GUJARAT TECHNOLOGICAL UNIVERSITY (GTU)

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

Course Title: Powder Metallurgy
(Course Code: 4362103)

Diploma Programme in which this course is offered	Semester in which offered
Metallurgy Engineering	Sixth

1. RATIONALE

This course is designed to know powder metallurgy as an alternative route to conventional metal processing. It is important to understand and appreciate the importance of powder metallurgy as an effective and profitable material processing route to produce a variety of products for engineering industries. This course provides detailed knowledge of different characteristics of metal powders, powder compaction methods, sintering process and various techniques used for powder production with the versatile nature of these techniques to produce a wide range of powders. This course aims to equip the student with the knowledge of various powder metallurgy operations that leads to get the best metallurgical qualities and economic products.

2. COMPETENCY

The course content should be taught and implemented with the aim to develop different types of skills so that students are able to acquire the following competency:

- **Apply the knowledge of various powder metallurgy operations to produce quality powder metallurgy product as per service requirements.**

3. COURSE OUTCOMES (COs)

The practical exercises, the underpinning knowledge and the relevant soft skills associated with the identified competency are to be developed in the student for the achievement of the following COs:

1. State the advantages, limitations and application of Powder metallurgy process.
2. Measure the various powder characteristics like apparent density, tap density and flow rate.
3. Acquainted the knowledge of Basic step of powder metallurgy process and metal powder production methods.
4. Understand the Mixing - Blending operations and basic methods of Powder compaction.
5. Explain the mechanism of sintering process of powder metallurgy.

4. TEACHING AND EXAMINATION SCHEME

Teaching Scheme (In Hours)			Total Credits (L+T+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 the sub-components of the COs. Some of the PrOs marked '*' are compulsory, as they are crucial for that particular CO. These PrOs need to be attained at least at the 'Precision Level' of Dave's Taxonomy related to 'Psychomotor Domain.'

Sr. No.	EXERCISES/ PRACTICAL	Unit No.	Approx. Hrs. Required
1.	To perform sieve analysis on given metal Powder sample.	II	04
2.	To measure the particle size and shape of metal powder by Optical Microscopy.	II	04
3.	To measure tap density and apparent density of given metal Powder sample.	II	04
4.	To measure flow rate of given metal Powder sample.	II	04
5.	To manufacture Copper powder by electrolysis method.	III	04
6.	To perform powder compaction operation of sample metal powder.	IV	04
7.	To perform Sintering operation on given compacted Powder metallurgy product.	V	04
	Total hours		**28 Hrs.**

Notes:

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.*

Sr. No.	Sample Performance Indicators for the PrOs.	Weightage in %
1	Operate equipment and set-up carefully	20
2	Safety precaution and safety gadgets used	20
3	Observation and recording of results	20
4	Interpretation of the result and conclusion	20
5	Submission of report within time limit and attendance in the laboratory	20

6. MAJOR EQUIPMENT/ INSTRUMENTS REQUIRED

These major equipment with broad specifications for the PrOs is a guide to procure them by the administrators to user in uniformity of practical's in all institutions across the state.

Sr. No.	Equipment Name with Broad Specifications	PrOs. No.
1.	Sieve Shaker Voltage : 220 V - 230 V Frequency : 50 - 60 Hz Timer : 0 - 60 Mint Quantity of sieves : 1 to 5 Nos.	1
2.	Optical Microscope Magnification: 50x – 1000x. Observation : Trinocular Head inclined at 45˚ and rotatable 360˚ Stand: A rigid and stable stand Focusing : Coarse and fine focusing by conveniently placed Separate knobs 1 div. 0.002mm. Objectives: Achromatic – M5x, M10x, M45x & M100x. Eye pieces: Wide field 10x.	2
3.	Planetary ball mill Rotation Speed : 70-670 rpm Smallest Fineness reaches : 0.1 mμ	5
4.	DC Power Source Amp: 5 to 10 for Electrolysis.	5
5.	Hydraulic press. Max Pressure : 5T or 10T Max working stroke : 125mm to 140mm Die materials : Stainless steel or Cr steel	6
6.	Sintering furnace. Maximum Temp. : 1700ºC Working Temp. : Up to 1600ºC Temp. Accuracy : ± 1ºC Inner Chamber: Ceramic Brick/Board.	7

