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Catalytic ash free coal gasification in a fluidized bed thermogravimetric analyzer

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Catalytic Ash Free Coal Gasification in a Fluidized Bed Thermogravimetric Analyzer

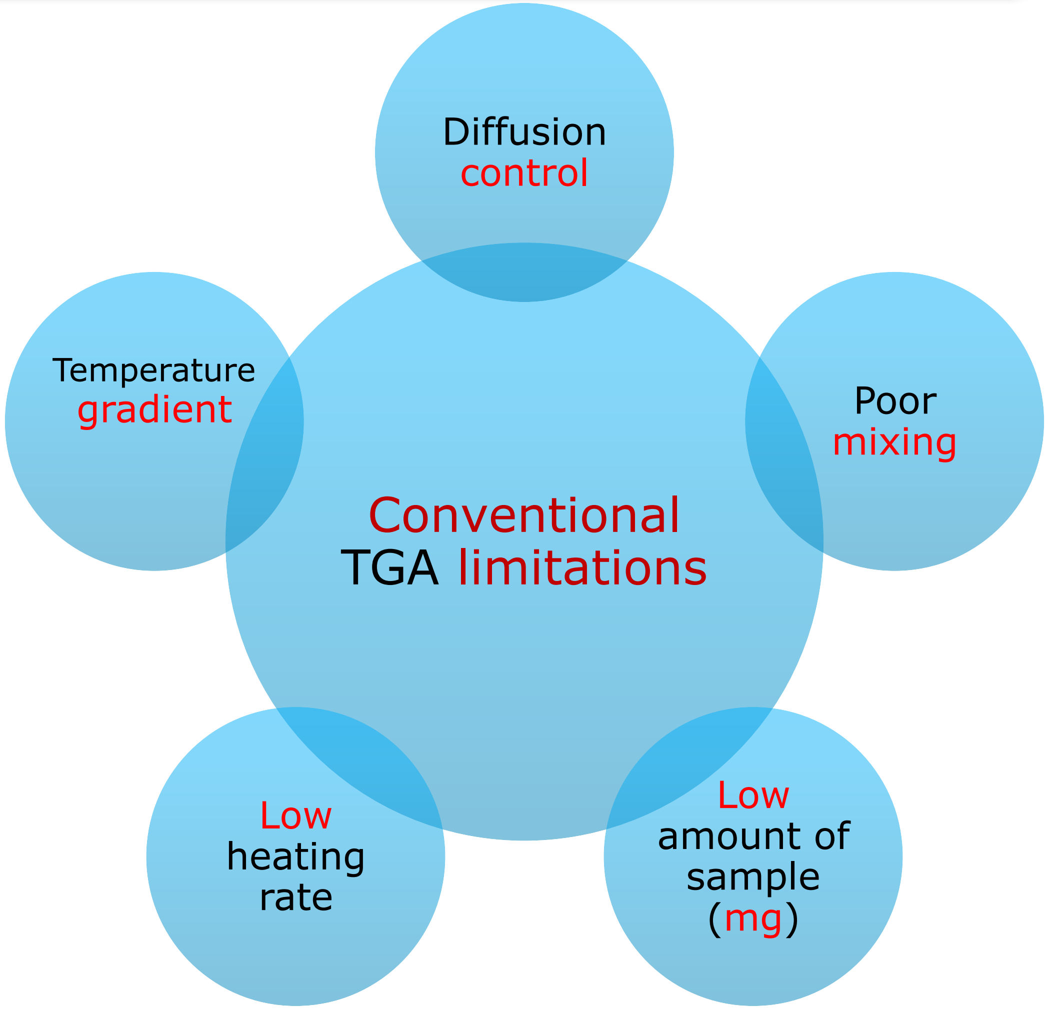
Speaker: **Said Samih**
PEARL Group, Prof. Jamal Chaouki

