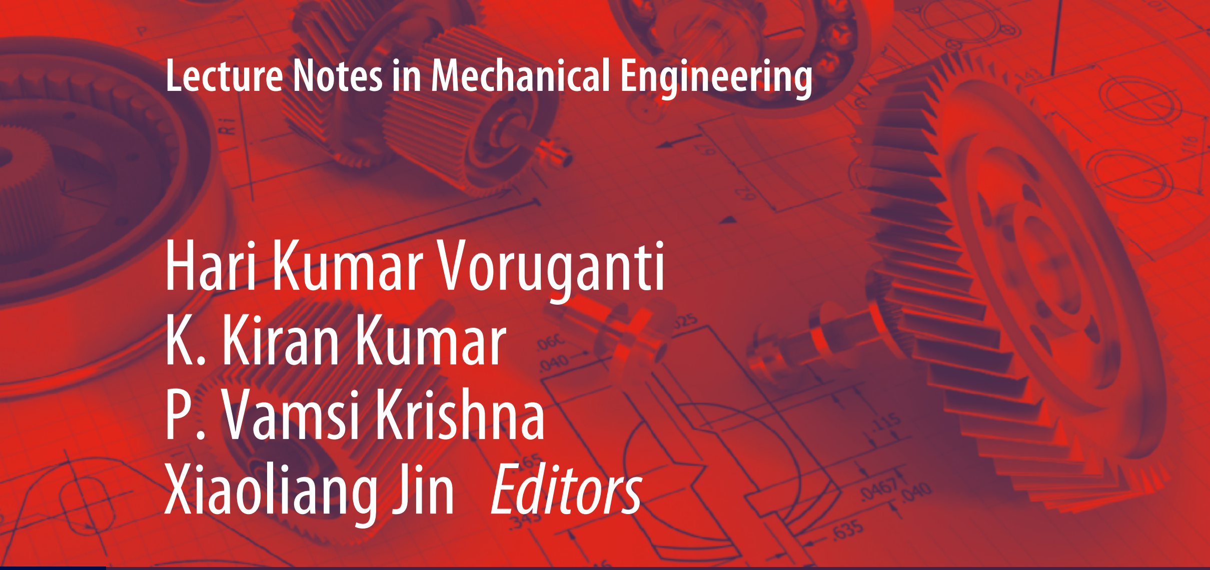

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Hari Kumar Voruganti
K. Kiran Kumar
P. Vamsi Krishna
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Preface

The main aim of the First International Conference on Applied Mechanical Engineering Research (ICAMER 2019) is to bring together all interested academic researchers, scientists, engineers, and technocrats and provide a platform for continuous improvement of mechanical engineering research.

ICAMER 2019 received an overwhelming response with more than 300 full paper submissions. After due and careful scrutiny, about 160 of them have been selected for oral presentation. The papers submitted have been reviewed by experts from renowned institutions, and subsequently, the authors have revised the papers, duly incorporating the suggestions of the reviewers. This has led to significant improvement in the quality of the contributions.

Springer publications have agreed to publish the selected proceedings of the conference in their book series of Lecture Notes in Mechanical Engineering (LNME). This enables fast dissemination of the papers worldwide and increases the scope of visibility for the research contributions of the authors.

This book comprises three parts, viz. thermal, design and production engineering. Each part consists of relevant full papers in the form of chapters. The thermal part consists of chapters on research related to IC engines, CFD, solar energy, automobiles, etc. The design part consists of chapters on computational mechanics, design of mechanisms, composite materials, tribology, and advanced areas like the isogeometric analysis. The production part consists of chapters on machining, new materials, additive manufacturing, unconventional manufacturing, and industrial engineering areas. This book provides a snapshot of the current research in the field of mechanical engineering and hence will serve as valuable reference material for the research community.

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Vancouver, Canada	Dr. Xiaoliang Jin

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We express our sincere thanks to all the deans, registrar, head of the departments, and faculty-in-charges of various units of NIT Warangal for their administrative support in making this effort possible.

Dr. Hari Kumar Voruganti
Dr. K. Kiran Kumar
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Contents

Thermal Engineering Section

Computational Study of Mixed Convection of Electronic Chips with Surface Radiation 3
Arnab Deb and S. K. Mandal

Combustion Performance of Hybrid Rocket Motor Under the Influence of Cylindrical Protrusion 11
Kabaleeswaran Manikandan, K. Lakshmi Das, N. Purushothaman and L. Karthik

Social and Economic Impact Assessment of Solar Water Pumping System on Farmers in Nagpur District of Maharashtra State of India 19
Devidas H. Yadav, Arunedra K. Tiwari and Vilas R. Kalamkar

Thermally Developing Region of a Parallel Plate Channel Partially Filled with a Porous Material with the Effect of Axial Conduction and Viscous Dissipation: Uniform Wall Heat Flux 27
J. Sharath Kumar Reddy and D. Bhargavi

Experimental Study of Closed-Loop Thermosyphon System Using Different Working Fluids 37
Mahasidha R. Birajdar and C. M. Sewatkar

Identifying Empirically Important Variables in IC Engine Operation Through Redundancy Analysis 45
Satishchandra Salam and Tikendra Nath Verma

Mixed Convective Heat Transfer with Surface Radiation in a Vertical Channel in Presence of Heat Spreader 53
S. K. Mandal, Arnab Deb and Dipak Sen

Experimental Analysis on Thermal Performance of a Solar Air Heater at Different Angular Positions 63
Sk. A. Rahaman, T. Eswar, S. J. Reddy and M. Mohan Jagadeesh Kumar

Surface Pressure Characteristics over Indian Train Engine 73
K. Vivek, B. Ashok Kumar, Karthick Dhileep, S. Arunvinthan and S. Nadaraja Pillai

Exergy Modelling of a Coal-Fired MHD Power Plant 81
Prabin Haloi and Tapan Kumar Gogoi

