an appropriate statistical analysis (analysis of variance) of results in order to understand the effects of the steel milling MQL 4340 and correlate the output variables. As a result we intend to know the effects of the MQF consistent tangential milling process and discordant steel SAE 4340 with carbide cutters.*

Keywords: *Milling , minimum amount of fluid , power rating, tool wear.*

1. INTRODUCTION

Currently, many researches and industries are looking for a more economical and environmentally correct solution to the issue of lubrication and cutting fluids in the machining process. Many studies have tried to, in response to this need, enabling the use of MQF technique in machining processes such as turning, milling, drilling and grinding. However, little is known about the steel milling 4340 using MQF. There were no studies addressing the same input conditions and output variables studied in this project. The project consists in the development, construction and application of a data acquisition system with a function to capture in real time during the machining process, the consumed power, and the acoustic emission generated vibration.

The mechanical metal sector has been using in machining the concept of monitoring parameters for quality control machines. In turning, milling and grinding there are already companies that monitor the condition of the cutting tool through real-time analysis of current consumed or engine power. The material selected for the study design is the SAE 4340 steel which is a steel high hardenability and good forgeability of great industrial use. Due to its characteristics it is applied to manufacturing crankshafts for airplanes, tractors, axles with high mechanical stress and vehicles in general. The airline industry is widely used due to its high strength and toughness that are critical in aeronautical projects for various applications, from parts used in the assembly of the aircraft as well as in tooling that are used for construction and assembly of aircraft (Torres, 2002).

The choice of the milling process for this project is because of the recent acquisition of a machining center with numerical control (CNC), with 5-axis and high-tech. In addition, the milling has not been explored in research in the Department. So, it was thougt to reconcile the use of a next-generation equipment already purchased and installed, a topic of great importance industrial and scientific unexplored.

The milling process is a widely used process in the metal mechanical industry, because with it can to obtain parts with complex geometries. Diniz et al. (2013), claim that the milling is a process whose operation is more expensive than the planing. They also claim that it is the appropriate process for the machining of surfaces that intersect each other, as well as being a process of great capacity for material removal.

Once the milling hardened steels has great industrial applicability and development, and the current trend of ecological sustainability concerns was applied in this study also the technique of minimal amount of fluid (MQF). By having the interrupted cut, the use of MQF in milling has been a viable alternative as it provides a cooling in the period in which the cutting edge does not touch the part.

Cutting fluids generate costs that can reach 20% of the total production cost (Sreejith and Ngoi, 2000). Besides the economic factor, the coolers agents can also cause serious damage to the environment and humans, and this justifies the search for new cooling methods, such as the MQF.

Based on this, a dynamic testing was done with abundant cooling (conventional) and subsequently using MQF, seeking to enable its use.

Importantly, the acquisition system used subsequently assist in research involving processes of machining materials such as metals, polymers, ceramics, composites etc., can be used in any machine tools such as lathes, milling machines and machining centers.

2. OBJECTIVES

Study the feasibility of using MQF in milling machining center for the hardened steel SAE 4340. Check the effect of increased fluid in the MQL system in relation ace output variables. Compare the shapes lubrication / cooling. Analyze the behavior of the roughness of the machined parts. Check the power ratting consumed during milling to different test conditions. Further analyze the wear and breakdowns of tools for different test conditions, comparing the behavior of carbide tools and wear.

3. JUSTIFICATION

This study is justified by the fact that the milling process is widely used in industries, moreover, this project studies the machining of the steel 4340 with great industrial application. Seek alternatives to reduce the cutting fluid volume through MQL, in a process of very important industrial machining, using a widely used material in vehicles, machinery and airplanes, may contribute economically to the process as well as reduce damage to the environment and operator health.

With regard to the concordant and discordant with MQF tangential milling machining centers little is known. Studies seeking to reduce the amount of cutting fluid in the process are required to be an alternative and possibly more environmentally correct feasible, since the cut intermittently provides a refrigeration is not due to cutting fluid (Armendia, 2010).

