Journal of Basic and Applied Engineering Research
p-ISSN: 2350-0077; e-ISSN: 2350-0255; Volume 6, Issue 2; January-March, 2019, pp. 71-75

http://www.krishisanskriti.org/Publication.html

Experimental Investigation of Ultrasonic Machining Process using Aa7075 Alloy

Krishna Prasad

Manufacturing Engineering
Lord Jegannath College of Engineering
E-mail: krishnaprasadfriends@gmail.com

Abstract—*The demand for miniaturized device and components is rapidly increasing in fields of aerospace, energy, optics, electronics and communication, automation and medical. Ultrasonic Machining (USM) is capable of machining hard and brittle materials such as advanced ceramics, glass and silicon used in many industries. The main reason why this machining process is used in the manufacturing area is because it evolves less heat in the process. All the operations done with the ultrasonic machining method are cost effective and best in results. Ultrasonic machining is an abrasive process which can create any material into hard and brittle form with the help of its vibrating tool and the indirect passage of abrasive particles towards the work piece. It is a low material removal rate machining process.*
The goal of this project is to conduct a feasibility study and investigate material removal mechanism for ultrasonic machining. The effect of the Amplitude of vibration, Frequency of vibration and Pressure on the material removal rate (MRR) and Surface Roughness (SR) will be study. In USM water is normally used as a coolant. The work piece used for investigation is a highly application oriented aerospace material AA 7075 aluminium alloy. It is an alloy with a strength comparable to many steels and has good fatigue strength and average machinability. It also has lower resistance to corrosion than many other aluminium alloys. In this work the experiment is designed by using Design of Experiment. Modeling of the entire process will be carried out by a prediction tools.

1.1 INTRODUCTION

The demand of miniaturized devices and components is increasing rapidly in fields of aerospace, energy, optics, electronics, communication, automation and medical. As per each work pieces' physical and chemical properties, different micro manufacturing processes are required. Typical micro products include medical implants, analysis equipment's, sensors, micro-scale pumps, ink jet printers, reading caps for hard drives, optical lenses, and pacemakers, etc.

1.2.2.1 Machining Time

The machining time of the ultrasonic grinding depends on the frequency of the vibration, material properties and grain size. The amplitude of the vibration may vary from 5 to 75 µm and frequency may vary from 19~25 kHz. Ample static force is also required to hold the job against the machining tool. A continues flow of abrasives suspension is also mandatory.

1.2.3 Process

An ultrasonically vibrating mill consists of two major components, a transducer and a sonotrode, attached to an electronic control unit with a cable. An electronic oscillator in the control unit produces an alternating current oscillating at a high frequency, usually between 18 and 40 kHz in the ultrasonic range. The transducer usually consists of a cylinder made of piezoelectric ceramic. The oscillating voltage is applied to electrodes attached to the transducer, which converts the electrical energy into mechanical vibrations. The transducer then vibrates the sonotrode at low amplitudes and high frequencies. The sonotrode is usually made of low carbon steel. A constant stream of abrasive slurry flows between the sonotrode and work piece. This flow of slurry allows debris to flow away from the cutting area. The slurry usually consists of water (20 to 60% by volume) and boron carbide, aluminum oxide and silicon carbide particles. The sonotrode removes material from the work piece by abrasion where it contacts it, so the result of machining is to cut a perfect negative of the sonotrode's profile into the work piece. Ultrasonic vibration machining allows extremely complex and non-uniform shapes to be cut into the workpiece with extremely high precision.

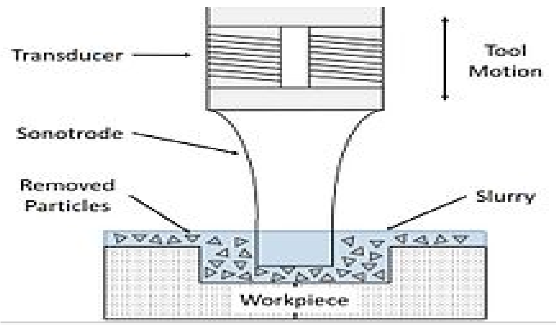

Figure 1.5 Ultrasonic Machining Process

Machining time depends on the workpiece's strength, hardness, porosity and fracture toughness; the slurry's material and particle size; and the amplitude of the sonotrode's vibration. The surface finish of materials after machining depends heavily on hardness and strength, with softer and weaker materials exhibiting smoother surface finishes. The inclusion of microcrack and microcavity features on the materials surface depend highly on the crystallographic orientation of the work piece's grains and the materials fracture toughness.

