AIR FORCE INSTITUTE OF TECHNOLOGY, KADUNA

FACULTY OF

DEPARTMENT OF

COURSE COMPACT

Course Title	**Fuels, Refractories and Furnaces**		
Course Code	**MME 427**	**Academic Session**	2025/2026
Course Status	Compulsory (C)	**Credit Units**	2
Name of Lecturer(s)	Engr. Nnaemeka Johnson-Anamemena	**Semester**	First
Name of Course Coordinator	Engr. Nnaemeka Johnson-Anamemena	**Course Coordinator's Telephone**	08054805352
Name of Technologist(s)	Nil	**Course Coordinator's Office Location**	MMED
Email of Course Coordinator	necojohnsona@yahoo.com	**Lecture Time**	
Consultation Hours	2:00 pm – 3:00 pm	**Lecture Venue**	MME427(L) HALL A

General Course Objectives
(Minimum of 5):

At the end of this course, the students should be able to meet the following objectives:

1. appreciate the centrality of the core course to the different specialties of metallurgical engineering;
2. identify conventional and newer sources of energy and characterization of fuels in terms of analysis and calorific value with problems;
3. identify and select suitable refractories for the building of specific furnaces;
4. design and build functional furnaces (blast furnace, reverberation furnace, electric furnace, open heath furnace converter and fluidized bed reactors);
5. carry out tests on coals to ascertain the cokeability and cakeability of such coal as metallurgical fuel and thus make the right choice of fuels for the blast furnace; and
6. carry out instrumentation and control in furnaces.

General Learning Outcomes
(Minimum of 5):

"Fuels, Refractories, and Furnaces" is a topic focusing on the efficient use of energy in industrial processes, covering the types, properties, and testing of various fuels; the design, operation, and temperature control of furnaces; and the selection and application of heat-resistant refractory materials that line these furnaces. Key aspects include understanding combustion, heat transfer, fuel utilization, different furnace designs, and the characteristics of refractory materials like oxides and ceramics used to contain high-temperature environments.

- Fuels

Definition: Substances that can be economically burned to release energy.
Types: Includes gaseous, liquid, and solid fuels, with a focus on their properties and the methods for their testing.
Utilization: Discusses the trends in fuel use, the physics and chemistry of combustion, and methods for optimizing heat generation from fuels.

- Furnaces

Purpose:
Thermal enclosures used in various industries (cement, glass, ceramics, metallurgy) for manufacturing processes.
Components:
Includes the furnace chamber, burner, and refractory lining.
Design & Operation:
Involves controlling temperature, managing gas flow and heat transfer, and the efficient utilization of fuel to achieve desired process temperatures.
Temperature Control:
Crucial for avoiding energy wastage from overheating or underheating, with accurate temperature measurement being a key component of operation.

- Refractories

Definition:
Heat-resisting materials that form the linings of furnaces and other high-temperature equipment.
Materials:
Classified into groups such as basic (MgO, CaO), non-basic (SiO_2, Al_2O_3, Cr_2O_3, ZrO_2), and carbon/graphite-based materials.
Selection:
Depends on the operating conditions, including temperature, chemical environment, and phases present (solid, liquid, gas).
Types:
Includes fireclay, high-alumina, silica, magnesite, zirconia, monolithic refractories, insulating bricks, and ceramic fibers.

Assessment Tasks	**Dates**
Assignment(s)	
Presentation(s)	
Test I	
Test II	
Exams	
Assessment Grading	**Maximum Scores Obtainable**
Assignment(s)	
Presentation(s)	
Test I	15
Test II	15
Exams	70
Total	100 marks

Course Requirements	**Course Descriptions or Contents**
1. Projector and screen 2. Smartboard 3. Whiteboard and marker(s)	**Contents:** Survey of main engineering fuel: solid, liquid and gaseous fuels; classification and testing of fuels; fuels and energy utilisation in the metallurgical industry with reference to coking coals for iron and steel production via blast furnace; introduction to coal and coke technology refractories; technology of production and services of main metallurgical refractories: silicon, magnesite, chrome-magnesite, alumina-silicate and other refractories; special refractories, their evaluation and applications in furnace construction; classification of metallurgical furnaces and reactors, their design and construction.