The high maintenance costs and disposal of the cutting fluid, in addition to the problems that these can bring to humans and the environment justifies the search for new modes of cooling, as is the case the MQF.

Therefore, comparative testing with abundant cooling were performed (conventional) and MQF in the new acquisition of materials and technology department, a machining center with numerical control (CNC), 5-axis and precision. Combining the use of a next-generation equipment purchased with a theme of technological innovation and great industrial and scientific application and with participation, support and partnership of Seco Tools company.

4. BIBLIOGRAPHIC REVIEW

4.1 Process of milling

The most widely used machining processes are the conventional as turning, milling, drilling etc., can be manual or automatic, through Computerized Numerical Controls (CNC).

The milling machining is a process where material removal of a particular piece of non-continuous mode is performed by rotary motion of a tool multicortante many cutting teeth, thus obtaining surfaces of different shapes (STEMMER, 1992). The milling can be concordant or discordant. The discordante miling is characterized by the case of forward direction angle start at zero and reach a maximum value at the end of the pass of the cutting edge. The direction of forward movement contrary to the direction of movement of the cutter and the cutting depth increases progressively from zero to a maximum value. The concordant miling is characterized by the angle starts with a maximum value and decreases to zero at the end of a cutting edge. In the table consistent cutting feed motion has the same direction as the rotational movement of the tool.

4.2 MQF

The use of cutting fluid in abundance is the most common process for machining requiring cooling and lubrication. However, this cooling mode is being gradually replaced by other methods due to increased rigor in laws and environmental damage, economic and health it can cause. An alternative is the use of MQF, which is already widely used in other machining processes. The MQF characterized by mixing compressed air and fluid, where the fluid consumption is less than 60ml / h to form a spray and the air pressure is 8 kgf/cmm^2.

The MQF technique is to apply a small amount of cutting fluid mixed with compressed air to form an aerosol by promoting: lubricating the workpiece contact zone - friction reducing tool; reducing the temperature, transforming the vaporization heat (the fluid) and driving the air flow (SHOKRANI, 2012).

It is an alternative to conventional cooling, especially when dry cutting is not applicable and does not wish to use the flood. MQF has some advantages over conventional manner, such as:

-Fluids used in smaller quantities;

-Reduzed problems with storage, treatment and disposal of fluid;

-Decrease or absence of problems with bacteria and fungi.

4.3 SAE 4340 steel

The material used in this study is the SAE 4340 steel. This steel is high hardenability parts of large thicknesses and high strength. Suitable for crankshafts aircraft, tractors, trucks and cars, rods, gears, shafts generally subject to great efforts. It is often used in mechanical equipmens under the action of dynamic stresses.

4.4 Power ratting

The level of material removal of a particular piece can be directly associated with the equipment power consumption (Gonçalves et al., 2010). The power sensor measures the power consumed by the motor or the frequency range of the engine, where its measurement is to measure the current and the motor voltage. Due to easy installation in equipment, power sensors are used in large-scale monitoring of machining equipment (JEMIELNIAK, 1999).

4.5 Tool wear

Wear is the progressive phenomenon on the surface of the tool due to the action of cutting, which changes the shape and therefore the original tool geometry. As for the wear, they are the result of several different mechanisms depending on the nature of the machined material and machining conditions prevail either of the mechanisms on the other.

This depends on the workpiece material and tool, the machining operation, the cutting conditions, tool geometry and employment and the application of cutting fluid efficiency (DINIZ et al.; 2001).

5. METODOLOGY

This research project is being developed in the machining laboratory at Unesp-Guaratingueta, using a machining center DMG brand model series DMU50ECO DMG Ecoline (Figure 1), for which it was developed and mounted a power data acquisition system.

The project dynamics is through experimentation, starting from preliminary tests to determine the parameters and variables more suitable to research as cutting speed, feed rate, feed per tooth, cutting depth, the conventional system flow and lubrication system of MQF, cutting fluids, etc.

