

Lecture Notes in Mechanical Engineering

Amar Patnaik
Ernst Kozeschnik
Vikas Kukshal *Editors*

Advances in Materials Processing and Manufacturing Applications

Proceedings of iCADMA 2020

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Lecture Notes in Mechanical Engineering

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Vikas Kukshal
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Foreword

I am greatly honored to write this foreword for the proceedings of the International Conference on Advances in Materials Processing and Manufacturing Applications 2020 (iCADMA-2020) held at MNIT Jaipur, Rajasthan, during November 5–6, 2020. The advanced materials and manufacturing processes are revolutionizing all the specialized areas in different fields such as electrical, electronics, mechanical, and civil. A high degree of novelty is needed in both structural and functional materials for achieving the goal of sustainability.

The conference has provided an excellent opportunity for academicians, researchers, technocrats, and students to present their research work in the emerging field of advanced material and manufacturing processes. The theme of the conference is immensely suitable for all the researchers exploring advanced material and manufacturing processes. The published chapter will certainly provide a future direction to the researchers working in the field of advanced materials and manufacturing.

The research articles published in the proceedings of iCADMA-2020 titled *Advances in Materials Processing and Manufacturing Applications* cover a wide range of very interesting topics. I appreciate the authors for their technical input and fruitful discussions and scientific interaction during the conference.

I would like to acknowledge the organizers from MNIT Jaipur and NIT Uttarakhand for organizing such an appropriate international conference.

I wish the authors good luck for their future endeavors.



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Preface

It is with great pleasure to introduce the proceedings of the *International Conference on Advances in Materials Processing and Manufacturing Applications (iCADMA-2020)* which was held online at Malaviya National Institute of Technology Jaipur, India, during November 5–6, 2020.

This book comprises selected papers from the presentations conducted during iCADMA-2020 endorsed by the Scheme for Promotion of Academic and Research Collaboration (SPARC). The conference was sponsored by SPARC and TEQIP-III National Institute of Technology, Uttarakhand. The conference drew the attention of various distinguished researchers and delegates from all over the world including Montenegro, Australia, Bangladesh, USA, Ecuador, Oman, Belgium, Estonia, and India. The conference consisted of eight keynote lectures and 23 technical sessions given by renowned researchers and scholars working in the areas of materials, manufacturing, optimization, industrial engineering, and tribological studies from all over the world. To grace the quality of the program, some peer-reviewed papers were invited for the presentation. Distinguished researchers from India, Austria, New Guinea, and Hungary were invited to deliver eight keynote lectures sharing the latest research discoveries in their respective areas of expertise. In the technical sessions, authors made oral presentations, and each presentation was confined to 10 minutes, followed by question and answer. One excellent presenter from each technical session was chosen for the best paper award depending on the technical merit, presentation, and application.

iCADMA-2020 focused on all broader aspects concerning advanced materials, materials manufacturing and processing, engineering optimization and sustainable development, and tribology for industrial application. iCADMA-2020 brought together scientists, engineers, researchers, and scientists from an engineering background as well as research scholars and faculties from IITs, NITs, IIITs, and other academic institutions. The conference was organized through Zoom. Authors shared the screen, and attendees could discuss their work via online platform. Overall, the conference was held successfully through the platform. The conference committee was dedicated to the success of the conference.

Foreign institute presenters were from University of Donja Gorica, Military Institute of Science and Technology, University of Technology Sydney, Chittagong University of Engineering and Technology, University of California Los Angeles, Tallinn University of Technology, Campus De Nayer, Sint-Katelijne Waver, and Technical University of Ambato, Huachi Campus. Presenting authors from government research institutes were from Metallurgy Corp. R&D BHEL, CSIR-Central Mechanical Engineering Research Institute, CSIR-Institute of Minerals and Materials Technology, Bhubaneswar, Odisha, India. Industrialists were from IEA Consultants, Bangalore, and Belimo Actuators India Pvt. Ltd., Mumbai.

All accepted papers were subject to peer review by the conference committee and invited international reviewers. The papers were selected based on their quality and their relevance to the conference.

I would like to express special gratitude to the members of the conference committee and organizers of the conference. I would also like to thank the reviewers for their valuable time and advice which helped in improving the quality of the papers selected for presentation at the conference and for publication in the proceedings. Finally, I want to thank the authors, the chairpersons, sponsors, and all the participants for their support for iCADMA-2020.

