GUJARAT TECHNOLOGICAL UNIVERSITY (GTU)

Competency-focused Outcome-based Green Curriculum-2021 (COGC-2021)
Semester-IV

Course Title: Polymer Additives and Compounding
(Course Code: 4342305)

Diploma programme in which this course is offered	Semester in which offered
Plastics Engineering (Sandwich Pattern)	4th Semester

1. RATIONALE

Various type of plastic materials have been developed for domestic use as well as industrial use such as bumper and internal parts of automobile, medical applications, marine applications, electrical & electronic appliances, aerospace and many other applications. All plastics have specific characteristics pertaining to their chemical structure and manufacturing process but lack in particular properties required for certain applications. Polymer additives are chemicals added to the base polymer to improve process-ability, reduce raw material costs, extend the life span, and/or achieve the desired physical or chemical properties in the final product. There are many additive options available and each one offers a specific improvement to the polymer's functionality or stability. Engineer will have to identify, analyze and choose the most relevant additive and its compounding method for specific application. Hence, this course has been designed to develop such competency and skills.

2. COMPETENCY

The purpose of this course is to help the student to attain the following industry identified competency through various teaching learning experiences:

- **Select proper additive for plastic product and and its compounding method.**

3. COURSE OUTCOMES (COs)

The practical exercises, the underpinning knowledge and the relevant soft skills associated with this competency are to be developed in the student to display the following COs:

a) Identify various additives for plastics.
b) Select appropriate additive for aid in polymerization.
c) Select proper additive for aid in processing.
d) Apply proper additive for end use application of plastic product.
e) Select appropriate method of compounding.

4. TEACHING AND EXAMINATION SCHEME

Teaching Scheme (In Hours)			Total Credits (L+T/2+P/2)	Examination Scheme				
				Theory Marks		Practical Marks		Total Marks
L	T	P	C	CA	ESE	CA	ESE	
2	0	2	3	30*	70	25	25	150

(*):Out of 30 marks under the theory CA, 10 marks are for assessment of the micro-project to facilitate integration of COs and the remaining 20 marks is the average of 2 tests to be taken during the semester for the assessing the attainment of the cognitive domain UOs required for the attainment of the COs.

***Legends:** **L**-Lecture; **T** – Tutorial/Teacher Guided Theory Practice; **P** -Practical; **C** – Credit, **CA** - Continuous Assessment; **ESE** -End Semester Examination.*

5. SUGGESTED PRACTICAL EXERCISES

The following practical outcomes (PrOs) are thesub-components of the COs.*Some of the **PrOs** marked **'*'** are compulsory, as they are crucial for that particular CO at the 'Precision Level' of Dave's Taxonomy related to 'Psychomotor Domain'*.

Sr. No.	Practical Outcomes (PrOs)	Unit No.	Approx. Hrs. required
1	Demonstrate classification of additives.	I	2
2	Collect and analyze bleeding & blooming in PVC sheet.	I	2
3	Compare the characteristics of Thermoset article with curing agent v/s Thermoset article without curing agent.	II	2
4	Apply cross-inking agent to prepare a product.	II	2
5	Prepare a product using suitable plasticizer.	III	4
6	Prepare FRP product using suitable release agent.	III	4
7	Observe the application of antistatic agent	IV	2
8	Prepare products with colorants using single screw extruder.	IV	2
9	Operate high speed mixer.	V	4
10	Operate Banbury mixer.	V	4
11	Operate Ribbon blender.	V	4
12	Prepare compounded material using twin screw extruder.	V	4
	TOTAL		**36**

Note

i. *More **Practical Exercises** can be designed and offered by the respective course teacher to develop the industry relevant skills/outcomes to match the COs. The above table is only a suggestive list.*

ii. *The following are some **sample** 'Process' and 'Product' related skills(more may be added/deleted depending on the course) that occur in the above listed **Practical Exercises** of this course required which are embedded in the COs and ultimately the competency.*

S. No.	Sample Performance Indicators for the PrOs	Weightage in %
1	Additive identification	10
2	Additive application	20
3	Additive compounding	20
4	Use of proper equipments	20
5	Operate screw extruders	30
Total		**100**

6. MAJOR EQUIPMENT/ INSTRUMENTS REQUIRED

This major equipment with broad specificationsfor the PrOs is a guide to procure them by the administrators to usher in uniformity of practicals in all institutions across the state.