WORLD-CLASS ENGINEERING

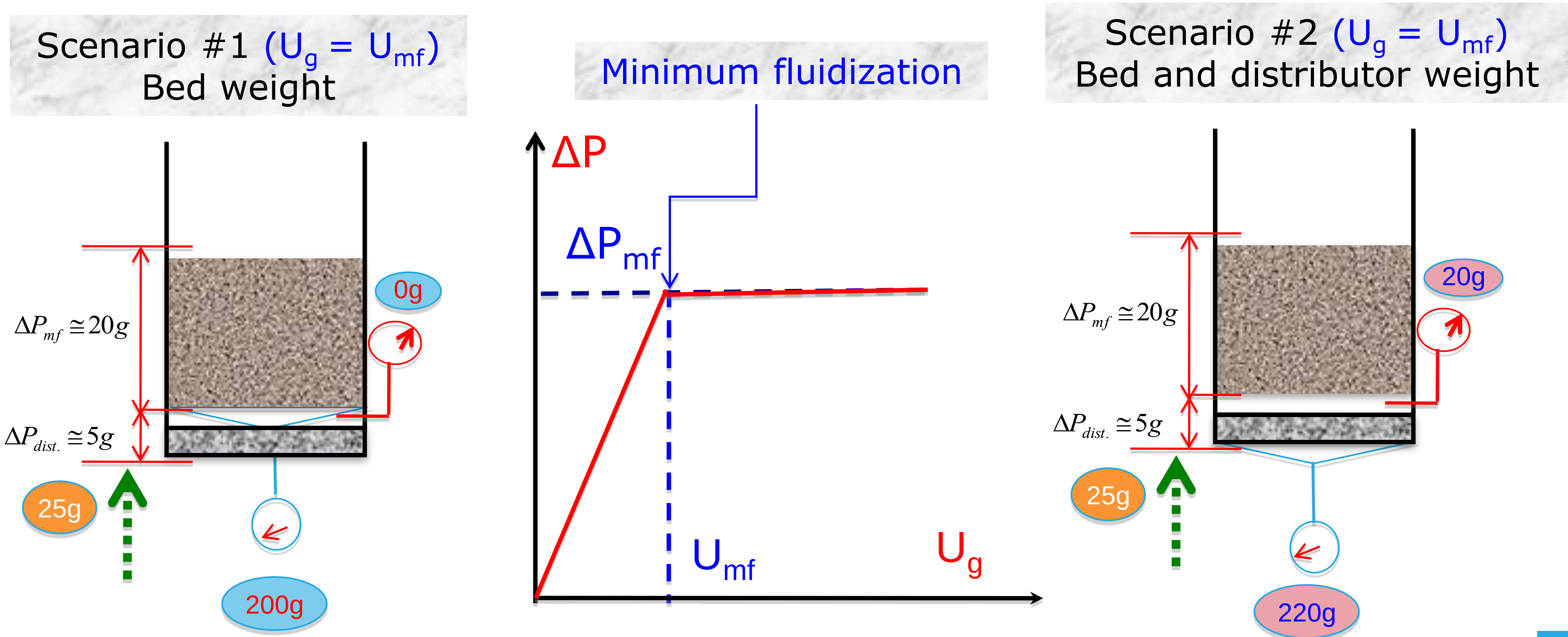
POLYTECHNIQUE MONTRÉAL

PROBLEMATIC: KINETIC STUDY

Problematic:
Conventional TGA Limitations

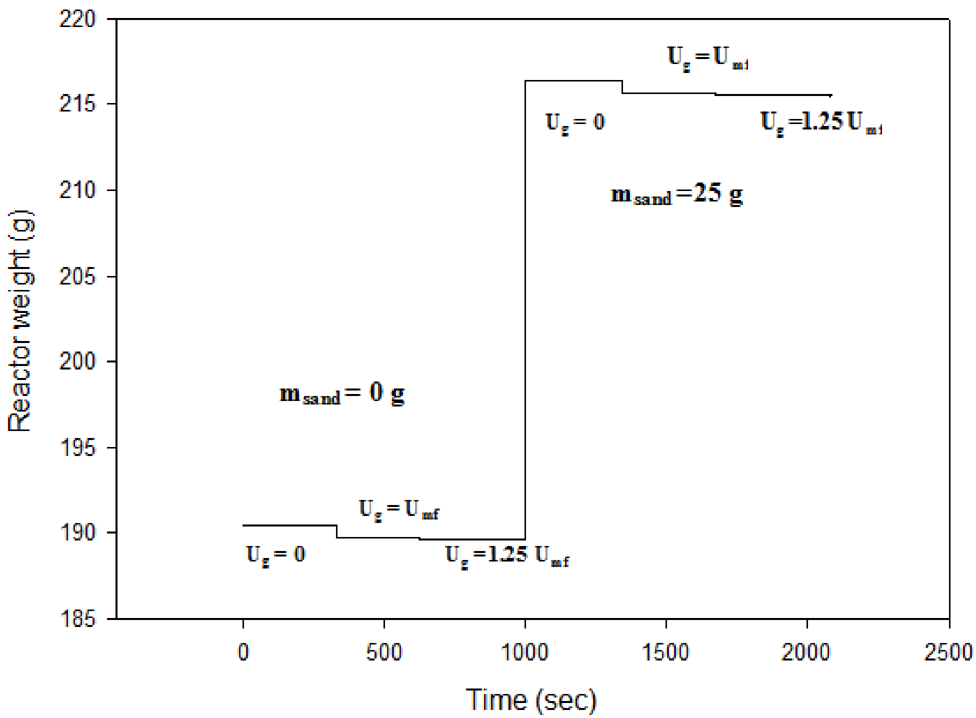


CONCEPT OF THE FLUIDIZED BED TGA



- **According to the 2nd scenario, the weight of the fluidized bed can be measured by the balance**
- **This is how we built the first fluidized bed TGA in the world**