1.3 Process Parameters and their Effects

During discussion and analysis as presented in the previous section, the process parameters which govern the ultrasonic machining process have been identified and the same are listed below along with material parameters

3. Amplitude of vibration (a_o) – 15 – 50 μm
4. Frequency of vibration (f) – 19 – 25 kHz
5. Feed force (F) – related to tool dimensions
6. Feed pressure (p)
7. Abrasive size – 15 μm – 150 μm
8. Abrasive material – Al_2O_3

-SiC

-B_4C

-Boronsilicarbide

-Diamond

- Flow strength of work material
- Flow strength of the tool material
- Contact area of the tool – A
- Volume concentration of abrasive in water slurry – C

1.4 Types

1.4.1 Rotary ultrasonic vibration machining

In rotary ultrasonic vibration machining (RUM), the vertically oscillating tool is able to revolve about the vertical center line of the tool. Instead of using abrasive slurry to remove material, the surface of the tool is impregnated with diamonds that grind down the surface of the part. Rotary ultrasonic machines are specialized in machining advanced ceramics and alloys such as glass, quartz, structural ceramics, Ti-alloys, alumina, and silicon carbide. Rotary ultrasonic machines are used to produce deep holes with a high level of precision.

1.4.2 Chemical-assisted ultrasonic vibration machining

In chemical-assisted ultrasonic machining (CUSM), a chemically reactive abrasive fluid is used to ensure greater machining of glass and ceramic materials. Using an acidic solution, such as hydrofluoric acid, machining characteristics such as material removal rate and surface quality can be improved greatly compared to traditional ultrasonic machining. While time spent for machining and surface roughness decrease with CUSM, the entrance profile diameter is slightly larger than normal due to the additional chemical reactivity of the new slurry choice. In order to limit the extent of this enlargement, the acid content of the slurry must be carefully selected as to ensure user safety and a quality product.

1.6 Advantages

1. It can be used to drill circular or non-circular holes on very hard materials like stones, carbides, ceramics and other brittle materials.
2. Non-conducting materials like glass, ceramics and semi precious stones can also be machined.
3. Machined all sorts of hard materials
4. Produces fine finished and structured results
5. Produces less heat
6. Various hole cut shapes due to vibratory motion of the tool

1.7 Disadvantages

1. It can be proved slower than the conventional machining processes.
2. Creating deep holes is difficult because of the restricted movement of the suspension.
3. It is arduous to select the perfect tool geometry for creating hole of certain dimension. The holes created may be of larger sizes because of side cutting.
4. High tool wear because of continuous flow of abrasive slurry.

1.8 Rotary Ultrasonic Machining

Using RUM for machining hard and brittle material is a conventional and cost saving approach. In Rotary Ultrasonic Machining process material is removed by ultrasonic machining and conventional grinding.

The components of the RUM process are: Ultrasonic spindle kit, feeding device and a coolant system. A coolant was injected between the tool and work piece which flushed away the debris. A good surface finish, improved hole accuracy and capability to drill a hole with low pressure was achieved by using RUM .The use of diamond integrated tool in RUM helped to improve hole accuracy and it was easy to drill a deeper hole.

3.1.4 Create Taguchi Design

Taguchi's method is very effective to deal with responses influenced by multi-variable. Taguchi's method of experimental design provides a simple, efficient and systematic approach to determine optimal machining parameters. Taguchi recommends Orthogonal Arrays (OA) for lying out of the experiments. In the Taguchi method, the results of the experiments are analyzed to achieve one or more of the following objectives:

1. To establish the best or the optimum condition for a product or process.
2. To estimate the contribution of individual parameters and interactions.
3. To estimate the response under the optimum condition.