S. No.	Equipment Name with Broad Specifications	PrO. No.
1	Single Screw Extruder	1,5,7,8
2	Twin Screw Extruder	1,2,5,7,12
3	Two Roll Mill	2,5,7
4	High Speed Mixer	1,5,7,9
5	Banbury Mixer	1,5,7,10
6	FRP Mould	1,3,4,6
7	Ribbon Blender	1,5,7,11

7. AFFECTIVE DOMAIN OUTCOMES

The following ***sample*** Affective Domain Outcomes (ADOs) are embedded in many of the above mentioned COs and PrOs. More could be added to fulfil the development of this competency.

a) Work as a leader/a team member.
b) Follow ethical practices.
c) Practice environmental friendly methods and processes to avoid pollution due to additives.

The ADOs are best developed through the laboratory/field-based exercises. Moreover, the level of achievement of the ADOs according to Krathwohl's 'Affective Domain Taxonomy' should gradually increase as planned below:

i. 'Valuing Level' in 1st year
ii. 'Organization Level' in 2nd year.
iii. 'Characterization Level' in 3rd year

8. UNDERPINNING THEORY

Only the major Underpinning Theory is formulated as higher level UOs of *Revised Bloom's taxonomy* in order development of the COs and competency is not missed out by the students and teachers. If required, more such higher level UOs could be included by the course teacher to focus on attainment of COs and competency.

Unit	Unit Outcomes (UOs) (4 to 6 UOs at Application and above level)	Topics and Sub-topics
Unit – I Introduction to Additives	1a. Understand polymeric compounds 1b. Identify objectives of additives 1c. Distinguish types of additives 1d. Describe environmental impact of additives	1.1 Overview of polymeric compounds 1.2 Objectives of additives 1.3 Bleeding and blooming of additives 1.4 Classification of additives 1.5 Environmental impact of additives
Unit – II Additives aids in Polymerization	2a. Identify additives for polymerization 2b. Describe functions of Catalyst and curing agents 2c. Compare function of free radical initiators and chain transfer agents 2d. Describe cross linking agents	2.1 Catalysts 2.2 Curing agents 2.3 Free radical initiators 2.4 Chain transfer agents 2.5 Cross linking agents
Unit – III Additives aids in Processing	3a. Identify additives for processing 3b. Describe functions of Plasticizers and lubricants 3c. Compare physical and chemical blowing agents 3d. Describe accelerators and flow promoters 3e. State need of release agents and Compatibilizers	3.1 Plasticizers and softeners 3.2 Lubricants 3.3 Blowing agents – Physical and Chemical 3.4 Accelerators 3.5 Flow promoters 3.6 Release agents 3.7 Compatibilizers
Unit – IV End-Use Modifying additives	4a.Identify additives for end use modifications 4b. Describe types of additives for end use modification 4c. Select proper additive for end use modification 4d.Distinguish various fillers and reinforcements	4.1 Heat Stabilizers 4.2 UV stabilizers 4.3 Antioxidants 4.4 Antistatic Agents 4.5 Colorants – Powders, Pigments and master batch 4.6 Coupling Agents 4.7 Flame retardants 4.8 Impact Modifiers 4.9 Fillers 4.10 Reinforcements 4.11 Slip agents

