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Full Length Article

ANN-NSGA-II dual approach for modeling and optimization in abrasive mixed electro discharge diamond grinding of Monel K-500

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ABSTRACT

Hybrid machining processes (HMPs) have attracted the attention of investigators from both academia and industry due to their enhanced process performance and capabilities while machining so-called difficult-to-cut materials. In this paper, the dual approach of Artificial Neural Network (ANN) and Non-Dominated Sorting Genetic Algorithm-II (NSGA-II) was used to model and optimize a new HMP called as Abrasive Mixed Electro Discharge Diamond Grinding (AMEDDG). Due to complex nature of AMEDDG process, the choice of an appropriate coalition of input factors is an effortful job for machinist. The central composite rotatable design was used to plan the experiments and ANN model was established to observe the effect of input machining parameters viz. Wheel speed, powder concentration, pulse current, and pulse-on-time on material removal rate (MRR) and average surface roughness (R_a). The established ANN model was found to be capable of forecasting the output responses within tolerable limits for the chosen set of machining parameters. An ANN-NSGA-II based dual approach was applied for multi-objective optimization of control factors in AMEDDG, and experimental validation directs that optimal data was in tolerable limits.

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1. Introduction

Hybrid machining processes (HMPs), in the present scenario, could offer possible solutions to machine difficult-to-cut materials. The HMPs combines two or more machining processes that take part in material removal by uniting potential advantages involved in both the processes and reducing limitations of individual processes [1]. In numerous HMPs, electro-discharge diamond grinding (EDDG) is recently being more popular for processing electrically conductive materials [2]. EDDG combines the electro-discharge erosion action of electric discharge machining (EDM) and the mechanical abrasion of diamond grinding for material removal, and therefore significantly improves the material removal rate (MRR) and average surface roughness (R_a) compared with the standalone EDM process [3].

Koshy et al. [4] elucidated the material removal intervention involved in EDDG through performing it on high speed steel (HSS) and reported a reduced specific energy as well as grinding force as results from the thermally softened workpiece. Further, the influence of the wheel speed on machining of HSS was inspected by Yadav et al. [5] and reported that the parameter is most significant for MRR. The EDDG was further configured for face grinding of WC-Co composite, and HSS and the performance was investigated [6]. The researcher indicated that high current and wheel-speed are more appropriate for high MRR. It is also revealed that the grinding wheel glazing occurs by lower current and low wheel-speed. To overcome the several issues like incessant damage of abrasive particles, higher wheel-wear-rate, gathering of debris and unusual arcing; Yadav and Yadava [7] developed slotted-electro-discharge diamond grinding (S-EDDG). They reported that S-EDDG performance is better as related to integral processes. The abrasive or powder addition in dielectric during EDM action

Abbreviations: HMPs, Hybrid machining processes; ANN, Artificial Neural Network; EDM, Electro discharge machining; EDG, Electric discharge grinding; ECA, Evolutionary computational algorithms; NSGA-II, Non-Dominated Sorting Genetic Algorithm-II; AMEDDG, Abrasive Mixed Electro Discharge Diamond Grinding; EDDG, Electro discharge diamond grinding; MRR, Material removal rate; WC-Co, Tungsten carbide-cobalt; S-EDDG, Slotted-electrical discharge diamond grinding process; CCRD, Central composite rotatable design; SCG, Scaled conjugate gradient; MSE, Mean square error; IEG, Inter electrode gap; PC, Powder concentration; CD, Crowing distance; SiC, Silicon carbide; HSS, High speed steel.

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Nomenclature

R_a	Average surface roughness	C	Pulse current
W	Wheel speed	T_{on}	Pulse on-time

results in favourable conditions for higher MRR and better surface finish. A modified version of EDDG called as Electrical Discharge Diamond Peripheral Surface Grinding has recently developed to machine Al/SiCp/B4Cp hybrid metal matrix composite [8]. Tag et al. [9] investigated EDDG while machining of polycrystalline diamond and showed the effectiveness of the process in machining hard material like a polycrystalline diamond. The application of EDDG in reaction-bonded silicon carbide was recently attempted by Rao et al. [2].