The optimum condition is identified by studying the main effects of each of the parameters. The main effects indicate the general trend of influence of each parameter. The knowledge of contribution of individual parameters is a key in deciding the nature of control to be established on a production process. The Analysis of Variance (ANOVA) is the statistical treatment most commonly applied to the results of the experiments in determining the percent contribution of each parameter against a stated level of confidence. The study of ANOVA table for a given analysis helps to determine which of the parameters need control and which do not (Ross, 1988). Taguchi suggests (Roy, 1990) two different routes to carry out the complete analysis. First, the standard approach; where the results of a single run or the average of repetitive runs are processed through main effect and ANOVA analysis (raw data analysis). The second approach, which Taguchi strongly recommends for multiple runs, is to use Signal-to-Noise (S/N) ratio for the same steps in the analysis. The S/N ratio is a concurrent quality metric linked to the loss function (Barker, 1990). By maximizing the S/N ratio, the loss associated can be minimized. The S/N ratio determines the most robust set of operating conditions from variation within the results. The steps involved in Taguchi's method are:

1. Identify the response functions and the process parameters to be evaluated.
2. Determine the number of levels for the process parameters and possible Interaction between them.
3. Select the appropriate orthogonal array and assign the process parameters to the orthogonal array and conduct the experiments accordingly.
4. Analyze the experimental results and select the optimum level of process parameters.
5. Verify the optimal process parameters through a confirmation experiment.

In the present investigation, both the analysis – the raw data analysis and S/N data analysis – have been performed. The effects of the selected USM process parameters on the selected performance characteristics have been investigated through the plots of the main effects based on raw data. The optimum condition for each of the performance characteristics has been established through S/N data analysis aided by the raw data analysis. No outer array has been used instead; experiments have been repeated three times at each experimental condition. The optimal process parameters are verified through a confirmation experiment.

Number of input parameter = 3

Number of levels = 3

L9 orthogonal array Taguchi design is used for designing my project work experimentation.

Open the MINITAB software and using the design of experiment methods to select the Taguchi Method of Design. Select the levels of our design as 3 and select the process parameter as 3.Select the L9 orthogonal array design from the designs.

3.2 Work piece Material

The material used for machining is 7075 aluminum alloy. 7075 is a precipitation hardening aluminium alloy, containing magnesium and silicon as its major alloying elements. Originally called "Alloy 61S," it was developed in 1935. It has good mechanical properties. It is one of the most common alloys of aluminium for general purpose use.

It is commonly available in pre-tempered grades such as 7075-O (annealed) and tempered grades such as 7075-T6 (solutionized and artificially aged) and 7075-T651 (solutionized, stress-relieved stretched and artificially aged).

3.3 EXPERIMENTAL SETUP

Rotary Ultrasonic Machining experiments were performed by using an in-house designed and built set up of ultrasonic machine. Ultrasonic vibration system (transducer and generator), positioning system (XYZ-stages), cutting force feedback sensor, system controller, machine spindle, tool holder and work piece holder are the basic component necessary to build the micro ultrasonic machine system. The system is an assembly of a piezoelectric ultrasonic transducer, a spindle for rotating tool and position of tool was controlled in X, Y and Z axes by a precision motion controller with 25 nm resolution. The work piece was vibrated ultrasonically at 39.5 KHz by mounting it on the free end of the transducer. A working fluid was injected into the gap between the tool and work piece. Figure 3.1 describes the system design. Figure 3.2 explains principle of operation of RUM. Figure 3.3 shows modified experimental set up of RUM.

Figure 3.3 Experimental set up of RUM

Experiments were conducted using the dental tool under the experimental conditions. Experiments were focused on understanding influence of different working fluid, spindle speed and static load on material removal rate, surface of work piece and tool shape after machining. The vibration frequency was 39.5 KHz and the amplitude was 1 µm. The machining time of each experiment was 60 sec. For RUM process water is normally used as coolant. Till now, no work has ever been reported on using soft particles as slurry medium in micro-RUM. In present work, milk was first introduced as new slurry in micro-RUM and a set of comparison experiments were conducted by adopting water with conventional PCD powder mixture and water only as slurry. Bovine milk, water and 1%wt Polycrystalline diamond powder (PCD-5) slurry were used as working fluids for experiments. Milk contains large and particles which are not brittle but they are the fat molecules, an enzyme varies in size 0.1 micron to 90 micron. The average diameter of the PCD abrasive particles is 5µm.

