Tire pyrolysis char as tar cracking catalyst for gasification of RDF in dual pyrolysis-gasification reactor

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Presentation summary

- Introduction
- Preparation and properties of studied tire pyrolysis char catalyst
- Goals
- Tar cracking activity test
- RDF gasification experiments
- Conclusion

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Pyrolysis

- Thermochemical process, no oxidizer
- Products
  - Solid – char – solid fuel, catalyst support, adsorbent
  - Liquid – tar, bio-oil – liquid fuel
  - Gaseous – pyrolysis gas – gaseous fuel, hydrogen separation

Gasification

- Thermochemical process based on partial oxidation of the feed
- Gasifying agents: air, oxygen, steam, CO_2
- Main product – synthesis gas
  - Heat and electricity production
  - Hydrogen separation
  - Synthesis of organic compounds (methanol)
- Side products
  - Ash – incombustible fraction of them feed, can contain unreacted carbon
  - Tar – undesirable product, impurity in synthesis gas

Tar

- Complex mixture of condensable hydrocarbons and their derivates
- Causes fouling, corrosion and catalyst poisoning in downstream processing units
- Tar removal
  - Physical means: condensation, absorption, filtration – expensive
  - Chemical means: thermal decomposition, catalytic decomposition

RDF

- Refuse-derived fuel
- Made from MSW by removing incombustibles and bio-degradable waste

Fraction	Paper	Foil	Plastics	Textile	RDF
RDF composition [wt. %]	63.17	15.78	19.1	1.94	100
Ultimate analysis [wt. % dry basis]					
C	35.0	76.5	66.4	50.3	47.8
H	5.0	12.8	9.16	6.4	7.05
N	0.05	0.1	0.94	3.3	0.29
S	0.08	0.12	0.35	0.33	0.14
O	39.4	1.78	9.42	31.3	27.6
Cl	0.07	0.09	3.53	1.8	0.08
Ash [wt. % dry basis]	20.4	8.69	10.2	6.6	17.0

Tyre pyrolysis char

- Suitable material for catalyst production (catalyst or catalyst support)
  - High specific surface area (requires activation)
  - High metal content (mostly Zn)
  - Combustible (advantage and disadvantage at the same time)
  - Can be impregnated with Ni, Fe and other catalytically active metals

