Preface

Mechanical engineering is a discipline that applies the principles of physics and materials science for analysis, design, manufacturing, and maintenance of mechanical systems. Nowadays, the term *manufacturing* is commonly applied to industrial production, in which raw materials are transformed into finished goods on a large scale. Materials science and engineering is a multidisciplinary field concerned with the composition, structure, properties, and applications of the various materials, such as metals, ceramics, plastics, and composites that are employed in science and technology as well as in industry.

Recently, there has been increased interest in dynamic methods and process advancements in mechanical, manufacturing, and materials engineering. This book captured the latest research developments in this subject, providing a learning and application of these important matters.

The current research book is a collection of cutting-edge research chapters in the field of mechanical, manufacturing, and materials engineering 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, manufacturing, etc.) or as a subject on mechanical, manufacturing, and materials engineering at the postgraduate level. But, in general, this research book can be used for teaching modern engineering.

Also, this book can serve as a useful reference for academics, manufacturing and materials researchers, mechanical, manufacturing and materials engineers, or professionals in related industries with mechanical engineering.

The purpose of this research book is to present a collection of twenty chapters illustrating the state-of-the-art and research developments to mechanical, manufacturing and materials science, and engineering. The main text of this book is organized into three sections. In first section three chapters are presented with emphasis in general aspects of mechanical engineering. In second section, eleven chapters are presented related to manufacturing. Finally, in the last section, six chapters are presented related to materials science and engineering.

To note, versions of these chapters were are also published in *International Journal of Manufacturing, Materials and Mechanical Engineering*, Volume 1, numbers 1-4, edited by J. Paulo Davim, published by IGI Global. They were published with appropriate modifications in an effort to encourage wider dissemination of research.

SECTION 1. GENERAL ASPECTS OF MECHANICAL ENGINEERING

A. Andrade-Campos (Chapter 1) describes development of an optimization framework for parameter identification and shape optimization problems in engineering. According to the author, the use of optimization methods in engineering is increasing. Process and product optimization, inverse problems, shape optimization, and topology optimization are frequent problems both in industry and science communities. In this paper, an optimization framework for engineering inverse problems such as the parameter identification and the shape optimization problems is presented. It inherits the large experience gain in such problems by the SiDoLo code and adds the latest developments in direct search optimization algorithms. User subroutines in Sdl allow the program to be customized for particular applications. Several applications in parameter identification and shape optimization topics using Sdl Lab are presented. The use of commercial and non-commercial (in-house) Finite Element Method codes to evaluate the objective function can be achieved using the interfaces pre-developed in Sdl Lab. The shape optimization problem of the determination of the initial geometry of a blank on a deep drawing square cup problem is analysed and discussed. The main goal of this problem is to determine the optimum shape of the initial blank in order to save latter trimming operations and costs.

Anirban Mitra *et al.* (Chapter 2) describe large amplitude forced vibration analysis of stiffened plates under harmonic excitation. According to the authors, large amplitude forced vibration behaviour of stiffened plates under harmonic excitation is studied numerically incorporating the effect of geometric non-linearity. The forced vibration analysis is carried out in an indirect way in which the dynamic system is assumed to satisfy the force equilibrium condition at peak excitation amplitude. Large amplitude free vibration analysis of the same system is carried out separately to determine the backbone curves. The mathematical formulation is based on energy principles and the set of governing equations for both forced and free vibration problems derived using Hamilton's principle. Appropriate sets of coordinate functions are formed by following the two dimensional Gram-Schmidt orthogonalization procedure to satisfy the corresponding boundary conditions of the plate. The problem is solved by employing an iterative direct substitution method with an appropriate relaxation technique and when the system becomes computationally stiff, Broyden's method is used. The results are furnished as frequency response curves along with the backbone curve in the dimensionless amplitude-frequency plane. Three dimensional operational deflection shape (ODS) plots and contour plots are provided in a few cases.

S. V. Gorabal *et al.* (Chapter 3) describe design and evaluation of hydro-pneumatic friction damper suspension system. According to the authors, perceived comfort level and ride stability are the two most important factors in the evaluation of suspension system in a mobile vehicle. It is extremely difficult to simultaneously maintain a high standard of vehicle ride, handling, and body control in the vehicle by using conventional passive suspension system. However, the use of active suspensions would result in better comforts than the passive ones. This paper presents the design and analysis of a pneumatic friction damper and hydro-pneumatic friction damper. A non-linear quarter car model is developed, which includes pneumatic actuation by pressure regulation. The performance of the proposed model was assessed in terms of level of vibration reduction. Simulations on a prototype model show that the proposed system has good performance and robustness.