CONCEPT OF THE PSEUDO VARIATION OF THE WEIGHT IN FBTGA

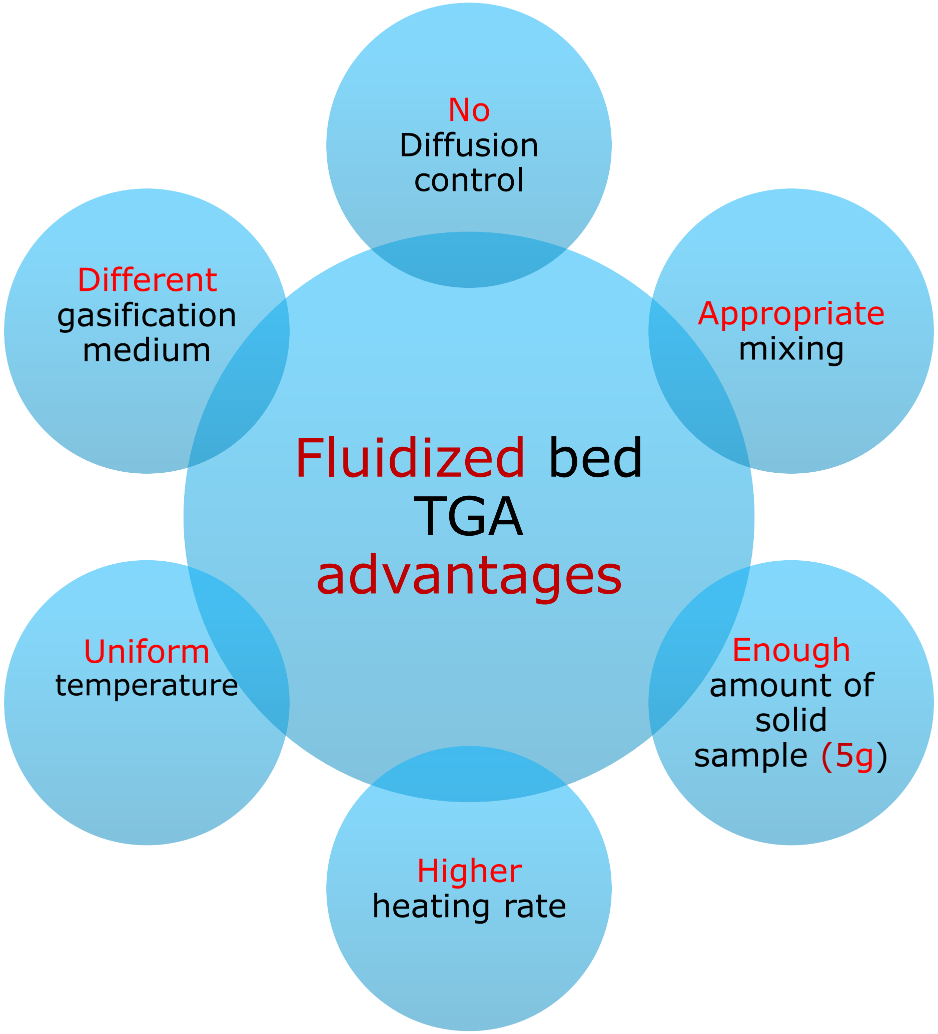


- The variation of the reactor **weight** was the **same** for **different** initial weights of the **bed** of **0 g** and **25 g**
- This **pseudo** variation of the weight is due to the **pressure drop** across the **distributor** and **filter** of the reactor

Source: Samih, S. and Chaouki, J. (2015), Development of a fluidized bed thermogravimetric analyzer. AIChE J., 61: 84–89. doi: 10.1002/aic.14637