It will be used as proof of the AISI 4340 steel body whose dimensions have been defined. The cutters are used carbide, with and without coating.

To carry out the project the conventional lubrication systems will be used (fluid in abundance) own the Machining Center and an MQF system (Compressed air and fluid) Machining of Studies Laboratory. Cutting fluids to be used have already been defined in terms of machining conditions and consultations with manufacturers.

The data acquisition comprising a computer system with a data acquisition board, a module channels, and a connecting cable between the plate and the channel module has been deployed and allows obtaining any of the variables measured in time real as cutting power, acoustic emission and vibration. The power sensor, acoustic emission sensor and vibration sensor have been coupled to the system.

During execution of preliminary tests the signal corresponding to the power captured by the data acquisition card is of the Hall-effect sensor trademark LEM model AT 100 B10. The roughness that will later be used is the roughness of the brand Mahr MarSurf M300 model, and tool wear will be measured with the stereoscopic Brand Mahr, MarVision MM200 model.

Figure 1 - a machining center DMG model DMU50ECO serie DMG Ecoline

5.1 Testing methodology

Initially we used the conventional method of lubrication for concordant operation (C) and discordant operation (D), tungsten carbide cutter with cover running 3 repetitions of testing for each condition.

6. DEVELOPMENT

6.1 Test specimen and cutting fluids

It was designed to test samples that could be machined so as to be possible for sufficient material removal to occur tool wear. The dimensions of the specimens were 100x70x25mm. It was determined that the samples were tempered and annealed with a final hardness of 56 HRc. The fluid used in the MQF is the LB-1100 lubricant ACCU-LUBE, suitable for operations that generate a lot of heat and machining hardened metals operations, and has no chlorine. For conventional machining was used lubricant BLASER VASCO 1000.

6.2 Tools

A partnership with Seco Tools company, based in Sorocaba. The Company donated two different tools for frontal milling and other two for tangecial milling, the MP16-16019R08Z3 M05- 3 cutting edges, MP16-16019R04Z6-M04 with cutting edges 6, and LOEX080408TR-M08 with 2 edges and XOMX10T308TR-ME07 with 4 edges.

6.3 Installation and calibration of the data acquisition system

It also performed the instalation and preparation of the data acquisition system and the data testing, adjusting machinery, equipment, sensors. The implanted data acquisition system consists of a computer equipped with a data acquisition board, a module channels, and a connecting cable between the plate and the channel module. This system allowed the obtaining of any physical variables by appropriate sensors or transducers, have been converted into proportional electrical signals. Preliminary tests with the data acquisition system were carried out to verify its functionality. For these tests it was used aluminum 2024. It was also performed the system calibration tests that have proven their functional capacity.

6.4 Definitive tests with conventional lubrication and MQF

First tests were conducted with a conventional lubricant, which uses cutting fluid in abundance for the concordant and discordant directions, varying all the tools, running 3 replicates for each test conditions, the machining direction concordant and discordant test and wear.

Later tests were conducted with the technique minimal amount of fluid. Again varying the direction of cutting tools and cutting fluid flows. The flow rates used were 120, 40 and 12 ml / hr, again performing 3 trials for each condition to the machining direction concordant and discordant test and wear. The cutting parameters were: cutting speed = 200 m / min, feed rate: 0.04 mm / tooth, RPM: 2609.

6.5 Power rating acquisition

For the acquisition of power consumed engine machining center effect sensors were used Hall brand LEM model AT 50 B10. The sensor signal (power) is captured by the data acquisition card and stored during the execution of the tests. Where by equation 1 below the acquired signal can be transformed into the power unit (Watts). Substituting the value of signal obtained and divided by 10, for the sensor captures amplitude voltages in the range of (0-10V), the value of the amplitude of the current 50, the value of the motor phase voltage (220 V), and the factor slip (0,92) of the engine, and by multiplying by being a three phase motor, which was used to transform signal acquired in Volts of a power consumed in watts.

$$P = \frac{value}{10} .50 .220 .0{,}92 .\sqrt{3} \tag{1}$$

6.6 Determination of wear and tool damage

Determining the wear of the tool was carried out by identifying what the type of fault or wear that has occurred due to the machining efforts. For this, we used the stereoscopic Mahr brand, model MM20 MarVision, since all estimated damage was possible to compare the lubrication methods.