		4.12 Electrostatic agents 4.13 Nucleating agents
Unit – V **Polymer Compounding**	5a. State purpose of compounding 5b. Identify requirements of compounding 5c. Identify methods of compounding 5d. Describe methods of compounding 5e. Select proper method of compounding	5.1 Introduction and purpose of compounding 5.2 Requirements of compounding lines 5.3 Mixing theory 5.4 Methods of Compounding ● Intensive dry mixers (High speed mixer) ● Internal intensive batch mixer (Banbury Mixer) ● Continuous Mixer ● Ribbon Blender ● Two Roll Mill ● Extruders – Single screw and twin screw

***Note**: The UOs need to be formulated at the 'Application Level' and above of Revised Bloom's Taxonomy' to accelerate the attainment of the COs and the competency.*

9. SUGGESTED SPECIFICATION TABLE FOR QUESTIONPAPER DESIGN

Unit No.	Unit Title	Teaching Hours	Distribution of Theory Marks			
			R Level	U Level	A Level	Total Marks
I	Introduction to Additives	4	3	3	1	07
II	Additives aids in Polymerization	5	3	4	2	09
III	Additives aids in Processing	7	4	4	2	10
IV	End-Use Modifying additives	10	6	10	4	20
V	Polymer Compounding	16	6	8	10	24
Total		**42**	**22**	**29**	**19**	**70**

***Legends:** R=Remember, U=Understand, A=Apply and above (Revised Bloom's taxonomy)*
***Note**: This specification table provides general guidelines to assist student for their learning and to teachers to teach and question paper designers/setters to formulate test items/questions assess the attainment of the UOs. The actual distribution of marks at different taxonomy levels (of R, U and A) in the question paper may vary slightly from above table.*

10. SUGGESTED STUDENT ACTIVITIES

Other than the classroom and laboratory learning, following are the suggested student-related ***co-curricular*** activities which can be undertaken to accelerate the attainment of the various outcomes in this course: Students should conduct following activities in group and prepare reports of about 5 pages for each activity, also collect/record physical evidences for their (student's) portfolio which will be useful for their placement interviews:

1. Students will prepare chart for classification of additives.
2. Students will prepare information of major additives use for plastics.
3. Students will prepare list of products made with use of additives and its applications.

11. SUGGESTED SPECIAL INSTRUCTIONAL STRATEGIES (if any)

These are sample strategies, which the teacher can use to accelerate the attainment of the various outcomes in this course:

f) Massive open online courses (***MOOCs***) may be used to teach various topics/sub topics.
g) Guide student(s) in undertaking micro-projects.
h) ***'L' in section No. 4***means different types of teaching methods that are to be employed by teachers to develop the outcomes.
i) About ***20% of the topics/sub-topics*** which are relatively simpler or descriptive in nature is to be given to the students for ***self-learning***, but to be assessed using different assessment methods.
j) With respect to ***section No.11***, teachers need to ensure to create opportunities and provisions for ***co-curricular activities***.
k) Guide students on how to address issues on environment and sustainability.
l) Collect information on additive manufacturing industries.
m) Visit to nearby compounding industries.
n) Video/animation on working of different type of compounding equipments.

12. SUGGESTED MICRO-PROJECTS

Only one micro-project is planned to be undertaken by a student that needs to be assigned to him/her in the beginning of the semester. In the first four semesters, the micro-project are group-based. However, in the fifth and sixth semesters, it should be preferably be ***individually*** undertaken to build up the skill and confidence in every student to become problem solver so that s/he contributes to the projects of the industry. In special situations where groups have to be formed for micro-projects, the number of students in the group should ***not exceed three.***

The micro-project could be industry application based, internet-based, workshop-based, laboratory-based or field-based. Each micro-project should encompass two or more COs which are in fact, an integration of PrOs, UOs and ADOs. Each student will have to maintain dated work diary consisting of individual contribution in the project work and give a seminar presentation of it before submission. The total duration of the micro-project should not be less than ***16 (sixteen) student engagement hours*** during the course. The student ought to submit micro-project by the end of the semester to develop the industry oriented COs.