Jaipur, India

Dr. Amar Patnaik
Convener and Organizing Secretary
iCADMA-2020

Acknowledgements

The editorial team sincerely acknowledge all the contributors of the book chapters. We are grateful to all the authors for their encouragement and support and for contributing the foreword to this book. Our special thanks to Scheme for Promotion of Academic and Research Collaboration (SPARC) for providing us the platform to organize the two-day International Conference on Advances in Materials Processing and Manufacturing Applications (iCADMA-2020). This conference was sponsored by the SPARC, the backbone of this conference, and supported by TEQIP-III, NIT Uttarakhand. We gratefully acknowledge all the participating authors and delegates from distinguished countries for transforming their work in the form of a book.

We extend our sincere thanks to Prof. Ernst Kozeschnik, TU Wien, Austria, for showering his abundant grace to knowledge the authors. We are grateful to Prof. Udaykumar R. Yaragatti, Director, MNIT, and Prof. S. L. Soni, Director, NIT Uttarakhand, for their constant motivation and support throughout the conference. We are also thankful to Prof. M. L. Mittal for his suggestions from time to time. We owe gratitude to Prof. Jyotirmay Mathur for his continuous mentorship from planning to execution of iCADMA-2020. We would also like to convey our sincere thanks to the respected Registrar, MNIT Jaipur, for providing all the necessary administrative support. A heartfelt thanks to the technical program committee and review board members for their valuable suggestion in making the conference a grand success. We also extend our sincere thanks to our eminent keynote speakers and technical session chairs from the scientific research community, academia, and industries for providing their valuable inputs for the success of the conference. We would like to take this opportunity to place on record our hearty thanks to organizing committee, administration, accounts, and dear students for their massive and sincere efforts.

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Abbreviations

ABS	Acrylonitrile butadiene styrene
AFM	Abrasive flow machining
AM	Additive manufacturing
AMMC	Aluminum metal matrix composites
ANOVA	Analysis of variance
ASS	Austenitic stainless steel
BA	Bagasse ash
BCS	Black cotton soil
BSPD	Brake system plausibility device
CBR	California bearing ratio
CFD	Computational fluid dynamics
CHA	Coconut husk ash
CNN	Convolutional neural network
CNT	Carbon nanotube
DFA	Design for assembly
DMLS	Direct metal laser sintering
DOE	Design of experiments
DOP	Depth of penetration
ECU	Engine control unit
EDM	Electrical discharge machining
EGTS	Epicyclic gear transmission systems
EMV	Electro-micro fluidic viscometer
FGM	Functionally graded materials
FSI	Free swell index
FSP	Friction stir processing
GFR	Gas flow rate
HAZ	Heat-affected zone
IOT	Internet of Things
LCA	Life cycle assessment
LL	Liquid limit

MAFM	Magnetically assisted abrasive flow machining
MFA	Mold flow adviser
MLI	Multilevel inverter
MRR	Material removal rate
MWCNT	Multi-walled carbon nanotubes
NDT	Non-destructive testing
NRP	Natural reinforced polymers
PBP	Payback period
PGT	Planetary gear trains
PI	Plasticity index
PL	Plastic limit
PMC	Polymer matrix composite
PVC	Polyvinylchloride
RE	Renewable energy
RMD	Regulated metal deposition
RMES	Root mean square error
RPS	Rice pericarp slag
SEM	Scanning electron microscope
SLM	Selective laser melting
SPD	Severe plastic deformation
SPV	Solar photovoltaic
SV	Servo voltage
SWH	Solar water heater
TWA	Three-wheeled auto rickshaws
TWR	Tool wear rate
UFG	Ultra-fine-grained
ZAV	Zero accident vision

