

COURSE OUTLINE

(1) GENERAL

SCHOOL	Engineering		
ACADEMIC UNIT	Mechanical Engineering		
LEVEL OF STUDIES	Undergraduate		
COURSE CODE	EN2500	SEMESTER	8th
COURSE TITLE	RHEOLOGY AND MOLDING PROCESSES OF POLYMERS		
INDEPENDENT TEACHING ACTIVITIES <i>if credits are awarded for separate components of the course, e.g. lectures, laboratory exercises, etc. If the credits are awarded for the whole of the course, give the weekly teaching hours and the total credits</i>	WEEKLY TEACHING HOURS	CREDITS	
Lectures	5	6	
<i>Add rows if necessary. The organisation of teaching and the teaching methods used are described in detail at (d).</i>			
COURSE TYPE <i>general background, special background, specialized general knowledge, skills development</i>	General background, specialized general knowledge		
PREREQUISITE COURSES:	-		
LANGUAGE OF INSTRUCTION and EXAMINATIONS:	Greek		
IS THE COURSE OFFERED TO ERASMUS STUDENTS	Yes (lecturing)		
COURSE WEBSITE (URL)	https://www.mie.uth.gr/?page_id=18450&lang=en		

(2) LEARNING OUTCOMES

<p>Learning outcomes <i>The course learning outcomes, specific knowledge, skills and competences of an appropriate level, which the students will acquire with the successful completion of the course are described.</i></p> <p>Consult Appendix A</p> <ul style="list-style-type: none"> • Description of the level of learning outcomes for each qualifications cycle, according to the Qualifications Framework of the European Higher Education Area • Descriptors for Levels 6, 7 & 8 of the European Qualifications Framework for Lifelong Learning and Appendix B • Guidelines for writing Learning Outcomes
<p>The purpose of this course is to provide undergraduate students with the knowledge to understand the basic principles of rheology and polymer processing. Students are first introduced to the concept of polymer, its basic properties (e.g. average molecular weight, glass transition temperature, macromolecular architecture), in order to understand how polymers and why they differ from other common materials. Students are then introduced to the concept of shear viscosity and viscous non-Newtonian fluids through various constitutive equations. The constitutive equations are then used to analyze one-dimensional flow problems in conduit-type geometries. Students are then introduced to the basic types of rheological measurements of polymeric melts and solutions: capillary viscometry and melt flow indices, which are accompanied by experimental data calculations and regression. The concepts of elongational viscosity (and melt strength), normal stresses and how they are measured are presented. Subsequently, the problems of polymeric melt instabilities that occur as they exit flow channels are introduced. It is presented how the elastic behavior of polymer melts is related to the type and extent of instability. Students are then introduced to dynamic rheological measurements and how one can derive information about molecular architecture and how it relates to the final properties of the product. The next piece of material is devoted to the basic method of making polymeric products: single-screw extrusion. The types of extruders, the structure and geometry of the screw are introduced, as well as how the polymer flow within the screw is modeled. Mixing elements (e.g. Maddock, Egan etc) mounted at the end of the screw are also presented. Detailed calculations are performed for torque and extruder power consumption. Next, the types of extrusion dies and extruders for film, film, tube and profile type are analyzed. Part of the analysis is devoted to describe the flow within the heads through calculations. How the flow is related to polymer rheology is also discussed. The heat transfer of the extruder and the die is then shown and calculated. Methods for designing extrusion dies through one-dimensional flow</p>

calculations and flow simulation software are presented and analyzed, combined with real rheological measurement data.

