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Cedric Briens
ICFAR

Mohammad Latifi
ICFAR

Franco Berruti
ICFAR

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A New Inductively Heated Mini Reactor for Biomass Pyrolysis and Gasification Tests

Mohammad Latifi, Franco Berruti,
Cedric Briens

**London, Ontario
CANADA**

Why a new test reactor?

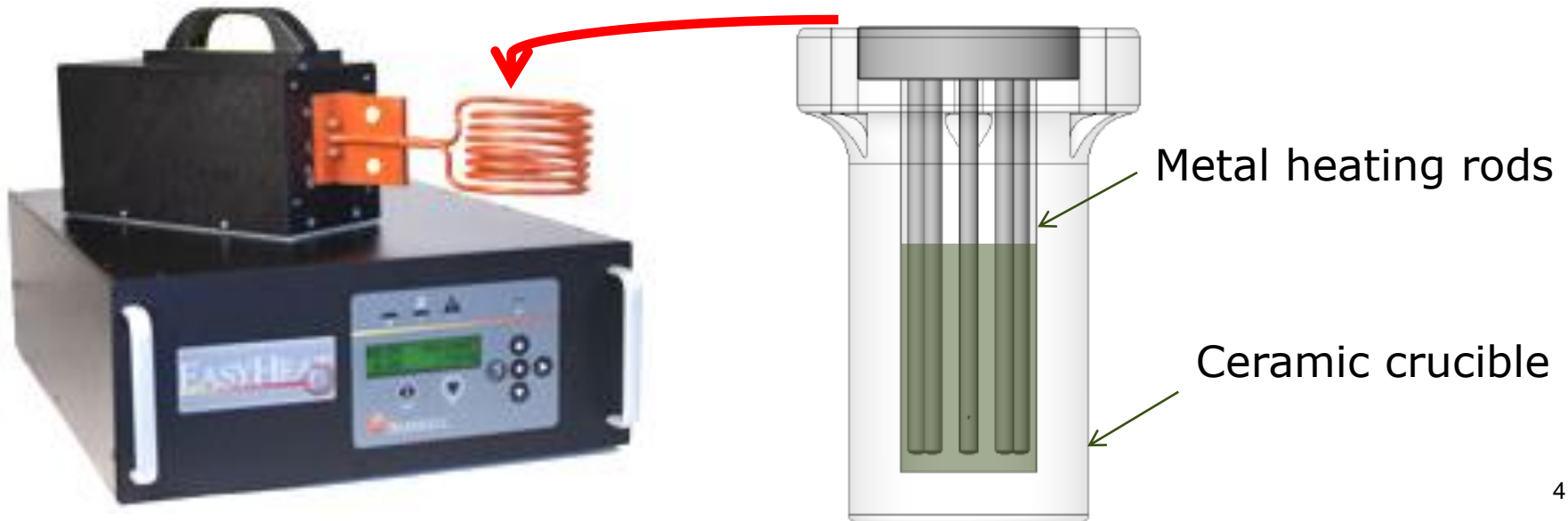
- Many important catalytic reactions are endothermic e.g.:
 - Catalytic cracking
 - Gasification
- Issues with traditional test reactors:
 - Heat is transferred from the wall into reactor
 - Low heat transfer coefficient:
 - High temperature gradient
 - Parasitic thermal cracking reactions
 - Seals for agitator may leak

