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Sanjoy K. Ghoshal · Arun K. Samantaray ·  
Sandipan Bandyopadhyay  
Editors

# Recent Advances in Industrial Machines and Mechanisms

Select Proceedings of IPRoMM 2022

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# Preface

This book presents a collection of selected papers presented at the “2nd International and 14th National Conference on Industrial Problems on Machines and Mechanisms (IPRoMM 2022)”, held during 22–23 December at the Indian Institute of Technology (ISM) Dhanbad, Jharkhand, India.

It was the invention of machines, more specifically the water and steam-powered machines and engines that heralded the beginning of the industrial revolution. Since then, mechanisms and machines have been integral parts of industrial development. As we embrace the paradigms of Industry 4.0, the mechanisms community face greater challenges, having to venture into relatively uncharted territories to solve problems which hitherto were not known to exist. Therefore, it is extremely important for the researchers and practitioners in this field to come together to discuss these problems towards finding collaborative solutions. IPRoMM 2022 was a successful step in this direction.

Recognising the need for industry–academia interactions, Association for Machines and Mechanisms (AMM) started a workshop, under the title of “Industrial Problems on Machines and Mechanisms”, in 1986. The first of these biennial workshops was held at Ahmedabad Textile Industry’s Research Association (ATIRA), with Mr. Ratna Prabhu at the helm of the organisation. The choice of the venue reflected the focal point of these workshops at that time, namely the problems associated with the textile industries. Over the years, these workshops grew significantly in participation, as well as the diversity of topics of deliberation. Eventually, IPRoMM was recognised as an international conference, with the first of the new series being titled the “1st International and 13th National Conference on Industrial Problems on Machines and Mechanisms”, which was held at the Birla Institute of Technology and Science (BITS) Pilani, Hyderabad Campus, in 2020.

This year, the conference drew 168 contributions from a wide variety of topics, including multi-body dynamics and mechanical vibrations, robotics and control, advanced manufacturing processes, fault detection and structural health monitoring, composites and advanced materials, biomedical engineering and biomechanics, thermal and thermo-fluidic analysis, soft computing techniques, AI/ML, and IoT. Based on initial desk review and single-blind peer reviews involving 194 reviewers,

77 papers were selected for oral presentation, while 12 were presented in the form of posters. Finally, after another round of quality assessment, 67 papers were included in this book.

The editors are greatly obliged to the authors for their contributions and the reviewers for their efforts towards ensuring the quality of the papers. They also thank IIT (ISM) for hosting this event and AMM for their guidance and support throughout the organisation process. Special thanks are due to the sponsors of the event for their liberal support. Last but not least, the editors acknowledge with thanks the efforts of the editorial team at Springer for bringing out this book in a timely manner.

Dhanbad, India  
Kharagpur, India  
Chennai, India

Sanjoy K. Ghoshal  
Arun K. Samantaray  
Sandipan Bandyopadhyay

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# Computational Analysis on the Three-Dimensionality of Turbulent Duct-Flow Subsequent to In-Plane Double Bends

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## Abstract

We present a computational study of Prandtl's secondary flow of the first kind in the presence of turbulence within a  $90^\circ$  in-plane double bend fitted between two straight ducts. Most of the previous papers available in the literature demonstrate the gross flow behaviours due to out-of-plane double bends. We, however, focus on capturing the local flow behaviours in an in-plane double bend and the progressive development of the flow downstream of the bend. We capture a pair of Dean vortices located downstream of the double bend. We trace the motion of higher velocity fluid particles within the vortices by in-plane velocity vectors directed from the pipe core towards the bend's outer side due to an unbalanced centrifugal force of the skewed flow. Our solutions nicely capture the decay of the in-plane flow (or secondary flow) and concurrent re-establishment of primary flow downstream of the bend. For engineering analyses, we introduce a new parameter called enhancement ratio ( $\epsilon$ ), a measure of the increase of the fluid velocity while passing through the bend.  $\epsilon$  decreases with increasing both Reynolds numbers ( $\text{Re}$ ) and curvature ratio ( $\overline{R}_c$ ). It is realized that the reduction of  $\epsilon$  is related to the corresponding fall in non-dimensional pressure loss.

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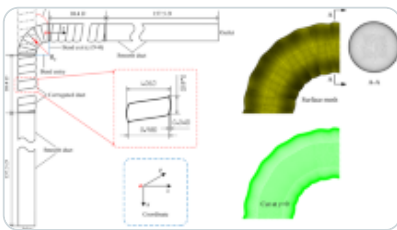
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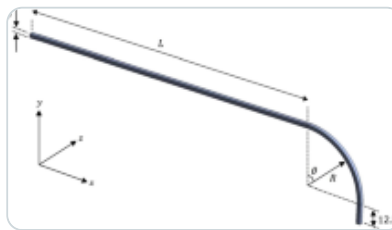
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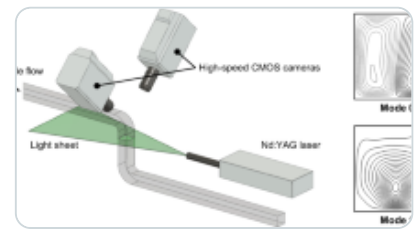
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