Design, Development and Analysis of Intake Manifold of Single-Cylinder Diesel Engine 91
Nikhil A. Bhave, Mahendra M. Gupta, Sandeep S. Joshi, Mohan G. Trivedi and Neeraj Sunheriya

Calibration of Reference Velocity and Longitudinal Static Pressure Variation in the Test Section of an Open-Type Subsonic Wind Tunnel 107
Neeraj Verma and Beena D. Baloni

Optimal Selection of Insulating Material for Energy Conservation in Steam Pipe Using Analytical Hierarchy Process 115
Mendu Siva Subrahmanyam, Imandi Aparna Devi and Beejapu Jagadeesh

Heat Transfer Enhancement Using Overlapped Dual Twisted Tape Inserts with Nanofluids 123
Rokkala Rudrabhiramu, K. Harish Kumar, K. Kiran Kumar and K. Mallikarjuna Rao

Flow Characteristic Study of Contraction of Compressor Intermediate S-Shaped Duct Facility 131
Manish Sharma and Beena D. Baloni

Alternate Heating Process in ESP Hoppers of Thermal Power Plant—An Experimental Pilot Investigation 143
R. Saravanan and Ramakotaiah Maddumala

Experimental Study on the Performance of Micro-aerial Vehicle Propeller 151
P. S. Premkumar, M. Sureshmohan, K. Siyuly, S. Vasanthakumar, R. Naveen Kumar, S. DenielaGrene and S. Sanjaykumar

Heat Transfer Enhancement of Al_2O_3-Based Nanofluid in a Shell and Helical Coil Heat Exchanger 159
Prabhakar Zainith and Niraj Kumar Mishra

Numerical Analysis of the Effect of Fluid–Structure Interaction on Heat Transfer in the Square Cavity Using OpenFOAM 167
Nikhil Chitnavis and Trushar B. Gohil

Experimental Investigation of the Effect of Particle Concentration and Temperature on Thermophysical Properties of Water-Based Metal-Oxide Nanofluids 175
Ramesh Babu Bejjam, K Kiran Kumar, S Venkata Sai Sudheer and N Praveena Devi

Pressure Drop in Vertical Pneumatic Conveying: Comparison Between Numerical Predictions with Existing Correlations 183
Pandaba Patro and Debasis Mishra

CFD Analysis in the Design of Diffuser for Air Cooling of Low-Concentrated Photovoltaic/Thermal (LCPV/T) Solar Collector 191
Rohit Meshram and P. D. Sawarkar

CFD Analysis of Wind Turbine with Different Flange Angles 199
S. M. Bichitkar, P. P. Buddiyal, S. S. Chavan, A. A. Kulkarni and V. B. Gawande

Performance and Emission Characteristics of Thermal Barrier Coating on Diesel Engine Fueled with Cottonseed Biodiesel 205
Badal Kudachi, Nitin Satpute, Nilaj N. Deshmukh and Bipin Mashilkar

Performance and Emission Analysis of Rapeseed Methyl Ester on DI Diesel Engine Using Artificial Neural Network 215
V. Amosu, S. K. Bhatti and S. Jaikumar

The Analytical Study of Velocity Slip on Two-Phase Flow in an Eccentric Annular Region 223
B. Umadevi, P. A. Dinesh and C. V. Vinay

Numerical Study on the Effect of Impeller Geometry on Pump Performance 233
Arshdeep Singh, Siga Satya Sekhar, S. Jayavel and Sudhir Varadarajan

Numerical Study of Hydrogen-Fueled Scramjet Performance with Passive Techniques 243
Obula Reddy Kummitha, K. M. Pandey and Rajat Gupta

Numerical Simulation of Heat Transfer and Fluid Flow Characteristics of Triangular Corrugated Wavy Channel 251
Meghna Das Chaudhury and Raju

Emission and Performance Characteristics of CI Engine with Diesel–Butanol Blends Using Intake Pressure Boost 261
Hemant Gowardhan, Amit Karwade and J. G. Suryawanshi

Thermal Design Methodology for Regenerative Fuel-Cooled Scramjet Engine Walls 269
G. Vijayakumar

Computational Studies of Shock Wave Boundary Layer Interactions in Hypersonic Flow Over Double Cone Geometries . . . 279
Siva Vayala and Ravi K. Peetala

Thermal Design and Testing of External Protuberance of Hypersonic Carrier Vehicle Airframe . . . 287
G. Vijayakumar, S. Narendar and J. Justina Geetha

The Effect of Diesel and Biodiesel Blends on CI Engine Performance and Emission Characteristics . . . 297
J. Venkatesu Naik, K. Kiran Kumar, S. Venkata Sai Sudheer and Mahesh Pallikonda

Numerical Analysis of Fluid–Structure Interaction of Blood Flow Through a Flexible Tube with 90-Degree Bend Using OpenFOAM . . . 303
Rishabh N. Jaiswal and Trushar B. Gohil

Design Engineering Section

Damage and Failure Analysis of Short Carbon Fiber Reinforced Epoxy Composite Pipe Using FEA . . . 313
Anju Verma, Apurba Mandal and Dungali Sreehari

Dynamic Performance Analysis of a Four-Ton Automobile Chassis . . . 321
P. Sowmya, K. Karthik Rajashekar, M. Madhavi and P. A. Sastry

Experimental Studies on Steel Beam-to-Column Connections Under Elevated Temperature . . . 335
A. Cinitha and V. Nandhini

Investigating the Influence of Higher-Order NURBS Discretization on Contact Force Oscillation for Large Deformation Contact Using Isogeometric Analysis . . . 343
Vishal Agrawal and Sachin S. Gautam

Simple Optimization Algorithm for Design of a Uniform Column . . . 351
Joji Thomas, Anshuman Kumar Sahu and Siba Sankar Mahapatra

Unbalance and Dynamic Parameters Estimation in a Rigid Rotor Mounted on Active Magnetic Bearings . . . 363
Prabhat Kumar, Vikas Kumar, Kundan Kumar and Lakhan Singh Meena

