Experimental Investigations of Tribological Aspects of Wire Electrical Discharge Machined Surface Concerning Surface Integrity

Shitole Prashant[1] Durgude Arun[2] Potphode Shreeram[3] Rupnavar Satish[4] Malave A. C.[5]
[1,2,3,4]Student [5]Assistant Professor
[1,2,3,4,5]SBPCOE, Indapur, India

Abstract— Wire-electrical discharge machining (WEDM) is non-traditional machining process in which a pulsed voltage difference between a wire electrode and a conductive workpiece initiates sparks which erode workpiece material. Removing material in such way is often advantageous when the workpiece material would be difficult to machine with traditional machining tools due to high strength, hardness, toughness, etc. This process has been used in commercial machine tools for nearly half a century. It is well known that the EDM process has detrimental impact on the surface integrity of machined surfaces. Each spark melts a small portion of the workpiece. A portion of this molten material is ejected and flushed away. The remaining material re-solidifies to form a surface layer known as the recast layer. This layer can contain an altered microstructure, tensile stresses, micro cracks, impurities which can lead to premature part failure when put to service. Surface integrity effects are depends upon both the wire-EDM process parameters and the chemical composition of the wokpiece. Experimentation has been done using Tauchi's L9 orthogonal array. Each experiment was conducted under different combinations of pulse on time, pulse off time and wire feed. The optimum machining parameter combination was obtained by using the analysis of signal-to-noise (S/N) ratio, analysis of means and analysis of variance (ANOVA) in Minitab 15 Software. The analysis of variance (ANOVA) was carried out to study the effect of process parameters on process performance.

Key words: WEDM, Recast Layer, Micro-Hardness, Taguchi's Method, Design of Experiment

I. INTRODUCTION

In wire EDM, the conductive materials can be machined with a series of electrical discharges (sparks) that are produced between accurately poisoned moving wire (the electrode) and the workpiece. High frequency pulses of alternating or direct current dischred from the wire to the work piece with small spark gap through an insulated dielectric fluid (water). Many sparks can be observed an one time. This is because actual discharges can occure more than one hundred thousand times per second, with discharge spark lasting in the range of 1/1,000,000 of second or less. The volume metal removed during this short period of spark discharge depends on the desired cutting speed and the surface finish required.

The heat of each electrical spark, estimated at around 15,000° to 21,000°Fahrenheit, erodes away a tiny bit of material that is vaporized and melted from the workpiece. These particles (chips) are flushed away from the cut with a stream of de-ionized water through the top and bottom flushing nozzles. The water also prevents heat built-up in the workpiece. Without this cooling, thermal expansion of the part would affect size and positional accuracy the ON and OFF time of the spark that is repeated over and over that removes material, not just the flow of electric current.

WEDM can machine anything that is electrically conductive regardless of the hardness, from relatively common materials such as tool steel, aluminum, copper, and graphite, to exotic space-age alloys including hastaloy, waspaloy, inconel, titanium, carbitde, polychrystalline diamond compacts and conductive ceramics. The wire dose not touch the workpiece, so there is no physical pressure imparted on the workpiece compared to grinding wheels and milling cutters. The accuracy, surface finish and time required to complete a job is extremely predictable and substantial increases in productivity are achieved.

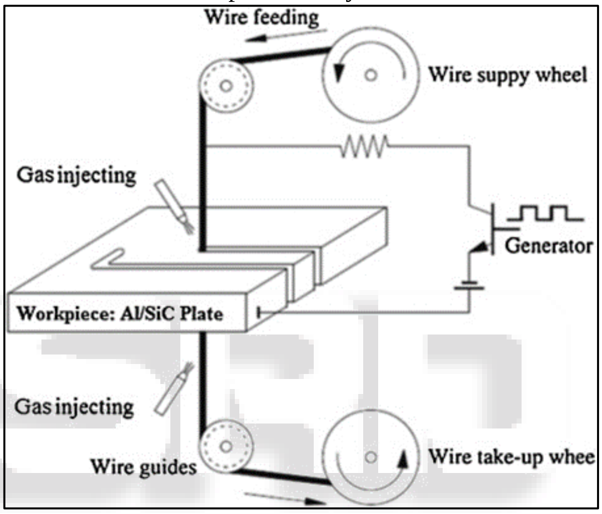

Fig.1 (a): Schematic of WEDM Process

II. LITERATURE SURVEY

1) Noor Zaman Khan, MohdAtif Wahid, Satyaveer Singh: A study on micro hardness in wire electrical discharge machining based on Taguchi's method is given in this paper. The optimum machining parameter combination was obtained by using the analysis of signal-to-noise (S/N) ratio, analysis ofmeans and analysis of variance (ANOVA). Further, the level of importance of the machining parameters on micro-hardness was determined by using ANOVA. The study shows that the Taguchi's method suitable to solve the stated problem with minimum number of trails.
2) Danial Ghodsiyeh, AbolfazlGolshan, Jamal Azimi Shirvanehdeh: Review on current research trends in WEDM is discussed here in this paper. They concluded that, it has been applied for the machining and micro-machining of parts with intricate shapes and varying hardness requiring high profile accuracy and tight dimensional tolerances. Optimization of the WEDM process parameters is essential because WEDM is an expensive and widely used process. The ultimate goal of the WEDM process is to achieve an accurate machining operation.

