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Synergy of $S\text{-}CO_2$ Power Cycle and CCS Systems

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Introduction

- S-CO_2 cycles are recently very perspective and are researched all around the world
- Many application: nuclear, geothermal, solar, waste heat recovery systems
- S-CO_2 cycle has several issues
  - One of issues is pinch point
    - The pinch point is caused by the variations of heat capacity of CO_2 and occurs when the heat capacity of the hot and cold streams (each at a different pressure level) intersect.
  - The pinch point can be removed in several ways
    - One of them is addition of small amount of other substance into the pure CO_2

S-CO_2 cycle

- It is difficult to use a 100 % pure CO_2 in the S-CO_2 cycles
- One may expect about 1% of mole fraction of other substances in it
- Impurities are present in working medium
  - the resulting mixture of CO_2 may lead to the disappearance of the pinch point in the regenerative heat exchanger
- the impurities have a negative effect on other components
  - Compressor
  - cooler

CCS technology

- The CCS systems are very perspective for the reduction of CO_2 from the flue gas of the fossil fired power plants
- The captured CO_2 is a multiple-component mixture
- Effect of the mixture on the CCS system components is same as in the S-CO_2 cycle
  - This effect is especially high for the transport and the storage part of the CCS system
- In the CCS systems CO_2 is used in the supercritical state or close to the critical pressure
  - The reason is the better transport properties of CO_2 mainly the high density

CCS technology – Transport of CO_2

- The CCS technologies are used to capture CO_2 from flue gas of the fossil fired power stations, transport it and store it on a selected place.
- The transport can be done in liquid or gaseous phase
  - The transport of the gaseous phase is done through pipeline.
  - The transport of liquid phase is done through tanks for CO_2, by ship, train or truck
- The transport parameters:
  - Pipelines operates from 8.6 to 20 MPa with the temperature from 4 °C to 38° C
  - The transport pressure for liquid CO_2 is in the range from 0.52 MPa up to 7.3 MPa and temperature is about -50 °C

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Mixtures from CCS

- The mixtures of CO_2 from capture differ based on the separation method of CO_2 and the type of industry
- The basic components of mixture from capture are N_2, O_2, CO, Ar, H_2S, H_2 and H_2O

Component	H_2O	H_2S	CO	CH_4	N_2	O_2	Ar	H_2	CO_2
	Ppm	Ppm	Ppm	vol.%*	vol.%*	vol.%*	vol.%*	vol.%*	%
Concentration	500	200	2000	< 4	< 4	-	< 4	< 4	>95.5%
*all non-condensable gases									

H_2O	H_2S	CO	CH_4	N_2	O_2	Ar	H_2	CO_2	NO_x	SO_2	SO_3
ppmv	ppmv	ppmv	ppmv	%	%	%	ppmv	%	ppmv	ppmv	ppmv
Pre-combustion											
0.1 – 600	0.2 – 34000	0 – 2000	0 – 112	0.0195 – 1	0	0.0001 – 0.15	20 – 30000	95 – 99	400	25	-
Post-combustion											
100 – 640	-	1.2 – 10	-	0.045 – 0.29	0.0035 – 0.015	0.0011 – 0.021	-	99.6 – 99.8	20 – 38.8	0 – 67.1	-
Oxy-fuel combustion											
0 – 100	-	50	-	0.01 – 0.2	0.01 – 0.4	0.01 – 0.1	-	99.3 – 99.4	33 – 100	37 – 50	20

Effect of mixtures

- The CCS systems and the S-CO_2 cycles have the same issues
- The mixtures will probably have a negative effect on the cycle efficiency and compressor station
- For CCS: the fraction of CO_2 is more than 95 % and the concentration of impurities is less than 5 %
- The effect of mixtures on a heat exchanger is quite small for 1 % of mole fraction of other substance
- The gaseous mixtures have an effect on the design, the heat transfer and the pressure drops

Mass flow of side with CO_2	2.5	[kg/s]
Mass flow of side with H_2O	2	[kg/s]
Inlet temperature of side with CO_2	60	[°C]
Outlet temperature of side with CO_2	32	[°C]
Inlet temperature of side with H_2O	25	[°C]
Pressure of side with CO_2	12	[MPa]
Pressure of side with H_2O	1.5	[MPa]