Solutions

- **Batch reactor**
 - **good control of residence time**

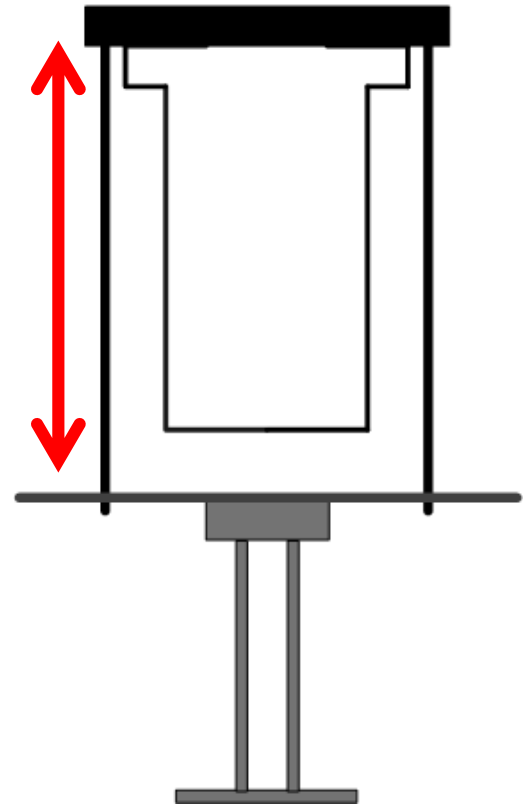
Solutions

- Batch reactor
 - good control of residence time
- **Low temperature difference between heating surface and catalyst bed:**
 - **induction heating of rods within bed**



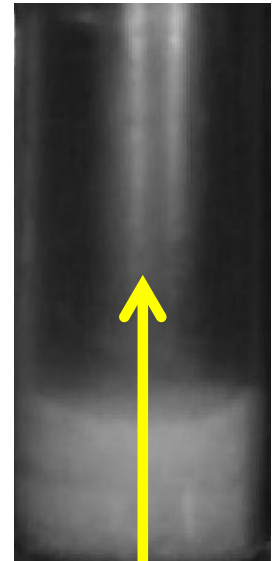
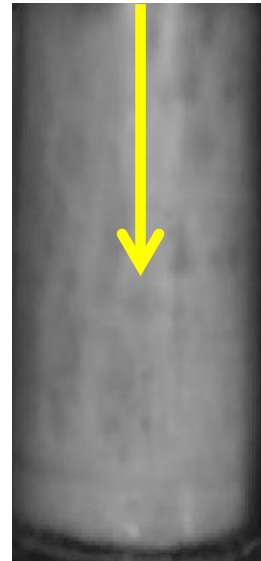
Solutions

- Batch reactor
 - good control of residence time
- Low temperature difference between heating surface and catalyst bed:
 - induction heating
- **No mechanical seal**
 - **jiggle bed**
(up and down motion)