Catalyst preparation procedure

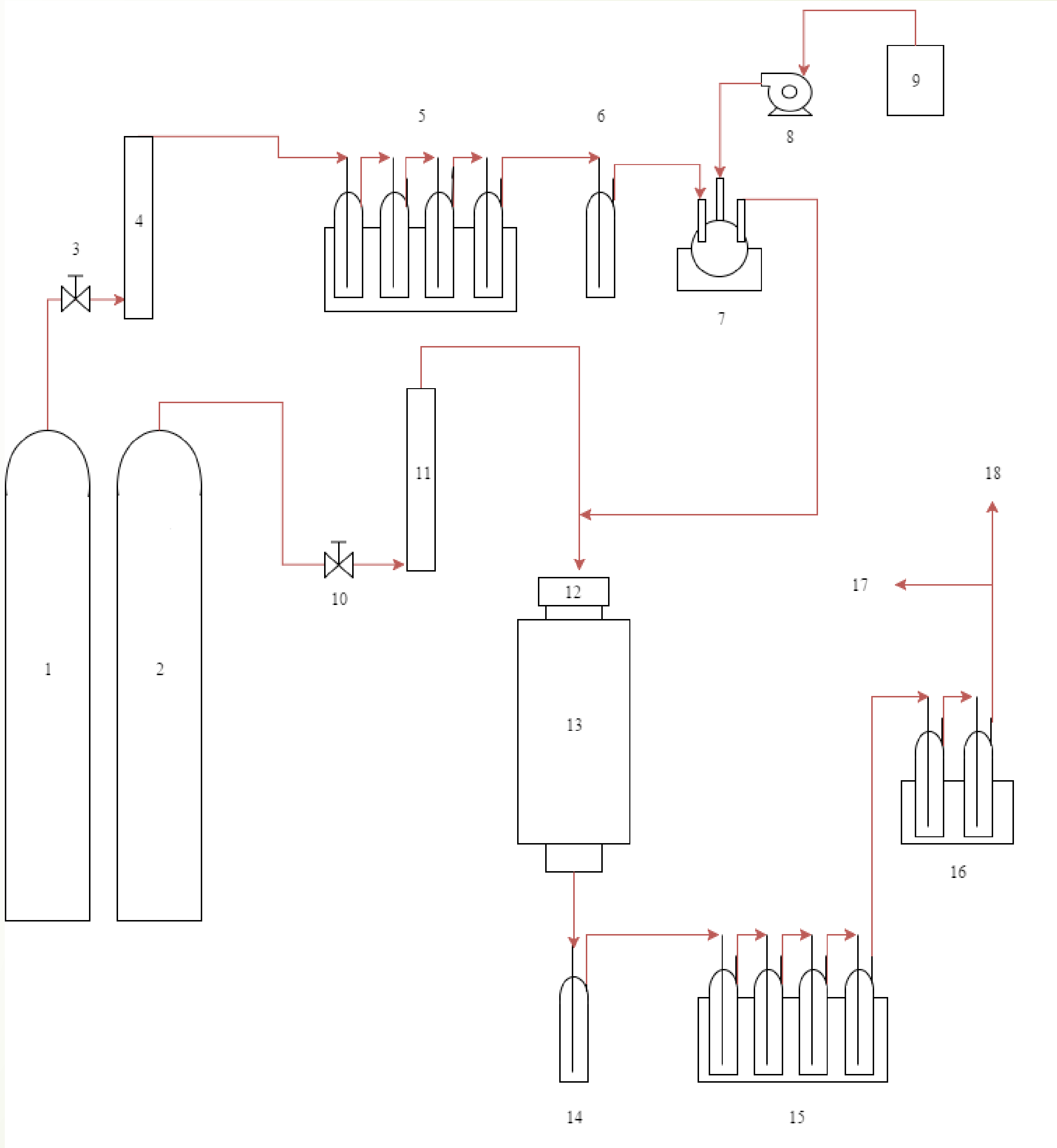
1. Pelletizing of raw char into pellets with a diameter of 5 mm and length of 5 mm
2. Drying in oven at 105 °C for 6 h
3. Carbonization in CO_2 atmosphere at 800 °C for 4 h
4. Impregnation with $Ni(NO_3)_2$ solution – 2 wt. % Ni loading
5. Drying in oven at 105 °C for 6 hours
6. Heat treatment in N_2 atmosphere at 800 °C for 2 h

	S_{BET} [m_2/g]	v_{pore} [cm^3/g]	d_{pore} [nm]
Raw char	45.0	0.394	24.6
Carbonized char	72.4	0.328	16.9
Impregnated char	66.9	0.315	18.4
Finalized catalyst	88.4	0.328	16.3

Goals

1. To test the activity of the catalyst on model tar compound – toluene
2. To test the activity of the catalyst on real tar from RDF gasification
3. To evaluate the impact of air flow and gasifier temperature on total tar yield and hydrogen content in the product gas