SOLUTION: KINETIC STUDY

Solution: Fluidized bed TGA

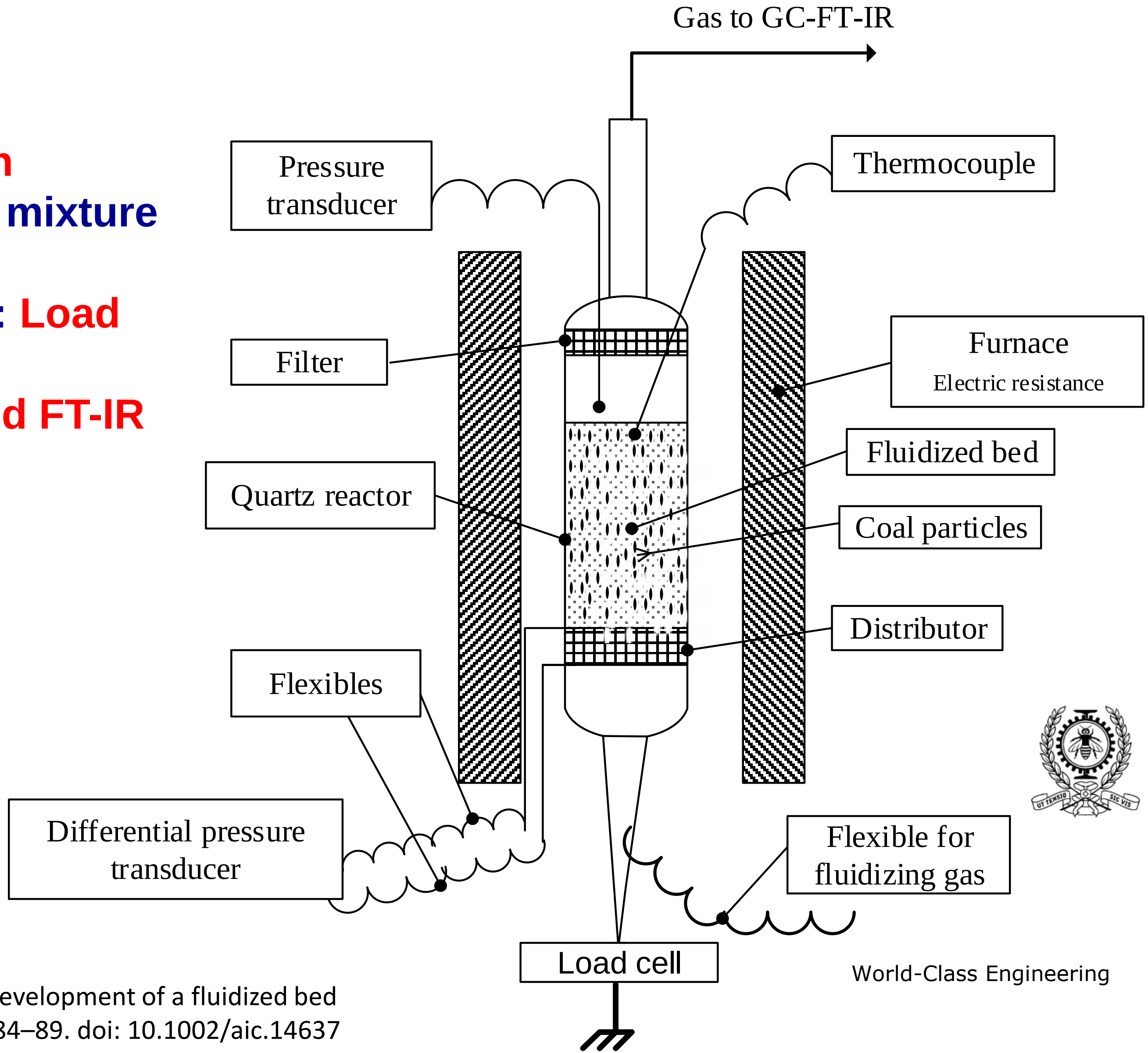


SCHEMATIC OF THE FLUIDIZED BED TGA

- ➢ **Heating rate: 50 K/min**
- ➢ **Fluidizing agent: Gas mixture (5% O2, 95 % N2)**
- ➢ **Weight measurement: Load cell**
- ➢ **Gas analyzing: GC and FT-IR**

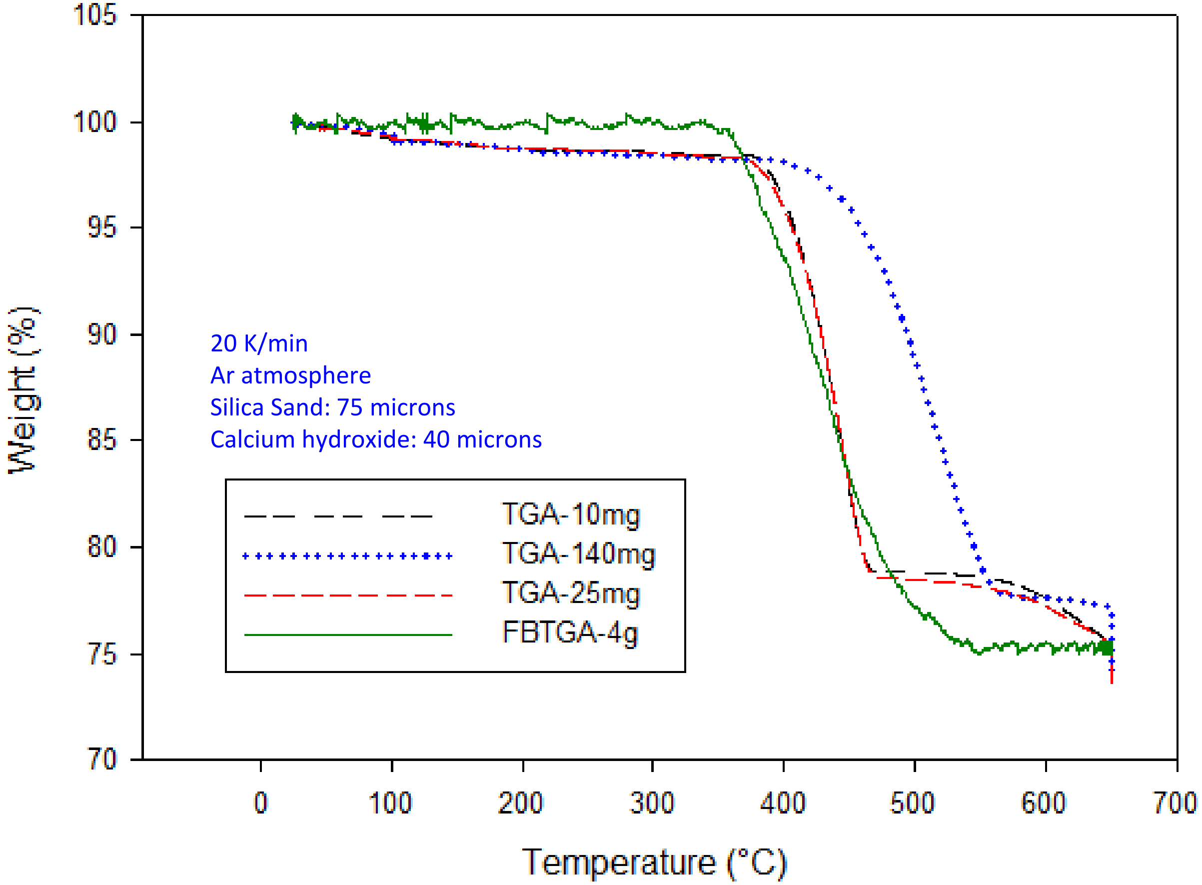
Quartz reactor:

