GUJARAT TECHNOLOGICAL UNIVERSITY

PLASTIC TECHNOLOGY (23)
POLYMER REACTION ENGINEERING AND RHEOLOGY
SUBJECT CODE: 2162304
B.E. 6th SEMESTER

Type of course: Core

Prerequisite: NA

Rationale: NA

Teaching and Examination Scheme:

Teaching Scheme			Credits	Examination Marks						Total Marks
				Theory Marks			Practical Marks			
L	T	P	C	ESE (E)	PA (M)		ESE (V)		PA (I)	
					PA	ALA	ESE	OEP		
3	0	2	5	70	20	10	20	10	20	150

Content:

Sr. No.	Content	Total Hrs	% Weightage
1	REACTION ENGINEERING [A] Introduction: Introduction to macromolecules and polymer reaction engineering, fundamental concepts, classifications of polymers based on polymerization mechanisms, study of molecular weight distribution, distinctive features of polymers and polymerization reactors as compared with monomers and their reactors, studies on changes in viscosity, density and rate constant with conversion. [B] KINETICS OF POLYMERIZATION : MW/MWD obtained for chain-growth, step-growth polymerization in batch reactor, plug-flow reactor (PFR) and continuous stirred tank reactor (CSTR), kinetic studies of cationic, anionic and free radical polymerization reactions. Ziegler-Natta catalyst in stereo-regular polymerization, kinetics mechanism in heterogeneous and stereo-regular polymerization reactions, rates of Ziegler-Natta polymerization, average chain length of polymer in stereo-regular polymerization. [C] KINETICS OF EMULSION AND SUSPENSION POLYMERIZATION : Introduction to bulk, solution, suspension and emulsion polymerization techniques, aqueous emulsifier solution, kinetic aspects of suspension and emulsion polymerization (Smith-Ewart Model), determination of total number of particles, molecular weight in emulsion polymerization, emulsion polymerization in homogenous CSTR, kinetics of dispersion polymerization. [D] Kinetics at High Degree of Conversion: Verification of the kinetic model and the gel effect in radical polymerization, equilibrium of radical polymerization, temperature effects in radical	15	35%

	polymerization, role of inter phase mass transfer in the selection and the design of polymerization reactor (especially step-growth polymerization reactors), diffusional effects in Ziegler-Natta polymerization, and metallocene catalyst for olefin polymerization.		
2	RHEOLOGY OF PLASTIC MATERIALS		
A	INTRODUCTION : Introduction to Rheological Principles, Definition & importance of Rheology, types of fluids, Non Newtonian fluids, time-dependent fluids, time independent fluids, viscous elastic fluids, Pseudoplastic fluids, Dilatant fluids, Bingham plastic fluids. Introduction to tensors, stress tensors and strain tensors, Basic equations of fluid mechanics - Continually equation, Couchy equation, Navier – stokes equation. Normal stress difference and Weissenberg's effect.	07	15%
B	VISCOELASTIC BEHAVIOUR : Stress relaxation, relaxation modulus, creep compliance dynamic modulus, dynamic compliance, dynamic viscosity, Mechanical models – Maxwell model, Voigt – Kelvin model, Zener model, Boltzmann Principle of Superposition. Time-temperature correspondence, time-temperature superposition, WLF equation, Glass-transition and theories of glass transition - free volume theory, thermodynamic theory and kinetic theory. Molecular theories – Rouse theory, Doi – Edward theory, Curtis – bird model.	10	15%
C	PARAMETERS INFLUENCING RHEOLOGY : Effect of pressure on viscosity. Effect of temperature, activation energy, effect of molecular weight and molecular weight distribution on viscosity, molecular at dependence of zero shear viscosity, effect of crosslinking, crystallinity branching, copolymerization, effect of fillers, fiber filled polymer melts, effect of plasticizers, shear rate dependence of viscosity.	08	15%
D	MELT FLOW ANALYSIS : Laminar flow through circular c/s, annulus, slit, parallel plates, irregular profiles. Flow analysis using power law, turbulent flow analysis, turbulence dumpling. Rheological models for extensional viscosity. Transition between laminar & turbulent flow, Ryan Johnson criterion, Application of Ryan Johnson criterion to power low fluids, extensional flow and rheological models for extensional viscosity. Flow in coni-cylindrical dies – pressure drop due to shear, pressure drop due to extensional flow and pressure drop at die entry, flow in wedge shaped die. Swelling due to shear stresses and swelling due to tensile stresses.	07	10%
E	RHEOMETRY : Basic concept of constant stress & constant strain, Different types of Rheometers–Cone and plate Rheometer, Concentric cylinder rheometer, parallel disk rheometer, concentric	04	10%