Experiments with toluene - apparatus



Experiments with toluene – conditions

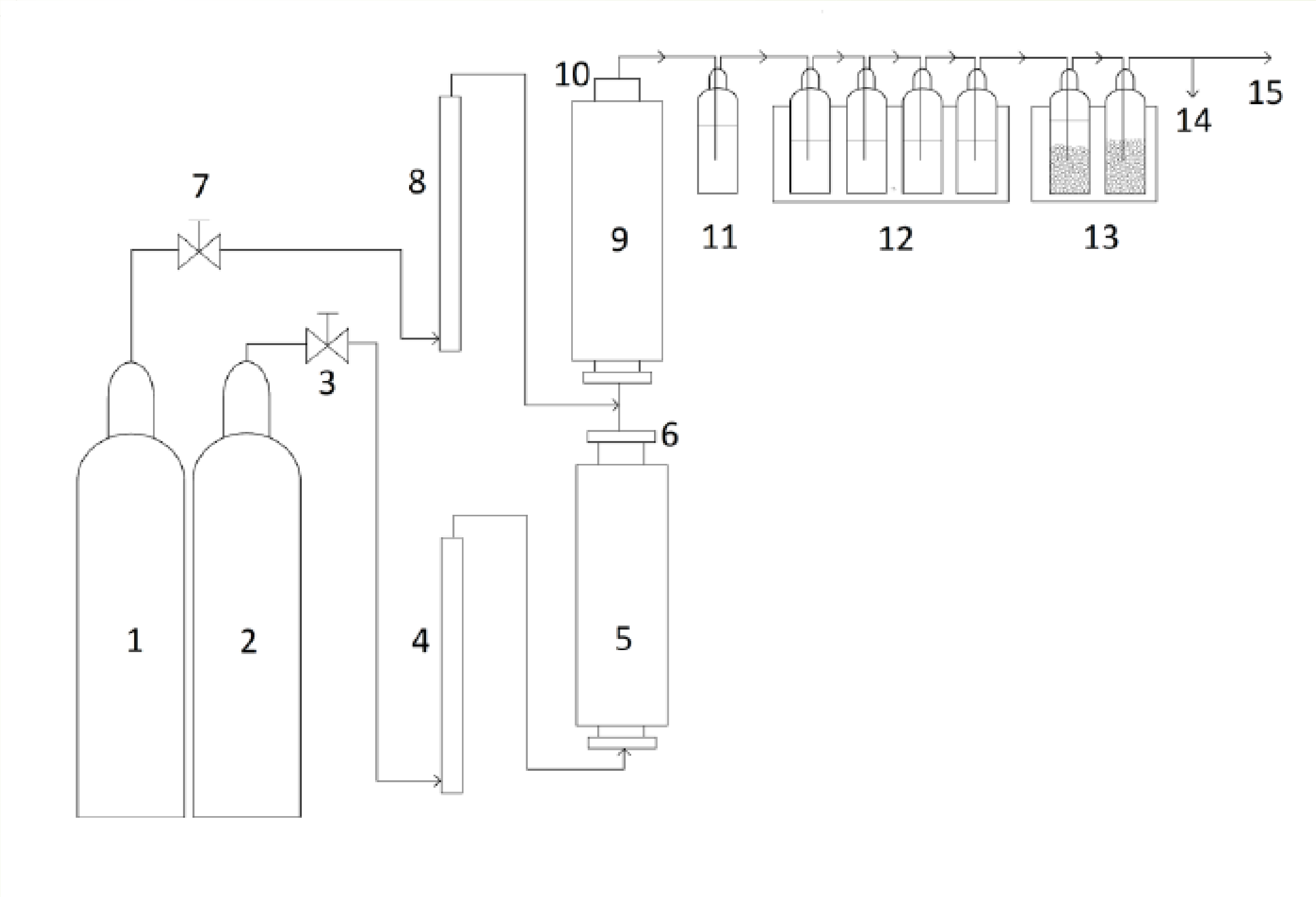
- Reactor temperature – 800 °C
- N_2 flow – 22.5 L/h
- CO_2 flow – 2.5 L/h
- Toluene feed – 3 mL/h – 2 vol. % in feed gas
- Catalyst mass – no catalyst or 10 g
- Experiment duration – 2 h

Experiments with toluene - results

	No catalyst	10 g carbonized catalyst	10 g finalized catalyst
Toluene conversion [wt. %]	72.7	93.5	94.0
Liquid yield [wt. %]	70.7	50.8	42.1
Coke yield [wt. %]	-	27.2	14.9
Gas yield [wt. %]	29.3	22.0	43.0

	No catalyst	10 g carbonized catalyst	10 g finalized catalyst
Methane [vol. %]	0.6	0.4	0.5
Other hydrocarbons [vol. %]	0.05	0.01	0.01
CO_2 [vol. %]	8.6	10.6	6.9
H_2 [vol. %]	1.3	3.5	5.4
CO [vol. %]	0.8	3.9	7.1
N_2 [vol. %]	88.7	81.6	80.1