- ➢ **Diameter: 2.5 cm**
- ➢ **Height: 15 cm**
- ➢ **Amount of coal: 5 g**
- ➢ **Bed material: Silica Sand (40 g)**
- ➢ **Catalyst: K_2TiO_3**



Source: Samih, S. and Chaouki, J. (2015), Development of a fluidized bed thermogravimetric analyzer. AIChE J., 61: 84–89. doi: 10.1002/aic.14637

EXPERIMENTAL VALIDATION OF THE FLUIDIZED BED TGA: CALCIUM HYDROXIDE DECOMPOSITION



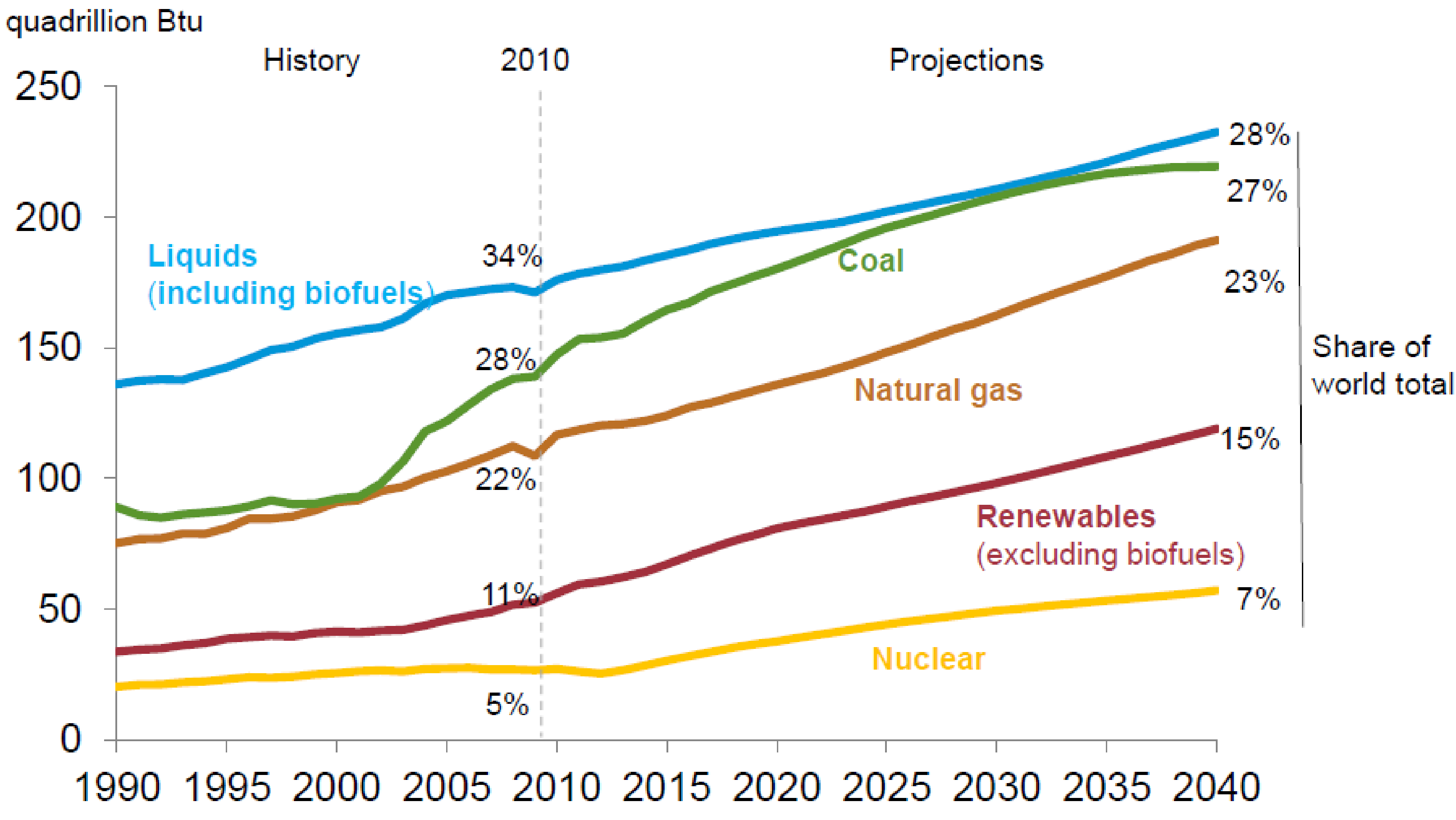
- **Inter and intra-particle diffusion were eliminated by using 4 g in the FBTGA: $Ca(OH)_2$ decomposition was carried out in one stage**

Source: Samih, S. and Chaouki, J. (2015), Development of a fluidized bed thermogravimetric analyzer. AIChE J., 61: 84–89. doi: 10.1002/aic.14637

OBJECTIVES

- ☑ **Develop a fluidized bed thermogravimetric analyzer (FBTGA)**
- ☑ **Study the effect of catalyst (K_2TiO_3) on ash free coal gasification is studied in the new FBTGA**