After successful course attendance, students will be able to

recognize and understand the typical properties of polymers,
 solve and analyze one-dimensional non-Newtonian viscous fluid flow problems in typical geometries (conduit, parallel plates),
 know the operating principles of a capillary viscometer and analyze the results of measurements for rheological characterization and classification of polymers,
 know how to measure and analyze the melt flow rate (MFR), a tool widely used in industry for quality control of all kinds of plastic products,
 know how to measure the elongational viscosity of polymeric melt and the melt strength, which are mainly used in the film, sheet and film industry,
 know, identify and analyze the types of instabilities when the material exits the extrusion channels and how the type of polymer affects the type and extent of the instability, thus the geometry and surface area of the product,
 know the principle of operating dynamic measurements and analyze their results to understand the structure of the polymer,
 understand the principle of single-screw extruder operation and the types of screws used depending on the rheological behavior of the polymer,
 understand the operating principle of the mixing elements at the end of the screw,
 calculate the pumping capacity, pressure drop, torque and power output of an extruder in combination with rheological data,
 design the extruder screw according to the rheology of the polymer,
 calculate the pressure drop, shear stress on the wall and other relevant quantities in the extrusion dies and how these results are used for design,
 carry out heat transfer calculations for the extruder and the extrusion dies

General Competences

Taking into consideration the general competences that the degree-holder must acquire (as these appear in the Diploma Supplement and appear below), at which of the following does the course aim?

<i>Search for, analysis and synthesis of data and information, with the use of the necessary technology</i>	<i>Project planning and management</i>
<i>Adapting to new situations</i>	<i>Respect for difference and multiculturalism</i>
<i>Decision-making</i>	<i>Respect for the natural environment</i>
<i>Working independently</i>	<i>Showing social, professional and ethical responsibility and sensitivity to gender issues</i>
<i>Team work</i>	<i>Criticism and self-criticism</i>
<i>Working in an international environment</i>	<i>Production of free, creative and inductive thinking</i>
<i>Working in an interdisciplinary environment</i>	<i>.....</i>
<i>Production of new research ideas</i>	<i>Others...</i>
	<i>.....</i>

- Search for, analysis and synthesis of data and information
- Working independently
- Decision-making
- Project planning and management
- Production of new research ideas
- Production of free, creative and inductive thinking

(3) SYLLABUS

- (1) **Basic properties of polymers:** Glass transition temperature, average molecular weight and molecular weight distribution, density, macromolecular architecture, etc.
- (2) **Shear viscosity:** Non-Newtonian Rheological Models: Ostwald-De Waele, Carreau-Yasuda, Cross. One-dimensional non-Newtonian flow in a conduit, between parallel and converging conduits. Non-Newtonian Couette flow. Flow analysis in capillary viscometer and melt flow indices (melt flow rate-MFR). Rabinowitsch correction. Non-isothermal flow. Method of measuring slip on the wall. Shear viscosity models for 3D flow analysis.
- (3) **Viscoelasticity:** Some unusual rheological phenomena. Deborah number and Weissenberg number. Maxwell fluid model. First and second normal stress difference. Extensional/elongational viscosity. Flows in sudden contractions. Bagley correction. Extensional viscosity calculations using the Cogswell method. Constitutive equations: Generalized Newtonian Fluid, Convected Maxwell

<p>Model, De Gennes model, K-BKZ model. Die swelling. Melt elasticity and stress relaxation phenomena.</p> <p>(4) Polymer instabilities at the exit of channels: sharkskin, melt fracture, die lip build-up (drool) and surface tearing of an extrudate containing natural fillers (such as wood chips, rice hulls, etc.).</p> <p>(5) Dynamic rheological measurements in rotating viscometers: Cone-plate and parallel plate rheometer. Small Amplitude Oscillatory Shear (SAOS) viscometry. Storage modulus, loss modulus, complex viscosity, Cox-Merz rule. Melt strength.</p> <p>(6) Single-Screw Extrusion (SSE): Melt pump design, melt-fed extruder flow calculations, Couette flow with positive and negative pressure gradients, extruder operating point, solid transport, types of rough barrels, melting in the extruder, pumping, screws with Maddock and Egan mixing elements, dispersive and distributed mixing, power consumption calculations, multi-flighted screws, calculations and analysis of a typical extruder.</p> <p>(7) Extrusion dies: (i) flat film extrusion dies, flat film design, polymeric materials used, (ii) blown film extrusion and relevant polymeric materials, blown film bubble shape, (iii) multilayer co-extrusion in flat film and blown film extrusion dies, instabilities due to viscosity incompatibility of layers, interfacial instabilities and multilayer one-dimensional flow analysis, (iv) pipe and tube extrusion, types of extrusion dies, weldlines, pipe calibration unit, corrugated pipes, Barlow equation for peripheral pipe burst strength, (v) profile extrusion, balanced and unbalanced flow, types of profile dies.</p> <p>(8) Twin Screw Extrusion (TSE): operating principles, types of screws, co-rotating and counter-rotating twin screw extruders, co-rotating fully intermeshing TSEs, Low speed counter-rotating intermeshing twin screw extruders</p>
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(4) TEACHING and LEARNING METHODS - EVALUATION

