

Increasing the productivity of the wire-cut electrical discharge machine associated with sustainable production



Ibrahim Maher^{a, b}, Ahmed A.D. Sarhan^{a, c, *}, Mohsen Marani Barzani^a, M. Hamdi^a

^a Centre of Advanced Manufacturing and Material Processing, Department of Mechanical Engineering, Faculty of Engineering, University of Malaya, 50603 Kuala Lumpur, Malaysia

^b Department of Mechanical Engineering, Faculty of Engineering, Kafrelsheikh University, Kafrelsheikh 33516, Egypt

^c Department of Mechanical Engineering, Faculty of Engineering, Assiut University, Assiut 71516, Egypt

ARTICLE INFO

Article history:

Received 16 October 2014

Received in revised form

10 June 2015

Accepted 10 June 2015

Available online 19 June 2015

Keywords:

Sustainable production

Energy consumption

Wire-cut EDM

ANFIS

Taguchi

ABSTRACT

Wire-cut electric discharge machining is a nontraditional technique by which the required profile is acquired using sparks energy. Concerning wire-cut electric discharge machining, high cutting rates and precision machining is necessary to improve productivity and achieve high quality of machined workpieces. In this research work, an experimental investigation was introduced to achieve higher productivity of the wire electrode associated with sustainable production in terms of product quality and less heat-affected zone. For this purpose, the effects of machining parameters including peak current, pulse on time and wire preloading were investigated using adaptive neuro-fuzzy inference system along with the Taguchi method. From this study, the optimal setting of machining parameters to achieve higher productivity and sustainability was identified. Moreover, Neuro-fuzzy modeling was successfully used to build an empirical model for the selection of machining parameters to achieve higher productivity at highest possible surface quality and minimum cost for sustainable production.

© 2015 Elsevier Ltd. All rights reserved.

1. Introduction

Wire-cut electric discharge machining (Wire-cut EDM) is an advanced machining process for machining complicated shapes of hard conductive materials (Sommer and Sommer, 2013). Wire-cut EDM is usually used when low residual stresses are required, because it does not entail high cutting forces for material removal. Wire-cut EDM can machine any electrically conductive materials regardless of the hardness, from common materials such as copper, aluminum, tool steel, and graphite, to unusual modern alloys including wafer silicon, Inconel, titanium, carbide, polycrystalline diamond compacts. Besides, Wire-cut EDM is also used to machine modern composite materials such as conductive ceramics (Ho et al., 2004; Maher et al., 2015c). In Wire-cut EDM, the workpiece is machined with a series of electrical sparks that are produced between the workpiece and the wire electrode. The wire electrode discharges high frequency pulses of alternating or direct current to

the workpiece through a very small spark gap with a nonconductive dielectric fluid. Many sparks can be easily seen instantaneously at the cutting zone because sparks happen more than one hundred thousand times per second (El-Hofy, 2005). Cutting rate and surface quality are usually used to optimize the material removal rate (productivity) during the period of spark discharge. The productivity in Wire-cut EDM associated with sustainable production depend on a large number of machining parameters, as shown in Fig. 1, like electrical spark (discharge current, pulse width, etc.), wire electrode (shape, tension, material and speed), workpiece (high and material), and nonelectrical (dielectric fluid and flow rate) parameters. Productivity and quality are directly related. Practically, the productivity increases with increasing the energy consumption (voltage, current, and pulse on time) and decreases with decreasing the energy consumption. On the other hand, surface finish would decrease with increasing the discharge voltage, current, and pulse width (Yeh et al., 2013; Yu et al., 2011).

In this research work, the authors would like to achieve higher productivity of the wire electrode in Wire-cut EDM associated with sustainable production in terms of work piece good surface quality and less heat-affected zone. Several efforts have been made to find the ideal machining conditions to enhance the productivity and improve the sustainability achieving high product quality by

* Corresponding author. Centre of Advanced Manufacturing and Material Processing, Department of Mechanical Engineering, Faculty of Engineering, University of Malaya, 50603 Kuala Lumpur, Malaysia. Tel.: +60 3 7967 4593; fax: +60 3 7967 5330.

E-mail address: ah_sarhan@yahoo.com (A.A.D. Sarhan).

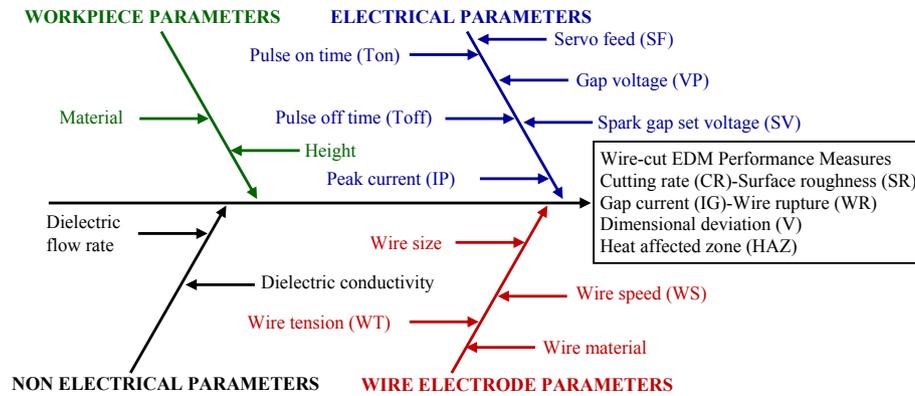


Fig. 1. W-EDM process parameters.

