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Original Research Article

Influence of the cut direction through the semi-finished product on the occurrence of cracks for X210Cr12 steel using WEDM

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ABSTRACT

Wire electrical discharge machining (WEDM) is a key technological process for the production of parts from semi-finished products to the final heat treatment as it also enables the machining of very hard material. The quality of an electro-erosive machined surface is a very important factor with regard to the consequent functionality and life cycle of the manufactured part. The occurrence of cracks or burned cavities is therefore an acceptable defect of the sub-surface area, which along with residual stress may lead to the destruction of the machining. This study deals with the influence of the cut direction through a semi-finished product on the occurrence of defects (cracks, burned cavities) regarding the influence of setting up the parameters of the machine (gap voltage, pulse on and off time, wire feed and discharge current) and the type of heat treatment of the material. In order to study the surface and sub-surface area of the machined samples, electron microscopy was used, including the use of the local EDX chemical analysis.

1. Introduction

Electrical discharge machining (EDM) methods of electrically conductive material is based on the use of heat energy generated by electrical discharges between electrodes (tool/workpiece) in the presence of dielectrics [1,2]. Melting and evaporation removes microscopic particles from the machined material, which are drained from the cutting area by a dielectric fluid current [3,4].

Wire electrical discharge machining (WEDM) is a cutting technology that uses a 0.3–0.02 mm electrode wires (see the scheme in Fig. 1). WEDeM is a fundamental technological process in many manufacturing industries, including aerocraft, automotive, military or the medical industries [5,6]. As a result of the broad use of this unconventional machining technology, demands on the performance characteristics are

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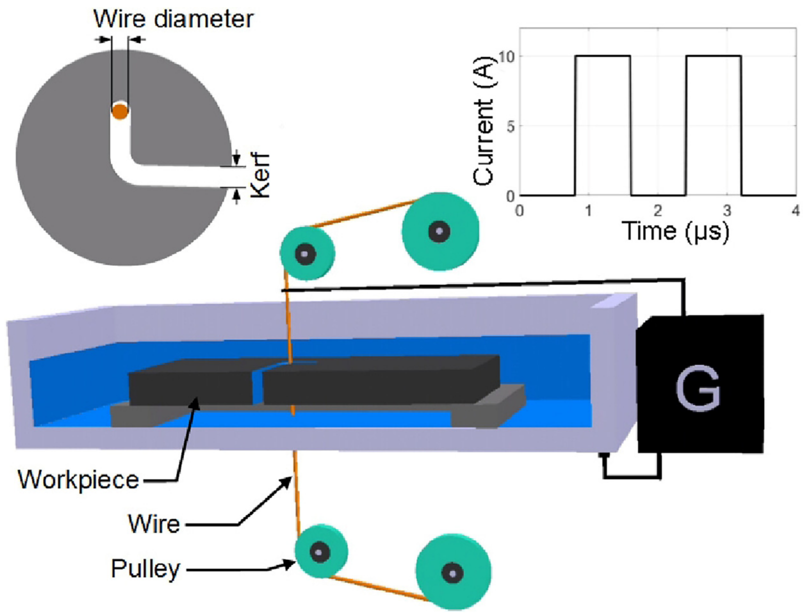

Fig. 1 – Schematics of electrical discharge wire machining.

continuously growing. It primarily deals with dimensional accuracy, speed of reducing material and the quality of the machined surface. These characteristics depend on the type of material and its heat treatment, on the wire electrode and dielectrics used, on the conditon of the machine and also on the selection of the erosion process parameters. Using the full potential of the electro-erosive wire machining process is very difficult due to the many possibilities of changing the parameters. For this reason, extensive research was carried out (16MnCr5 steel machined using WEDM [7], pure aluminum machined using WEDM [8], comparison of morphology and topography of surfaces after WEDM [9], Ti–6Al–4V machined using WEDM [10], effect of width of kerf on machining accuracy [11]) with the objective to predict the resulting quality of the machined surface of various construction material with and without heat treatment. Another objective of this research was to study the defects of an electro-erosive machined surface, on which micro-cracks and cracks may occur. These can further expand with the influence of inner stress in the machining and initiate the occurrence of larger cracks on the entire surface of the particular part.

Klink [28] focused in their study on the minimization or removal of the thermal damage in the main cut by subsequent multiple trim cuts at a reduced discharge energy. They claim that although wire EDM is the most detrimental to surface integrity compared to hard turning and grinding, the degree of thermal damage does not depend only on process conditions but also on EDM generators. Thus, with the development of low energy generators and EDM strategy, thermal damage could be minimized. Kuruvila [29] studied the determining parametric influence and optimum process parameters of wire EDM using Taguchi's technique and Genetic algorithm, where pulse-on duration, current, pulse-off duration, bed-speed and flushing rate were considered as the important input parameters. Hot Die Steel was chosen as a material for the experiments, which confirmed the efficiency of the approach employed for optimization of process parameters. In their study Huang [30] used martensitic stainless steel for multi-cutting passes by WEDM, where the steel was roughly machined at first cutting pass, semi-finished by two cutting passes, and then finished by one cutting pass. For all four cutting passes a negatively polarized wire electrode was employed (with the heat-affected zone developed), then some finished specimens were further extra-finished by using the positively polarized wire electrode (without any heat-affected zone detected). The difference was further on explained based on the theory of electrical discharging and metallurgical physics. Lodhi [31] also focused on Taguchi's methodology in their research, based on which an attempt to optimize the machining conditions for surface roughness has been made. In the experiments pulse-on-time, pulse-off-time, peak current, and wire feed were varied; whereas an orthogonal array, the signal-to-noise ratio, and the analysis of variance were used to study the surface roughness. According to the results obtained, the discharge current was the most influential factor on the surface roughness. Bobbili [32] focused on the influence of machining parameters on surface roughness and material removal rate of high strength armor steel using WEDM. The experiment was also based on Taguchi's technique employing six process parameters, such as pulse-on-time, pulse-off-time, wire feed, flushing pressure, spark voltage, and wire tension. It was observed that pulse-on-time, pulse-off-time, and spark voltage proved to be significant variables to material removal rate and surface roughness. Huang [33] studied the process of multi-cutting of quenched and tempered high-speed steel with WEDM by using a brass wire electrode. Their experiment resulted in the detection of the surface alloying between the steel and wire electrode materials in the recast layer. Meanwhile, the martensitic transformation could also be found. Zhang [34] tried to