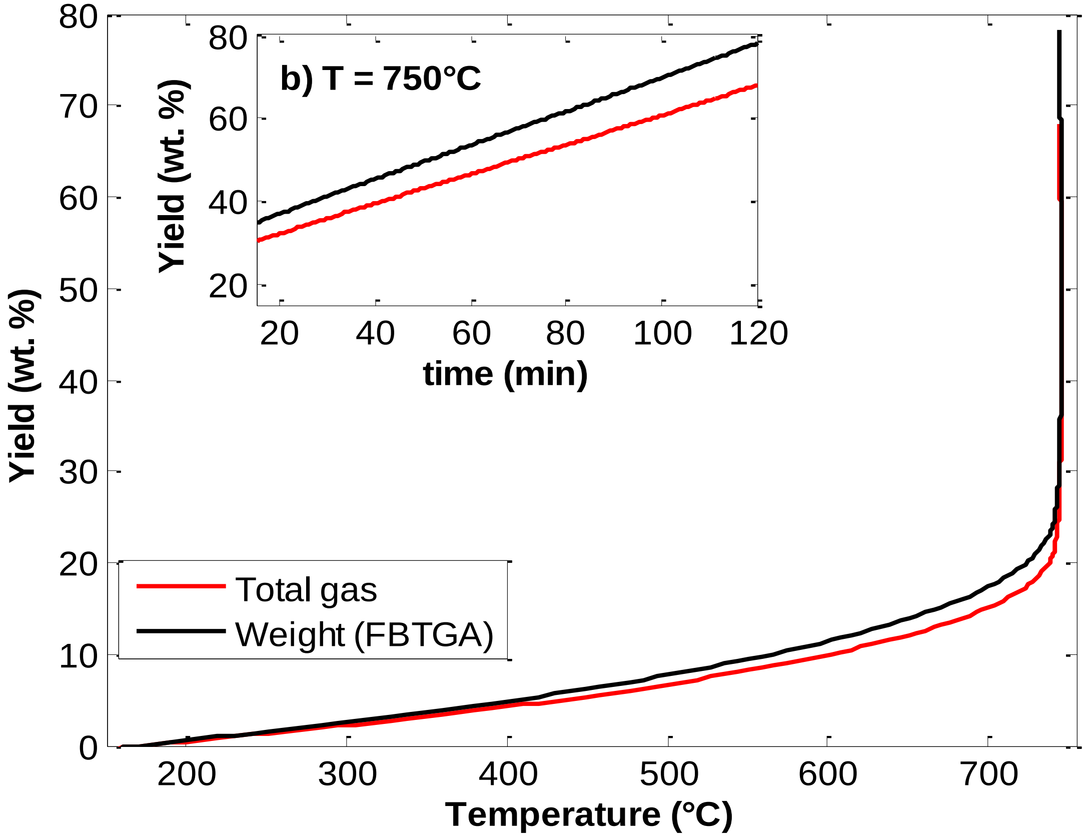
WORLD ENERGY CONSUMPTION



Source: EIA, International Energy Outlook 2013

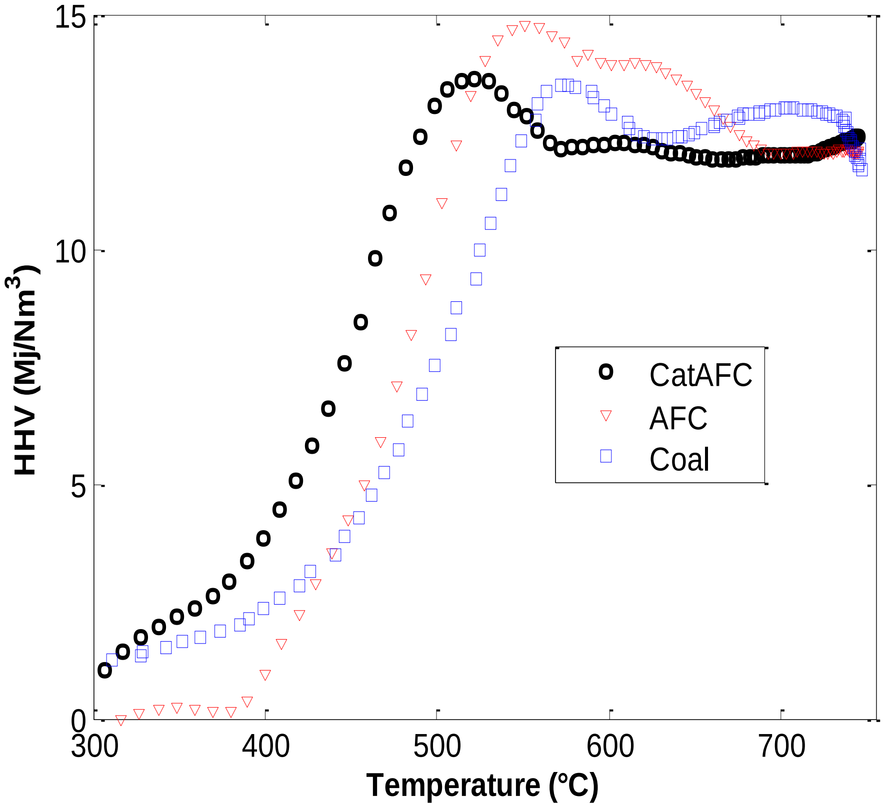
- **Coal will continue to be the most consumed source of energy worldwide**
- **Coal is the most polluting source of energy**

