Preface

Nowadays, there has been increased interest in developing computational methods for optimizing manufacturing technology. This book captured the latest research developments in this subject, providing applications of this important matter. Today, due to the great complexity of manufacturing technology and the high number of parameters used conventional approaches are no longer sufficient. Therefore, in manufacturing, computational techniques have achieved several applications, namely, manufacturing processes monitoring and control, manufacturing parameters modelling, process optimisation, process planning, et cetera.

The current research book is a collection of cutting-edge research chapters in the field of computational methods for optimizing manufacturing technology contributed by leading researchers from across the globe.

This research book can be used as a support book for final undergraduate engineering course (for example, mechanical, industrial, manufacturing, etc) or as a subject on computational methods in manufacturing at the postgraduate level. But, in general, this research book can be used for teaching modern manufacturing engineering.

Also, this book can serve as a useful reference for academics, manufacturing and computational sciences researchers, mechanical, industrial and manufacturing engineers, and professionals in related industries with manufacturing technology.

The purpose of this research book is to present a collection of fifteen chapters illustrating the state-of-the-art and research developments to computational methods for optimizing manufacturing technology.

Pranab K. Dan *et al.* (Chapter 1) describe applications of soft-computing methods in Cellular Manufacturing. According to the authors, the essential problem in Cellular Manufacturing System (CMS) is to identify the machine cells and subsequent part families with an aim to curtail the intercell and intracell traffic, known as Cell Formation Problem (CFP). This chapter portrays the need of soft-computing methods to model the CFP to attain enhanced solutions. The novelty of this chapter is in developing a hybrid state-of-the-art metaheuristic approach, namely SAHCF (Simulated Annealing Heuristic to Cell Formation), to solve the binary CFP, and further, a Fuzzy-ART based hybrid technique is framed to solve the generalized CFP using operational time. The proposed techniques are tested on the test datasets published in the past literature. Both the techniques are shown to outperform the published methods available in literature and attained enhanced results by exceeding the solution quality on the test problems.The originality of this study lies in designing simple and efficient methodologies to produce near optimal solutions for the shop-floor managers with minimum computing abilities and time.

M. Kanthababu (Chapter 2) describes multi-objective optimization of manufacturing processes using evolutionary algorithms. According to the author, recently evolutionary algorithms have created more interest among researchers and manufacturing engineers for solving multiple-objective problems. The objective of this chapter is to give readers a comprehensive understanding and also to give a better insight into the applications of solving multi-objective problems using evolutionary algorithms for manufacturing processes. The most important feature of evolutionary algorithms is that it can successfully find globally optimal solutions without getting restricted to local optima. This chapter introduces the reader with the basic concepts of single-objective optimization, multi-objective optimization, and evolutionary algorithms, and also gives an overview of its salient features. Some of the evolutionary algorithms widely used by researchers for solving multiple objectives have been presented and compared. Among the evolutionary algorithms, the Non-dominated Sorting Genetic Algorithm (NSGA) and Non-dominated Sorting Genetic Algorithm-II (NSGA-II) have emerged as most efficient algorithms for solving multi-objective problems in manufacturing processes. The NSGA method applied to a complex manufacturing process namely plateau honing process considering multiple objectives has been detailed with a case study. The chapter concludes by suggesting implementation of evolutionary algorithms in different research areas that hold promise for future applications.

F. Nagata *et al.* (Chapter 3) describe self control and server-supervisory control for multiple mobile robots and applicability to intelligent DNC. According to the authors, multiple mobile robots with six PSD (Position Sensitive Detector) sensors are designed for experimentally evaluating the performance of two control systems. They are self-control mode and server-supervisory control mode. The control systems are considered to realize swarm behaviors such as Ligia exotica. This is done by using only information of PSD sensors. Experimental results show basic but important behaviors for multiple mobile robots. They are following, avoidance, and schooling behaviors. The collective behaviors emerge from the local interactions among the robots and/or between the robots and the environment. The objective of the study is to design an actual system for multiple mobile robots, and to systematically simulate the behaviors of various creatures who form groups, such as a school of fish or a swarm of insect. Further, the applicability of the server-supervisory control scheme to an intelligent DNC (Direct Numerical Control) system is briefly considered for future development. DNC system is an important peripheral apparatus which can directly control NC machine tools. However, conventional DNC systems can neither deal with various information transmitted from different kinds of sensors through wireless communication nor output suitable G-codes by analyzing the sensors information in real time. The intelligent DNC system proposed at the end of the chapter aims to realize such a novel and flexible function with low cost.