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SECTION 2. MANUFACTURING

Michaela R. Appleby *et al.* (Chapter 4) describe an investigation into the environmental impact of product recovery methods to support sustainable manufacturing within small and medium-sized enterprises (SMEs). According to the authors, the effects of climate change and government legislation has changed the way in which manufacturers can dispose of their waste, encouraging SMEs to source alternative disposal methods such as those indicated in the waste hierarchy. It is economically and environmentally beneficial to use product recovery methods to divert waste from landfills. The environmental impact of two product recovery methods, remanufacturing and repairing, has been compared via a carbon footprint calculation for a UK-based SME. The calculation identified that repairing has a lower carbon footprint than remanufacturing; however, this only extends the original life-cycle of the product, whereas remanufacturing provides a new life-cycle and warranty, and is therefore seen as the most preferable method of product recovery to support sustainable manufacturing.

Carmine Lucignano *et al.* (Chapter 5) describe recycling of waste epoxy-polyester powers for foam production. According to the authors, this chapter proposes a new foaming technology (solid-state foaming) to produce structural foams from waste thermosetting resins. The proposed technology is easy and does not require specific and expensive equipments. Solid tablets are produced by cold compaction of resin powder, and foam by heating in an oven. Composite foams can be produced by mixing fillers and resin powder before the cold compaction. In the experiment, an epoxy-polyester (EP-PE) resin powder, deriving from the waste of a manufacturer of domestic appliances, was used with montmorillonite (MMT) particles. Resulting foams with a filler content ranging from 0 to 10 wt% were characterized in terms of physical and mechanical properties (by compression tests). Although the effect of the MMT content seems to be negative for the adopted resin, the feasibility of producing composite foams by recycling waste industrial powders is shown. The properties of the unfilled foams are sufficient for many industrial applications.

T. Srikanth Reddy *et al.* (Chapter 6) describe application of particle swarm optimization for achieving desired surface roughness in tungsten-copper alloy machining. According to the authors, an automated planning system extracts data from design models and processes it efficiently for transfer to manufacturing activity. Researchers have used face adjacency graphs and volume decomposition approaches which make the feature recognition complex and give rise to multiple interpretations. The present work recognizes the features in prismatic parts considering Attributed Adjacency Matrix (AAM) for the faces of delta volume that lie on rawstock faces. Conceptually, intermediate shape of the workpiece is treated as rawstock for the next stage and tool approach direction is used to recognize minimum, yet practically feasible, set of feature interpretations. Edge-features like fillets/undercuts and rounded/chamfer edges are also recognized using a new concept of Attributed Connectivity Matrix (ACM). In the first module, STEP AP-203 format of a model is taken as the geometric data input. Datum information is extracted from Geometric Dimension and Tolerance (GD&T) data. The second module uses features and datum information to arrive at setup planning and operation sequencing on the basis of different criteria and priority rules.

Ashfaq Khan *et al.* (Chapter 7) describe Laser sub-micron patterning of rough surfaces by microparticle lens arrays. According to the authors, Laser surface patterning by Contact Particles Lens Arrays (CPLA) has been widely utilized for patterning of smooth surfaces, but there is no technique developed by which CPLA can be deposited on a rough surface. For deposition of CPLA, conventional techniques require the surface to be flat, smooth, and hydrophilic. In this study, a new method for the deposition

of CPLA on a rough surface is proposed and utilized for patterning. In this method, a hexagonal closed pack monolayer of SiO2 spheres was first formed by self-assembly on a flat glass surface. The formed monolayer of particles was picked up by a flexible sticky surface and then placed on the rough surface to be patterned. A Nd:YVO4 laser was used to irradiate the substrate with the laser passing through the sticky plastic and the particles. Experimental investigations have been carried out to determine the properties of the patterns.

M. S. Che Jamil *et al.* (Chapter 8) describe a finite element study of buckling and upsetting mechanisms in Laser forming of plates and tubes. According to the authors, Laser beam forming has emerged as a viable technique to form sheet metal by thermal residual stresses. Although it has been a subject of many studies, its full industrial application is not yet established. This article aims to complement the existing research in the area of laser forming in order to gain a better understanding of the process. A numerical investigation of laser forming of stainless steel sheets has been carried out and validated experimentally using a High Power Diode Laser (HPDL). Three processing parameters are tested: laser power, beam diameter, and plate thickness. Also, laser bending of stainless steel tube is simulated and compared against the published experimental data. The main underlying mechanisms of laser forming are demonstrated through the simulations.