Recently, Unune et al. [10,11] performed EDDG while machining Nimonic 80A and Inconel 718 in the presence of abrasive mixed dielectric and named process as abrasive mixed electro discharge diamond grinding (AMEDDG). They claimed a considerable improvement in MRR by mixing silicon carbide (SiC) abrasives in the dielectric (See Fig. 1.).

The AMEDDG process is a recent development in the area of EDDG and needs further exploration regarding the analysis of process performance in terms MRR and R_a on different materials. It is a well-known fact that the discharge behavior of any electro-discharge machining (EDM) variants is unpredictable and non-isoenergetic which causes unequal material removal in each discharge [12]. Speculative behavior in AMEDDG is attributed from the same fact and due to which, it is very challenging even for a skilful machinist to attain an optimal performance benchmark by optimizing the control variables. The evolutionary computational algorithms (ECA) like genetic algorithms (GAs) and particle-swarm optimization were used to treat multi-objective optimization problems [13]. Several studies developed process models of EDDG process based on analytical, statistical and intelligent techniques to predict the performance measures like MRR and R_a based on control variables [14,15]. However, owing to the multifarious and non-linear correlation among the control variables and performance variables, it is relatively challenging to establish a model of an accurate process for determining optimal machining conditions in EDDG process. The soft computing methods such as ANN, GA have presented large competency in explaining the problem of complex non-linearity [16,17]. The ANN modelling provides benefits like the capability to arrest complex and non-linear behavior of process factors; learning and generalization of data patterns; quick learning rate tolerating noise in data [18,19]. Unune and Mali [15] developed and claimed more prediction accuracy of ANN model as compared to RSM model while predicting the performance of EDDSG process.

The GA, over a past decade and beyond, has already proven to effective approach in solving multi-objective optimization problems with conflicting objectives. The GA uses genetic operators to find optimal solutions without any assumptions about the search space. GA works with a population of feasible solutions and, therefore, it can be used in multi-objective optimization problems to capture a number of solutions simultaneously [20]. The NSGA-II is competent and famous ECA to solve multi-objective optimization problems due to three special characteristics, fast non-dominated sorting approach, fast crowded distance estimation procedure and simple crowded comparison operator. Several investigators involved ANN and NSGA-II approach in modelling and optimization of input machining parameters in different fabri-

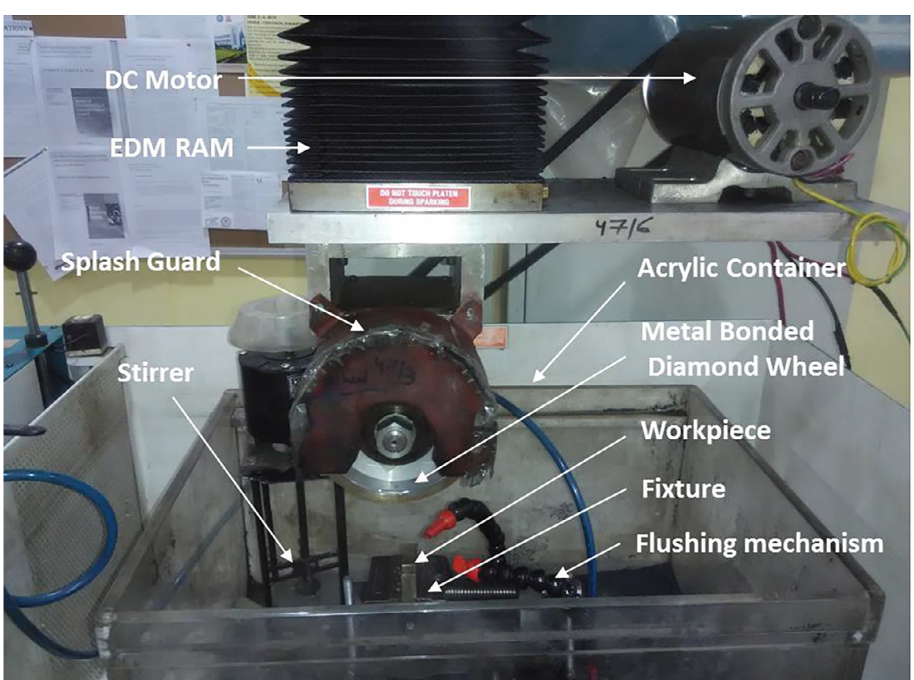

Fig. 1. Photograph of AMEDDG Setup [10]

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