The University of Western Ontario

Faculty of Engineering

Department of Chemical and Chemical engineering

Institute for Chemicals and Fuels from Alternative Resources (ICFAR), London, Ontario, Canada

Effects of Temperature and Residence Time on the Thermal Cracking of Bio-oil for Syngas Production

Mohammad Latifi, Lorenzo Ferrante,

Cedric Briens, Franco Berruti, Desmond Radlein

The Evolution of Energy

Introduction

- **Syngas:**
  - Mix of H_2 and CO
  - Can be used to synthesize chemicals and clean fuels
  - Now produced from fossil fuels such as natural gas

- **Producing syngas from biomass:**
  - Renewable resource
  - No net greenhouse gas emissions

Introduction

- **Direct conversion of biomass to syngas:**
  - Simple
  - Transportation of biomass is expensive

- **Two stage process:**
  1) Local plants convert biomass to bio-oil
  2) Central plant converts bio-oil to syngas
  - Transportation is much easier
  - Valuable chemicals extracted from bio-oil

Research Objectives

➢Convert to syngas a bio-oil produced by Dynamotive from sawdust

➢Thermal cracking of bio-oil in a hot fluidized bed of attrition-resistant silica sand

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Gasification Reactions

- **Thermal cracking**

$$C_nH_mO_K \leftrightarrow C_xH_yO_z + gases\left(H_2, H_2O, CO, CO_2, CH_4, \ldots\right) + coke$$

- **Steam reforming reaction**

$$C_nH_mO_k + (n-k)H_2O \leftrightarrow nCO + \left[\left(n + \frac{m}{2} - k\right)\right]H_2$$

- **Water gas shift reaction**

$$CO + H_2O \leftrightarrow CO_2 + H_2$$

- **Methane formation**

$$CO + 3H_2 \leftrightarrow CH_4 + H_2O$$

$$CO_2 + 4H_2 \leftrightarrow CH_4 + 2H_2O$$

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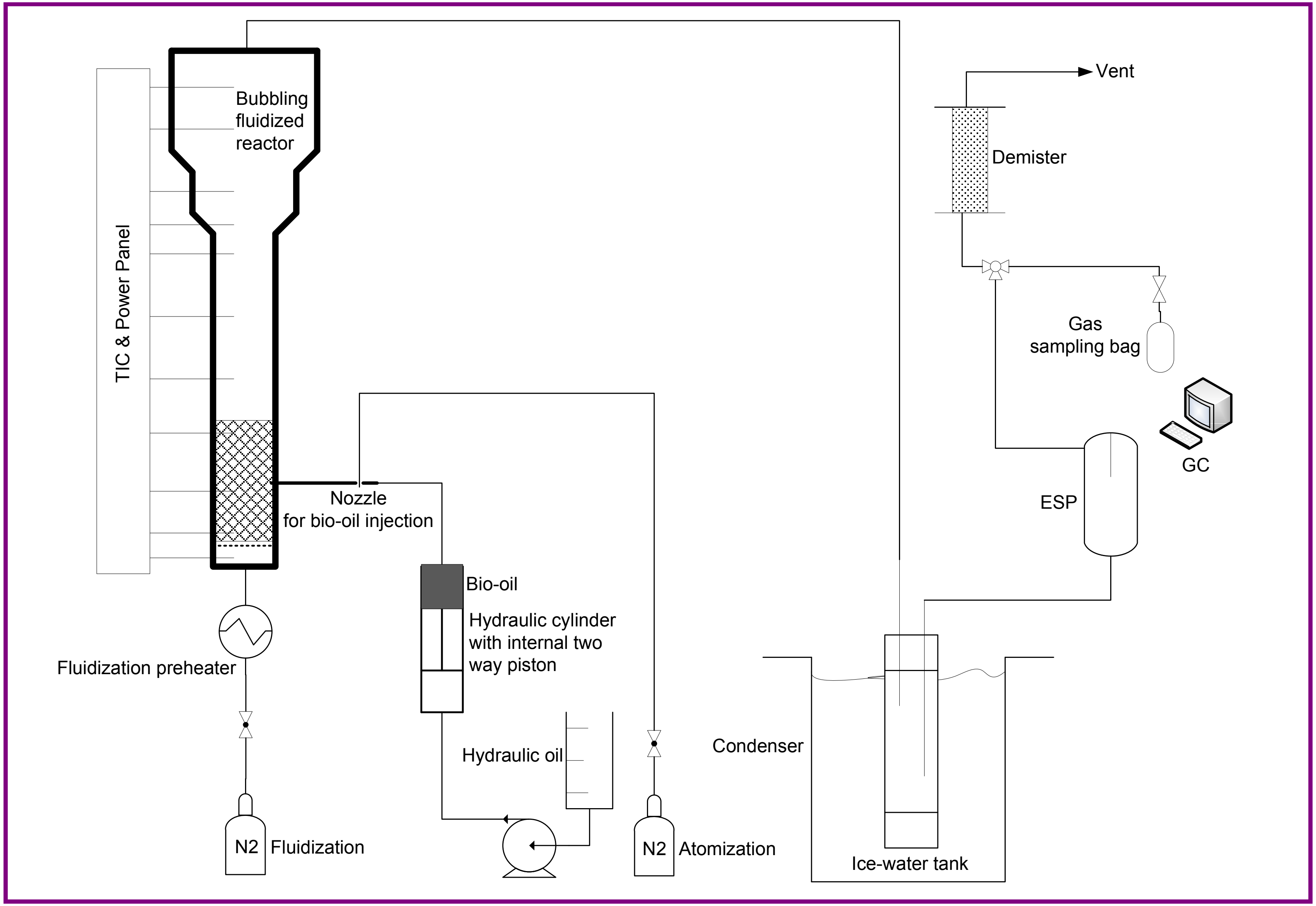
Pilot Plant for Bio-oil Gasification