DELIVERY	Classroom	
<i>Face-to-face, Distance learning, etc.</i>		
USE OF INFORMATION AND COMMUNICATIONS TECHNOLOGY	Web-based learning support	
<i>Use of ICT in teaching, laboratory education, communication with students</i>	Using Powerpoint slides Post educational material at the course website Lab exercises and homework problems	
TEACHING METHODS	<i>Activity</i>	<i>Semester workload</i>
<i>The manner and methods of teaching are described in detail. Lectures, seminars, laboratory practice, fieldwork, study and analysis of bibliography, tutorials, placements, clinical practice, art workshop, interactive teaching, educational visits, project, essay writing, artistic creativity, etc.</i> <i>The student's study hours for each learning activity are given as well as the hours of non- directed study according to the principles of the ECTS</i>	Lectures	70
	Homework	35
	Independent study	45
	Course total	150

<p>STUDENT PERFORMANCE EVALUATION</p> <p>Description of the evaluation procedure</p> <p><i>Language of evaluation, methods of evaluation, summative or conclusive, multiple choice questionnaires, short-answer questions, open-ended questions, problem solving, written work, essay/report, oral examination, public presentation, laboratory work, clinical examination of patient, art interpretation, other</i></p> <p><i>Specifically-defined evaluation criteria are given, and if and where they are accessible to students.</i></p>	<p>I. Final written examination (60%).</p> <p>II. Homework (20%) on a weekly basis.</p> <p>III. Laboratory exercises (20%) in molecular weight distribution calculations, rheological measurements of capillary viscometer, single-screw extruder design, flat-film and blown-film design, heat transfer calculations, flow in profile dies.</p>
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(5) ATTACHED BIBLIOGRAPHY

Suggested bibliography

- J. Vlachopoulos and N.D. Polychronopoulos, Understanding Rheology and Technology of Polymer Extrusion, First Edition, Polydynamics Inc, Dundas, Ontario, Canada (2019)
- S. Middleman, Fundamentals of Polymer Processing, McGraw Hill (1977)
- R.B. Bird, R.C. Armstrong, O. Hassager, Dynamics of Polymeric Liquids vol. 1, Wiley (1987)
- D.H. Morton-Jones, Polymer Processing, Chapman and Hall, London (1989)
- C.W. Macosko, Rheology: Principles, Measurements and Applications, VCH Publishers (1994)
- J.M. Dealy, K.F. Wissbrun, Melt Rheology and its Role in Plastics Processing, Chapman and Hall, London (1996)
- T.D. Papathanasiou and D.C. Guell, Flow Induced Alignment in Composite Materials, Woodhead Publishers (1997)

Related academic journals

- Journal of Rheology
- Rheologica Acta
- Journal of Polymer Science Part B: Polymer Physics
- Applied Rheology
- Macromolecules
- International Polymer Processing
- Polymer Engineering and Science
- Advances in Polymer Technology
- Rapid Prototyping Journal
- Additive Manufacturing