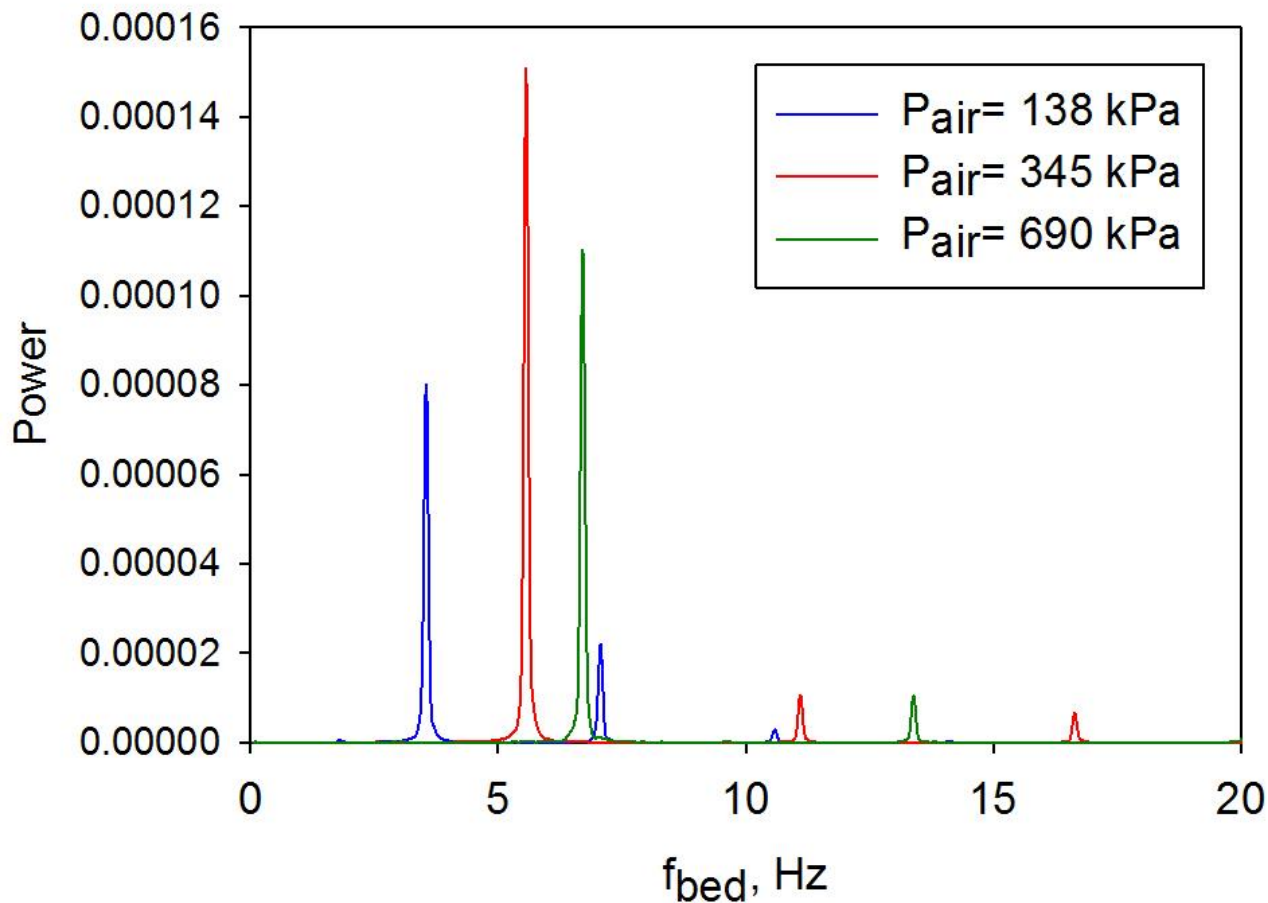
Solutions

- Batch reactor
 - good control of residence time
- Low temperature difference between heating surface and catalyst bed:
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Optimum frequency and amplitude

- **Analysis of color variations**



Heat transfer performance

Heat transfer coefficient from metal rods to catalyst bed

For various conditions:

$h_w \left(\frac{W}{m^2 \cdot ^\circ C} \right)$
45
80
220
493

→ similar to what can be obtained in a fluidized bed

Comparison with studies with pilot plant fluidized catalytic reactors

- Catalytic cracking of acetic acid

Molar steam to carbon ratio = 6				Molar steam to carbon ratio = 3			
	Catalysts tested by Medrano <i>et al.</i> (2009)		This study	Catalysts tested by Vagia and Lemonidou (2010)			This study
<i>Catalyst</i>	<i>Ni/Al,Ca0.5</i>	<i>Ni/Al,Mg0.2</i>	<i>X</i>	<i>5%Ni</i>	<i>10%Ni-1</i>	<i>10%Ni-2</i>	<i>X</i>
H ₂	0.84	0.87	0.84	0.88	0.83	0.87	0.78
CO	0.18	0.14	0.17	0.27	0.30	0.31	0.27
CO ₂	0.71	0.85	0.79	0.73	0.67	0.69	0.65
CH ₄	0.00	0.00	0.04	0.00	0.03	0.00	0.06
C ₂ H ₄ +C ₂ H ₆	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Conversion	0.90	0.99	1.00	1.00	1.00	1.00	1.00