Investigating the Influence of Geometrical and Material Parameters on Peeling Behaviour of a Gecko Spatula . . . 373
Saipraneeth Gouravaraju and Sachin S. Gautam

Quantitative Analysis of Tribological Performance on Al–CSA Composite Using Orthogonal Array 381
R. Siva Sankara Raju, B. Venkata Siva and G. Srinivasa Rao

Pre-strain in Dielectric Elastomer Actuator; Challenges Towards Structure–Property Relationship 389
Dhananjay Sahu, Om Prakash Prabhakar, Raj Kumar Sahu and Karali Patra

Modified Electromechanical Model for Dielectric Elastomer Cylindrical Actuators 397
Om Prakash Prabhakar, Dhananjay Sahu and Raj Kumar Sahu

A Numerical Study to Investigate the Modal Analyses of Cracked Airplane Wing (NACA2415) 405
Gaurav Verma, Anshul Sharma and Yogesh K. Prajapati

Synthesis and Characterization of Nano-grease for Automotive Wheel Bearing Application 413
Pankaj S. Ghatage, Abhijeet P. Shah and Dhananjay Kumbhar

Hamiltonian-Based Solutions of Certain PDE in Plasma Flows 423
Vivek S. Sharma, Parag V. Patil and Milan A. Joshi

Low-Cost Test Rig for Demonstrating Single Plane Balancing Using Vibrations 433
N. V. S. Shankar, K. V. Jitendra, H. Ravi Shankar and M. Manikumar

Nonlinear Dynamic Analysis of Automotive Turbocharger Rotor System 443
S. Bala Murugan, Rabindra Kumar Behera and P. K. Parida

On the Response of a Beam Structure to a Moving Mass Using Green's Function 455
Sudhansu Meher, Suraj Parida and Rabindra Kumar Behera

A Programmatic Approach for the Prediction of Service Life of Deep Drawing Die Using ANN 465
Vishal Naranje and Sachin Salunkhe

Thermo-Mechanical Analysis of Unidirectional PALF Composites Using Micromechanical Approach 475
Anurag Jasti and Sandhyarani Biswas

Analysis and Selection of Bio-stents Using Finite Element Method 485
Jannatul Bashar and K. Jayabal

Electromechanical Responses of Dielectric Elastomers 495
Moumita Tewary and Tarapada Roy

Design, Manufacturing, and Testing of Feeding and Bending Mechanism 505
Vijay V. Mehta, Vedant K. Parmar, Nirav P. Maniar and Jasmin P. Bhimani

Design and Kinematics of a Coal Bunker Scraper Guide-Mechanism 513
Bijoy Ramakrishnan, Alex Sherjy Syriac, Chetan Chaudhari, Aditya Shah and S. S. Chiddarwar

Measurement of Elastic Modulus and Damping Properties of Friction Stir Processed Pure Metals Using Impulse Excitation Technique 521
K. Venkateswara Reddy, R. Bheekya Naik, Sandeep Yadav, G. Madhusudhan Reddy and R. Arockia Kumar

Dynamic Response of FGM Kirchhoff's Plate 529
Pratikshya Mohanty and Rabindra Kumar Behera

Comparative Study of Various Defects in Monolayer Graphene Using Molecular Dynamics Simulation 539
Kritesh Kumar Gupta, Aditya Roy and Sudip Dey

Application of Single-Sided NMR and Acousto-Ultrasonic Methods for NDE of Composite Structures 547
S. K. Sahoo, R. N. Rao, Srinivas Kuchipudi and M. K. Buragohain

Effect of Material Damping on the Vibration Response of Cantilever Beams in Dynamic Environment 557
L. Viswanadham, R. N. Rao and Ch. Sri Chaitanya

Active Vibration Control in Turbocharger Rotor System with the Use of Electromagnetic Actuator 563
Rajasekhara Reddy Mutra and J. Srinivas

Coupled Analysis of Underwater System by Numerical Approach 571
V. Rama Krishna, B. Ajay Kumar, O. R. Nandagopan, N. Ravi kumar and U. Urban Kumar

Design and Analysis on Reinforced Carbon–Basalt Fibres Composite Laminate 581
S. Nagarjuna Reddy and M. Trivikrama Sankar

Optimum Geometry of Steering Mechanism for an Automobile 591
R. Venkatachalam and A. Padma Rao

Influence of Surface Textures by Ink-Jet Print Followed by Chemical Etching Process on the Performance of HSS Cutting Tool 603
K. Nagendra Prasad and Ismail Syed

Effect of Temperature on the Tribological Performance of MoS_2–TiO_2 Coating Material 611
Avinash V. Borgaonkar and Ismail Syed

Topology Optimization Using Strain Energy Distribution for 2D Structures 619
Srinivasan Bairy, Rafaque Ahmad and Hari K. Voruganti

Kinematic Analysis for Optimum Manipulability and Trajectory Planning of Human Leg 633
Abhijeet Dhoke, V. V. M. J. Satish Chembuly and Hari K. Voruganti

Structural Topology Optimization: Methods and Applications 643
Rafaque Ahmad and Hari K. Voruganti

A Multi-objective Optimization Method Based on Nelder–Mead Simplex Search Method 655
Vivek Kumar Mehta and Bhaskar Dasgupta

Production and Industrial Engineering Section

Performance and Life Cycle Analysis of Soybean Oil-Based Minimum Quantity Lubrication in Machining of Ti6Al4V 671
Rukmini Srikant Revuru and Nageswara Rao Posinasetti

Investigations on Corrosion Behaviour in Micro-Milling of Biomedical Grade Ti–6Al–7Nb Alloy 679
S. P. Leo Kumar and D. Avinash

Optimization of Machining Parameters for Multi-performance Characteristics in Milling of Composite Solid Propellants Using RSM 687
Kishore Kumar Katikani, A. Venu Gopal and Venkateseara Rao Vemana

The Effect of ZrO_2 and TiO_2 Reinforcing Agent on the Microstructure and Mechanical Properties of Hydroxyapatite Nanocomposites 699
Vemulapalli Ajay Kumar, Penmetsa Rama Murty Raju, Nallu Ramanaiah and Siriyala Rajesh