increasing the cutting rate and decreasing the surface roughness (Barzani et al., 2015; Kant and Sangwan, 2014). Nourbakhsh et al. (2013) studied the effect of injection pressure, servo reference voltage, time between two pulses and pulse width on surface integrity, wire rupture and cutting speed. It was revealed that cutting speed increases as pulse width increases; surface roughness decreases as the time between the two pulses decreases; and wire rupture is sensitive to injection pressure, wire mechanical tension, time between two pulses and pulse width. Besides, Gökler and Ozanözgü (2000) studied the effects of cutting parameters on the surface roughness of 1040, 2379 and 2738 steel and practical Wire cut-EDM results have been acquired. El-Hofy (2005) revealed that during Wire-cut EDM, the discharge temperature can reach up to 12,000 °C, and metallurgical changes happen in the workpiece surface layer. Moreover, a thin heat affected zone layer of 1 μm at 5 μJ energy to 25 μm at high energy is formed. Levy and Maggi (1990) introduce that the heat-affected zone together with the solidified layer reaches 25 μm. The zone under the machined surface can be annealed. In addition, some of molten material is not ejected into the dielectric fluid and chills quickly, mainly by heat conduction into most of the workpiece, resulting in a hard surface. The annealed layer depth is proportional to the energy used in the cutting process. It is around 50 μm for finish cutting to approximately 200 μm for high cutting rates, as shown in Fig. 2 (El-Hofy, 2005; McGeough, 1988). The recast layer appears at different spark erosion conditions and it contains many pockmarks, globules, cracks, and micro cracks. There are three types of recast layers. Type 1 is a featureless, single layer less than 10 μm thick. Type 2 is an etchable, single layer 10–20 μm thick. Type 3 is a multilayer, 20 μm thick or greater, and consists of overlapping solidified layers (Tomlinson and Adkin, 1992). Researchers have carried out several investigations and have noted that this layer is obvious under all machining conditions, including when water is used as dielectric material (Jangra et al., 2011; Ramasawmy et al., 2005).

To acquire low surface roughness and small heat-affected zone, low discharge energy parameters (low energy consumption) with high dielectric flushing rate are required. However, such

parameters decrease the material removal rate. This implies that a high cutting rate with minimum surface defects is difficult to attain from a single parameter setting. To achieve the productivity of the wire electrode and good quality associated with sustainable production and low energy consumption; mathematical modeling between Wire-cut EDM parameters and performance measures should be obtainable to manufacturers. Theoretical and empirical approaches are commonly used for Wire-cut EDM modeling (Patil and Brahmkankar, 2010). Owing to the simplified and mandatory assumptions, the theoretical models yield big errors between the predicted and experimental results. Nevertheless, empirical models are limited to specific experimental conditions. The Taguchi method and response surface methodology (RSM) are the most often employed statistical techniques for determining the relationship between different controllable parameters and output performance (Davoodi and Tazehkandi, 2014; Hewidy et al., 2005). Moreover, Fuzzy logic and feed forward neural network has been used to model the process and correlate the parameters with the performance measures (Marani Barzani et al., 2015; Ooi et al., 2015). ANFIS has also been applied to model the process of predicting machining performance (Maher et al., 2015a, 2014). Although the optimization of process parameters have been considered in these techniques, there are limited studies about energy consumption of the wire-cut EDM, which are important for factor economics.

Because Wire-cut EDM involves multi-performance characteristics, the main objective of this study is to find a combination of Wire-cut EDM parameters to achieve rapid cutting speed as well as low surface roughness and small heat-affected zone to meet the demands for increasing the wire electrode productivity and product quality associated with sustainable production and low energy consumption. For this reason, ANFIS modeling is introduced as it is one of the soft computing techniques that play an important role in input–output parameter relationship modeling. Using ANFIS model, we can predict the required level of performance to increase the productivity at highest possible level of product quality for sustainable production.

2. Experimental work

In this research work, the experiments are carried out in wire-cut electric discharge machine to improve the productivity associated with better surface quality and minimum energy consumption for sustainable production. This section describes the experimental setup and the machined samples preparation for morphological characterization.

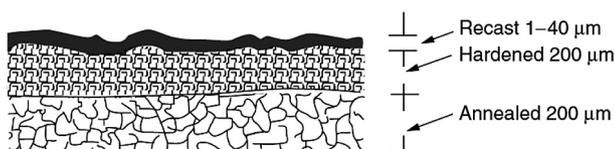


Fig. 2. EDM heat affected zone (El-Hofy, 2005).

متن کامل مقاله

دریافت فوری ←

ISIArticles

مرجع مقالات تخصصی ایران

- ✓ امکان دانلود نسخه تمام متن مقالات انگلیسی
- ✓ امکان دانلود نسخه ترجمه شده مقالات
- ✓ پذیرش سفارش ترجمه تخصصی
- ✓ امکان جستجو در آرشیو جامعی از صدها موضوع و هزاران مقاله
- ✓ امکان دانلود رایگان ۲ صفحه اول هر مقاله
- ✓ امکان پرداخت اینترنتی با کلیه کارت های عضو شتاب
- ✓ دانلود فوری مقاله پس از پرداخت آنلاین
- ✓ پشتیبانی کامل خرید با بهره مندی از سیستم هوشمند رهگیری سفارشات