Experimental conditions

- Atomization and fluidization gas: Nitrogen
- Source of steam: Water in bio-oil
- Temperature: 500 °C - 700 °C
- Pressure: atmospheric
- Two silica sands: d_{psm} = 80 µm and 200 µm
- Mass of bed: 1.5 kg and 3.0 kg
- Residence time varied by changing the reactor volume

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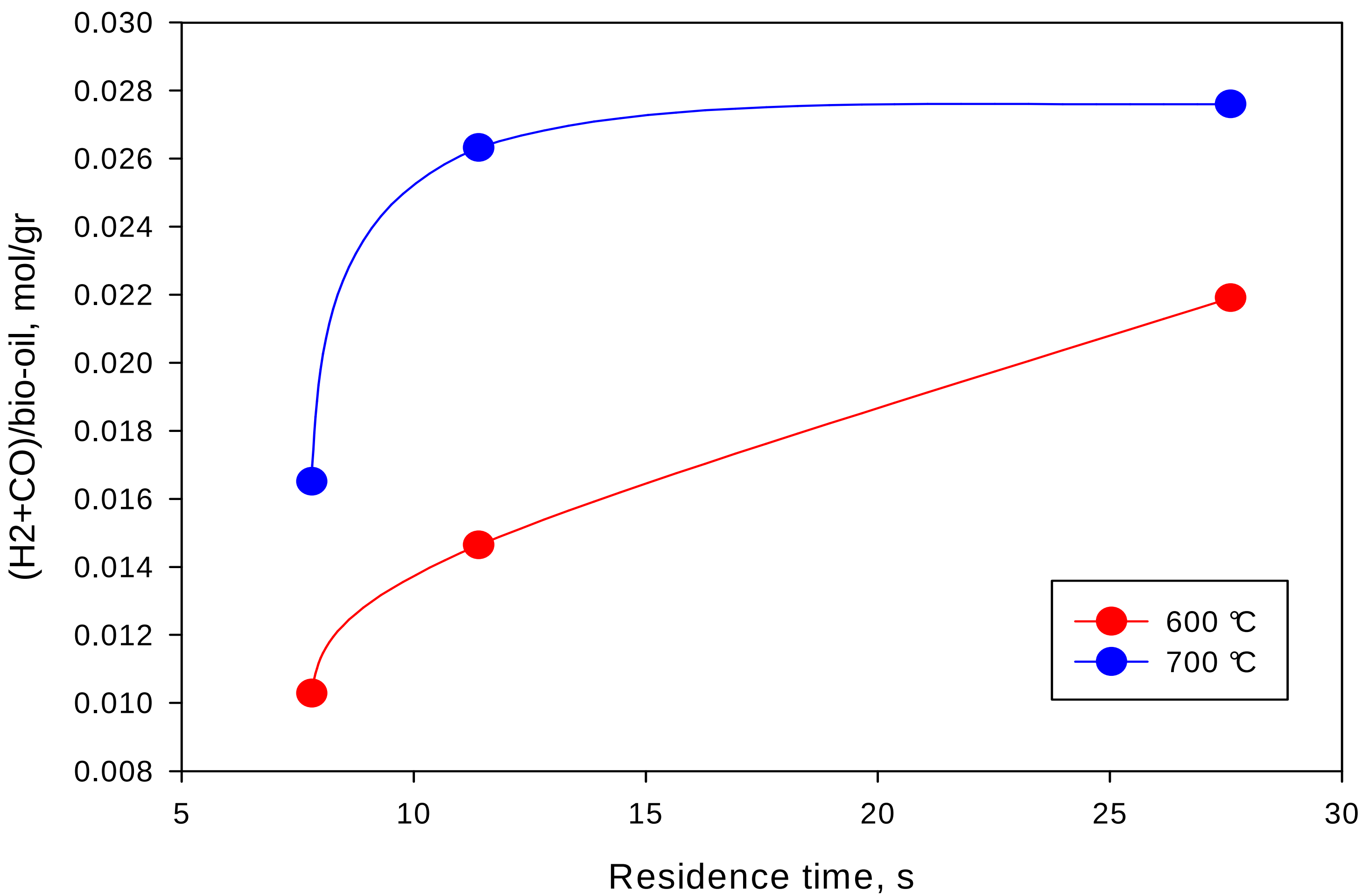
Experimental results- Effect of Residence Time