Optimization of Machining Parameters for Vibration-Assisted Turning of Ti6Al4V Alloy Using Analysis of Variance 713
D. Venkata Sivareddy, P. Vamsi Krishna and A. Venu Gopal

Characterisation and Performance Measure Evaluation of Nanofluid Blended Thin-Film Temperature Gauges 725
P. Jayesh, Sheikh Afridhi and Abhay Mohan

Base Transesterification of Ineffectual Soybean Oil Using Lab Scale Synthesized CaO Catalyst 735
Rakesh Singh Ningthoujam, Ronaldo Singh Naorem, Denin Singh Langpokpam, Thokchom Subhaschandra Singh and Tikendra Nath Verma

Solid Lubricant Effect on the Microstructure and Hardness of the Functionally Graded Cemented Tungsten Carbide 745
Rityuj Singh Parihar, Srinivasu Gangi Setti and Raj Kumar Sahu

Experimental and Microstructural Analysis of TIG and MIG Welding on Dissimilar Steels 753
A. Aravind Reddy and Abu Sufyan Malik

Thermal Management of Avionic Packages Using Micro-blower 763
K. Velmurugan, V. P. Chandramohan, S. Karunanidhi and D. Sai Phaneendra

Evaluation of Mechanical Properties of Banana and S-glass Fiber-Reinforced Hybrid Nanosilica Composite 775
P. Srinivas Manikanta, M. Somaiah Chowdary and M. S. R. Niranjan Kumar

Tribological Behaviour of Carbon Fibre Polymer Composites Reinforced with Nano-fillers 791
Shylesh K. Siddalingappa, Bhaskar Pal, M. R. Haseebuddin and K. Gopalakrishna

Environment Effect on Impact Strength of Pistachio Shell Filler-Based Epoxy Composites 801
Sandeep Gairola, Somit Gairola and Hitesh Sharma

Performance Improvement of Nanofluid Minimum Quantity Lubrication (Nanofluid MQL) Technique in Surface Grinding by Optimization Using Jaya Algorithm 809
Sharad Chaudhari, Rahul Chakule and Poonam Talmale

Wear Resistance of Structural Steels Having Ultra-Low Carbon to High Carbon Concentration 817
Soumya Sourav Sarangi, Lavakumar Avala and D. Narsimhachary

Experimental Investigation on Laser Beam Welded Joints of Dissimilar Metals and Optimization of Process Parameters Using Firefly Algorithm 823
B. Narayana Reddy, P. Hema, Y. Prasanth Reddy and G. Padmanabhan

Parametric Optimization of Electrical Discharge Grinding on Ti–6Al–4V Alloy Using Response Surface Methodology 831
Murahari Kolli and Adepu Kumar

Mathematical Modeling of Material Removal Rate Using Buckingham Pi Theorem in Electrical Discharge Machining of Hastelloy C276 843
P. Ravindranatha Reddy, G. Jayachandra Reddy and G. Prasanthi

Effect of Exfoliated Vermiculite as Thickening and Foaming Agent on the Physical Properties of Aluminium Foam 853
V. V. K. Lakshmi, V. Arun Vikram, K. V. Subbaiah, K. Suresh and B. Surendra Babu

Multi-response Optimization of Process Parameters in Turn-Milling Processes—An Experimental Approach 861
K. Arun Vikram, C. Ratnam, V. V. K. Lakshmi and R. D. V. Prasad

On the Role of Amylum Additive-Based Cutting Fluids in Machining—An Experimental Investigation 873
R. Padmini, P. Vamsi Krishna and P. Jeevan Kumar

Tensile Property of Ultra-High Molecular Weight Polyethylene Fibre and Its Composite Laminate 881
Arun Kumar Singh, Dharmendra Kumar Shukla and N. Eswara Prasad

Experimental and Numerical Modeling of ECMM on Al 7075 T6 Alloy 889
K. Samson Praveen Kumar and G. Jaya Chandra Reddy

FEM Modeling of Coated Tools to Study the Influence of Coating Thickness 899
M. Khirod Kumar, Manne Hareesh, P. Vamsi Krishna and S. Sambhu Prasad

Effect of Graphene Nanofluid on Machining Inconel 718 913
Siva Bevara, M. Amrita, Sanjay Kumar and B. Kamesh

Mechanical Properties of AA 7075-Nano ZrO_2 Reinforced Matrix Composites 921
B. Prasanna Nagasai, S. Srikanth and J. A. Ranga Babu

Experimental Investigation on Friction Stir Welding of HDPE Reinforced with SiC and Al and Taguchi-Based Optimization 929
S. Ramesh Babu, S. R. K. Hudgikar and Y. Poornachandra Sekhar

Design and Simulation of Porous Ti–6Al–4V Alloy Structures for Additive Manufacturing of Bioimplants 941
A. Rudra Kumar, S. Rambabu and K. Sri Harsha

Effect of Tool Geometry and Heat Treatment on Friction Stir Processing of AA6061 947
Karan Chauhan, M. V. N. V. Satyanarayana and Adepu Kumar

Analysis of Micro-cracks and Micro-hardness in White Layer Formation on Machined Surfaces in EDM Process 955
K. Leela Kumar, Ch. Srinivasa Rao, B. Sateesh and M. S. R. Viswanath

Multi-objective Optimization of Submerged Friction Stir Welding Process Parameters for Improved Mechanical Strength of AA6061 Weld Bead by Using Taguchi-L18-Based Gray Relational Analysis . . . 965
Laxmana Raju Salavaravu and Lingaraju Dumpala

Investigation on Wear Behaviour of AA5052/SiC/Al_2O_3 Hybrid Composite Fabricated Using Stir Casting Process 975
V. G. Shanmuga Priyan, R. Malayalamurthi and S. Kanmani Subbu

Numerical Modelling of High Energy Density Beam-Assisted Machining of Hardened Armour Steel 983
A. Sahu, A. N. Jinoop, C. P. Paul, Adepu Kumar and K. S. Bindra