3) Kumar Anish, Dr. Kumar Vinod, Dr. Kumar Jatindar: The effect of WEDM performance, recast layer and wire accuracy. The ultimate goal of the WEDM process is to achieve an accurate machining operation without compromising the machining performance.
4) This is mainly carried out by understanding the interrelationship between the various factors affecting the process and identifying the optimal machining condition for the infinite number of the combinations.
5) Rajeev Kumar and Shankar Singh: The current research trends in WEDM are discussed in this paper and the resent advancement in the materials has become a challenge for WEDM process to be used in the coming decades. So, therefore it is very necessary to make continuous improvement in the current WEDM process to increase their productivity and efficiency. The main objective of the WEDM process is to Obtaine the optimal parameters without making compromise with its performance measures..
6) Thomas R. Newtona, Sheyaes N. Melkotea, Thomas R. Watkins, Rosa M. Trejob: Investigation of the effect of process parameters on the formation and characteristics of recast layer in wire-EDM of Inconel 718 is given in this paper. Inconel 718 is a high nickel content superalloy possess high strength at elevated temperatures and resistance to oxidation and corrosion. An experimental investigation was conducted to determine the main EDM parameters which contribute to recast layer formation in Inconel 718. It was found that average recast layer thickness increased primarily with energy spark, peak discharge, current and current pulse duration.

III. History of WEDM

The beginning of EDM came during the Second World War when to Russian physicists B. R. and N. I. Lazarenko published their study on the inversion of the electric discharge wear effect. Which related to the application to manufacturing technology of the capacity of electrical discharges, under control distribution, to remove metal.

EDM was being used at that time to remove broken taps and drills.

The early “Tap- Busters” disintegrated taps with hand fed electrods, burning a hole in the center of the tap or drill, leaving the remaining fragments that could be picked out.

This saved workpieces being scrapped and to be made over again.

IV. Objectives

- To design and conduct series of experiments which will reveal the impact of various WEDM process parameters on the thickness on the recast layer formed in advanced material.
- To investigate wire-EDM process parameters, which have an effect on formation of recast layer in advanced material.
- Investigate the characteristics of this recast layer.
- To find the effect of recast layer on micro hardness of selected materials.
- To investigate optimum parameters by use standard optimization technique.

V. Methodology

The research described in this thesis will attempt to solve the problems detailed in the previous points. To meet these ends, the following goals have been set:

1) Introduction
2) Literature Survey
3) Material selection for Experimentation
4) Design of Experiments
5) To conduct series of experiments which will revel the impact of various parameters on the thickness of the recast layer formed in selected advanced material.
6) To measure recast layer thickness for each run of specimen.
7) To measure Micro hardness for each run or specimen.
8) To investigate Wire-EDM parameters, which have an effect on formation of recast layer and on micro hardness in advanced material.
9) To investigate optimum parameters by use of standard optimization technique.

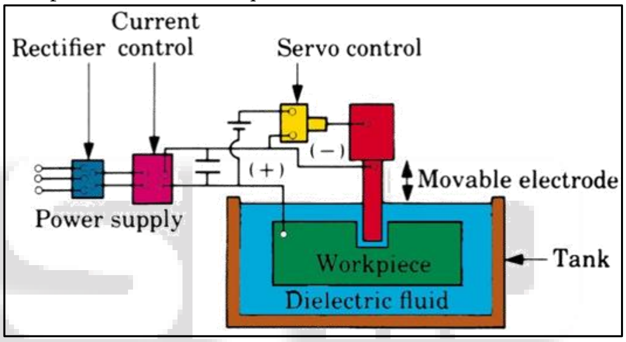

Fig. 4: Components & Working of WEDM

VI. Components of a Wire-Electrical Discharge Machining

A. *Computer Numerical Control*

Today’s numerical control is produced with the leads of the operator in mind. Programs, machine coordinates, cutting speeds, graphics and relevant information is displayed on color monitor, with easy to use menus. Numerical control offers the capabilities of scalling, mirror imaging, rotation, axis exchange an assist programs. This enables operator to produce an entire family of parts from a single program without the need to edit the program.

B. *Battery (Power Supply)*

When wire EDM machines were first introduced in the United States, they were equipped with power supplies that could achieve less than one square inch per hour. Today, most machines are rated to cut over 20 square inches per hour and faster. Faster or slower speeds are obtained depending on the workpiece material, part thickness, wire diameter, type of wire, nozzle position, flushing condition and required part accuracy.