Yield of Syngas (H_2+CO) for 1.5 kg sand (d_{psm}=200 µm)

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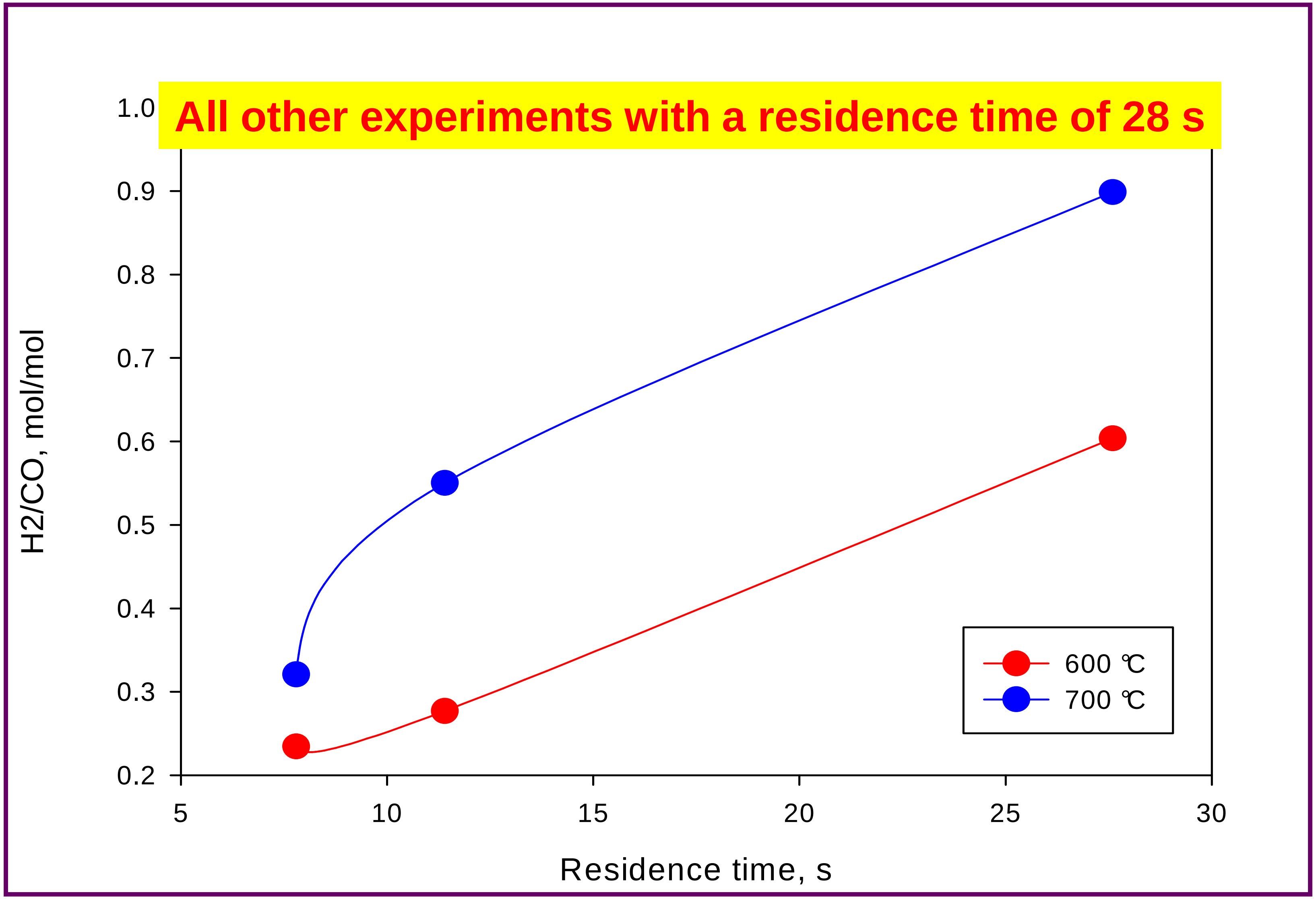
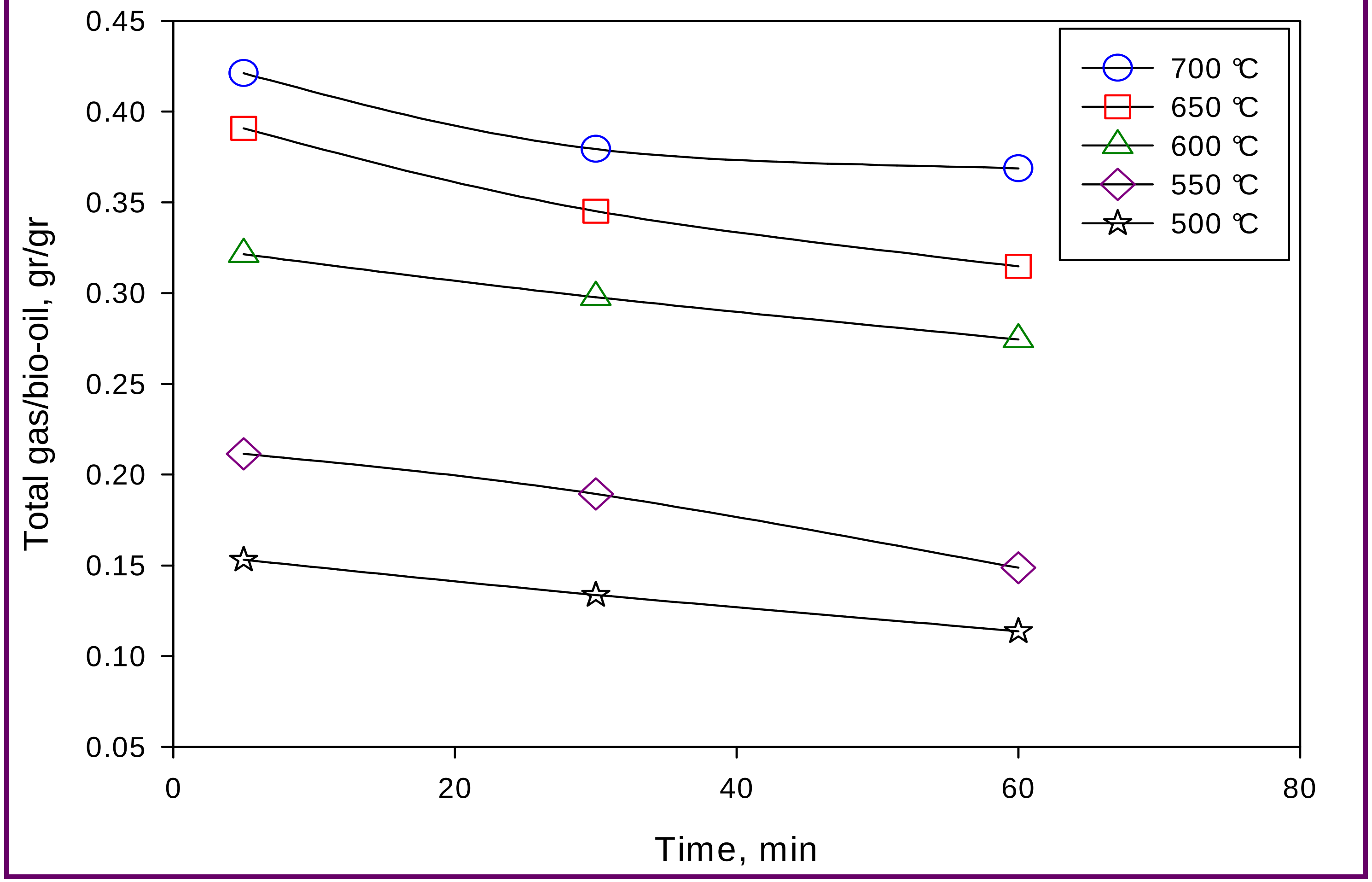
Experimental results- Effect of Residence Time



