ESE-827: Energy from Biomass: Thermochemical Processes - 3 CHs

Course Description:

1. The current unsustainable use trends of petrochemical fuels has increased the demand for renewable energy alternatives, and thermochemical processes such as gasification will be required to meet these demands. Gasification is a process that involves the high-temperature partial oxidation of carbon-containing fuels such as lignocellulosic biomass to produce a product gas consisting of hydrogen, carbon monoxide, carbon dioxide, methane, and condensable aromatic liquids known as tars. The non-condensable product gas can be either purified into synthesis gas, a mixture of hydrogen and carbon monoxide used in Fischer-Tropsch synthesis of gasoline or diesel fuel, or sent to gas engines for the generation of heat and electricity. As a renewable and environmentally friendly energy source, biomass and their gasification and combustion for fuel, heat and power production are gaining an increasingly important role worldwide. The objective of this course is to provide a state-of-the-art presentation of the biomass gasification and the modeling strategies of biomass gasification and combustion. The first of its kind professional course in Pakistan will provide baseline and advanced knowledge on the most important gasification technologies as the way of solid fuels (biomass) conversion to refined gas (synthetic gas, methane, hydrogen), liquid fuels and energy (IGCC).

2. **Course Objectives**

   a. To provide a thorough understanding of various renewable feedstock of importance to Pakistan, their availability and attributes for bio-energy production.
   b. To provide a thorough understanding of the broad concept of second and third generation biofuel production from biomass and other low-cost agro-residues and bio-wastes.
   c. To provide students with tools and knowledge necessary for bio-energy facility operations.
   d. To teach our students to analyze and design processes for bio-energy production.

e. Gain a comprehensive understanding of the principle and application of bioenergy systems
f. Understand the availability of biomass feedstocks in different area and weather condition and their potential attributes to energy production.
g. Understand concepts of the gasification and combustion, and the conversion processes of biomass feedstock to energy.
h. Explain the key points in the operation of bioenergy facility.
i. Learn how to analyze and design a bioenergy system according to the availability of feedstock.

3. **Course Outcomes:**

a. Understand the availability of biomass feedstocks in different area and weather condition and their potential attributes to bio-energy production
b. Have the knowledge of biomass gasification technologies, biomass preparation for the process, gasification media production, gas conversion and purification and quality parameters of gasification products, syngas utilization, basic synthesis of fuels and chemicals from syngas.
c. Understand chemical reactions involved in biomass conversion, particularly by gasification, enhancing modeling skill of gasification providing basic knowledge of gasification thermodynamics and kinetics.
d. Be able to prepare the process design of biomass gasification (feedstock preparation unit, gasifier, gas conversion and purification unit; co- and poly-generation processes) as well as to prepare mass and energy balance of the gasification processes.

Detailed Course Contents with suggested contact hours

No.	Topics	CHs
1.	a. **Introduction** (1) Biomass Resources (Biomass Atlas) (2) Modes of Biomass utilization for Energy (3) Routes of Biomass Conversion Processes and	6

	biofuels production technologies (4) Success Stories around the world and Pakistan b. **Characteristics of Biomass Fuels** (1) -Fuel analyses – (2) Sample preparation – (3) Characterization and chemical analyses of solid, liquid and gas samples from technical plants (4) Relevance of feed properties for gasification processes	
2.	c. **Physical Conversion** (1) Dewatering and drying Fundamentals, moisture content and conversion requirements, methods (2) Size reduction: Fundamentals, Steam explosion (3) Densification: Types of Densification Devices, Properties of Densified Fuels (4) Separation: Municipal solid waste, Virgin biomass, Extraction (5) Practice Case Study	6
3.	d. **Thermochemical Conversion** (1) Pyrolysis: Torrefaction, Slow and Fast Pyrolysis, Charcoal Production. (2) Gasification: Fundamentals, Fixed bed Gasifiers, Technical and operations; problems with Fixed bed Gasifiers, Fluidized bed Gasifiers, Entrained Bed Gasifiers, Comparison between Fixed bed and Fluidized bed Gasifiers, Gas Treatment, Equilibrium and Kinetic Considerations. (3) Combustion: Fundamentals, Furnaces, Fixed bed systems, Fluidized bed systems, Emission reduction, Steam cycle, Residential and small commercial systems, Solid waste incineration, Electric power	21

	production, operating problems (4) Practice case study (Experiment on existing downdraft and updraft gasifiers)	
4.	(1) Co-generation process (heat and electricity production) (2) Poly-generation process (heat, electricity and chemical production) (3) IGCC without and with CCS 2 (4) Drawing up of mass and energy balances for selected coal/biomass gasification systems (5) Evaluation of the techno- and eco-efficiency of gasification processes (6) Process modelling of biomass pyrolysis and gasification including thermodynamics laws and chemical reactions principles. (7) Economic evaluation/preparation of business plan (Group exercise)	12
	Total Contact Hours	45

Recommended Reading (including Textbooks and Reference books).

1. Christopher Higman: Gasification, Elsevier, 2008
2. Peter Quaak, Harrie Knoef and Hubert Stassen: Energy from Biomass-A Review of Combustion and Gasification Technologies, World Bank Technical Paper No. 422 Energy Series 1999.
3. A.V. Bridgwater: Advances in Thermochemical Biomass Conversion, Springer, 2008
4. H.A.M Knoef: Handbook Biomass Gasification, BTG, 2005.
5. Bhattacharya S.C. and Salam P.A.: A Review of Selected Biomass Energy Technologies, RERIC, 2006
6. Donald L. Klass: Biomass for Renewable Energy, Fuels, and Chemicals, Academic Press, 1998

7. C. Y. WereKo - Brobby and E. B. Hagan: Biomass Conversion and Technology, John Wiley and Sons, 1996.
8. Souza-Santos M.L,: Solid Fuel Combustion and Gasification, Marcel Dekker Inc. 2004.
9. Prabir Basu: Combustion and Gasification in Fluidized Beds, CRC, 2006
10. Prabir Basu: Biomass Gasification and Pyrolysis: practical design and theory, 2010