Experimental Investigation of Electro-Discharge Machining on NIMONIC 80A Through Response Surface Methodology 991
G. Vishnu Pramod Teja, K. Saraswathamma, P. Murali Krishna and G. Tejeswara Rao

Optimization of Minimum Quantity Lubrication Parameters 1001
M. Amrita, R. R. Srikant and V. S. N. Venkata Ramana

Experimental Investigation and Mathematical Modeling for Material Removal and Tool Wear in Making of Rectangular Channels by Electric Discharge Machining (EDM) on Aluminum–Boron Carbide Composite Sintered Preform 1011
Suresh Gudipudi, Selvaraj Nagamuthu, Kanmani Subbu Subbian and Surya Prakasa Rao Chilakalapalli

Investigation on the Microstructure and Mechanical Properties of AZ91D Magnesium Alloy Plates Joined by Friction Stir Welding 1021
Nagabhushan Kumar Kadigithala and C. Vanitha

Mechanical Characterization of Unidirectional Banana–Glass Fiber-Reinforced Hybrid Composites 1031
Ch. Naveen Reddy, M. Bhargav and Ajay Kumar Kaviti

Experimental Investigation of Ultrasonic Flaw Defects in Weld Clad Materials Using NDT Technique 1039
P. Ravindra Kumar, G. Vijay Kumar, K. Naga Murali and R. B. S. S. Kishore

An Effective and Economical Method to Improve Structural Homogeneity and Mechanical Properties of Al–Mg Alloy Processed by ECAE 1053
Ananda Babu Varadala, Swami Naidu Gurugubelli and Sateesh Bandaru

Characterization of Kenaf/Aloevera Fiber Reinforced PLA-Hybrid Biocomposite 1061
P. Ramesh, B. Durga Prasad and K. L. Narayana

Performance Analysis of Different Tool Shape in Electric Discharge Machining Process with Vegetable Oil as Dielectric Fluid 1069
B. Singaravel, K. Chandra Shekar, G. Gowtham Reddy and S. Deva Prasad

Experimental and Finite Element Analysis of Fracture Toughness of Chilled LM13 MMC 1079
H. S. Harshith and Joel Hemanth

Design and Fabrication of Die Back Door for Manufacturing of Cylinder Liners 1089
T. Vadivelu, C. Vijaya Bhaskar Reddy and G. Prasanthi

Fabrication and Characterization of Functionally Graded Composites Using Friction Stir Processing 1103
B. Venkatesh, T. Sadasiva Rao and Adepu Kumar

Multi-Parametric Optimization of Electrical Discharge Machining of Inconel-690 Using RSM-GRA Technique 1113
Bhavani Marturi, Murahari Kolli, Adepu Kumar, Seelam Pichi Reddy and Sai Naresh Dasari

Effect of Nanoparticles Addition on Microstructural and Mechanical Properties of Friction Stir Welded 2014 Aluminium Alloy 1127
Kethavath Kranthi Kumar, Adepu Kumar and Divya Sachan

Investigation on Influence of Hybrid Nanofluid/MQL on Surface Roughness in Turning Inconel-718 1137
Mechiri Sandeep Kumar, V. Vasu and A. Venu Gopal

Fuzzy Logic and Regression Modelling of Machining Parameters in Turning AISI 1040 Steel Using Vegetable-Based Cutting Fluids with Extreme Pressure Additive 1147
B. Satheesh Kumar, Neelam Parimala and P. Vamsi Krishna

A New Approach in Establishing Stable Machining Parameters Using Frame Statistics and Kurtosis 1159
V. Srinivasa Rohit, A. Venu Gopal and L. Rama Krishna

Design and Ergonomic Work Posture Evaluation of Garbage Disposal Pushcart 1169
P. Jayesh, A. Gopala Krishna, M. Vishal, Abhay Mohan and Sheikh Afridhi

Redesigning of Electric Plug for Assembly Time Reduction Using DFA 1179
V. Naga Malleswari, B. SurendraBabu and Ch. Praneeth

Analysis and Optimization of Queueing Systems in Airports—Discrete Event Simulation 1189
Rishabh Jain, Hrishikesh Bedekar, K. Jayakrishna, K. E. K. Vimal and M. Vijaya Kumar

An Extensive Study of Multi-level Inventory Lot Sizing Optimization Problem 1195
V. V. D. Sahithi, C. S. P. Rao and M. Srinivasa Rao

About the Editors

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Thermal Engineering Section

Computational Study of Mixed Convection of Electronic Chips with Surface Radiation

Arnab Deb and S. K. Mandal

Abstract In this present study, the effect of heat spreader in a horizontal channel consisting of electronic chips with mixed convection and surface radiation is examined. SIMPLER algorithm with finite volume method is used to solve governing equations using ANSYS 16.2 software. Results show the increase in the performance of heat transfer with an increase in the values of governing parameters like Reynolds number and emissivity of the spreader.

Keywords Heat spreader · Mixed convection · Radiation · Electronic chip

1 Introduction

The dependability of the basic electronic components of a device has key importance in the overall reliability of the device. Electronic equipment becomes less efficient if it exceeds a specific temperature limit. As the temperature is increased, the failure rate is enhanced exponentially. So, control of the temperature of the electronic parts is a vital issue in the design and operation. A virtuous literature survey suggests that many of the studies are focused on heat transfer augmentation with the utility of various shaped control elements. Various forms of vortex generators can be used to enhance the heat transfer such as protrusions, inclined blocks, wings, fin and ribs, winglets [1, 2] in different geometries like circular, non-circular channel under turbulent flow [3–5] as well as laminar flows [4]. Effect of surface radiation along with mixed convection also improves the heat transfer performance [6, 7]. Electronic chip covered by heat spreader can also be used to enhance the rate of heat transfer. It also avoids direct contact of air with the chips.