M. Chandrasekaran *et al.* (Chapter 4) describe online machining optimization with continuous learning. According to the authors, in offline optimization of machining process with traditional or soft computing techniques, the functional relationship between the tool life and the cutting parameters are often assumed. Application of these techniques on the shop floor involves a number of constraints and has many limitations in its implementation. The complex machining process gets influenced by multiple process parameters particularly in a finish turning operation which often determines the final quality of the parts. In this work, an online optimization methodology with continuous learning is proposed and applied to finish turning process. Surface roughness is predicted using a virtual machine modeled with neural network and empirical equation. Minimization of machining cost is considered as an optimization objective. Optimization is carried out using simplex search or a fuzzy optimization method to determine optimum process parameters. The simulated data obtained from online machining can be stored and used for online learning of machining process. An artificial intelligence (AI) based online learning strategy proposed in this work determines the optimum cutting condition accurately without consuming significant time and resources at the shop floor. The new approach is more suitable and economical for shop floor applications.

N. A. Fontanas *et al.* (Chapter 5) describe computational techniques in statistical analysis and exploitation of CNC machining experimental data. According to the authors, extracting CNC machining data on- or off-line demands thorough and careful planning. Exploitation of this data can be carried out by statistical methods, in order to obtain the most influential parameters along with their respective level of significance. However, significance of machining parameters varies according to the posed quality characteristics at each machining phase. In actual experiments, measuring devices and assemblies are used and data is recorded in computer archives. To shorten the production time and cost, machining processes are planned on CAM software especially when complex part geometries, such as sculptured surfaces, are involved. Hence, planning machining experiments using CAM software modules is an efficient approach for experimentation on the actual CNC machine tools. Data extraction and statistical analysis methodologies are presented along with respective machining experimental examples.

V. N. Gaitonde *et al.* (Chapter 6) describe application of particle swarm optimization for achieving desired surface roughness in tungsten-copper alloy machining. According to the authors, the tungsten-copper electrodes are used in the manufacture of die steel and tungsten carbide workpieces due to high thermal and electrical conductivity of copper, spark erosion resistance, low thermal expansion coefficient, better arc-resistance, non-welding, and high melting temperature of tungsten. Since tungsten-copper electrode is more expensive than traditional electrodes, there is a need to study the machinability aspects, especially the surface roughness of turned components, which has a greater influence on product quality. The present chapter deals with the application of response surface methodology (RSM) for the development surface roughness model for turning of tungsten-copper alloy. The experiments were planned as per full factorial design (FFD) with cutting speed, feed rate, and depth of cut as the process parameters. The proposed surface roughness model was employed with particle swarm optimization (PSO) to optimize the parameters. PSO program gives the minimum values of surface roughness and the corresponding optimal machining parameters.

Shutong Xie *et al.* (Chapter 7) describe models and optimization techniques of machining parameters in turning operations. According to the authors, machining parameters optimization is one of the most essential and interesting problems in manufacturing world. Efficient optimization of machining parameters can produce high-quality products with low cost and high productivity. So many process optimization models of the turning operations with one or two tools are established in order to realize various machining aims. Due to the complexity of optimization models, many new optimization techniques are proposed to solve them. Major optimization techniques are neural networks, fuzzy sets, genetic algorithms, simulated annealing, ant colony optimization, particle swarm optimization, immune algorithm, et cetera. In this chapter, the authors present a thorough and comprehensive discussion on various soft computing techniques, especially meta-heuristic algorithms, concerning optimization of machining parameters in both single-tool and multi-tools turnings. In addition, some future challenges and research trends are also discussed in this chapter.

A. P. Markopoulos (Chapter 8) described simulation of grinding by means of the finite element method and artificial neural networks. According to the author, simulation of grinding is a topic of great interest due to the wide application of the process in modern industry. To date, several modeling methods have been utilized in order to accurately describe the complex phenomena taking place during the process, the most common being the Finite Element Method (FEM) and the Artificial Neural Networks (ANN). In the present work, a FEM model and an ANN model for precision surface grinding, are presented.

