Multi-Objective Optimization of EDM Process Parameters using Taguchi Method, Principal Component Analysis and Grey Relational Analysis

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ABSTRACT

This paper investigates multi-objective optimization of electrical discharge machining process parameters using a new combination of Taguchi method and principal component analysis based grey relational analysis. In this study, three conflicting performance characteristics related to surface integrity such as surface roughness, white layer thickness and surface crack density are considered in electrical discharge machining of RENE80 nickel super alloy. The process parameters considered are peak current, pulse on time and pulse off time. The experiments are conducted based on Taguchi method and these experimental results are used in grey relational analysis and weights of the corresponding performance characteristics are determined by principal component analysis. The weighted grey relational grade is used as a performance index to determine optimum process parameters and results of the confirmation experiments indicate that the combined approach is effective in determining optimum process parameters.

Keywords: Electrical Discharge Machining, Grey Relational Analysis, Multi-Objective Optimization, Principal Component Analysis, Taguchi Method, Weighted Grey Relational Grade

INTRODUCTION

Electrical discharge machining (EDM), a nontraditional machining method is capable of processing ‘difficult to machine materials’ easily to desired complex shapes with high precision and dimensional accuracy. It is extensively used in machining very hard, high strength, high temperature resistant materials used in aerospace, automotive, tool and die
industries (Ho & Newman, 2003). EDM can machine any electrical conductive material and its advantage is that there is no physical contact between the electrode and work piece. The quality of the surface characteristics of parts produced by EDM heavily depends on large number of process parameters. The key factor of interest in EDM is the selection of optimum parameter setting such that the surface integrity characteristics are improved, otherwise the components may fail during usage especially in aerospace applications. The significant surface integrity characteristics are surface roughness (SR), white layer thickness (WLT) and surface crack density (SCD) which judge the machining performance and are conflicting in nature. In practice, these should be very low as they reduce the fatigue life of the EDM components under severe thermal and mechanical loadings during service (Bhattacharyya, Gangopadhyay, & Sarkar, 2007). RENE 80 nickel base super alloy is one such super alloy which has wide applications in aerospace industries due to its high hardness, high degree of strength and creep properties coupled with oxidation and corrosion resistance at elevated temperatures (Ezugwu, Bonney, & Yamane, 2002). It is difficult to machine this super alloy using conventional machining processes due to its high hardness, low thermal conductivity and high affinity to react with the tool materials at high temperature generated during machining (Choudhary & El-Bardie, 1998). RENE 80 can be machined by EDM and selection of optimum process parameters is crucial in attaining the required surface integrity characteristics in critical aerospace parts.

The manufacturing industries are now looking at multi objective optimization as they cannot compromise with a single objective optimization in the present day rapid changing environment and moreover, majority of the real world problems involve multi objective optimization. Among the various multi-objective optimization methods, GRA has become a powerful tool to analyze processes with multiple performance characteristics in recent years (Jeyapaul, R., Shahabudeen, P., & Krishnaiah, 2005). Jung and Kwon (2010) applied GRA for optimizing machining parameters like input voltage, capacitance, resistance, feed rate and spindle speed in micro EDM for minimization of diameter and maximization of aspect ratio. Lin and Lee (2009) focused their studies on optimization of multiple performance characteristics in magnetic force assisted EDM using GRA. Chiang and Chang (2006) addressed optimization of wire EDM process using multiple response analysis based on GRA. Process parameters such as pulse on time, pulse off time, voltage, wire feed, dielectric flow and cutting radius of work piece and responses such as metal removal rate and SR are considered. Lin, Lin and Ko (2002) used GRA based Taguchi method for multi response optimization of metal removal rate, electrode wear ratio and SR considering process parameters such as discharge current, pulse on time and pulse off time. Concluded that GRA based Taguchi method is more straight forward than the fuzzy based Taguchi method. Kao, Tsao and Hsu (2010) addressed multi-objective optimization of EDM process parameters for machining Ti-6Al-4V using L9 orthogonal array combined with GRA. Assigned equal weights to responses and the results show an improvement in material removal rate, SR and electrode wear ratio by 12%, 19% and 15% respectively. Similarly, many researchers applied GRA to different machining processes. Pan, Wang, Wei and Sher (2007) used Taguchi based GRA to find optimum setting in laser welding of titanium alloy and it is observed that there is an improvement in all the characteristics as compared to conventional welding except SR which increased drastically and concluded that all performance characteristics cannot be improved simultaneously in certain situations. Pawade and Joshi (2011) used GRA for optimization of SR and cutting forces in high speed machining of Inconel 718. Assigned weights to responses arbitrarily and concluded that different weights for different responses may lead to different optimum solutions.

From literature studies it is observed that many researchers and academicians decided weights of each performance characteristic
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