Vassilios Iakovakis *et al.* (Chapter 9) describe the impact of FEM modeling parameters on the computed thermo-mechanical behavior of SLA copper shelled electrodes. According to the authors, in this study, the authors use the finite element method to model and analyse a cylindrical copper shelled SLA electrode for EDM operations, which is investigated experimentally in literature. A uniform silver paint thickness and copper shell thickness is assumed around the SLA epoxy core. In the experiment, 2-D analysis was used due to the axisymmetric shape, and steady state and transient die sink EDMing simulations were followed. Modelling parameters are varied and their impact on the resulting temperature and stress fields is evaluated. The intermittent nature of the electrode thermal loading is also simulated with FEM transient analysis. It is shown that, using the finite element method, the influence of the copper shelled SLA electrode manufacturing and EDM-process parameters can be studied.

Alakesh Manna and Amandeep Kundal (Chapter 10) describe micro machining of nonconductive Al2O3 ceramic on developed TW-ECSM setup. According to the authors, advanced ceramic materials are gradually becoming very important for their superior properties such as high hardness, wear resistance, chemical resistance, and high strength to weight ratio. However, machining of advanced ceramic like Al2O3-ceramics is very difficult by any well known and common machining processes. Normally, cleavages and triangular fractures generate when machining of these materials is done by traditional machining methods. It is essential to develop an efficient and accurate machining method for processing advanced ceramic materials. For effective machining of Al2O3-ceramics, a traveling wire electrochemical spark machining (TW-ECSM) setup has been developed. The developed TW-ECSM setup has been utilized to machine Al2O3 ceramic materials, and subsequently, test results are utilized to analyze the machining performance characteristic. Different SEM photographs show the actual condition of the micro machined surfaces. The practical research analysis and test results on the machining of Al2O3 ceramics by developed TWECSM setup will provide a new guideline to the researchers and manufacturing engineers.

A. P. Markopoulos *et al.* (Chapter 11) describe 3D finite element modeling of high speed machining. According to the authors, this paper presents simulation of high speed machining of steel with coated carbide tools. More specifically, Third Wave Systems AdvantEdge commercial Finite Element Method code is employed in order to present turning models, under various machining conditions. As a novelty,

the proposed models for High Speed Machining of steel are three-dimensional and are able to provide predictions on cutting forces, tool and workpiece temperatures, chip formation, and chip morphology. Model validation is achieved through experimental work carried out under the same conditions as the ones used in modeling. For the experimental work, the principles for design of experiment were used in order to minimize the required amount of experiments and obtain useful results at the same time. Furthermore, a Taguchi analysis is carried out based on the results. The analysis indicates that there is a good agreement between experiment and modeling, and the proposed models can be further employed for the prediction of a range of machining parameters, under similar conditions.

Amrita Piyadarshini *et al.* (Chapter 12) describe a finite element study of chip formation in orthogonal machining. According to the authors, this chapter examines the plane strain 2D Finite Element (FE) modeling of segmented, as well as continuous chip formation while machining AISI 4340 with a negative rake carbide tool. The main objective is to simulate both the continuous and segmented chips from the same FE model based on FE code ABAQUS/Explicit. Both the adiabatic and coupled temperature displacement analysis has been performed to simulate the right kind of chip formation. It is observed that adiabatic hypothesis plays a critical role in the simulation of segmented chip formation based on adiabatic shearing. The numerical results dealing with distribution of stress, strain, and temperature for segmented and continuous chip formations were compared and found to vary considerably from each other. The simulation results were also compared with other published results; thus validating the developed model.

L. M. Alves *et al.* (Chapter 13) describe cold end forming of welded steel tubes. According to the authors, the production of custom and specific tube end shapes by cold end forming using a die is generally limited to seamless tubular parts. Current research work in the field follows the same trend as that of industry and, therefore, there is no accumulated experience, no practical design rules, and no information available in the specialized literature concerning the utilization of tube end forming for shaping the end of thin-walled welded tubes. This paper is concerned with the lack of knowledge and is a contribution towards the understanding of the mechanics of deformation of tube end forming applied to welded tubes. The presentation addresses the influence of major operating parameters on the formability limits of the process with the purpose of understanding feasibility and establishing design rules for the benefit of those who design tubular parts in daily practice. The authors effectively contribute to transferable technological knowledge opening new market opportunities that stimulate innovations among carbon and stainless steel tubular products.

Z. Y. Jiang *et al.* (Chapter 14) describe their study on oxidation of stainless steels during hot rolling. The oxidation of stainless steels 304 and 304L during hot rolling is studied in this paper. Results show the oxide scale thickness decreases significantly with an increase of reduction, and the oxide scales of both 304 and 304L stainless steels were found more deformable than the steel substrate. Surface roughness shows a complicated transfer during the hot rolling process due to the complexity of oxide scale characteristics. Also, surface roughness decreases with an increase of reduction. The friction coefficient increases with reduction in all cases, and the increase is more significant in the case of the 304 stainless steel than that of 304L stainless steel.