Lecture Schedule			
Week No.	**Topics** *(Itemize distinct and measurable topics using alphabets)*	**Weekly Objectives of Distinct Topics** *(Minimum of 3)*	**Self-Study Questions based on Weekly Objectives of Topics** *(Minimum of 3 applied questions)*
Week 1	- Conventional and newer sources of energy - Characterization of fuels: Analysis and calorific value with problems	The students should be able to meet the following objectives: i. State conventional and newer sources of energy. ii. Characterize fuels through proximate and ultimate analysis to estimate calorific value.	1. Explain energy consumption as economic growth and the usage of fossil fuel energy source as it relates to environment sustainability and energy security. 2. Using neat flow sheet diagram show the classification of energy resources. 3. What is meant by Fuel Characterization?
Week 2	- Principles of conversion of fuels: Carbonization, Gasification and Hydrogenation	i. State the principles of conversion of fuels: carbonization, gasification and hydrogenation. ii. Identify principles of fuel combustion.	4. State the chemical reaction of producer gas from coal/coke + (atm air + steam). Is it an exothermic reaction?
Week 3	- Principles of fuel combustion and Numerical problems	i. Solve numerical problems.	5. For a coal containing 80% C and 6% ash, the coke produced per ton of coal would be (a) 750 kg with 8% ash (b) 800 kg with 8% ash

<table>
<tr><td></td><td></td><td></td><td>(c) 650kg with 8.8% ash
(d) 600 kg with 9% ash

6. The proximate analysis of coal is: Moisture 2.4%, Volatile Matter 29.4%, Fixed Carbon 58%, Ash 9.7% and Sulphur 0.5%. Its gross calorific value is 7650 Kcal/Kg. Calculate proximate analysis and calorific value on
(a) Moisture free basis
(b) Dry ash free basis</td></tr>
<tr><td>Week 4</td><td></td><td>i. Solve numerical problems.</td><td>7. Compare the gross and net calorific value on moist and dry basis of (a) bituminous coal and (b) anthracite coal. The compositions are
<table><tr><th></th><th>Bituminous coal (wt %)</th><th>Anthracite coal (</th></tr><tr><td>Carbon</td><td>78</td><td>84</td></tr><tr><td>Hydrogen</td><td>5</td><td>1.9</td></tr><tr><td>Oxygen</td><td>4.5</td><td>4</td></tr><tr><td>Nitrogen</td><td>1.2</td><td>0.6</td></tr><tr><td>Ash</td><td>7</td><td>6.7</td></tr><tr><td>Moisture</td><td>4.3</td><td>2.8</td></tr></table></td></tr>
<tr><td>Week 5</td><td>- Classification of refractories and their service properties</td><td>i. State the classification of refractory (e.g., oxidic refractories - basic, acidic, and neutral) and special type refractory (e.g., Silicon carbide, cermets and SiAlON).
ii. Identify their service properties.</td><td>8. What is a refractory and why is it required?