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) Correlate the powder metallurgy process with conventional metal processing techniques.
b) Discuss the application of Powder metallurgy product in various industries.
c) List down the process variable of powder metallurgy operations.
d) Participates in class discussion related to advancement in powder metallurgy technology.
e) Work as independently individuals, displays teamwork, displays leadership quality and professional commitment to ethical practice on daily basis.
f) Practice environment friendly methods and processes.
g) Be aware about the safety aspects during the various stage of Powder metallurgy process.

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

The major underpinning theory is given below based on the higher level UOs of Revised Bloom's taxonomy that are formulated for development of the COs and competency. If required, more such UOs could be included by the course teacher to focus on attainment of COs and competency.

Unit	Major Learning Outcomes	Topics and Sub-topics
Unit – I Introduction to Powder metallurgy process	1.a Describe Powder metallurgy process with basic steps. 1.b Discuss Advantages, Limitation and Application of Powder metallurgy.	1.1 Definition of Powder metallurgy. 1.2 Basic steps of Powder Metallurgy process. 1.3 Advantages, Limitation and Application of Powder metallurgy.

Unit	Major Learning Outcomes	Topics and Sub-topics
Unit – II Characteristics of metal powder	2.a Discuss the concept of Particle size, shape and size distribution. 2.b Explain the various Characteristics of powder mass.	2.1 Particle size, shape and size distribution. 2.2 Characteristics of powder mass such as apparent density, tap density, flow rate etc. 2.3 Properties of green compacts and sintered compacts.
Unit – III Metal powder production methods	3.a Classify various process used powder production. 3.b Describe various different types of powder production method.	3.1 Study various powder production methods like a. Atomization b. Reduction from oxide c. Electrolysis d. Crushing e. Milling f. Condensation of metal vapour g. Hydride and carbonyl processes
Unit – IV Powder Mixing – Blending and Compaction Methods	4.a Explain Powder Mixing – Blending operation. 4.b Discuss powder Compaction in detail.	4.1 Powder Mixing – Blending operation. 4.2 Fundamentals of powder compaction. 4.3 Types of compaction presses 4.4 Compaction tooling 4.5 Role of lubricants. 4.6 Single and double die compaction. 4.7 Isostatic pressing and hot pressing.
Unit – V Sintering & Sintered Products	5.a Explain mechanism of sintering process in powder metallurgy. 5.b Discuss Sintered Products of powder metallurgy.	5.2 Definition and Mechanism of sintering. 5.3 Stages and effect of variables. 5.4 sintering atmospheres and furnaces. 5.5 liquid-phase sintering. 5.6 Study of sintered bearings, cutting tools, metallic filters, friction and antifriction parts and electrical contact materials.

9. SUGGESTED SPECIFICATION TABLE FOR QUESTION PAPER DESIGN

Unit No.	Unit Title	Teaching Hours	Distribution of Theory Marks			
			R Level	U Level	A Level	Total Marks
I	Introduction to Powder metallurgy process	03	02	03	00	05
II	Characteristics of metal powder	06	04	09	04	17
III	Metal powder production methods	08	06	10	04	20
IV	Powder Mixing – Blending and Compaction Methods	06	05	07	04	16
V	Sintering & Sintered Products	05	04	05	03	12
	Total	**28**	**21**	**34**	**15**	**70**

Legends: R = Remember; U = Understand; A = Apply and above levels (Bloom's revised taxonomy)

Notes:

1. This specification table shall be treated as a general guideline for students and teachers. The actual distribution of marks in the question paper may slightly vary from above Table.
2. Ask the questions from each topic as per marks weightage. Numerical questions are to be asked only if it is specified. Optional questions must be asked from the same topic.