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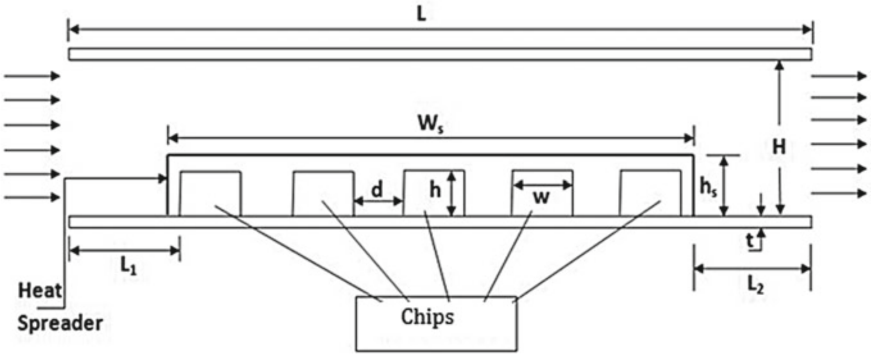

Fig. 1 Schematic diagram of the problem

2 Problem Description

The schematic diagram of a rectangular parallel plate channel with five identical electronic chips covered by a rectangular heat spreader is shown in Fig. 1. Electronic chips are located at the bottom wall of the channel maintaining a spacing of ‘*d*’ with successive chip. Channel has a length ‘*L*’ and a width ‘*H*’. Each chip has a width ‘*w*’ and height ‘*h*’. The heat spreader has a width of ‘W_s’ and height ‘h_s’. Left face of the first chip maintains a distance of ‘L_1’ from the inlet and right face of the 5th chip is positioned at a distance of ‘L_2’ from the outlet. Walls of the channel has a fixed thickness of ‘*t*’. Each chip with volumetric heat-generating capacity of 100,000 W/m^3 is chosen in the present case. Fluid properties are supposed to be constant.

3 Governing Equations and Boundary Conditions

For a two-dimensional, steady, incompressible, laminar flow the governing equations are given as follows:

$$\frac{\partial U}{\partial X}+\frac{\partial V}{\partial Y}=0 \tag{1}$$

$$U\frac{\partial U}{\partial X}+V\frac{\partial U}{\partial Y}=-\frac{\partial P}{\partial X}+\frac{1}{Re}\left(\frac{\partial^2 U}{\partial X^2}+\frac{\partial^2 U}{\partial Y^2}\right) \tag{2}$$

$$U\frac{\partial V}{\partial X}+V\frac{\partial V}{\partial Y}=-\frac{\partial P}{\partial Y}+\frac{1}{Re}\left(\frac{\partial^2 V}{\partial X^2}+\frac{\partial^2 V}{\partial Y^2}\right)+\frac{Gr}{Re^2}\theta \tag{3}$$

$$U\frac{\partial \theta}{\partial X}+V\frac{\partial \theta}{\partial Y}=\frac{1}{RePr}\left(\frac{\partial^2 \theta}{\partial X^2}+\frac{\partial^2 \theta}{\partial Y^2}\right) \tag{4}$$

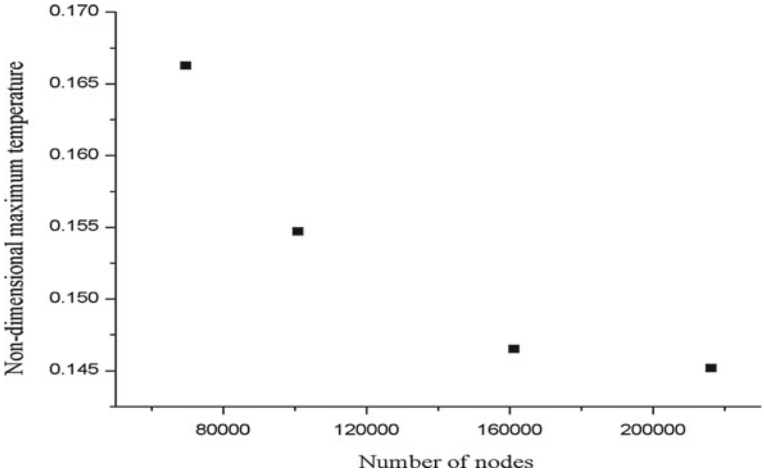

Fig. 2 Variation of non-dimensional maximum temperature with number of nodes

Surface to surface radiation model is used considering all internal surfaces are grey, opaque and diffuse. Air is a non-participating medium. No-slip boundary conditions are employed at surfaces. Couple boundary conditions are used at wall-to-fluid and wall-to-wall boundaries [7]. At inlet, velocity inlet boundary condition and at outlet, pressure outlet boundary condition is imposed.

4 Grid Independence Test

Grid independence study is conducted for $Re = 250$. A non-uniform grid is used all through the domain along with very fine grids in front of the chips and spreader. Figure 2 shows that by increasing the total number of nodes from 161,265 to 216,279, a change is only less than 1% on the maximum non-dimensional temperature. Hence, the node of 161,265 is considered in whole study for time limits.

5 Results and Discussions

Present study is conducted for diverse Reynolds number ($Re = 100$, 250 and 500), various emissivity values of heat spreader ($\boldsymbol{\varepsilon}_{\mathrm{s}} = 0.1$, 0.3, 0.5, 0.7 and 0.9) by fixing emissivity of substrate at 0.9 to create sufficient data for non-dimensional temperature ($\boldsymbol{\theta}$). In this investigation, the dimensionless geometric parameters have been taken as $L_1 = 2H$, $L_2 = 8H$, $d = w$.