Yield of molar ratio of H_2/CO for 1.5 kg sand (d_{psm}=200 µm)

Experimental results- Effect of Temperature



Yield of Total gas (H_2, CO, CO_2 and CH_4) for 1.5 kg sand (d_{psm}= 200 µm)

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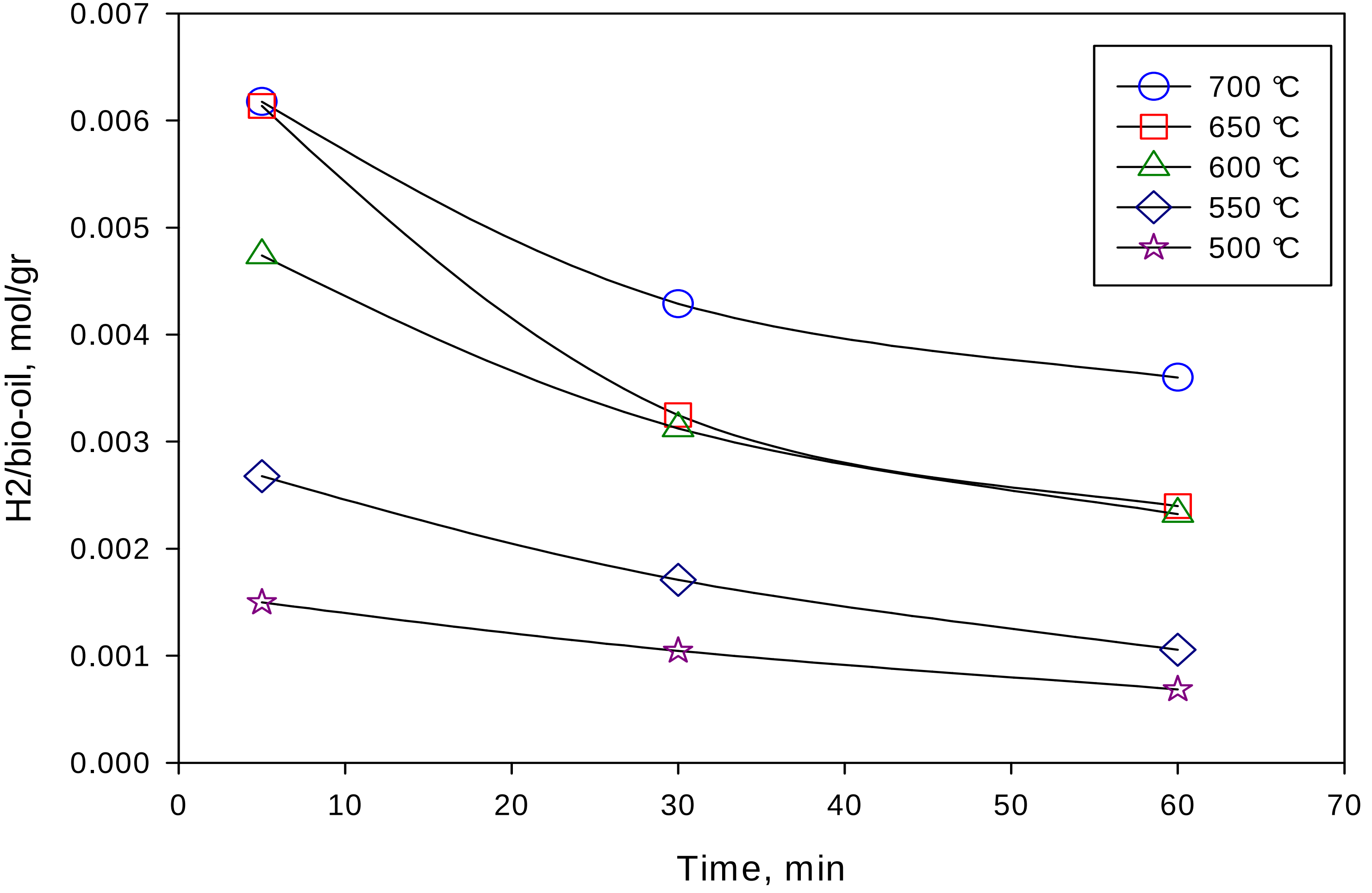
Experimental results- Effect of Temperature



Yield of H_2 for 1.5 kg sand (d_{psm}= 200 µm)