A suggestive list of micro-projects is given here. This has to match the competency and the COs. Similar micro-projects could be added by the concerned course teacher:

13. SUGGESTED LEARNING RESOURCES

Sr. No.	Title of Book	Author	Publication with place, year and ISBN
1.	Plastics Additives Handbook	Zweifel H., Ralph D. M, SchillerM.	Hanser Pubulications, 2009, 9781569904305
2.	Plastic Extrusion Technology	Hensen F.	Hanser Gardener Publishers, NewYork, 1989, 9780195207606
3.	Calendering of Plastics	Elden R.A., Swan A. D.	American Elsevier Publishing , New York, 1971, 9780592054391
4.	Plastics Engineering Handbook	Frados J.L	Van Nostrand Reinhold, New York, 1976, 9780442224691
5.	Chemical Additives for the Plastics Industry	Radian Corporation	Noyes Data Corporation, New Jersey, 1987, 9780815511144
6.	Additives for Plastics Handbook	Murphy J.	Elsevier Advance Technology, 2007, 9780080498614
7.	Plastics Compounding and Polymer Processing	Kohlgruber K., Bierdel M & Rust H.	Hanser Publications, 2021, 9781569908372
8.	Plastics Additives and Testing	Subramanian M.N	Wiley,2013, 9781118710555
9.	A Concise Introduction to Additives for Thermoplastic Polymers	Fink J.K	Wiley, 2010, 9780470624234

14. SOFTWARE/LEARNING WEBSITES

1. https://books-library.net/files/books-library.online-06132030Fg0Q5.pdf
2. https://www.degruyter.com/document/doi/10.1515/psr-2016-0130/html?lang=en
3. https://www.sciencedirect.com/topics/engineering/reinforcing-filler
4. https://www.youtube.com/watch?v=9Ety1aVbW0M
5. https://youtu.be/tpztnm2eXbY
6. https://www.bpf.co.uk/plastipedia/additives/Default.aspx
7. https://polymerdatabase.com/Additives/Polymer%20Additives.html

15. PO-COMPETENCY-CO MAPPING

Semester I	Polymer Additives and Compounding (Course Code:)									
	POs and PSOs									
Competency & Course Outcomes	**PO 1** Basic & Discipline specific knowledge	**PO 2** Problem Analysis	**PO 3** Design/ development of solutions	**PO 4** Engineering Tools, Experimentation &Testing	**PO 5** Engineering practices for society, sustainability & environment	**PO 6** Project Management	**PO 7** Life-long learning	**PSO 1** An ability to apply principles of material selection, product & mold/die design and development in plastic engineering.	**PSO 2** An ability to conduct safe and environment friendly manufacturing and recycling of plastic products.	**PSO 3** (If needed)
Competency **Select proper additive for plastic product and its compounding method.**	3	2	2	2	3	1	2	2	1	
Course Outcomes										
1 Identify various additives for plastics.	3	1	1	1	3	1	1	1	1	
2 Select appropriate additive for aid in polymerization.	2	1	1	1	2	1	1	1	1	
3 Select proper additive for aid in processing.	2	1	2	1	2	1	1	1	1	
4 Apply proper additive for end use application of plastic product.	2	1	2	1	2	1	1	1	1	
5. Select appropriate method of compounding.	2	2	2	3	3	1	2	1	1	

Legend: '**3'** for high, '**2**' for medium, **'1'** for low or **'-'** for the relevant correlation of each competency, CO, with PO/ PSO

16. COURSE CURRICULUM DEVELOPMENT COMMITTEE

GTU Resource Persons

Sr. No.	Name and Designation	Institute	Contact No.	Email
1	Shri Dharmendra M. Makwana Head of Plastic Engineering	G.P., Valsad	9426359006	1224dmm@gmail.com
2	Shri Jaymin R. Desai Lecturer in Plastic Engineering	G.P., Ahmedabad	9428159779	jayminrdesai@yahoo.com
3	Shri Ajay S. Amin Lecturer in Plastic Engineering	G.P., Valsad	9426044254	ajayamin2000@yahoo.co.in