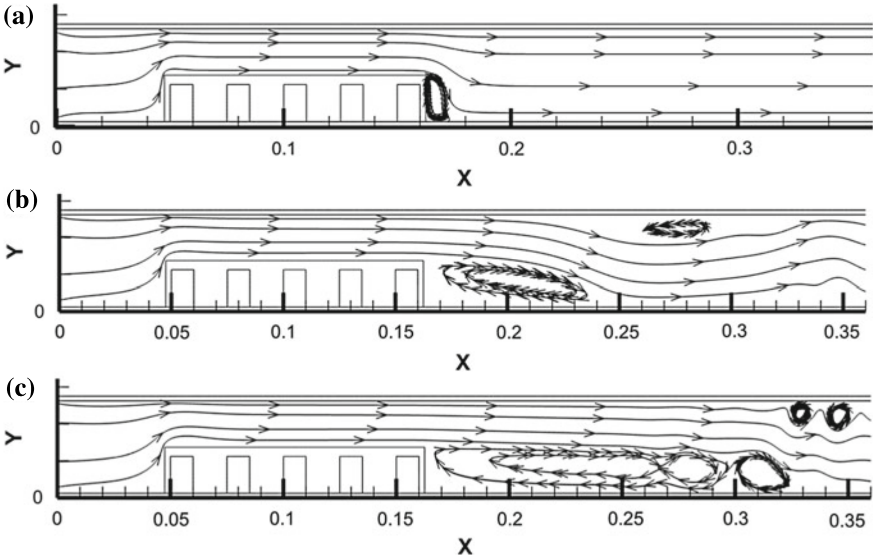

Fig. 3 Streamline for $\boldsymbol{\varepsilon}_S = 0.5$ at **a** $Re = 100$, **b** $Re = 250$ and **c** $Re = 500$

5.1 Influence of Reynolds Number on Heat Transfer

One of the considerable parameters in this present numerical study is Reynolds number. Flow field is characterized by using streamline as shown in Fig. 3. Temperature distribution is shown in Fig. 4.

From Fig. 3, it is observed that with the increase in Reynolds number, recirculation strength behind the spreader increases due to sudden increase in cross-sectional area which leads to backward pressure drop. At higher Reynolds number, a weak flow reversal takes place near the top wall of the channel due to sudden expansion of cross-sectional area. Figure 4 depicts that with the increase in Reynolds number, thermal boundary layer thickness decreases and also temperature of the channel decreases. As, due to radiation, heat is transferred from spreader to top wall of the channel, and thus, thermal boundary layer is also developed at the top wall which decreases with increase in Reynolds number.

5.2 Influence of Heat Spreader Emissivity on Heat Transfer

Figure 5a depicts that with the increase in emissivity of heat spreader, non-dimensional temperature decreases. When emissivity changes from 0.1 to 0.9, maximum temperature changes from 347 to 334 K as radiative interaction between spreader and wall increases. Figure 5b depicts the effect of surface radiation on

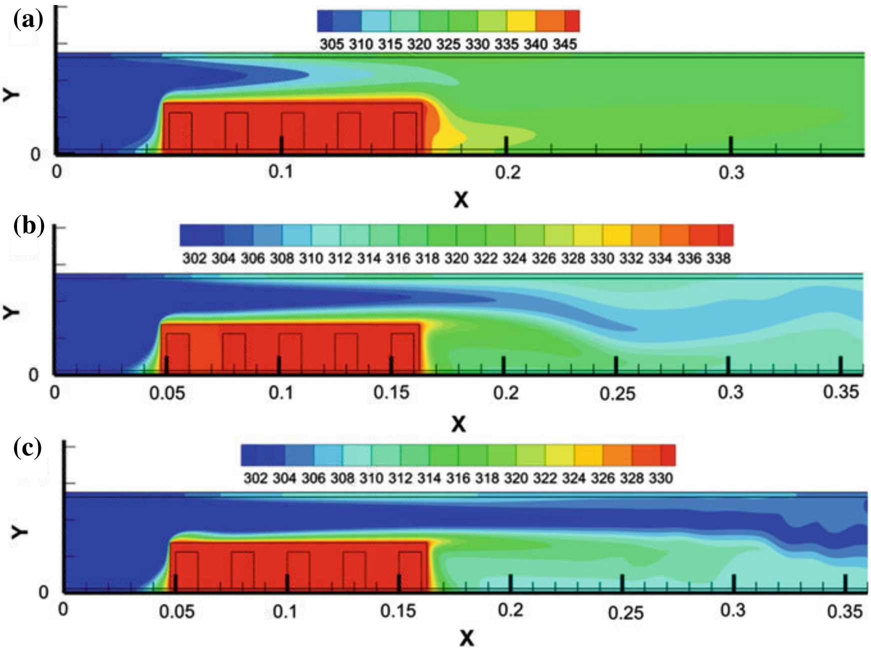

Fig. 4 Temperature distribution for $\varepsilon_s = 0.5$ at **a** $Re = 100$, **b** $Re = 250$ and **c** $Re = 500$

total heat transfer. At $Re = 250$, when spreader emissivity 0.1, the contribution of radiation is 7.65%, while for emissivity 0.9, it is 31.87%. At higher Reynolds number, the contribution of surface radiation on total heat transfer decreases as mixed convection effect dominates. Temperature distribution for various emissivities of heat spreader is shown in Fig. 6.

6 Conclusions

From the above analysis, it is observed that with the increase in Reynolds number, maximum temperature within the channel decreases and also, contribution of radiation decreases. Again, it is observed that with the increase in spreader emissivity, the temperature at the chip surface decreases.

