



DESIGN OF PRECISION MACHINES

PROF. JITENDRA P. KHATAIT

Department of Mechanical Engineering
IIT Delhi

PRE-REQUISITES : UG courses in Engineering Mechanics, Kinematics and Dynamics of Machines, and Solid Mechanics

INTENDED AUDIENCE : UGs and PGs from Mechanical, Materials, Aerospace, Automotive, Civil, and other related engineering branches. Working professionals associated with mechanical design of products, machines, etc.

COURSE OUTLINE :

The course gives an insight into the conceptual design of mechanisms used in products, machines, and devices used in various domains. The course aims to enable the student to recognize problem areas, generate design alternatives and make design choices to achieve precision and reliability, and avoid over-constraints in the design.

The course contents include lectures & hands-on experience covering fundamental concepts in precision machine design; controlling Degrees-of-Freedom, exact-constrained design; design of elastic mechanisms/ flexures/ compliant mechanisms; friction, hysteresis and micro-slip; actuators and sensors for precision motion; slideways for long range precision motion, and dynamics of precision mechanisms. The course contents also include different case studies.

ABOUT INSTRUCTOR :

Prof. Jitendra Prasad Khatait has been with the Department of Mechanical Engineering at IIT Delhi since 2014. His Ph.D. degree (2013) is from University of Twente, Netherlands. He is B.E. (2000) in Mechanical Engineering from IIT Roorkee (formerly University of Roorkee) and M.Tech. (2002) in Design of Mechanical Equipment from IIT Delhi. He also has a specialized Masters in Technological Design (MTD) in Mechatronics through a joint program between National University of Singapore (NUS) and Eindhoven University of Technology (TU/e), Netherlands in 2005.

Prof. Khatait has designed precision electro-mechanical systems at ASML, Netherlands (2013 – 2014) including lithography machines. While at Singapore Institute of Manufacturing Technology (SIMTech, 2005 – 2008), A-STAR, he has designed ultra-precision motion stages using air bearings and linear motors for semiconductor applications. He had small stints at Daewoo Motors and Maruti Suzuki, India.

Over the years, Dr. Khatait has involved in various research activities like designing and developing kinetic energy storage system, ultra-precision motion stages, micro-manipulation systems, and surgical assists. A recent development is of a test bed for minimally invasive surgery (MIS)/ laparoscopy using remote centre of motion (RCM, as in Da Vinci surgical robot) to demonstrate efficacy of precision adjustment vis-à-vis component manufacturing precision. He has also designed compliant mechanism based precision imprinting system for microfluidic applications.

His teaching emphasizes the role of compliant mechanisms, precision engineering, and exact-constrained design techniques needed to achieve ultra-precision. These additions, drawing on his work experience in Singapore and Netherlands, add a unique dimension to the usual Mechanical Engineering design curriculum. Hands on engagement with student teams and start-ups has enabled the next generation at IIT Delhi to target design of precision systems alongside fabrication of precision components.

COURSE PLAN :

Week 1: INTRODUCTION TO PRECISION MACHINES

- Applications – Semiconductor equipment, precision machines, robotics, etc.

Week 2: FUNDAMENTAL CONCEPTS IN PRECISION DESIGN

- Design principles
- Definitions and terminology

Week 3: CONTROLLING DEGREES OF FREEDOM

- DOFs and Constraints
- Exact-constrained design
- Over-constraints
- Case-studies

Week 4: DESIGN FOR STIFFNESS

- Stiffness calculation
- Parallel v/s series
- Design using sheet metals

Week 5 & 6: FLEXURES

- Building blocks
- Cross flexures, flexure parallel guiding
- Sheet and wire flexure with reinforcement
- Folded sheet flexure, hole flexure
- Case studies

Week 7: FRICTION, HYSTERESIS AND MICROSLIP

- Virtual backlash, hysteresis
- Hysteresis in clamped joints
- Hysteresis-free connection

Week 8: NON-CONTACT BEARINGS

- Air bearings
- Flexure bearings

Week 9: SLIDEWAYS FOR LONG RANGE PRECISION MOTION

- Design using air bearings
- Air bearing stages

Week 10: ACTUATORS AND SENSORS

- Linear drives
- Sensors and encoders

Week 11: DYNAMICS OF PRECISION MECHANISMS

- Transient response – second order system
- Backlash induced dynamics
- Examples of avoiding backlash

Week 12: CASE-STUDIES