

Fuel Characterization, Ash and Deposit Formation, Corrosion in Utility Boilers

Course type and level: Ph.D.-Level Course, Technical University of Denmark

Ph.d. – level, 3 ECTS-points. The course is given provided that there are at least 12 people who sign up.

Organizer: Dr. Flemming J. Frandsen, DTU Kemiteknik, ff@kt.dtu.dk.

Course description:

The course covers all relevant aspects of ash and deposit formation, and, corrosion in systems utilizing solid fuels for heat and power production, including fuel and ash characterization techniques, formation and transport of different ash fractions, adhesion of ash species, deposit formation, shedding of deposits, and, corrosion, as well as boiler aspects and case studies, from Danish and European Power Stations. There is also special sections dedicated to trace element chemistry in industrial processes, as well as formation of green ecological biochar.

The course provides a combination of information on methods of characterization of fuels and ashes, including Simultaneous Thermal Analysis, Scanning Electron Microscopy, chemical fractionation analysis and studies of ash rheology, boiler design, and, finally, an outline of formation of ash deposit, through a number of consecutive steps:

- Release of ash forming elements during pyrolysis, and subsequent char burnout.
- Formation of aerosols from flame-volatile ash-forming species or elements, heterogeneous condensation of ash forming species, and formation and entrainment of residual ash, during char burnout.
- Transport of the different ash forming species from the bulk gas to the heat transfer surfaces of the system.
- Adhesion and consolidation of ash forming species on heat transfer surfaces.
- Build-up, sintering, shedding, and heat transfer in deposits
- Trace element chemistry in industrial processes
- Formation of green ecological biochar: focus on trace element chemistry removal, during pyrolysis

A number of case studies from CHP plants dedicated to biomass or waste thermal conversion (grate fired units), plants co-firing coal with either waste or biomass (mainly straw), or plants firing biodust, will be outlined.

In addition, means of modeling ash and deposit formation will be presented, including global equilibrium analysis, empirical ash chemical indices, plant indices, and reactor or advanced flow models for detailed modeling of ash chemical interactions, flow and deposition in modern utility boilers.

The course will provide insight into a significant number of R&D-activities within EU, EFP, PSO, STVF, NordEn and other funding organs over the years, as well as an insight into 30+ years of research on ash, deposits and corrosion. A number of other important research institutions in this field will also be introduced, as will names of important contributors to the current understanding on ash and deposit formation, corrosion, and trace element emissions.

Course Objectives

The course is offered in order:

- To help **reaching the UN Climate Targets**, since it has a strong focus on optimized and efficient, low-emission energy utilization, as well as on circular resource economy;
- To **attract the best students** to M.Sc.- and Ph.D.-projects;
- To **shed light on research and development activities** within this important area, and;
- To **provide continuing education** for **industrial and governmental employees**, as well as **funding agents.**

Learning objectives

The specific aim of the course, is that students will be able to;

- **Explain basic** physical and chemical **differences between solid fuels** like coal, biomass, waste etc., be able to **characterize solid fuels**, and **to interpret fuel analyses** of them
- **Interpret and utilize data from advanced fuel and ash analyses** (SEM, DTA/TGA, chemical fractionation, ash melting temperatures)
- **Describe** chemically and physically, how critical ash-forming elements are **released** to the gas phase, the mechanisms for **formation of aerosols and fly ash** particles, and **explain how ash is transported from bulk gas to heat transfer surfaces**
- **Quantify** the processes of **deposit build-up**, **sintering** and **shedding**
- **Explain** the fundamentals of **high-temperature corrosion** in thermal fuel conversion systems
- C**alculate viscosities** as a function of temperature and composition, **temperature profiles** in a deposit, **rates of deposit build-up** and **sintering**, as well as **porosity changes vs. time**.

Who should attend this course

The main target groups for the course are:

- **University students (M.Sc. or PhD-level):** Typically students just starting on a M.Sc.- or Ph.D.-project, in need of a thorough introduction to the subject.
- **Industrial employees:** Industrial people who have been employed in industry for 5-10 years or more, and now need an up-grade on the latest development within research in ash deposition and corrosion.
- **Fuel suppliers:** Industrial people, who buy fuels worldwide and need the latest upgrade on how to characterize fuels with respect to operational or emission problems
- **Boiler manufacturers:** Industrial people who design boilers for customers and need the latest news and understanding of how to possibly minimize ash deposition and corrosion in thermal fuel conversion systems.
- **Government environmental regulators and funding agents:** New funding programs and evaluation of research applications are done by people, whom we need to post-educate to ensure maximum focus on research in this field.

What will you do in this course

- Watch illustrative and explaining presentations for each lesson in the course:
- Read supplementary literature, downloadable from the web. Many details of the course material lies in the supplementary reading
- Read directly downloadable course material in the shape of pdf-files containing written material about the different subjects and copies of presented PPT-slides
- Fulfil assessments in the shape of exercises provided as part of the course.

Course form:

The course will consist of a number of lectures, dealing with the following specific issues;

- Fuel characterization and analytical techniques (SEM, STA, viscosity measurements, chemical fractionation)
- Release of ash species (mainly K, S and Cl, in fixed-beds and entrained flow reactors)
- Formation of residual ash and aerosols in thermal fuel conversion systems
- Transport of ash species (including quantification of ash transport and adhesion of ash species)
- Deposit build-up, consolidation, and shedding (including heat transfer in deposits, sintering of deposits)
- Modeling of deposit formation
- High-temperature corrosion of heat transfer surfaces
- Use of additives to minimize deposit formation and corrosion
- WtE Plants
- Case studies (grate-fired units, suspension-firing)
- Trace element chemistry in industrial processes
- Biochar formation as a tool in recirculation of phosphorous to nature

Before each presentation, a number of relevant papers, reports (supplementary reading) will be submitted electronically to the students. The teaching will be in English.

Pre-qualification:

None specific, although a certain knowhow about ash chemistry would be preferable. A solid background can be gained by reading Frandsen, F.J.; *Ash Formation, Deposition and Corrosion When Utilizing Straw for Heat and Power Production*; **Doctoral Thesis, Technical University of Denmark, ISBN-9788792481405, 2011.**

Exam:

The course does not provide a regular exam, the students will be evaluated by fulfilling 5 theoretical exercises on different ash-related topics, e.g.;

- Estimation of viscosity of Si-rich ashes, by use of models and charts
- Heat Transport to/ in the deposits, including the estimation of a deposit surface temperature.
- Transport and adhesion of ash species as a function of flow regime, temperature, and deposit characteristics.
- Sintering/consolidation of the deposits (porosity and strength calculations vs. deposit chemistry and structure)
- Quantification of deposit chemistry, including the quasi-chemical ash chemistry approach.
- Quantification of the release of the critical elements (K, S, Cl)

Other subjects may appear.

All exercises MUST be reported incl. spreadsheets and supplementary data/information.

Course registration and venue:

Sign-up for the course is done by sending an email to Dr. Flemming J. Frandsen, ff@kt.dtu.dk

The course is given provided that there are at least 12 people who sign up. It can be Zoom/Teams-based but can also be provided as physical teaching.

It is NOT a shopping course, so you are not allowed in on individual lectures, either you take the course or you do not.