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Review of the impact of residual stresses on various parameters during a wire-cut EDM cutting process

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ABSTRACT

Wire cut EDM is a very sophisticated technique that is utilized in precision manufacturing. Because of the tiny residual stresses that exist inside a grain, mostly as a consequence of the existence of dislocations and other crystalline defects, residual stresses produced duringcutting operations must be taken into consideration. The primary goal of this study is to give an overview of current developments in the field of residual stress generation and theirimpact on different factors such as surface roughness, dielectric material utilized, and pulse on time during wire cut EDM. Examine the methods for measuring residual stress briefly as well.

Keywords: *Wire-Cut EDM, Residual Stresses, Performance Parameter, Advance ManufacturingProcess.*

1. INTRODUCTION

For precise component production, the WEDM is well known cutting technique. Wire electrical discharge is used in the nuclear reactor and automobile industries to manufacture complex, high-precision components. The WEDM method uses a pulsating current to erode material at the work piece and tool. At the conclusion of the discharge cycle, part of the molten metal solidifies again and is deposited on the cutting surface.

The tensions that remain in a material or body after manufacturing and processing arereferred to as residual stresses. Techniques for measuring residual stress measure strains rather than stresses. The residuals are then calculated using material characteristics likeYoung's modulus, Poisson's ratio, and Young's ratio.

2. LITERATURE SURVEY

J. Crookall et al. [1] at the University of California, San Diego discovered that electro- discharge machining induces extremely high residual tensile stresses. Residual stresses in various materials are proportional to their thermal and other characteristics and are usually unaffected by the tool electrode and dielectric material. They were found using the bending- deflection method, which is a very sensitive approach for constantly monitoring deflections caused by electrochemical cell stresses.

J. Liu et al. [2] simulate residual stress generation in die-sinking EDM of the ASP 23 tool steel, a novel modelling technique accounting for large random discharges has been devised. The highest value of average residual stress is determined in the subsurface rather than at the top surface, which is consistent with experimental results. The low residual stress on the surface is a result of the roughness of the surface.

B. Ekmekci et al. [3] investigates in their study that high tensile residual stresses are seen to increase quickly with depth, reaching a maximum value around the yield strength, and then rapidly decaying to compressive residual stresses in the material's core. This pattern isdependent on the thermal characteristics of the work piece material and the dielectric liquid. Additionally, there is a strong relationship between the n hardness depth and the afflicted layers.

R. Pan et al. [4] observed in their research that residual stresses are often generated during the quenching of aluminium alloys and pose a danger of cracking or distorting duringfollowing production operations. It is critical to investigate ways for minimising the RS in quenched components. Cold rolling (CR) was used in this study to remove the RS from quenched AA7050 blocks. Although CR converts near-surface residual stresses from high compression to high tension in the rolling direction, it achieves exceptional

RS alleviation in the core.

B. Ekmekci et al. [5] in their research work concludes that the dielectric liquid and electrode type have been investigated with the impact of retention of austenite and residual strainsusing X-ray diffraction methods on the structure of the white layer in electric discharge machining surfaces. The current study indicates that when machining with kerosene dialectic liquid, the surface is saturated with carbon regardless of the tool electrode material. However,residual Austenite forms on the surface as a result of carbon absorption from the graphite toolelectrode when using de-ionized water dielectrics.

H.-T. Lee et al. [6] perform the study to determine the effect of the EDM parameters on different elements of the surface integrity of AISI 1045 carbon Steel, this research carried outsmall area electro-discharging (EDM), using a low wear-rate cupper/tungsten electrode in the diameter of 1.5 mm. The findings show that visible fractures in larger white layers are alwaysapparent. It is observed that the MRR, SR and surface fracture density diminish during a prolonged period of the pulse.

S. Bhattacharya et al. [7] introduce the FE method that has been applied to simulate residualstresses generated the during WEDM cutting on the HAZ of P91 steel. Residual stresses areof Tensile in nature and can affect the service life of the components subjected to fatigue loading. This paper also describes the size of craters and heat affected zone.

W.P. Rehbach et al. [8] perform the study and develop an EDM drilling process for measuring residual stress in high-performance materials whose stress state is difficult to obtain using a commonly used technology called high-speed (HS) hole-drilling (ASTM Standard E837). SKD11 (JIS) tool steels were prepared at various pre-stress levels to simulate any residual stress that may exist in the work pieces. The experimental results indicate that the stress measurement curves for both EDM conditions are parallel to the ideal curve. This demonstrates the feasibility of measuring residual stress on materials with a high degree of hardness and wear resistance.

K. Bonny et al. [9] discovered that wire-EDM produces more friction and wear than grindingand polishing. This trend was confirmed by X-ray diffraction measurements, which revealed residual tensile surface stresses in WC following wire- EDM, in contrast to compressive surface stresses following ground and polished equivalents. Additionally, the researchers discovered that reduced surface quality had a significant effect on (running-in) wear behaviour, including binder depletion, residual surface stress, thermal grain cracking, and increased surface roughness.