9. To design refractory for a given requirement:
i. List and briefly explain three (3) properties required in a refractory.
ii. What are the available Refractory materials in terms of their oxidic and special types respectively?</td></tr>
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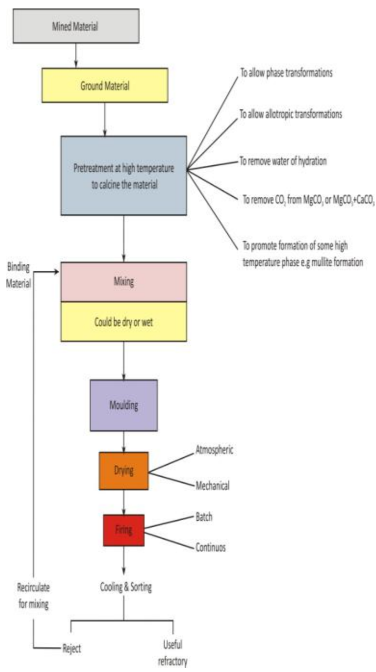
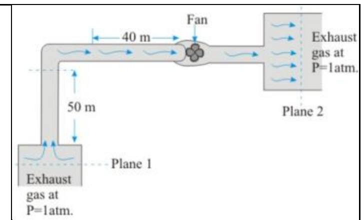
Week 6	- Manufacture of common refractory like silica, alumina fireclay, dolomite, magnesite	i. State the types of common refractories with examples ii. Explain the manufacturing process  	10. Consider the design of a cylindrical electric resistance furnace. The heating coil should have 1250°C maximum temperature at steady state when the power supply is 750 watts. The outer diameter of a ceramic tube on which heating coil is to be wound is 0.08 m. The insulation is fireclay inside and asbestos magnesia outside. Asbestos-magnesia can sustain a maximum temperature of 900°C. Determine the thickness of the two insulation layers when the total insulation thickness is minimum. Length of furnace is 0.7 m. Given: outer shell temperature 45°C,K_fireclay=0.72 W/mK and K_abestosMag=0.12 W/mK . Assume 25% of total power is lost from both ends.
Week 7	Assignment(s) and/or Presentation(s)		
Week 8	- Types of furnaces and their role in high temperature applications, - Fluid flow in furnaces: macroscopic energy balance and its application to Design of chimney and flow measuring devices	i. State transport phenomena in furnaces: fluid flow ii. State the mechanical energy balance within a furnace	11. What is a furnace? 12. List and explain the components of a furnace.

Week 9	- Heat transfer in furnaces: Conduction, convection and radiation with suitable examples to design refractory lining, and heating of load through flame and convection	i. Demonstrate a flow meter design ii. Identify the basics of heat transfer	 13. The duct is rectangular cross section 0.2 m × 0.3 m and is joined by an elbow as shown in the figure. Total length of the duct is 90 m. Calculate horse power of the fan from the following data. The exhaust gas flow rate is $\frac{40\ m^3}{min}$ (at 1 atm and T = 298 K) Friction losses due to contraction and expansion are **0.4 and 1** respectively. $(\mu/\rho)_{air} = 1.77 \times 10^{-6}\ m^2/s$ at 1073 K. Use $f = 0.0791(Re)^{-1/4}$ to calculate friction factor. Equivalent length for elbow $\left(\frac{Le}{De}\right) = 20$. **Hint:** Apply mechanical energy balance between plane 1 and 2 and get the following expression
Week 10	- Flame temperature and heat utilization; concept of available heat and fuel consumption, - Principles of waste heat recovery and design of heat exchangers and burners, - Heat balance diagrams with illustrations,	i. Estimate of heat losses in furnaces ii. Calculate steady state heat flow in furnaces and heat exchangers iii. State the various types of heat exchanger (e.g., parallel flow recuperator, counter-	14. Calculate the composite factor for the closed system of two black surfaces A_1 and A_2 under the following conditions: a) when A_2 is very large or A_1 is very small (b) $\frac{A_2}{A_1} = 1$ (c) $\frac{A_2}{A_1} = 1, F_1 = 0$, (d) $\frac{A_2}{A_1} \to 0,\ F_1 \to 0$

	- Fuel economy in industrial furnaces, - Oxygen addition to combustion process, - Energy efficient operation of furnaces with illustrations, - Instrumentation and control in furnaces Concept of carbon credit (carbon-offset) and its relation with energy efficiency.	current recuperator and cross flow recuperator)	
Week 11	Continuous Assessment Test(s)		
Week 12	Tutorials/Revisions		
Week 13-15	Exams		

Recommended Books *(Must be itemized using alphabets with complete bibliographic information)*
References: **(1)** R. Schuhmann: Metallurgical Engineering, Vol.1 Engineering Principles **(2)** O.P.Gupta: elements of fuels, furnaces and Refractories, Khanna Publishers **(3)** D. R. Poirier and G.H.Geiger: Transport: Transport Phenomena is materials processing 1994. **Online**: https://nptel.ac.in/courses/113104058 and https://nptel.ac.in/courses/113104008

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