RESULT AND DISCUSSIONS

4.1 Regression Models

Regression methods are used to analyze data from unplanned experiments, such as might arise from observation of uncontrolled phenomena or historical data. Regression methods are also very useful in designed experiments where something has "gone wrong". The general purpose of multiple regressions is to learn more about the relationship between several independent or predictor variables and a dependent or criterion variable.

The factors considered for prediction are Rotational Speed, Amplitude of vibration and Frequency of vibration and the corresponding output parameter is Material Removal Rate.

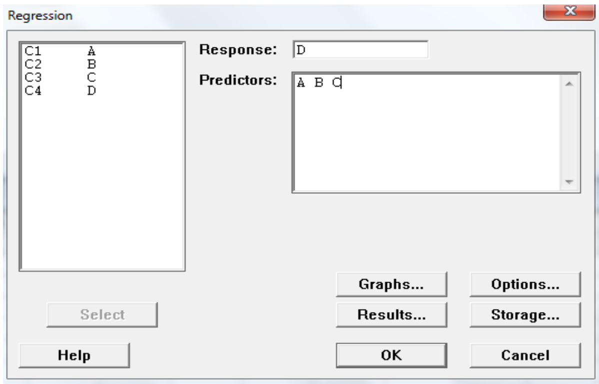

Fig 4.1 Selection of Input and Outputs for Regression

4.1.2 RESULT OBTAINED IN REGRESSION ANALYSIS

Based on the prediction results of regression analysis for the output parameter the regression equations is given below

The regression equation is:

MRR = 1.51 + 0.0372 A + 0.0265 B + 0.00109 C

4.2 Adaptive Neuro Fuzzy Inference System

Artificial intelligence is the study of ideas that enable computers to be intelligent. It works with the help of artificial neurons and some scientific theorems, also it have an ability to find out the solution based on factors rather than on a preset series of steps. Artificial neural networks are composed of interconnecting artificial neurons. An artificial neuron is a function formed as a crude model or abstraction of biological neurons. The main goal of the artificial neural network is to transform the input parameters into meaningful outputs parameters. Fuzzy Logic dispense a more efficient and resourceful path to work out Control Systems. It is mainly based on some rule basis. For developing an intelligent systems artificial neural network and fuzzy logic are the natural complementary tools. When dealing with unanalyzed data neural networks are bottom level computational anatomy, which accomplish effectively. Fuzzy logic mainly concerned with reasoning on an upper level, using linguistic data obtained from domain experts. However, fuzzy logic system deficit the capability to acquire knowledge of and can't modify themselves to a curren domain. At the same time, even though neural networks can acquire knowledge, they are non-transparent to the user. The integrated neuro fuzzy systems can merge the parallel computation and learning capacities of neural network with the knowledge representation like a human being and explaining capacities of fuzzy systems. As a conclusion, a neural network becomes huge translucent, while fuzzy logic systems becomes capable of learning. An adaptive neuro fuzzy inference system utilizes a hybrid learning algorithm that merges the least square estimator and the gradient descent process. It is the sugeno fuzzy model which has been recommended for creating fuzzy rules from a given input output data set.

4.2.1 Structure of adaptive neuro fuzzy inference system (ANFIS)

Adaptive neuro fuzzy inference system model has been constructed with Gaussian membership function (gaussmf) with 2 membership functions for all input parameters and linear membership function for output parameter. For adaptive neuro fuzzy inference system two types of optional optimization methods used for training the membership function parameter training. They are back propagation method and the hybrid method. In this project I use hybrid method. Hybrid method is a combination of least squares estimation with back propagation. All the input parameters are entered into the adaptive neuro fuzzy inference system and trained with 100 epochs. The final adaptive neuro fuzzy inference system model with 3 input parameters and 1 output parameter is shown in the figure 4.5.