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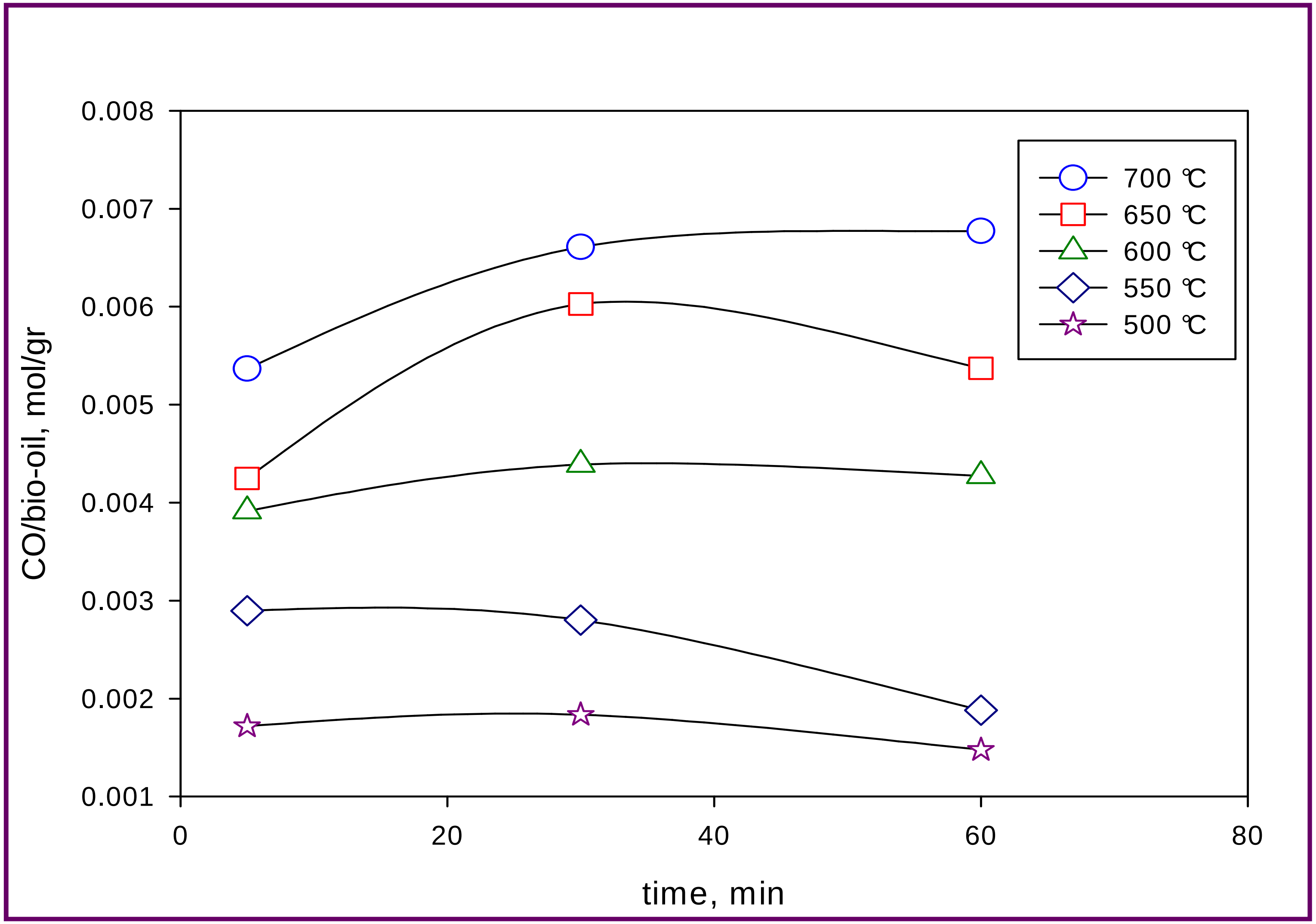
Experimental results- Effect of Temperature



Yield of CO for 1.5 kg sand (d_{psm}= 200 μm)