C. *Mechanical Section*

Machine movement is accomplished with precision lead screws with recirculating ball bearings on all axes that are driven by AC motors. Before shipping the machine's position is checked and any errors or backlash are corrected by pitch error compensation that is permanently stored in the computer's memory.

D. Wire

When wire-EDM was first introduced, copper wire was used on the machines because it conducted electricity the best. But as speeds increased, its limitations were soon discovered. The low tensile strength of copper wire made it subject to wire breaks when too much tension was applied. Poor flush ability was another problem, due to cropper's high thermal conductivity.

Wire diameters ranges from .004" through .014" with .010" being the most commonly used. The wire originates from supply spool, then passes through a tension device.The wire being passes through a set of precision, round diamond guides, and is then transported into a waste bin. The wire can only be used once, due to it being eroded from the EDM process.

E. Dielectric system

Wire-EDM uses deionized water as the dielectric compared to vertical EDM's that use oil. The dielectric system includes the water reservoir, filteration system, deionization system, and water chiller unit. During cutting, the dirty water is drained into the unfiltered side of the dielectric reservoir where the water is then pumped and filtered through a paper filter, and returned to the clean side on the dielectric tank.

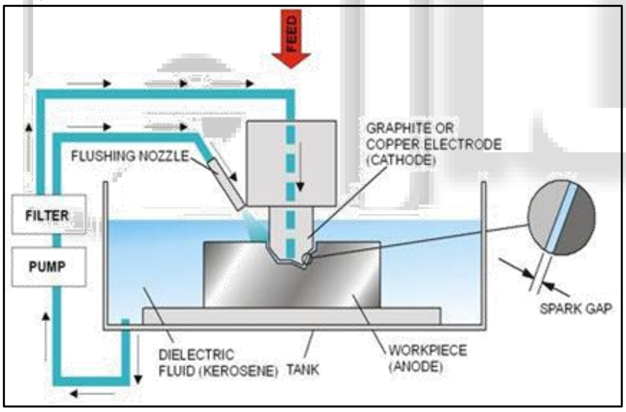

Fig. 2: Block Diagram WEDM

VII. Scope for the Future Work

Advanced materials can be manufactured by wire-EDM, the resulting recast layer must be characterized, and its formation must be understood. This project will develop a new data base for determination of parameters contributing for recast layer formation, which will help industries to predict and avoid fatigue failure of components.

To study surface integrity in Wire-EDM of advanced engineering materials which will help for the selection of proper process parameters for Wire-EDM of newly developed materials, such the machining of advanced engineering materials. Micro-fabrication, turning of metal bond diamond wheels and others, is not readily early available. It is currently used in the heat- treating industry for muffles, furnace components, heat-treating baskets, trays as well as in gas turbines, cryogenic tanks, and as fasteners or high temperature springs for aerospace applications.

As these system are environmental friendly and safe, one can except the scope of these system to expand both domestically and in emerging market. Also these system can be used in remote areas where lack of electricity. Thus further work is necessary to study to increase the performance of system. In conventional refrigeration system, compression machines are employed, which requires high-grade energy as input and this, is in the form of electricity. Therefore it is better to use the Vapour absorption refrigeration system which gives scope of utilizing low grade energy source i.e. solar panel for generating cooling effect which is dominated by high grade energy driven compression technology. Absorption refrigeration system provides large potential for reducing heat pollution of the environment. Therefore, in future it is decided to compare the performance between conventional systems and vapour absorption system using solar thermal energy.

VIII. Process Parameters

There are many process parameters which influences surface integrity after machining and has found effects like altered microstructure, tensile stresses, micro cracks, impurities which can lead to premature part failure when put to service so these parameters must be optimized to avoid failure of component.

Various wire –EDM parameters are listed below:

1) Peak discharge current
2) Pulse on time
3) Pulse off time
4) Spark energy
5) Wire feed
6) Wire diameter
7) Wire material
8) Dielectric properties
9) Dielectric flushing pressure

Amongst the above stated process parameters the input parameters for experimentation are to be selected for actual practice and measuring response in terms of Tribological Aspects and Surface integrity of the parameters selected.

A. For this Project Work the Input Parameters Are

1) Pulse on time (T○n) (μs)
2) Pulse off time (T○f) (μs)
3) Wire Feed (Wf) (m/min)

For this Project Work the Output Parameters Are

1) Recast layer thickness (μm)
2) Micro hardness (VH)

IX. Conclusion

After performing this Experiment we conclude following points:

1) Advanced materials like high nickel content superalloys or maranging steels possess high strength at elevated temperatures and resistance to oxidation and corrosion. The non-traditional manufacturing process of wire-electrical discharge machining (WEDM) possesses many advantages over traditional machining during the

manufacture of these superalloys parts. However, certain detrimental effects are also present.

2) Though DOE series of experiments are conducted on selected material and experimental investigation can be conducted to be determine the main machining parameters which contribute to recast layer formation in wire-EDM these materials and the results obtained are optimized using standard optimization techniques.

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