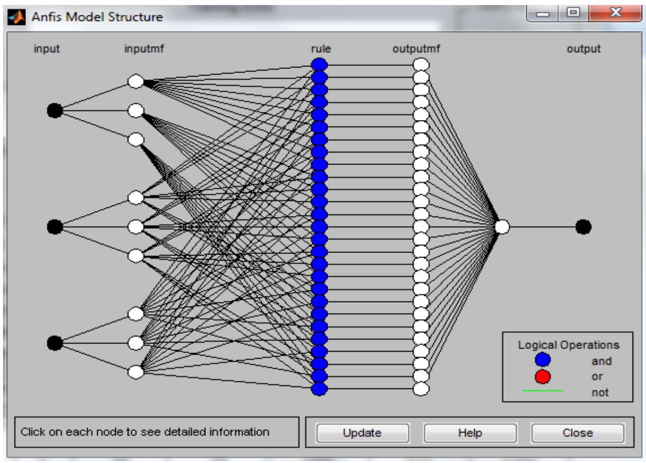

Figure 4.4 Training Error

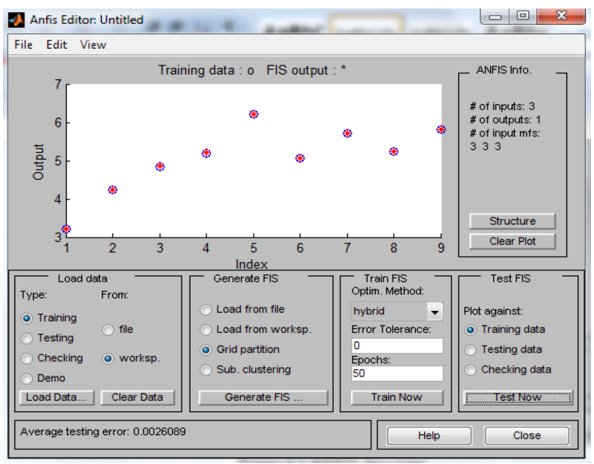

Figure 4.5 ANFIS Structure

CONCLUSION

Finally I am concluded that the investigation of Ultrasonic Machining process parameters by using modeling techniques.

Three major controllable parameters are Amplitude of vibration, Frequency of vibration and Pressure are considered for the present work.

The material used for machining is 7075 aluminum alloy. Empirical relationships were established to predict the output parameters Material Removal Rate of the work piece by incorporating independently controllable USM process parameters.

The experimental design for the work is carried out using Taguchi design of experiment through Minitab software. The prediction of the actual output parameter by using two methods like Regression analysis and Adaptive Neuro Fuzzy Inference System. From the obtained result the ANFIS based prediction model gave an accurate prediction when compared with Regression method.

RERFERENCES

[1] M. Adithyan, and V. C. Venkatesh, “Production Accuracy of Holes In Ultrasonic Drilling”, Wear, Vol. 40, No. 3, pp. 309–318, 1976.

[2] M. Komaraiah,., M.A. Manan, P.N. Reddy, and S. Victor,“Investigation of surface roughness and accuracy in ultrasonic machining”, Precision Engineering, Vol. 10, No.2,pp. 59-65, 1988.

[3] R. Singh and J. S. Khamba, “Mathematical Modeling of Tool Wear Rate In Ultrasonic Machining of Titanium”, International Journal of Advanced Manufacturing Technology, vol. 43, pp. 573–580, 2009.

[4] V. Kumar, “Optimization and Modeling of Process Parameters Involved in Ultrasonic Machining of Glass Using Design of Experiments and Regression Approach”, American Journal of Materials Engineering and Technology, Vol. 1, No. 1, 13-18, 2013.

[5] V. Kumar and J.S. Khamba, “Parametric Optimization of Ultrasonic Machining of Co-Based Super Alloy Using The Taguchi Multi-Objective Approach”, Production Engineering Research and Development, Vol. 3, pp. 417–425, 2009.

[6] J. Kumar and J.S. Khamba, “Modeling The Material Removal Rate In Ultrasonic Machining of Titanium Using Dimensional Analysis”, International Journal of Advanced Manufacturing Technology, vol. 48, pp. 103–119, 2010.

[7] R.S.Jadoun, K Pradeep, B.K Mishra and R.C.S. Mehta, “Optimization of Process Parameters For Ultrasonic