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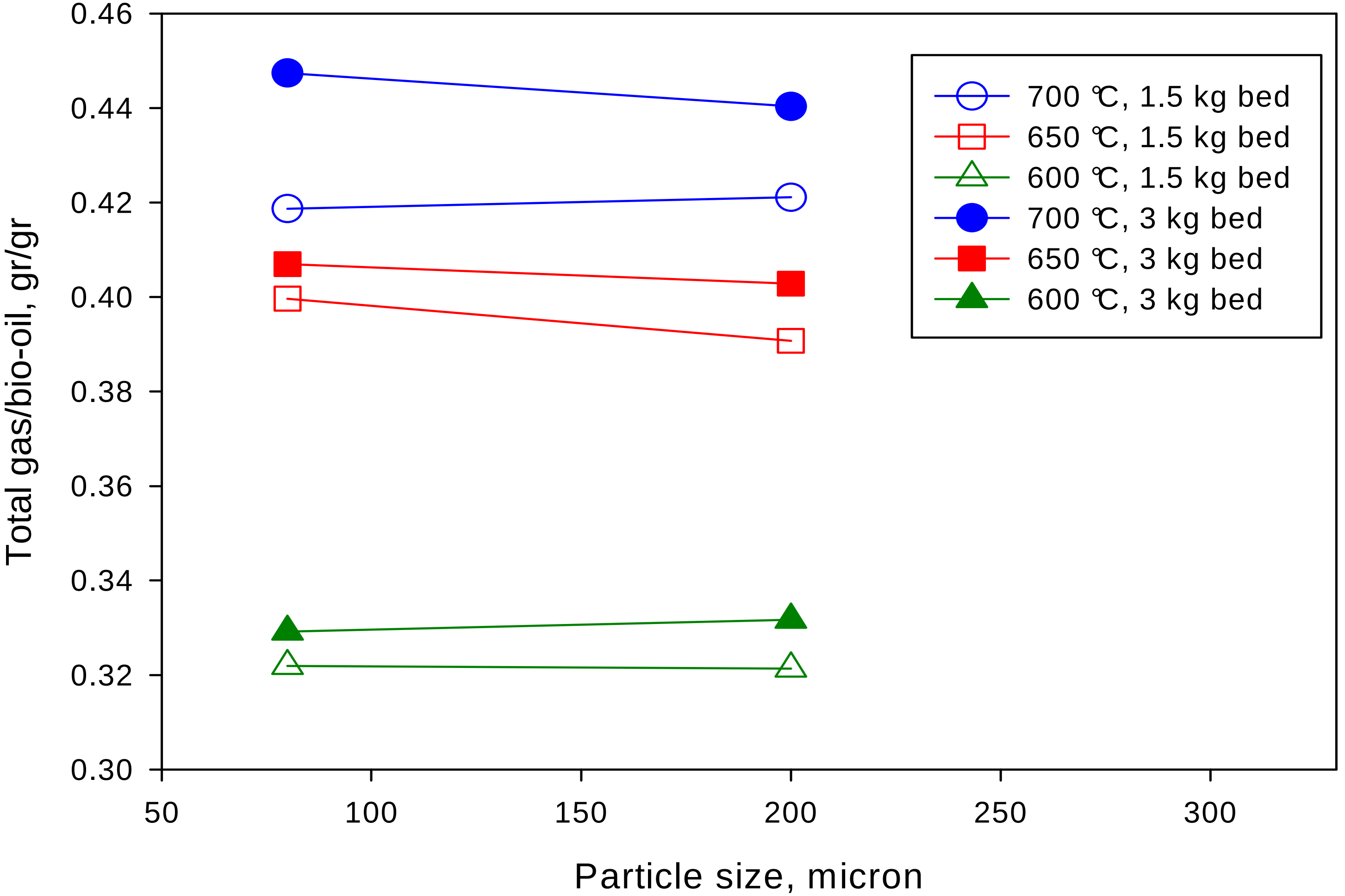
Experimental results- Effect of Particle Size