Furthermore, a new approach, a combination of the aforementioned methods, is proposed, and a hybrid model is presented. This model comprises the advantages of both FEM and ANN models. The three kinds of models described in this work are able to accurately predict several grinding features that define the outcome of the process and the quality of the final product.

K. Palanikumar *et al.* (Chapter 9) describe application of Taguchi method with Grey fuzzy logic for the optimization of machining parameters in machining composites. According to the authors, glass fiber reinforced plastic (GFRP) composite materials are continuously displacing the traditional engineering materials and are finding increased applications in many fields such as automobile, marine, sport goods, etc. Machining of these materials is needed to achieve near-net shape. In machining of composite materials optimization of process parameters is an important concern. This chapter discusses the use of Taguchi method with Grey-fuzzy logic for the optimization of multiple performance characteristics considering material removal rate, surface roughness and specific cutting pressure. Experiments were planned using Taguchi's orthogonal array with the cutting conditions prefixed. The cutting parameters considered are workpiece (fiber orientation), cutting speed, feed, depth of cut and machining time. The machining tests were performed on a lathe using coated cermet cutting tool. The results indicated that the optimization technique is greatly helpful in achieving better surface roughness and tool wear simultaneously in machining of GFRP composites.

Alakesh Manna (Chapter 10) describe Taguchi, Fuzzy logic and Grey relational analysis based optimization of ECSM process during micro machining of e-glass-fibre-epoxy composite. According to the author, the development of composite materials and related advancement in design and manufacturing technologies are one of the most important achievements in the history of materials. Composites are multifunctional materials having unprecedented mechanical and physical properties that can be tailored to meet the requirements of a particular application. With the vast and rapid growth of engineering materials towards the direction from metal to non-metal and there after to ceramic and composites, the modern manufacturing industries have developed an increasing demand for machining of those advanced engineering materials irrespective of their hardness, toughness, configurational complexity, microstructure, electrical conductivity or electrically non conductive properties etc. with the ultimate goal of developing highly sophisticated products for achieving greater precision, speed, temperature resistance, wear resistance and lower weight. In machining, the selection and optimization of machining process parameters is the key step to achieve high quality of product without cost inflation. In this chapter, the use of Taguchi method, Fuzzy logic and Grey relational analysis based on an L_{16} (4^5) orthogonal array for optimizing the multi response process characteristics during electrochemical spark machining (ECSM) of electrically non-conductive e-glass-fibre-epoxy composite (e-glass-FEC) is reported. An electrochemical spark machining setup has been designed and fabricated for micro machining of e-glass-FEC and experimental results are utilized for optimizing the process parameter (DC supply voltage, Electrolyte concentration and Gap between tool and auxiliary electrode) with considerations of the multiple responses such as material removal rate and over cut on hole radius effectively. From the analysis, it is found that at higher setting value of DC supply voltage (e.g. 70 volts) and at moderate setting value of electrolytic concentration (e.g. 80 g/l) and 180 mm gap between tool and auxiliary electrode the material removal rate (MRR) is maximum. Utilizing the test results, mathematical models for MRR and overcut on hole radius are developed to predict the setting value of ECSM parameters in advance.

Tauseef Uddin Sididiqui & Mukul Shukla (Chapter 11) describe modeling and optimization of abrasive Water Jet Cutting of Kevlar fiber-reinforced polymer composites. According to the authors, this chapter presents a detailed study of abrasive water jet (AWJ) cutting of thin and thick Kevlar fiber-reinforced polymer (FRP) composites used in transport aircraft and anti-ballistic applications. Kevlar composites are considered to be very challenging to machine using traditional techniques. Most of the research conducted in the area of AWJ cutting has been limited to single response optimization. However, in real life machining, the performance of a process/product demands multi-objective optimization (MOO). No work has been reported till now using different MOO techniques for AWJ cutting of Kevlar FRP composites. Experimental modeling of depth of cut and various design of experiments based single and multi-objective optimization studies are presented here. Statistical analysis of variance has been performed to rank the different process parameters and estimate their effects on various AWJ cut kerf quality characteristics. The studies conducted in this chapter are likely to prove beneficial to the AWJ community in performing modeling and simultaneous optimization of multiple quality characteristics.