7. RESULTS AND DISCUSSION

7.1 Statistical Analysis

To better understanding of the experiment, it was done a statistical analysis of the data obtained experimentally. It was developed the experiment design study for full factorial, with the determination of three main factors (lubrication, milling type and direction of cutting) that directly influence on the data obtained and the necessary number of levels for each factor, the levels for their time has the function of presenting the condition or situation of variation in the factor. Repeating three times was used for the study, totaling 96 combinations for the 3 factors and subsequent levels.

7.2 Power rating

Considering the power rating, using a statistical analysis of variance, it can be obtained the value of effective interation between each factor. The obtained data are shown in the table 1.

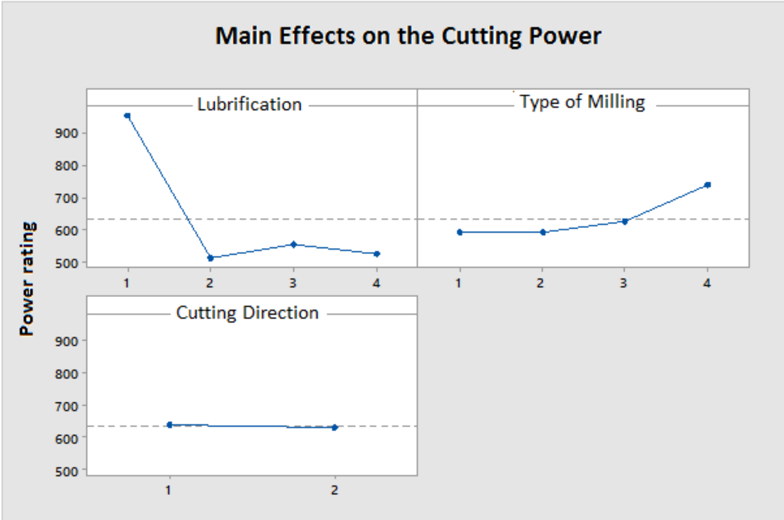
Table 1 – Analysis of variance for the cutting Power

Analysis of variance fo the cutting power			
lubrification	3	219,96	0
type of milling	3	31,40	0,000
cutting direction	1	0,62	0,434
lubrification*type of milling	9	1,02	0,436
lubrification* cutting direction	3	1,24	0,304
Type of milling* cutting direction	3	4,57	0,006
lubrification*type of milling* cutting direction	9	1,19	0,032
Error rate	64	#	#
Coefficient of determination	R-Sq(adj) = 91,14%		

For the power, few interactions are significant, as can be seen by the PValue or even the value of F. Only the lubrication factors and type of milling (tool change) can influence the power values. The cutting direction can be neglected.

Interactions only type milling cutter to effect was significant, it can be said that it is unnecessary to display the graphics of other interactions since the observed trend that would be analogous.

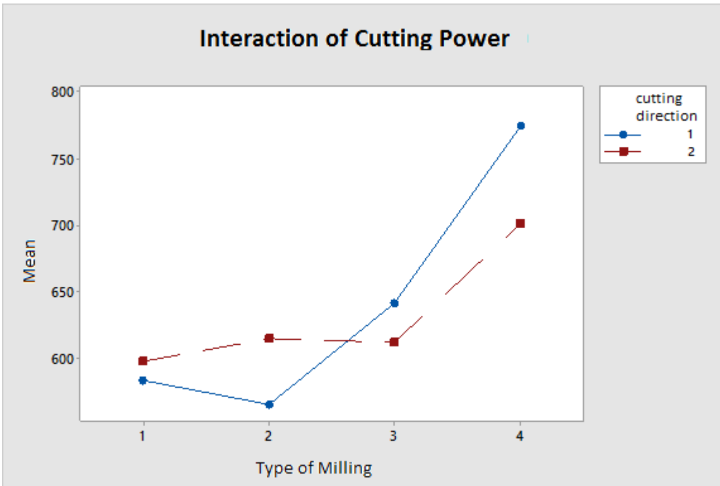
The value of R2 also explain that the average straight from these values are explained almost entirely, covering over 91% of the data.