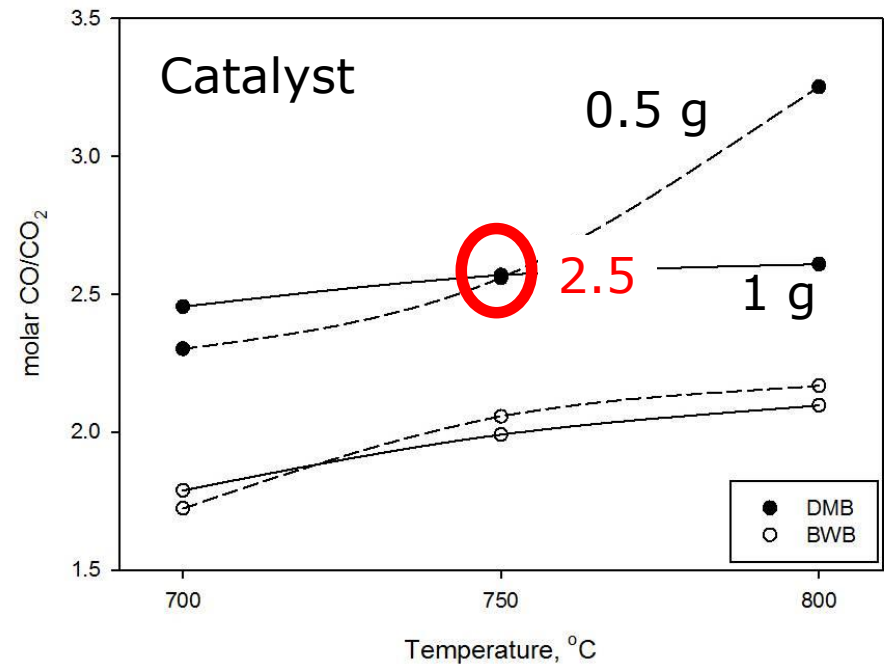
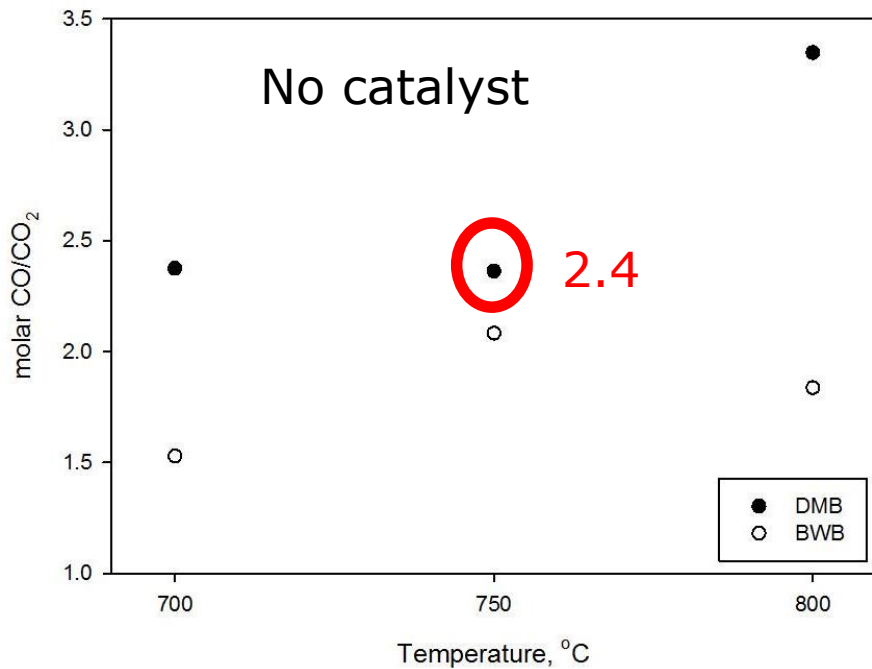
→ excellent agreement between JBR results and pilot plant fluidized beds