Bulent Ekmekcia et al. [10] on the surfaces of electric discharge machined components, significant residual tensions occur. They rise in value as they approach the surface and eventually achieve their maximum worth. This highest value is close to the material's ultimate tensile strength. The layer removal approach is utilised in this work to determine the residual stress profile generated by die sinking type EDM as a function of depth under the surface. On samples machined with extended pulse durations, cracking and its effects are alsoinvestigated.

Philips Analytical et al. [11] the author describes the process of creating and configuring an electronic database for elastic constants. For materials having cubic, hexagonal, or tetragonal crystal symmetry, calculation models such as Voigt, Reuss, and Hill are provided. Data entries are checked to avoid the introduction of new typing mistakes.

Hwa-Teng Lee et al. [12] the measurement of residual stress in AISI D2 cold work tool steelis investigated using the electro discharge machining (EDM) hole-drilling technique. The microstructure and hardness of the white layer that had re-solidified on the EDMed surface were studied using scanning electron microscopy, transmission electron microscope, and Nano indentation methods.

Shuvra Das et al. [13] in this paper, a finite element-based model of the electric discharge machining (EDM) process is introduced. The transitory temperature distribution, liquid-to- solid-state material transition, residual stress, and ultimate crater shape are all predicted bythe model. In the near future, the model will be extended to mimic the impacts of numerous pulses.

Y.H. Guua et al. [14] AISI D2 tool steel was used for the investigation of electrical discharge machining (EDM). A study was conducted to determine the surface characteristics and machining damage produced by EDM in terms of machining parameters. The results show that the thickness of the recast layer and the roughness of the surface are related to the amount of power used. Increased peak currents result in an increase in the melting of the material, resulting in significant damage to the surface and subsurface areas of the structure.

F. Ghanem et al. [15]This research looks at how machining affects the fatigue life of an EN X155CrMoV12 tool steel (SAEJ438b) The cutting processes of electro-discharge machining (EDM), which has a high energy density, and milling, which is more traditional, were compared. When comparing the EDM samples to the milled samples, it was discovered that the fatigue limit was reduced by about 35%. This was ascribed to the presence of a tensile residual stress state after EDM, which was coupled with substantial phase change and hydrogen embrittlement to produce the observed results. Compressive residual stresses were found in the milled surfaces, despite the fact that there was no microstructural change or surface cracking.

J.F. Liu et al [16] the current EDM modelling approaches are only capable of simulating onedischarge. In die-sinking EDM of the ASP 23 tool steel, a novel model has been created to predict residual stress generation. The highest value of average residual stress is found in the subsurface rather than the top surface, which is consistent with experimental results. To produce reduced tensile residual stress, lower discharge energy is desired in EDM.

A. Umapathi et al.[17] Using synchrotron radiation X-rays from BL-11 at INDUS-2, RRCAT, Indore, India, the residual stress distribution due to laser peening without coating (LPwC) was studied. The findings demonstrate that depending on the titanium alloy, LPwC causes greater and deeper residual stress. Although compressive residual stress (CRS) was found in the majority of instances, tensile residual stress (TRS) was only found in a handfulof them.

N.S. Rossini et al. [18] many constructed structures and components have residual stresses. For different types of components, several methods for measuring residual stress have been devised. The purpose of this study is to identify the various residual stress measuring methods and to give an overview of some of the most recent advancements in this field. The breadth, physical limitations, advantages, and drawbacks of each approach are outlined.Finally, it suggests some possible future development directions.

X. Yanga et al. [19] the generation mechanism of residual stress and its distribution were simulated using molecular dynamics techniques in this research. Residual stress is one of the key features of the surface machined by electrical discharge machining (EDM). It wasdiscovered that during discharge, a greater pressure gradient was formed in the melting area. This indicates that cracks can easily form in the re-solidified layer.

Yukio Ueda et al. [20] in a new article, a new method for measuring three-dimensional residual stresses is provided. The approach is used to calculate residual stresses in a quenchedshaft, and it is shown to be reliable and practical. It is based on Sachs' finite elementapproach, which he developed in 1975.

Philip Allen et al. [21] in many materials, micro electro-discharge machining (micro-EDM)is an excellent method for achieving burr-free machined micron-size holes. A thermo- numerical model that replicates a single spark discharge process is used to investigate material removal. The impacts of critical EDM parameters like pulse length on the crater dimension and tool wear % are investigated using the numerical model. The model predicts that when the pulse rate increases, the percentage of tool wear falls, with molybdenum havinga considerably greater percentage of tool wear than steel under machining circumstances.

3. CONCLUSION

The following are the findings based on various literature reviews.

- Residual stresses in different materials are related to their thermal and other properties, andthey are generally unaffected by the tool electrode and dielectric material.
- Between the hardness depth and the number of affected layers, there is a significantconnection.
- The subsurface, rather than the top surface, has the greatest average residual stress value.In EDM, decreased discharge energy is sought to minimise tensile residual stress.
- It was found that a larger pressure gradient was generated in the melting region duringdischarge. This implies that fractures in the re-solidified layer are likely to develop.
- Increased pulse rate results in a decrease in the percentage of tool wear.
- The material removal rate, surface roughness, and surface fracture density all decreasewith the duration of the pulse.

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