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EXAM IN SUBJECT TEP4170
HEAT AND COMBUSTION TECHNOLOGY
(Varme- og forbrenningsteknikk)
Monday 15 August 2011 Time: 0900 – 1300

The exam is only available in English. The answers can be written in Norwegian or English.

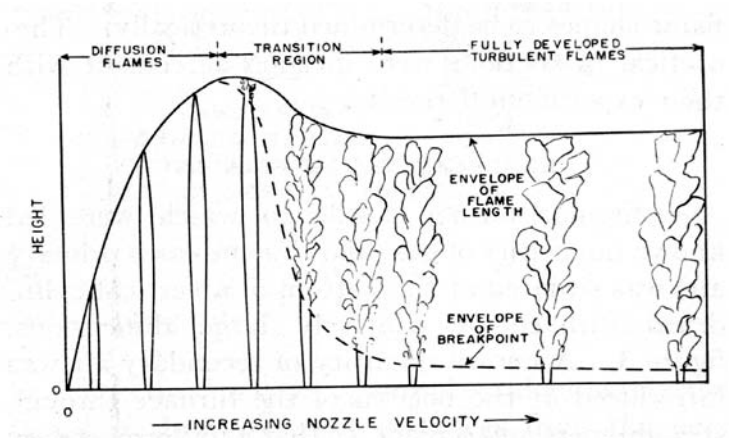
Permitted aids: D – No printed or handwritten aids. Certain simple calculator.

- Please do not use red pencil/pen, as this is reserved for the censors.
- Read through the problems first. Begin with the problem where you feel that you have the best insight. If possible, do not leave any problems blank. Formulate clearly, it pays off!

NOTE: The decimal sign is comma.

Problems:

1)
The figure is taken from a paper by Hottel and Hawthorne, 1949, and shows a sketch of an experiment with a jet flame.
--Explain what the sketch shows.



2)
-- Explain mean-value modeling (Reynolds-averaged modeling) (Norw: “middelverdi-modellering”).
-- Mention other methods for modeling/simulation of turbulent flow and/or turbulent combustion and explain what distinguish these methods from the averaged methods.

3)
A combustion reaction can be regarded as a simple, one-step reaction between a fuel and an oxidizer (air). We write

$$1 \text{ kg fuel} + r \text{ kg oxidizer} \rightarrow (1+r) \text{ kg product}$$

--What is *r* here?

--Determine *r* for methanol, CH_3OH. Molar masses (kg/kmol): CH_3OH: 32; air: 29

--If an expression for the reaction rate of fuel, R_{fu}, is know, how can the reaction rates of oxidizer and product be expressed?

4)
-- What is a conserved scalar?
--The quantity $(Y_{br} - \frac{1}{r} Y_{ox})$ can be a conserved scalar. Show this and specify the required assumptions.
--Define the mixture fraction.

5)
--Develop the equation (partial differential or "transport") for the mean mixture fraction.

6)
--Sketch the curve for the 3-dimensional energy spectrum, $E(\kappa)$, for steady-state isotropic turbulence with a high Reynolds number. (κ is the vawe number). Explain what the curve shows.
-- What is the relation between turbulence (kinetic) energy and the energy spectrum $E(\kappa)$?
-- Mark the universal equilibrium range (Norw: "jamvektsområdet") and the inertial subrange (Norw: "det trege området") in the sketch.
-- Develop "Kolmogorov's 5/3-law".

7)
--What is the content of Kolmogorov's hypothesis of local isotropy?
--What are the Kolmogorov micro scales and how are they obtained?

8)
--Describe where and how soot is formed in non-premixed (diffusion) flames of simple geometries?

--When does soot occur in premixed flames?

9)
-- Mention the different types and of elementary reactions taking part in chain reactions and explain their roles in the chain.

10)
The analysis of a biomass sample gives a moisture content of 15% (by mass); a dry-matter elemental composition of 49% C, 44% O, 6% H, 1% ash (mass basis); and a dry-matter lower heating value (Norw: "nedre brennverdi") of 19 MJ/kg.

The moist fuel is burned with $\lambda = 1{,}1$, that is 110% of the stoichiometric (theoretical) amount of air. The combustion is complete (all C to CO_2; all H to H_2O).

-- Determine the mass of CO_2, H_2O and O_2 in the product, per kg of moist fuel.
-- Determine the effective heating value (that is, the lower heating value of the moist fuel).

The evaporation of water (h_{fg}) takes 2,47 MJ/kg.
Molar masses (kg/kmol): C: 12; O: 16; H: 1