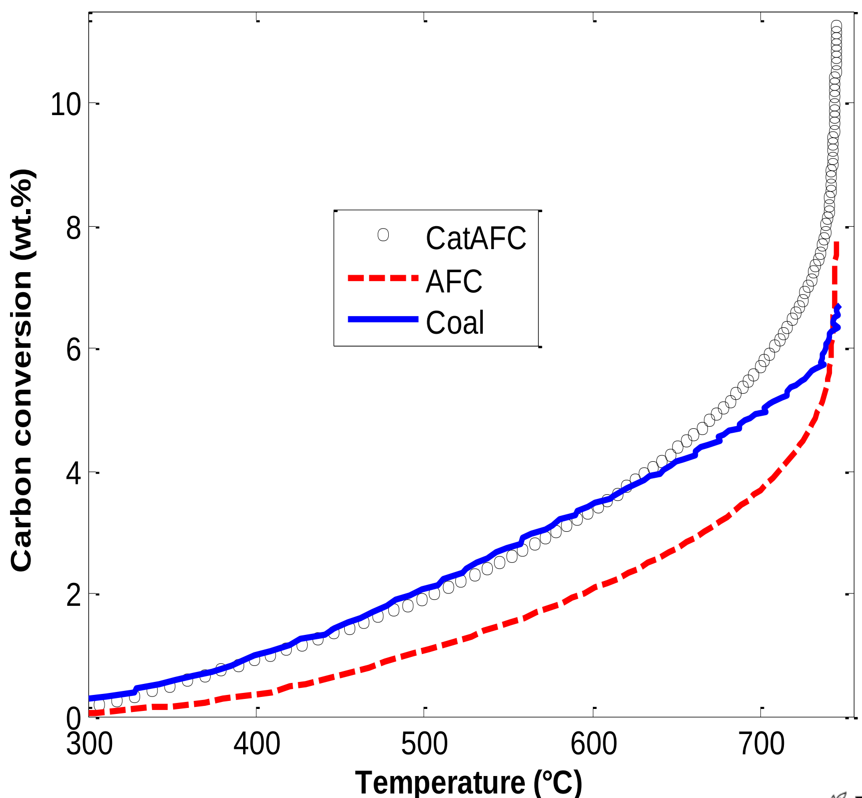
ASH FREE COAL GASIFICATION IN FBTGA



- **AFC gasification in a fluidized bed TGA: weight loss vs. total product gas**

CATALYST EFFECT ON GASIFICATION





- ❑ **Higher high heating value of the product gas at low temperature**
- ❑ **Higher carbon conversion with potassium catalyst: reaction rate was accelerated**

KINETIC MODELING FROM FBTGA (MINIMUM 22 PARAMETERS)

No.	Chemical reaction	Reference
R1	$C+\alpha O_2 \rightarrow 2(1-\alpha)CO+(2\alpha-1)CO_2$	Wurzenberger et al. (2002) & Lee et al. (1998)
R2	$C + H_2O \rightarrow CO + H_2$	Wurzenberger et al. (2002) & Groppi et al. (2000)
R3	$C+CO_2 \rightarrow 2CO$	Wurzenberger et al. (2002) & J. Macak and J. Malecha (1978)
R4	$C+2H_2 \longrightarrow CH_4$	Neogi et al.(1986) & Inayat et al.(2010)
R5	$CO+1/2O_2 \rightarrow CO_2$	Kim et al.(2000) & J. Adanez and F. G. Labiano(1990)
R6	$CH_4+2O_2 \rightarrow CO_2+2H_2O$	Wurzenberger et al. (2002) & Groppi et al. (2000)
R7	$H_2+1/2O_2 \leftrightarrow H_2O$	Wurzenberger et al. (2002) & Groppi et al. (2000)
R8	$CO+H_2O \leftrightarrow H_2+CO_2$	Wurzenberger et al. (2002) & Watkinson et al.(1991)
R9	$CH_4+H_2O \rightarrow 3H_2+CO$	Wurzenberger et al. (2002) & Watkinson et al.(1991)
R10	$Tar \rightarrow \nu_{CO}CO+\nu_{CO_2}CO_2+\nu_{CH_4}CH_4+\nu_{H_2}H_2+\nu_{tar}tar_{inert}$	Hajaligol et al. (1982)
R11	$CH_{1.522}O_{0.0228}+0.867O_2 \rightarrow CO+0.761H_2O$	K. M. Bryden et al. (1996)

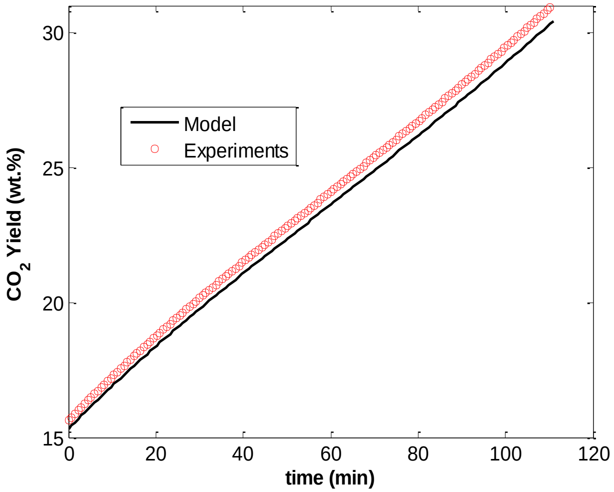
CATALYST EFFECT ON WATER GAS SHIFT REACTION