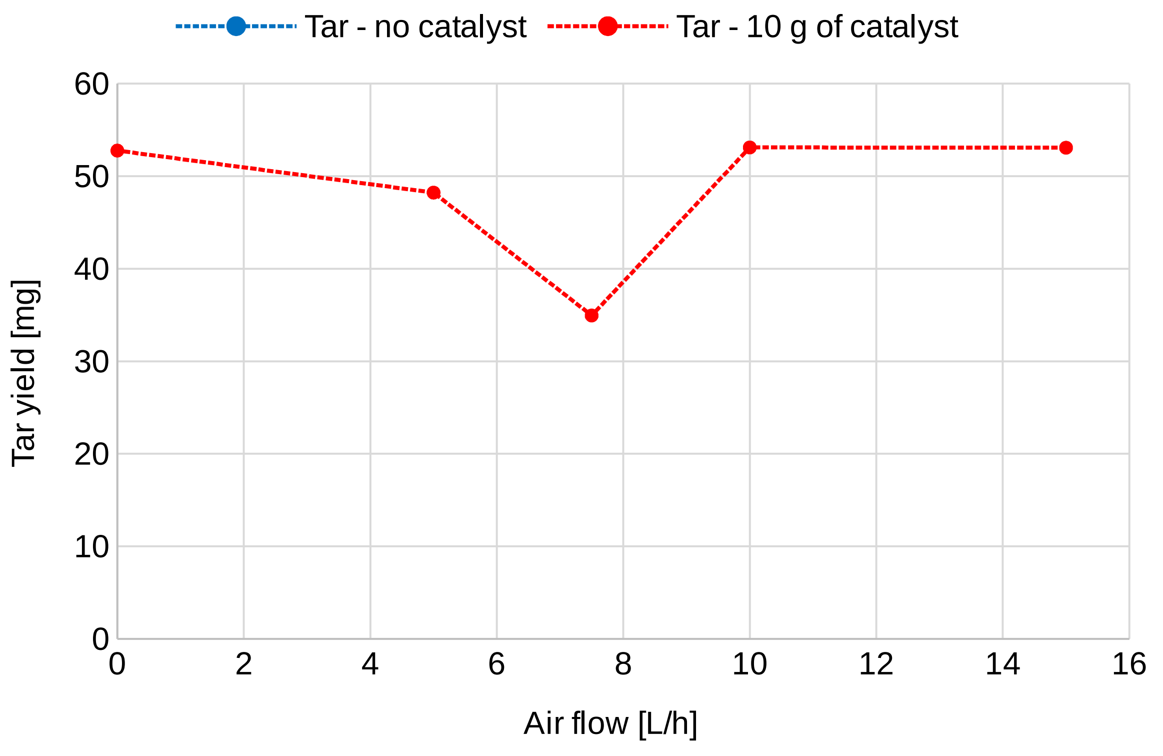
Dual pyrolysis-gasification reactor experiments - apparatus