R. A. F. Valente *et al.* (Chapter 12) describe developments in finite element technology and optimization formulations for sheet metal forming. According to the authors, this contribution aims to provide a comprehensive overview of some research developments in the field of computational mechanics and numerical simulations applied to metal forming processes. More specifically, this chapter aims to encompass three main fields of research applied to plastic forming processes: (i) the development of alternative finite element formulations for the simulation of sheet metal forming processes; (ii) the development and discussion of distinct optimization procedures and formulations suitable for the characterization of constitutive parameters to be used in numerical simulations, relying on experimental result data; (iii) the study of non-conventional forming processes, particularly the case of single-point incremental forming operations. For each of these topics, a summary of the formulations and main ideas will be provided, as well as a list of references for the interested reader. The main goal of this chapter is, therefore, to provide a comprehensive source of information for researchers from both academia and industrial worlds, about some recent achievements and future trends in the numerical simulation field.

Luis M. M. Alves & Paulo A. F. Martins (Chapter 13) describe joining sheets to tubular profiles by tube forming. According to the authors, this chapter presents an innovative forming process for joining sheet panels to tubular profiles at room temperature. Finite element analysis and experimentation are utilized to understand the deformation mechanics of the process, to identify the operational feasibility window, and to discuss the capabilities across the useful range of working conditions. The feasibility of the proposed joining process is demonstrated by presenting conceptual applications and industrial prototypes comprising a seat-back bottom frame and a hand-brake system of an automotive. Results show that joining sheets to tubular profiles by means of tube forming can successfully replace conventional joining technologies based on mechanical fixing with fasteners, welding, or structural adhesive bonding.

R. Venkata Rao (Chapter 14) describes modeling and optimization of gas metal arc welding (GMAW). According to the author, the weld quality is greatly affected by the operating process parameters in the gas metal arc welding (GMAW) process. The quality of the welded material can be evaluated by many characteristics such as bead geometric parameters, deposition efficiency, weld strength, weld distortion, et cetera. These characteristics are controlled by a number of welding process parameters and it is important to set up proper process parameters to attain good quality. Various optimization methods can be applied to define the desired process output parameters through developing mathematical models to specify the relationship between the input parameters and output parameters. The method capable of accurate prediction of welding process output parameters would be valuable for rapid development of welding procedures and for developing control algorithms in automated welding applications. This chapter presents the details of various techniques used for modeling and optimization of GMAW process parameters. The optimization methods covered in this chapter are appropriate for modeling and optimizing the GMAW process. It is found that there is high level of interest in the adaptation of RSM and ANN techniques to predict responses and to optimize the GMAW process. Combining two optimization techniques, such as GA and RSM, would reveal good results for finding out the optimal welding conditions. Furthermore, efforts are required to apply advanced optimization techniques to find out the optimal parameters for GMAW process at which the process could be considered safe and more economical.

Ilmaru Juutilainen *et al.* (Chapter 15) describe a tutorial to developing statistical models for predicting disqualification probability. According to the authors, different industries utilize statistical prediction models that predict the product properties in process planning, control and optimization. An important aim is to decrease the number of disqualifications. The model can prevent disqualifications efficiently if the disqualification probability is predicted accurately. This study gives step-by-step instructions for developing, validating, comparing, and visualizing models that predict the disqualification probability with high accuracy. The work summarizes industrially applicable statistical modeling methods that are most suitable for the development of accurate predictors for the disqualification probability. Currently, the information on such statistical methods, e.g. quantile regression, modeling of distribution shape, and joint modeling of mean and deviation, is scattered in the existing literature. The main contribution of this work is that it pulls together this methodology into a unified framework which allows the comparative analysis of probability predictors that are based on the different approaches. The proposed modeling procedure (ProPred) is demonstrated using three manufacturing industry applications. In the case applications, the predictors generated using the ProPred procedure are 10-30% more efficient in avoiding disqualifications by means of process planning and control operations than the baseline predictors.

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