Graphic 1 – Main effects for the cutting power

Excluding the peak in lubrication 1, it is interesting to note that for the MQF smaller cut power values with a small increase only for tangential milling were obtained, and with respect to the straight cutting senses became very close to the average of the average indicating process stability.

As the cutoff power is the power delivered to the tool edge and consumed in the chip removal is interesting smaller power values, describing the MQF as great lubrication process, especially in consideration of the machining of a hardened steel. There was no interaction of the third order.



Graphic 2 – Interaction between type of milling and cutting direction

For the tangential milling, the power valuest both as discordant and concordant milling were higher. So the best would be to employ the frontal operation to get the best out of power.

7.3 Tools Wear

Since the definition and the study of failures of cutting tools is very important factor for a good understanding of the machining processes, it was observed all malfunctions and wear of the tools used by separating the analysis of tools used with the technique of minimal amount of fluid and used in conventional lubrication. With this study is expected to meet or determintar the existence of influences on the higher occurrence of faults in the tools with the modification of lubrication.

Qualitatively and quantitatively analyzed the damage and wear occurred. For milling using conventional lubrication, and considering the carbide insert with two cutting edges (ME07 tool), the edges of the three used pellets were analyzed. One crater wear of the edges found, probably caused by an increase in temperature and pressure in machining, in other edges only was found flank wear width of 0.096 and 0.06 mm thick.

Figure 2 – Crater wear and flank wear on the insert with 2 cutting edges with conventional lubrication

Stiil in conventional lubrication and frontal milling, the insert with 4 cutting edges had only flank wear, with dimensions of 0.034 mm and 0,038mm, much smaller than those seen in the tablet 2 edges, due to the fact the increased number of edges . For the tangential milling, the tool with 3 cutting edges presented frontal wear with dimensions of 0.044; 0.023 and 0.032 mm for each of the three edges.

In the use of the MQF some peculiarities were found. To use the insert with 2 cutting edges apresented some flanks wears of the order to 0,063mm and 0,094mm. On the other hand, for the face milling insert with four edges, the flank wear found were 0.032; 0,015mm and 0.02mm with one of the edges having a chipping due to excessive wear front.

Figure 3 –Flank wear on the insert with 2 cutting edges for the frontal milling using MQF and a chipping on the insert with 4 cutting edges for the frontal milling using MQF

8. CONCLUSION

Considering the data obtained during the project, in applied statistical analysis becomes required a more detailed study of interactions and combinations of factors that have proven significant, because only then can allowed to be found better conditions for the use of the MQF and their optimization points. The variance tables, it is important to note that with the values of P and F gives a higher validity of the treatment, as the charts show only tendencies, closed between limits.

The data obtained for MQF relative potency were satisfactory in more general than or equivalent to abundant lubrication, which encourages continuing research in this area. To the wear found in the tools used, measurable wear of flank or front were very low, of less than 0.1 mm order. And using the MQF tools showed the highest levels of wear but they were rarely more problematic, such as chipping or notch wear, which could lead to breaking of the edge and significantly influence the workpiece surface finish.

It was found that in different tools and different flows made it possible to better understand the concordant and discordant milling for hardened steel with application of MQF, and upon the data obtained and analyzed statistically, the MQF has performed very satisfactory, with no major variations in surface quality and enabling good surface quality. Therefore, the feasibility of using MQF in milling machining center for steel hardened 4340 was confirmed, favoring the largest study of milling conditions with MQF technique for future application in the industry, bringing many economic benefits, and sustainable.

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