Yield of Total gas (H_2, CO, CO_2 and CH_4)
for 1.5 kg and 3.0 kg sand beds (d_{psm}=80 µm and 200 µm)

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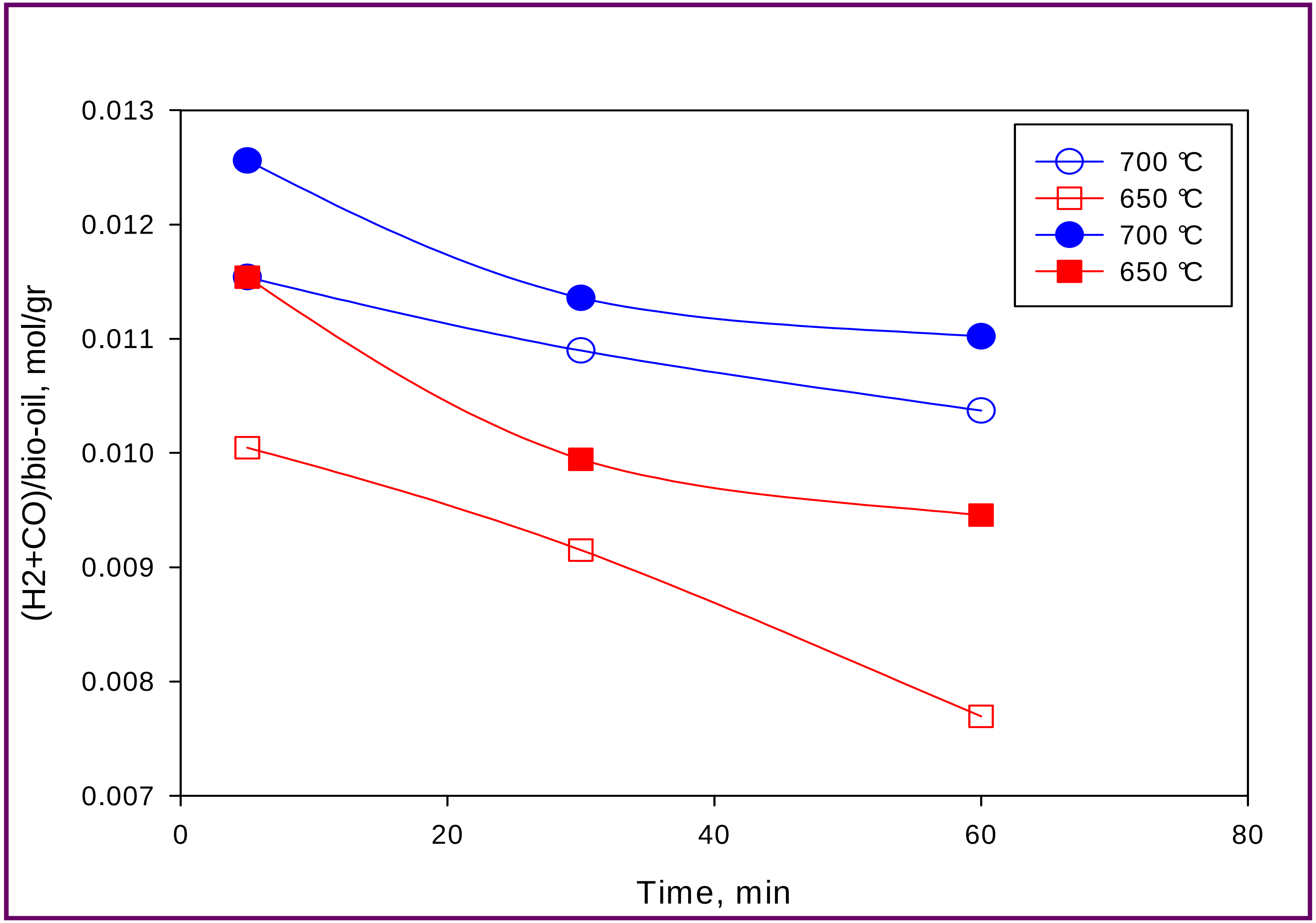
Experimental results - Syngas (H_2+CO) Production