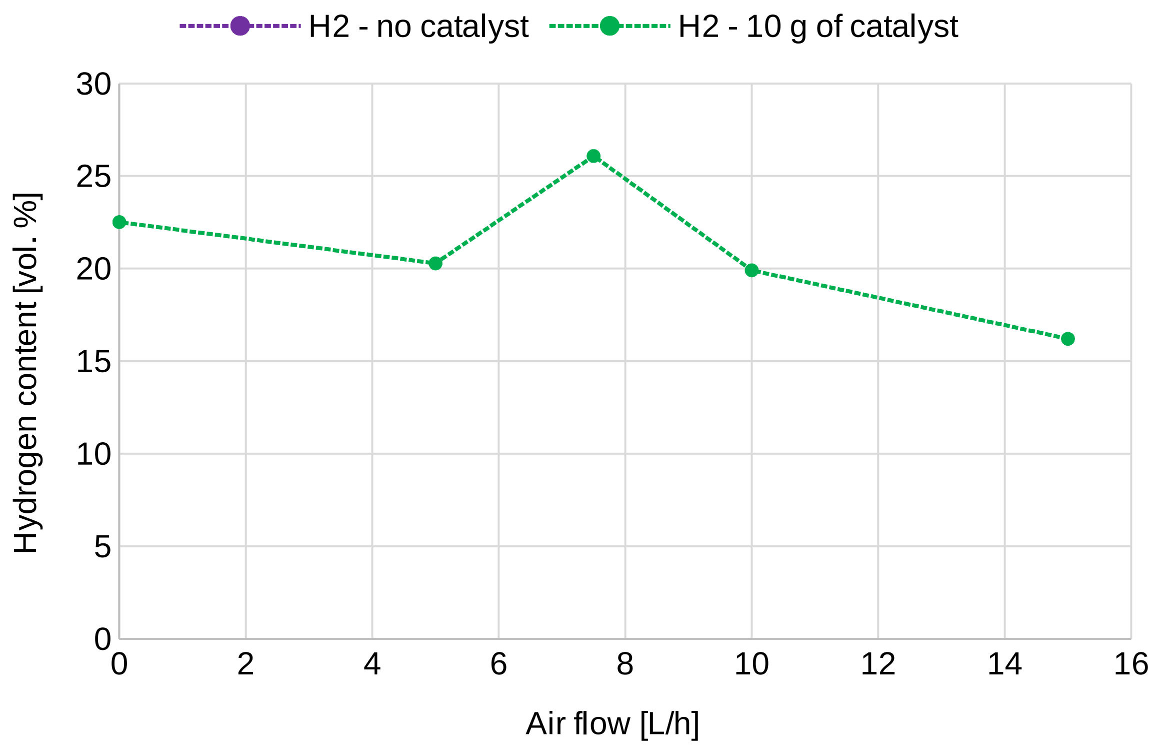


Dual pyrolysis-gasification reactor experiments - conditions

- Pyrolysis reactor – 550 °C
- Gasification reactor – 700-900 °C
- N_2 flow – 15 L/h
- Air flow – 0-15 L/h
- Catalyst mass – none or 10 g of finalized catalyst
- RDF – 10 g
- Experiment duration – 1 h

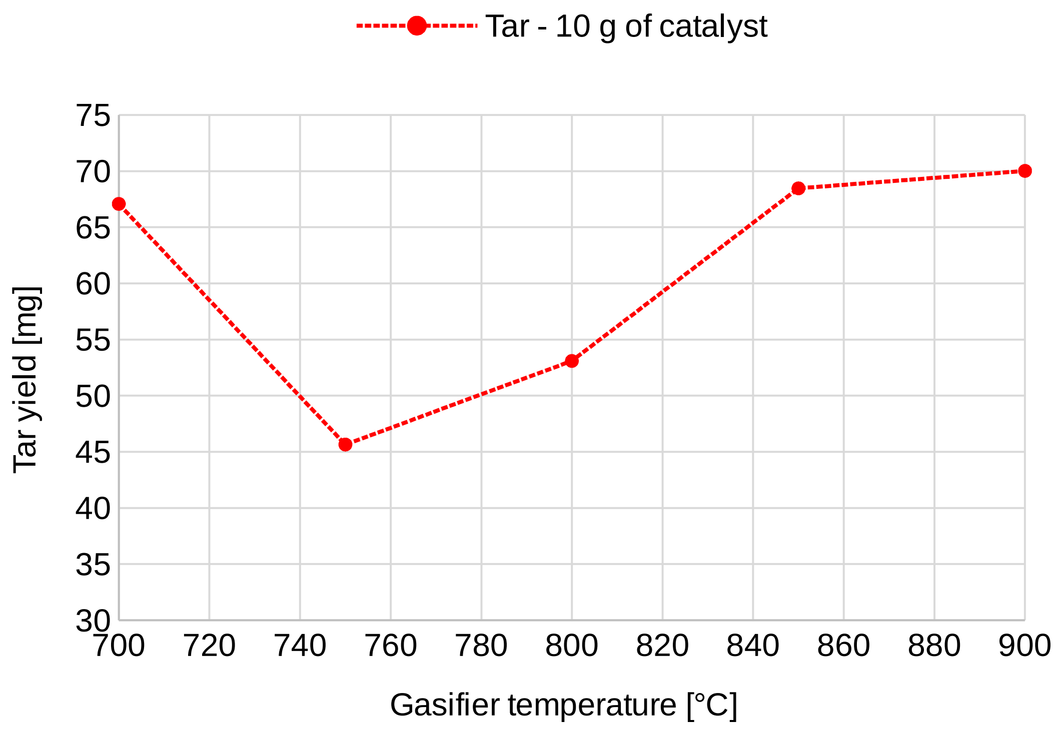
Dual pyrolysis-gasification reactor experiments - results