Gasification of bio-oil

- Bed:
 - 10 g of sand (106-220 μm)
 - commercial catalyst (two catalysts were tested)
- Liquid feedstock:
 - 4 μl injected
 - Two types of bio-oils from wood pyrolysis:
 - Oak bio-oil produced by Dynamotive (DMB)
 - Birch wood bio-oil produced at 475 $^{\circ}\text{C}$ at ICFAR (BWB)

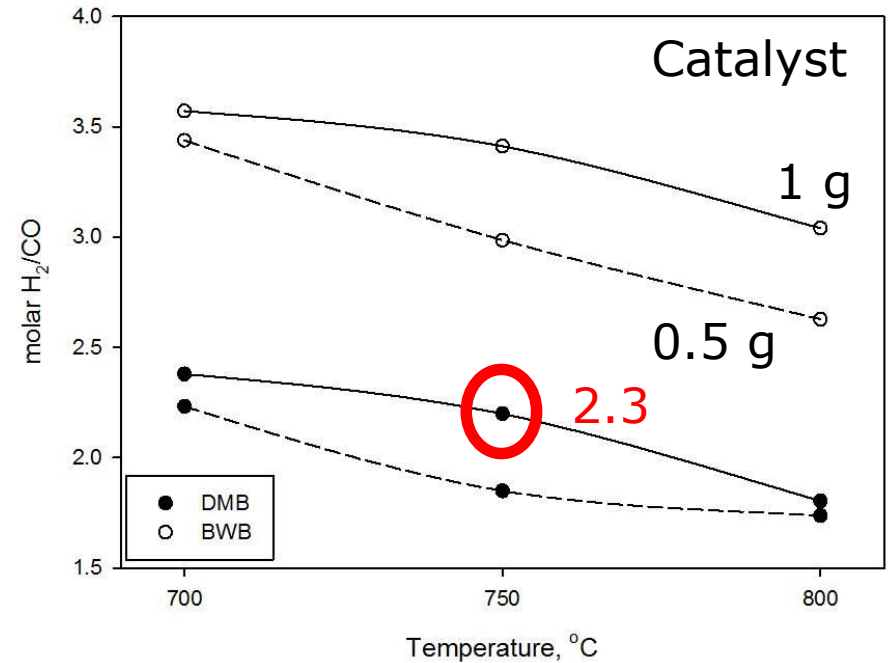
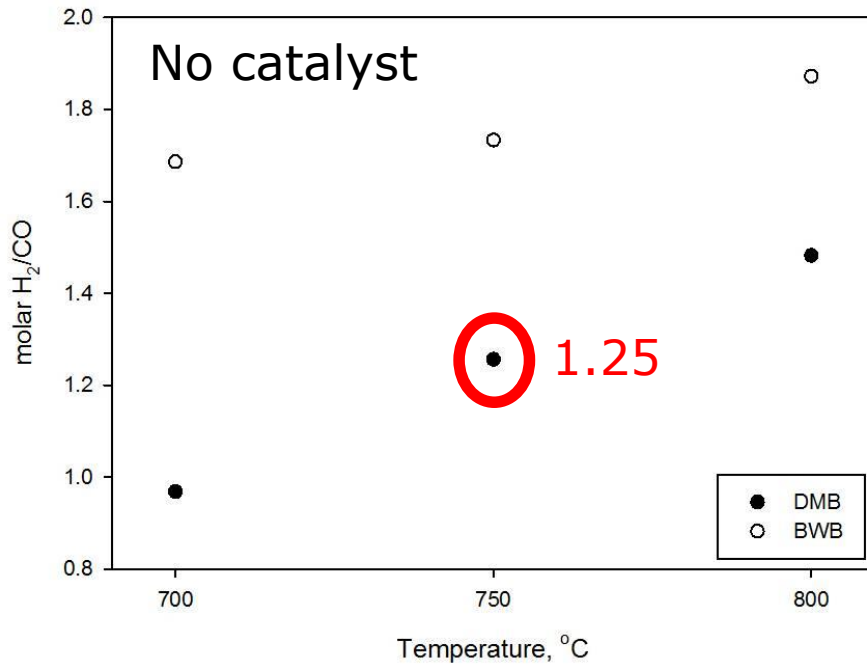
Gasification of bio-oil