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

1. Visit nearby industries engaged in Powder metallurgy production (if any) and study the processes are being used.
2. Make a chart for showing steps of different powder metallurgy operation.
3. Discuss recent developments in field of powder metallurgy.
4. Group discussion on pros and cons of powder metallurgy process as compare to other conventional metal processing techniques.
5. Group discussion on environmental issues and control in the powder metallurgy Industries.

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:

- **a)** Massive open online courses (MOOCs) may be used to teach various topics/sub topics.
- **b)** Guide student(s) in undertaking micro-projects.
- **c)** Different types of teaching methods that are to be employed by teachers to develop the outcomes.
- **d)** 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.
- **e)** With respect to section No.10, teachers need to ensure to create opportunities and provisions for co-curricular activities.
- **f)** Guide students on how to address issues on environment and sustainability using the knowledge of this course.
- **g)** Encourage students to read codes and standards.

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 is 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 must 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:

1. Prepare the Flow chart showing production of component through powder metallurgy route.
2. Model preparation of Powder Atomization from waste materials.
3. Collection of Various Metal powders and measure Characteristics of each powder mass.
4. Presentation on recent application of Powder Metallurgy in several fields.
5. Prepare the table / Chart showing different Powder production/ Powder Compaction Methods.

13. SUGGESTED LEARNING RESOURCES

Sr. No.	Title of Book	Author / Editor	Publication with place, year, and ISBN
1.	Introduction to Powder Metallurgy	A. K. Sinha	Dhanpatrai Publication, New Delhi, ISBN-10. 9383182148; ISBN-13. 978-9383182145.
2.	Powder Metallurgy: Science, Technology and Materials	Anish Upadhyaya, Gopal Shankar Upadhyaya	Universities Press; 1st edition (19 January 2011), ISBN-10 : 1439857466 , ISBN-13 : 978-1439857465
3.	Powder Metallurgy: Science, Technology and Applications	P. C. Angelo, R. Subramanian, B.Ravisankar	PHI Learning; 2nd edition (31 October 2022); PHI Learning Pvt. Ltd. ,Delhi ISBN-10 : 939181848X ISBN-13 : 978-9391818487
4.	Fundamental Principles of Powder Metallurgy	W.D.Jones	Publisher : Edward Arnold; London, 1960 ASIN : B0007IXN18
5.	Powder Metallurgy	S.A. TSukerman	Publisher : Pergamon (22 October 2013) ASIN : B01DJDHOT4
6.	Handbook of Powder Metallurgy	H.H.Hausner	Publisher : Chemical Publishing Company (June 30, 1973) ISBN-10 : 0820602191 ,ISBN-13 : 978-0820602196
7.	Powder Metallurgy ASM Handbook, Vol-VII.	Volume Editors : Prasan K. Samal, Joseph W. Newkirk	A S M International (30 December 2015), ISBN-10 : 1627080872, ISBN-13 : 978-1627080873

14. SOFTWARE/LEARNING WEBSITES

1 http://nptel.ac.in/
2 http://www.ipmd.net
3 https://www.youtube.com/watch?v=Y0EXdgjC9PA
4 https://www.mpif.org/IntrotoPM.aspx
5 https://www.iqsdirectory.com/articles/powder-metal-parts/powder-metallurgy.html

15. PO-COMPETENCY-CO MAPPING

Semester VI		Powder Metallurgy [Course Code: 4362103]						
		POs						
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
Competency		**Apply the knowledge of various powder metallurgy operations to produce quality powder metallurgy product as per service requirements.**						
Course Outcomes								
CO1:	State the advantages, limitations and application of Powder metallurgy process.	3	-	1	1	2	-	1
CO2:	Measure the various powder characteristics like apparent density, tap density and flow rate.	3	2	1	3	1	2	2
CO3:	Acquainted the knowledge of Basic step of powder metallurgy process and metal powder production methods.	3	2	3	2	1	2	2
CO4:	Understand the Mixing - Blending operations and basic methods of Powder compaction	3	1	2	2	2	3	1
CO5:	5. Explain the mechanism of sintering process of powder metallurgy.	3	2	1	2	1	2	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:

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