Yield of syngas for 1.5 kg (open symbols) and 3.0 kg (closed symbols) sand (d_{psm}= 200 μm)

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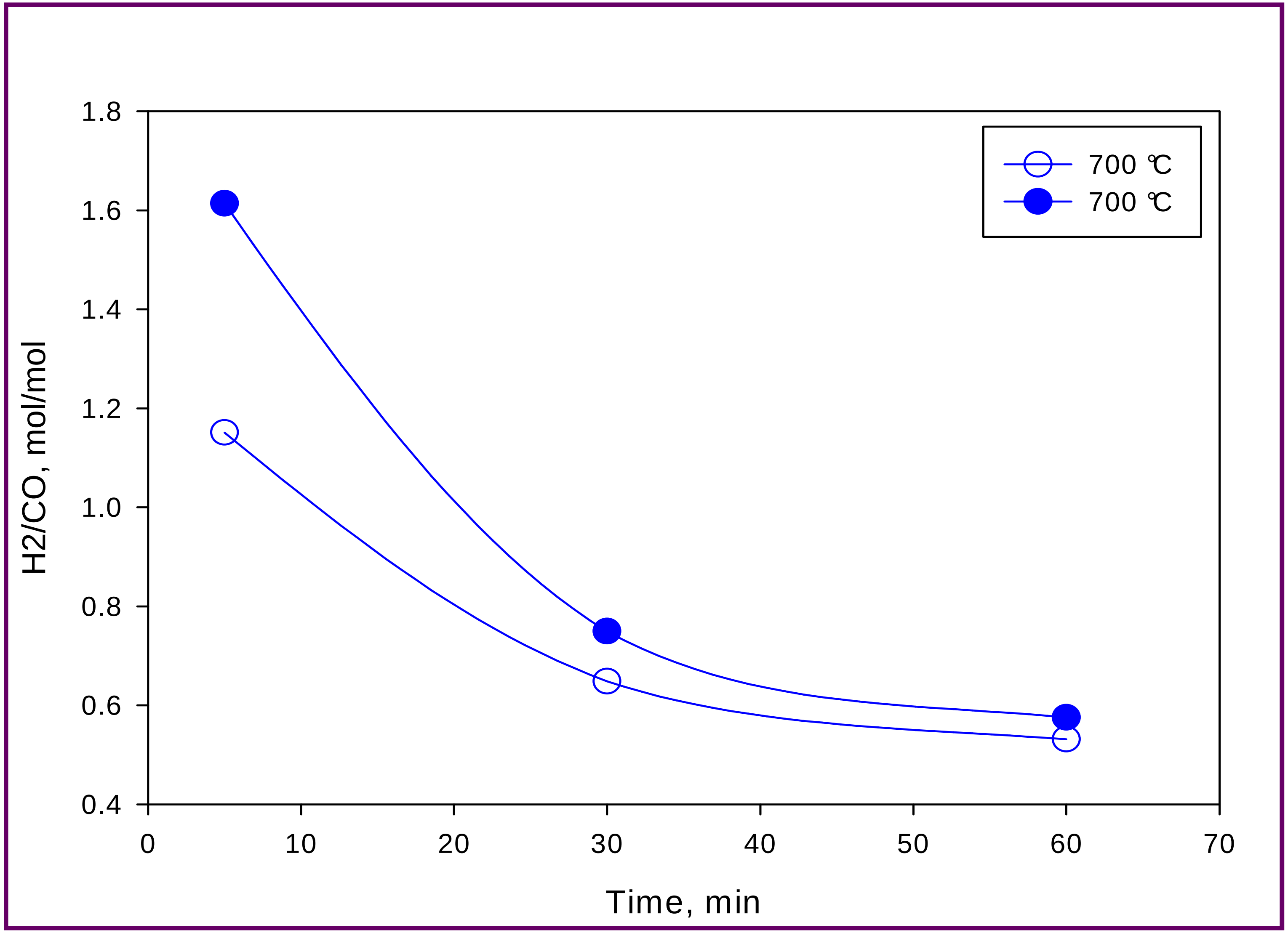
Experimental results- H_2/CO



H_2/CO molar ratio

for 1.5 kg (open symbols) and 3.0 kg (closed) sand (d_{psm}=200µm)

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Conclusions

- Similar results obtained with two particle sizes:
  - ⟹ sand has no catalytic effect
  - ⟹ no significant heat or mass transfer limitations
- Coke formation:
  - ⟹ reduction with time of the gasification yield
- Longer residence times and higher temperatures
  - ⟹ better syngas yield and quality