Optimization of Wire EDM Process Parameters for Machining of INVAR 36 Alloy



Ankita Mohanty, Rupam Mohapatra, and Supriya Priyadarshini Das

Abstract Wire EDM is an eco-friendly, non-traditional machining process with no contact between the workpiece and the wire electrode and has a widespread usage in the field of medical industry, automobile industry, etc. The purpose of this present work is to optimize various wire EDM input parameters for machining of INVAR 36. The Taguchi technique was used to carry out the optimization. The control parameters like pulse-on-time (T_{on}), pulse-off-time (T_{off}), servo voltage (SV) and wire feed rate (Wf) were chosen to analyse the effect of various parameters on material removal rate (MRR) and surface roughness (SR) of INVAR 36 alloy. To optimize the material removal rate (MRR) and surface roughness (SR), a total of 9 (L_9 orthogonal array) experiments were performed. The Taguchi method was applied by using MINITAB 17 software to maximize MRR and minimize SR. The optimum level of process parameters for MRR was found to be 25 μ s pulse-on-time, 46 μ s pulse-off-time, 5 mm/min wire feed rate, 30 V servo voltage and for surface roughness (SR) 25 μ s pulse-on-time, 19 μ s pulse-off-time, 3 mm/min wire feed rate, 20 V servo voltage.

Keywords Wire EDM · INVAR 36 · Taguchi technique · Surface roughness · Material removal rate

1 Introduction

Invar 36, Fe-(64–36 wt%) Ni is the most common iron–nickel alloy found in 1896 and is basically used in opto-mechanical engineering. Invar 36 alloy is ferromagnetic and is characterized by low coefficient of thermal expansion (CTE) below its Curie temperature (279 °C) and has excellent mechanical properties. Invar alloy is widely used where high-dimensional stability is the main requirement. Its modulus

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of elasticity remains almost constant for wider range of temperature. Owing to the high work hardening and high ductility, it is difficult to cut. Besides, in the cutting process of Invar 36, high ductile chips are easily generated and seriously affect the life of cutting tools and production efficiency [1–6]. Wire cut electric discharge machining (WEDM) is the best available option to overcome these problems. Wire cut EDM is an advanced thermal-assisted, non-conventional machining process which is widely used in the manufacturing, automotive and aerospace industry. The most prominent characteristic of this process is that the cutting tool never comes in contact with the workpiece. Also there is no force, mechanical stresses, and vibration during the machining process. The travelling wire has a very small diameter (0.02–0.3 mm), and this helps the machine to make small cuts. The wire acts as the electrode and the material wear out due to the high amount of heat that tends to melt material [7]. The material is flushed out with the dielectric medium (distilled water, kerosene, ethylene glycol, etc.). The dielectric medium works as spark conductor and for cooling the tool, workpiece and the spark area. Wire EDM is considered to be a significant development in the field of non-traditional machining. It has high accuracy rate which can produce intricate shapes, cuts, etc [8]. In spite of this, proper selection of process parameter remains a challenging job.

Debta et al. [9] found that in WEDM process, with the increase of pulse-on-time (T_{on}), the cutting velocity increases; whereas, the kerf width and taperness of the machined profile reduce after an optimal value. However, wire tension has no significant effect on the machining performances. Sharma et al. [10] studied the effect of various input process parameters (T_{on} , T_{off} , I_p , T_w) on the response characteristics (MRR, I_g , MT) by using Taguchi L9 orthogonal array of AISI D2 die steel (13 mm diameter) using a 0.25 mm dia wire electrode and found T_{off} has been the leading significant factor for MRR. Maurya et al. [11] performed wire electric discharge machining on Nicrofer 5716. Experiments were performed utilizing Taguchi's L9 orthogonal array. Further, the responses are modelled with the response surface methodology approach for eliminating the residuals from the input as well as responses to create quadratic relationship among input and response variables with high adequacy and precision. Singh et al. [12] studied the dimensional deviation in wire EDM of M42 HSS using cryogenically treated brass wire and used ANOVA for significance and found variation of around 3.15% from the predicted value. Divya et al. [13] used Taguchi method for single objective optimization and grey relational analysis for multi-objective analysis to optimize the input process parameters: (T_{on}), pulse-off-time (T_{off}), peak current (I_p), servo voltage, wire feed rate and wire tension of Inconel 825. Sivaprakasam et al. [14] enumerated the effect of graphite nanopowder suspended in dielectric medium of micro-wire EDM process of Inconel alloy. Kumar [15] developed a fuzzy model in MATLAB to predict fuzzy response parameters in WEDM process on stainless steel material (AISI 630) and compared the experimental result with the fuzzy predicted result and found that the system gives an overall 90% accuracy from the fuzzy model.