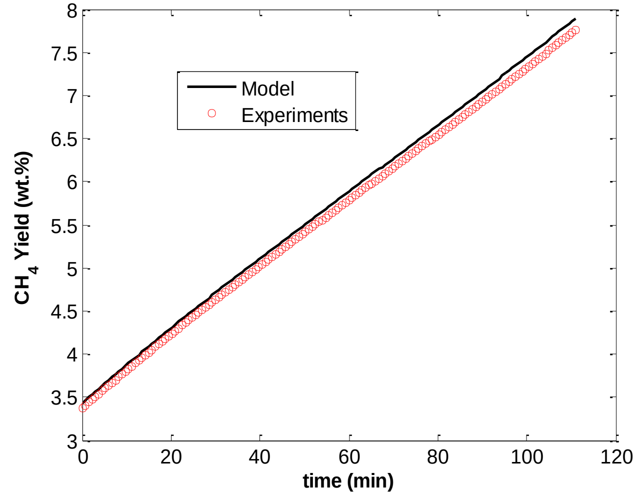
Catalyst	Activation energy (kJ/mol)	Reference
Fe_2O_3/ZrO_2	105-111	A. A. Hakeem et al. (2015)
Gold/ferrochrome	88.2	G. N. Vajani et al. (2011)
$3.5Ni-2K/10CeO_2-Al_2O_3$	155	N. A. Pechimuthu et al. (2006)
Pt@SiO2	70	Y. Wang et al. (2012)
Li/MgO	158	I. Balint et al. (2000)
K_2TiO_3	**44.3**	**This work**
None	**101.9**	**This work**
None	162.6	A. P. Watkinson et al. (1991) & B. J. C. Wurzenberger et al. (2002)

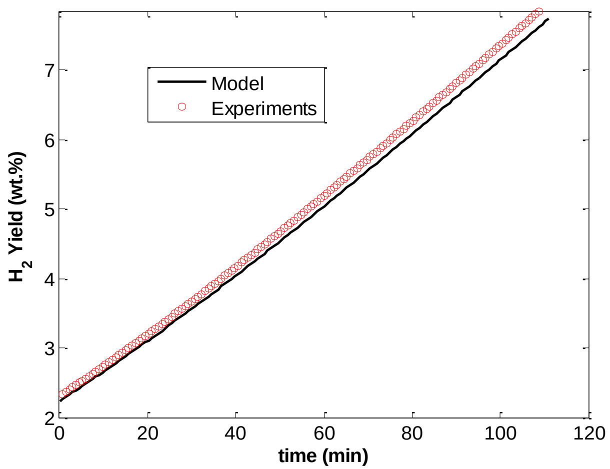
CATALYST EFFECT ON METHANE REFORMING REACTION

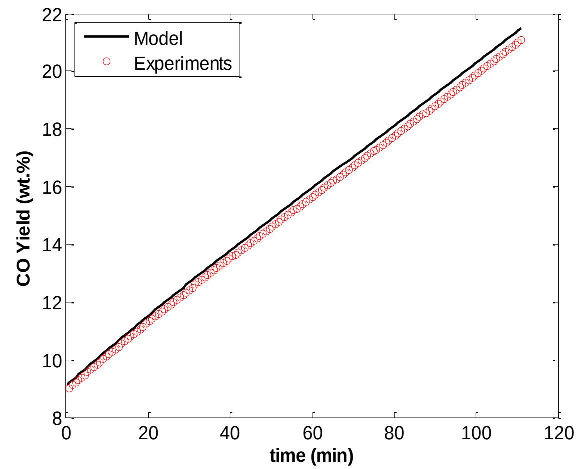
Catalyst	Activation energy (kJ/mol)	Reference
K-based	113-124	M. H. Halabi et al. (2010) & M. H. Park et al. (2015) & T. W. Kim et al. (2015)
Ni/y-Al2O3	133.9	T. W. Kim et al. (2015)
Rh/Al2O3	111	J. Wei et al. (2004)
Platinum	114	K. Gosiewski et al. (1999)
Ce0.9Gd0.1O2-x (CGO)	153	E. Ramirez-Cabrera et al. (2000)
Ni/Mg/K/Al2O3	93	A. M. Robinson et al. (2015)
Ni/La/Al2O3	85.2	M. H. Park et al. (2015)
Ni/La-Co/Al2O3	99.4	M. H. Park et al. (2015)
K_2TiO_3	**71.9**	**This work**
None	**108**	**This work**
None	124.7	A. P. Watkinson et al. (1991) & B. J. C. Wurzenberger et al. (2002)

GAS YIELDS FROM THE CATALYTIC AFC GASIFICATION IN FBTGA









- **Experiments and model results are in good agreement**

CONCLUSION

- Fluidized bed TGA was developed : The unique FBTGA in the world
- Effect of catalyst (K_2TiO_3)on ash free coal gasification is studied in new FBTGA
- Novel kinetic parameters were found for CO shift and methane reforming reactions
- Model and experiments results are in good agreement

END

THANKS FOR YOUR ATTENTION