	rotating disk rheometer, controlled stress rotational Rheometer, Torque Rheometers – Extruder type.		

Suggested Specification table with Marks (Theory):

Distribution of Theory Marks					
R Level	U Level	A Level	N Level	E Level	C Level
15	**15**	**15**	**15**	**10**	**0**

Legends: R: Remembrance; U: Understanding; A: Application, N: Analyze and E: Evaluate C: Create and above Levels (Revised Bloom's Taxonomy)

Note: This specification table shall be treated as a general guideline for students and teachers. The actual distribution of marks in the question paper may vary slightly from above table.

Reference Books:

1. Anil Kumar and R.K. Gupta, "Fundamentals of Polymer Engineering", 2nd edition, Marcel Dekker, 2003.
2. Neil A. Datson, Rafael Galvan, Robert L. Laurence and Mathew Tirrel, "Polymerization Process Modeling", VCH Publishers, Inc., 1996.
3. F. Joseph Schork, Pradeep B. Deshpande and Kenneth W. Leffew, "Control of Polymerization Reactors", Marcel Dekker, 1993.
4. Gupta S. and Anil Kumar, "Reaction Engineering of Step Growth Polymerization", Plenum Press, New York, 1987.
5. "Encyclopedia of Polymer Science and Engineering", 2nd edition, John Wiley & Sons, 2005.
6. Polymer Melt Rheology, F.N. Cogswell, John Wiley and Sons, 1981, [1st edition].
7. Melt Rheology and its Role in Plastic Processing Theory and Applications, Kurt F. Wissburn, Van Nostrand, Reinhold, John M. Dealy, Chapman & Hall,1995.
8. Introduction to Polymer Viscoelasticity & Rheology, John .J. Aklonis, [2ndedition].
9. Polymer Reaction engineering by K.H.Reichert
10. Richard C. Progelhof and James L. Throne, Polymer Engineering Principles, Hanser Publishers, New York, 1993.
11. R.S. Lenk, Polymer Rheology, Applied Science, London,

Course Outcome:

After learning the course the students should be able to:

1. Know the fundamentals in polymerization reactor design, with the knowledge of kinetics
2. Understand Rheology of Plastic Materials and apply the same

List of Experiments:

1. To study different types of fluids with examples.
2. To find M.F.I of different polymers using melt flow indexer.
3. To study the variation in viscosity with respect to temperature using capillary rheometer.
4. Fitting of rheological models using capillary rheometer [power low model, Ellis model etc.].

5. Estimation of Bagley's correction factor using capillary rheometer.
6. Study of cone and plate viscometer.
7. Study of Torque Rheometer.
8. Study of Brook field's viscometer.
9. Study of oscillating disc viscometers for rheological characterization of elastomers.

Design based Problems (DP)/Open Ended Problem:

1. Study the design of Polymerization Reactors

List of Open Source Software/learning website:

1. www.wikipedia.org
2. www.sciencedirect.com
3. www.mit.edu

ACTIVE LEARNING ASSIGNMENTS: Preparation of power-point slides, which include videos, animations, pictures, graphics for better understanding theory and practical work – The faculty will allocate chapters/ parts of chapters to groups of students so that the entire syllabus to be covered. The power-point slides should be put up on the web-site of the College/ Institute, along with the names of the students of the group, the name of the faculty, Department and College on the first slide. The best three works should submit to GTU.