30 s residence time



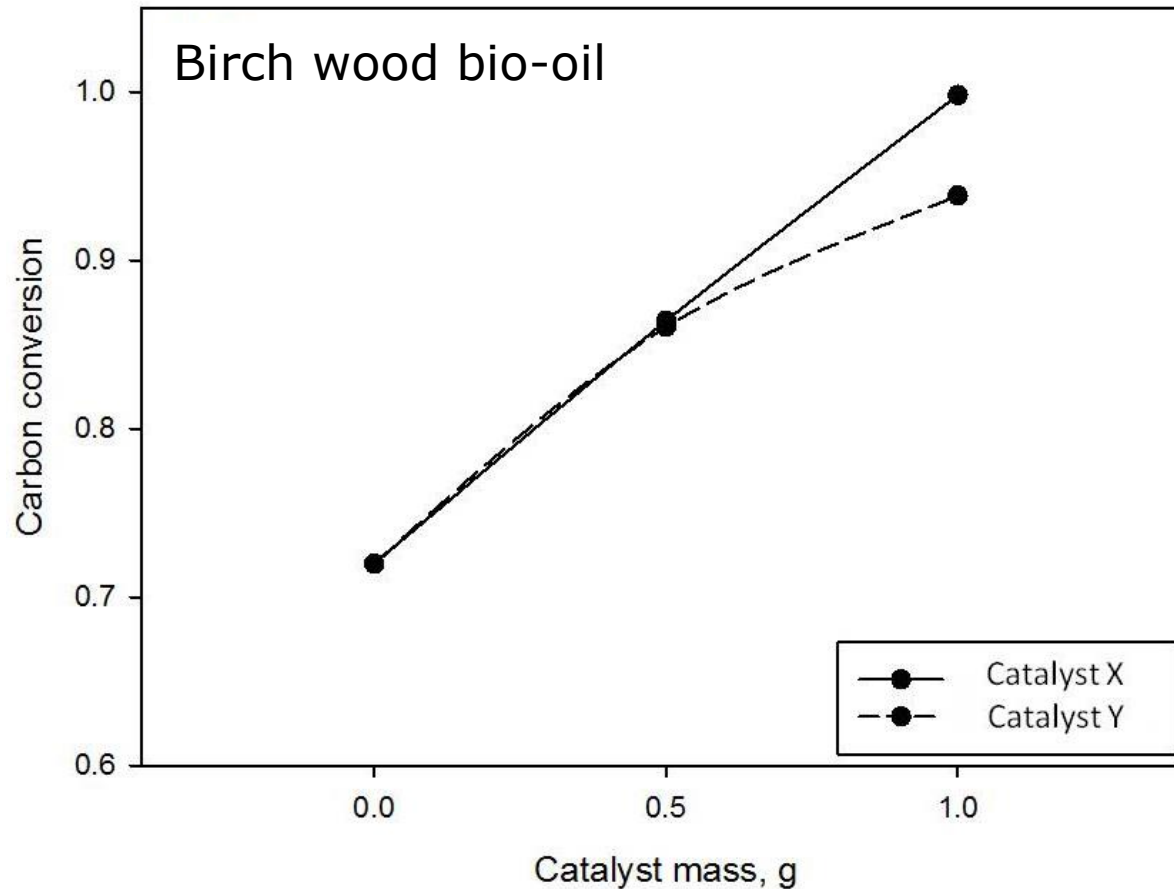
Gasification of bio-oil

30 s residence time



Gasification of bio-oil

800 °C , 30 s residence time



Conclusions

- The jiggle bed reactor:
 - effective batch micro reactor for catalyst testing
 - convenient
 - ideal for endothermic reactions
- Simulates typical fluidized bed reactors