SECTION 3. MATERIALS SCIENCE AND ENGINEERING

R. V. Rao (Chapter 15) describes material selection using a novel multiple attribute decision making method. According to the author, selection of a most appropriate material is a very important task in design process of every product. There is a need for simple, systematic, and logical methods or mathematical tools to guide decision makers in considering a number of selection attributes and their interrelations and in making right decisions. This paper proposes a novel multiple attribute decision making (MADM) method for solving the material selection problem. The method considers the objective weights of importance of the attributes as well as the subjective preferences of the decision maker to decide the integrated weights of importance of the attributes. Furthermore, the method uses fuzzy logic to convert the qualitative attributes into the quantitative attributes. Two examples are presented to illustrate the potential of the proposed method.

R. T. Durai Prabhakaran *et al.* (Chapter 16) describe attribute based selection of thermoplastic resin for vacuum infusion process (a decision making methodology). According to the authors, the composite industry looks toward a new material system (resins) based on thermoplastic polymers for the vacuum infusion process, similar to the infusion process using thermosetting polymers. A large number of thermoplastics are available in the market with a variety of properties suitable for different engineering applications, and few of those are available in a not yet polymerised form suitable for resin infusion. The proper selection of a new resin system among these thermoplastic polymers is a concern for manufactures in the current scenario, and a special mathematical tool would be beneficial. In this paper, the authors introduce a new decision making tool for resin selection based on significant attributes. This article provides a broad overview of suitable thermoplastic material systems for vacuum infusion process available in today's market. An illustrative example—resin selection for vacuum infused of a wind turbine blade—is shown to demonstrate the intricacies involved in the proposed methodology for resin selection.

Sourav Sarkar *et al.* (Chapter 17) describe reciprocating wear behaviour of two dimensionally reinforced carbon –phenolic and carbon-epoxy composites. According to the authors, a comparative study has been carried out on performance of two-dimensionally reinforced carbon/phenolic (C/P) and carbon/epoxy (C/E) composites, subjected to low amplitude reciprocating wear at different temperatures. The C/P composite has shown greater wear rate than the C/E composite, with the difference being modest at room temperature, and larger at 250 °C. The values of coefficient of friction, surface roughness, and depths of craters on worn surfaces have been measured, which along with surface morphologies examined by scanning electron microscope have been correlated to both amount of weight loss and mechanisms of damage by wear.

Suman Kalyan Das and Prasanta Sahoo (Chapter 18) describe a roughness optimization of electroless Ni-B coatings using Taguchi method. According to the authors, in this chapter, the authors present an experimental study of roughness characteristics of electroless Ni-B coatings and optimization of the coating process parameters based on L27 Taguchi orthogonal design. Three coating process parameters are considered viz. bath temperature, reducing agent concentration, and nickel source concentration. It is observed that concentration of reducing agent together with bath temperature play a vital role in controlling the roughness characteristics of the coatings. The analysis yields the optimum coating parameter combination for minimum roughness. A reduction of about 15% is observed in roughness at the optimal condition compared to the initial condition. The microstructure, composition, and the phase content of the coating are also studied with the help of scanning electron microscopes energy dispersive X-ray analysis, and X-ray diffraction analysis, respectively.

M. A. Shah (Chapter 19) describes Al2O3 nanobricks via an organic free route using water as solvent. According to the author, the chemical synthesis of nanomaterials has been studied by few researchers, but innumerable improvements and better methods have been reported in the past few years. This new approach of preparing aluminum oxide (Al2O3) nanobricks is based on a soft reaction of aluminum powder and de-ionized (DI) water at 200ºC without use of any additives or surfactants. Powder X-ray diffraction studies reveal that the as prepared nanobricks are highly crystalline in nature and by morphological investigations using FESEM, it was revealed that the bricks are rectangular in shape having width of 90±15nm and breadth of ~200nm, which was confirmed by high resolution TEM. The technique could be extended and expanded to provide a general, simple, and convenient strategy for the synthesis of nanostructures of other functional materials with important scientific and technological applications. The prospects of the process are bright and promising.

F. M. Al-Marzouki *et al.* (Chapter 20) describes preparation of copper oxide (CuO) nanoparticles and their bactericidal activity. According to the authors, single crystalline nanoparticles of copper oxide (CuO) having almost uniform particle size of ~40±10nm have been synthesized by a facile and versatile route. The technique employed is free from toxic solvents, organics, and amines, and is based on a simple reaction of copper powder and de-ionized water (DI) at very low temperatures of 180ºC. The morphology, chemical composition, and crystalline structure of the nanoparticles were carefully investigated by the various characterization techniques. Besides simplicity, the advantages of producing nanoparticles by this method are that it is easeful, flexible, fast, cost effective, and pollution free. The synthesized nanoparticles are under investigations for various applications including their antibacterial activity.

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