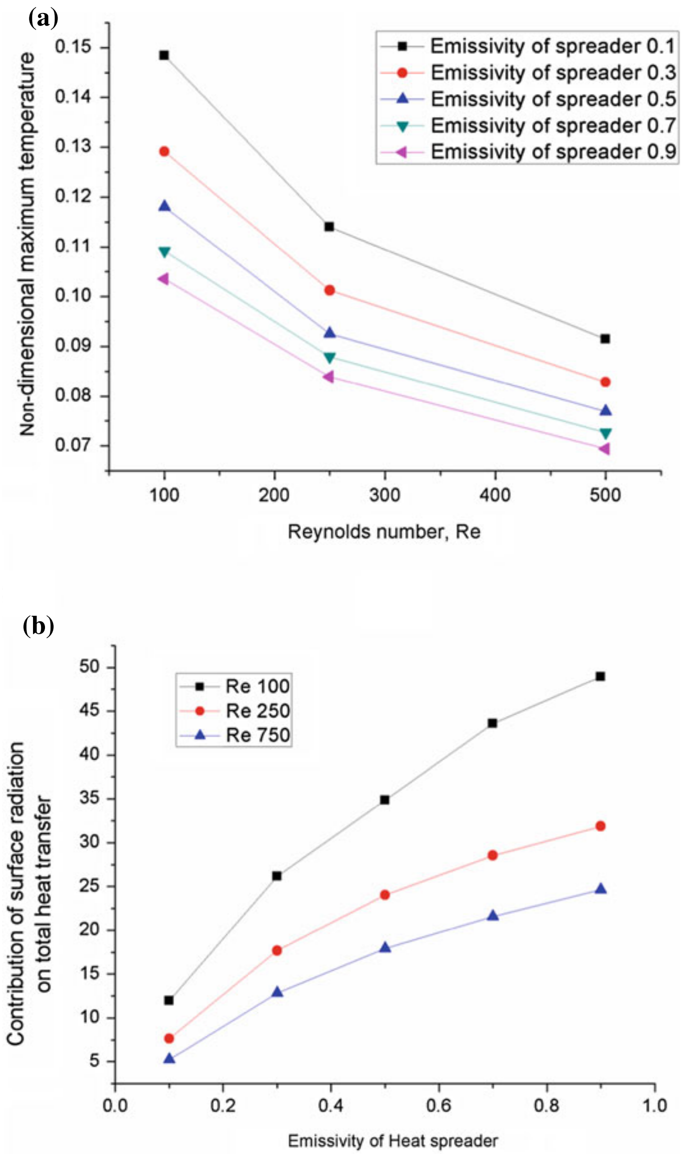

Fig. 5 Graph **a** variation of non-dimensional temperature with *Re* for different emissivity, **b** contribution of radiation on total heat transfer for different *Re*

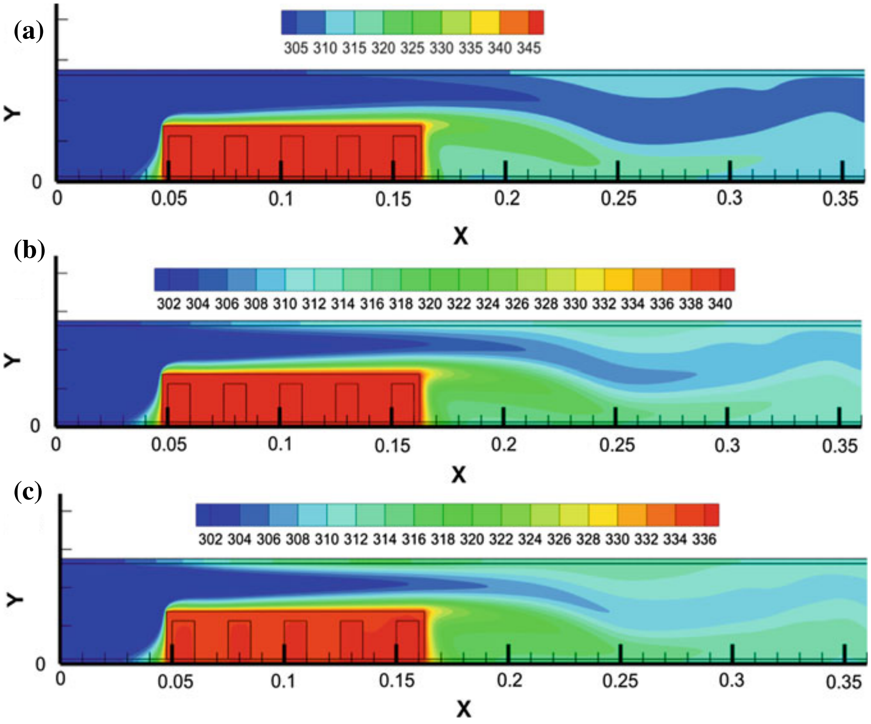

Fig. 6 Temperature distribution for $Re = 250$ **a** $\varepsilon_s = 0.1$, **b** $\varepsilon_s = 0.3$ and **c** $\varepsilon_s = 0.7$

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Combustion Performance of Hybrid Rocket Motor Under the Influence of Cylindrical Protrusion

Kabaleeswaran Manikandan, K. Lakshmi Das, N. Purushothaman and L. Karthik

Abstract The sequence of hybrid rocket motor static firings is performed, with and without cylindrical protrusion, to evaluate the combustion behavior of bee-wax fuel grain. Firing is done for the injection pressures of 2.75 bar, 4.15 bar, and 5.51 bar, respectively, all firings are done for an identical firing duration of 7 seconds. Experimental outcome confirms the addition cylindrical protrusion as vortex generator yield an average of 45% higher regression rate than that of the baseline rocket motor. Among all injection pressures, modest 4.15 bar with cylindrical protrusion shows a significant improvement in the combustion performance by exhibiting the enhanced regression rate as well as mass consumption rate of the fuel grain. Hence, the addition of cylindrical protrusion as a vortex generator to the classical hybrid motor promise to improve the combustion performance of the bee-wax fuel grain.

Keywords Hybrid rocket · Regression rate · Vortex generator · Bee-wax fuel grain

1 Introduction

Propulsion systems play the major role as a workhorse for the space launch vehicles to accomplish its mission. Different rocket engines are used in the launch vehicles based on their mission requirements. Currently, solid, liquid and cryogenic engines are employed to perform the mission task. Among these engines, solid and liquid engines are widely used in the primary stages of the launch vehicles. Even though, these engines are used primarily both engines has some characteristics, which need to be addressed to optimize the vehicle performance. The hybrid rocket is naturally safer than other rocket engines, where the oxidizer is stored as a liquid and the fuel as a solid. Hybrid rocket motors are less susceptible to chemical explosion than conventional solid and bi-propellant liquid designs [1]. The main shortcoming of

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