



Special Course on Ash and Deposit Formation, Corrosion in Utility Boilers

Ph.D.-Course, Technical University of Denmark

Title, English: Formation of ash and deposits during thermal conversion of coal, biomass and waste.

Ph.d. – level, 5 ECTS-points.

Organizer: Associate Professor Flemming 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.

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 to the heat transfer surfaces.
- Build-up, sintering, shedding, and heat transfer in deposits

A number of case studies from plants dedicated to biomass or waste thermal conversion (grate fired units) or from plants co-firing coal with either waste or biomass (mainly straw) 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 20+ 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 form:

The course will consist of a number of presentations, 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)
- Corrosion of heat transfer surfaces
- Use of additives to minimize deposit formation and corrosion
- Case studies (grate-fired units, suspension-firing)
- Modeling of deposit formation
- Experiences on deposit probe measurements in full-scale boilers
- Utilization of ash as fertilizer
- Reuse of ash from thermal conversion systems
- Refinery of metals from mineral ores

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 4 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.

Price and course registration:

5000,- dkr. (Danish kroner), which will include Course material, 5 x lunch, coffee/tea/refreshments (morning + afternoon), and a Course dinner.

Housing and travel will be on your own expense. Hotel facilities are available nearby in Lyngby downtown.

Sign up, by sending an email to ff@kt.dtu.dk, stating your name, affiliation, contact information and any dietary needs. Signing up is binding. **Students from NTNU and Åbo Akademi are free of charge due to a common graduate school agreement.**

Payment should be made available to:

Danske Bank, Reg. No. 4183, Account No. 42 63 97 20 07, IBAN No. DK 57 3000 4263 9720 07, SWIFT Code DABADKKK.

REMEMBER IN THE PAYMENT TO MENTION THAT IT CONCERNS PROJECT NO. 50994—This is rather crucial, thanks.

Course plan:

Date:	Place:	Subject:
Jan. 19	003/229	Fuel characterization and analytical techniques (SEM, STA, Viscometer), Release of critical ash-forming species, Formation of aerosols and residual fly ash
Jan. 20	003/229	Ash transport, deposit build-up, consolidation, and shedding , Modeling of Deposit Formation
Jan. 21	003/229	Corrosion of heat transfer surfaces: Material aspects, Ash Chemistry and Corrosion in WtE Plants, Use of additives to minimize deposit formation and corrosion
Jan. 22	049/229	Case studies: Straw-firing, coal-straw co-firing, suspension-firing of straw, Probe Measurements in Full-Scale Boilers
Jan. 23	003/229	Ash Chemistry in Cement Manufacturing (guest lecture), Minerals and Refinery of Ores, Aluminium Production: Now and in a Historical View (guest lecture), Utilization of ash as fertilizer (guest lecture), Summary of the course and evaluation

New material.

Further info: Flemming J. Frandsen, ff@kt.dtu.dk, Mobile: +4551206689.

Detailed Course Program

Time:	Monday, January 19	Tuesday, January 20	Wednesday, January 21	Thursday, January 22	Friday, January 23
09:00	Welcome Background FF	Transport of Ash Species PAJ	Corrosion in Boilers: Intro FF	Probe Measurements FF	Ash Utilization Nicolai Bech
10:00	Fuel Characterization FF	Deposit Build-Up PAJ	Corrosion in Full-Scale Melanie Montgomerie	Case studies: Grate firing and Co-Firing in Susp. FF	Cement Clinker Quality Ebbe Skyum-Jøns
11:00	Fuel Characterization FF	Deposit Heat Transfer FF	Corrosion in Lab-Scale Sunday Okoro	Case Studies (JEAH): Operational problems in	Alumina Production Benny Raahauge
12:00	Lunch	Lunch	Lunch	Lunch	Lunch
13:00	Release of Critical Elements HAW	Deposit Shedding PAJ	Ash and Corrosion Problems in WtE Plants AJP	Case Studies (HAW): Suspension Firing of Straw/Wood Pellets	Ash as Fertilizer Veronika Hansen
14:00	Formation of aerosols HAW	Modelling of Deposit Formation FF	Use of Additives to Prevent Corrosion HAW	Case Studies (JJOHA): Flame Measurements	Course Summary FF
15:00	Formation of Residual Ash FF	Exercise	Exercise	Lab-Scale Studies (AJP): Suspension Firing of Straw/Wood Pellets	
16:00	Exercise	Exercise	Guided Lab-Tour (PAJ)	Exercise	
18:00			Course Dinner (All)		