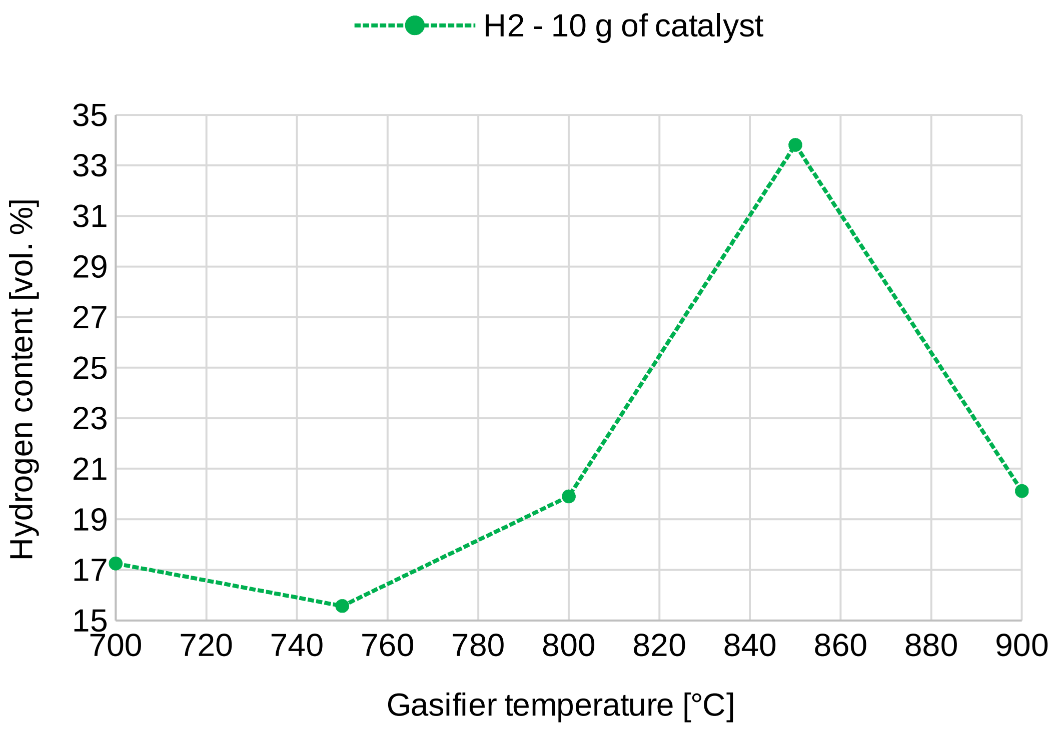




Gasifier temperature – 800 °C

Dual pyrolysis-gasification reactor experiments - results





Air flow - 10 L/h

Conclusion

- Tire pyrolysis char is a suitable catalyst and catalyst support which promotes tar decomposition
- Nickel loading increases catalyst activity and decreases coke formation of the surface of the catalyst
- In experiments with RDF gasification, catalyst presence decreased total tar yield by up to 69 %
- Lowest tar yield was achieved at gasifier temperature of 750 °C and air flow of 7.5 L/h
- The highest H_2 production was achieved at 850 °C
- Gasifier operation temperature above activation temperature of the catalyst leads to removal of volatiles from the catalyst. Thus, tar is produced from the catalyst itself.