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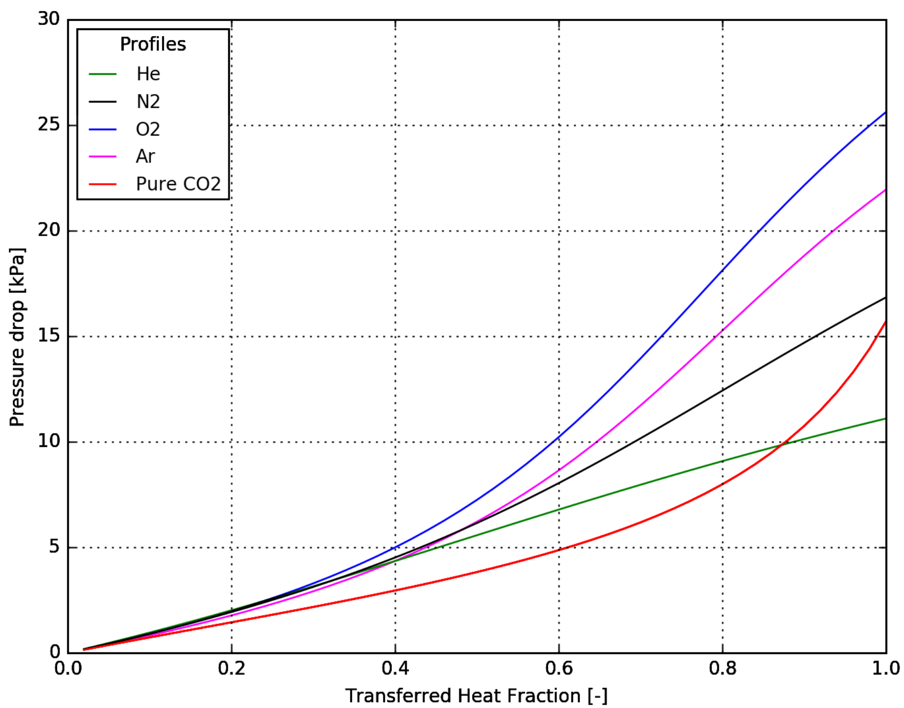
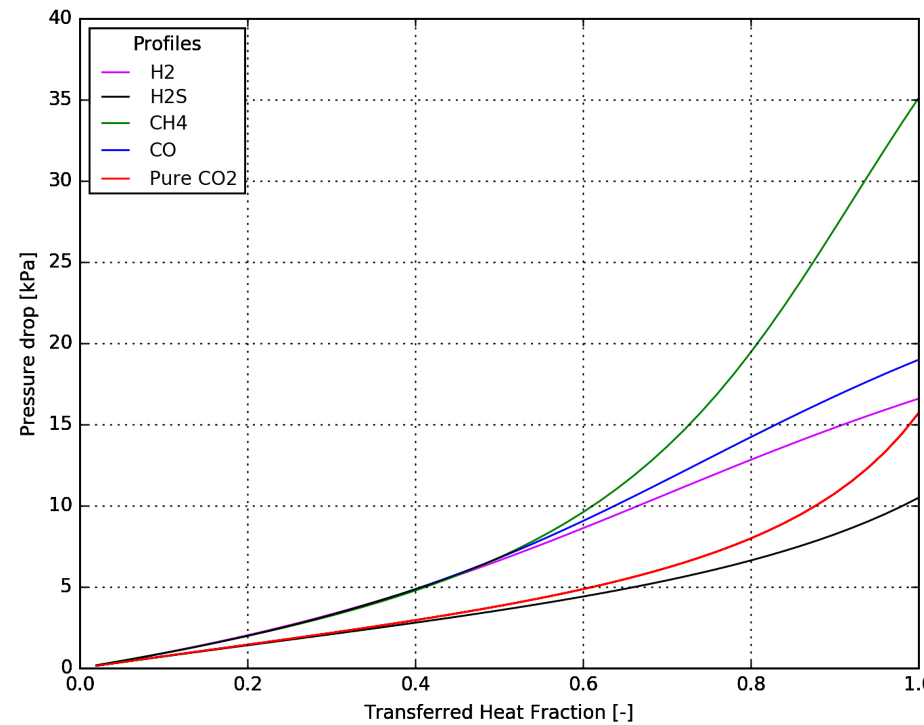
Effect of mixtures





Mole fraction	0.01	0.05	[-]
Pure CO_2	2.33		[m]
CO_2 with He	2.60	4.91	
CO_2 with Ar	2.44	3.17	
CO_2 with CO	2.52	3.65	
CO_2 with O_2	2.49	3.49	
CO_2 with N_2	2.51	3.45	

- Shell and tube heat exchanger in the counter current flow arrangement
- The outer casing consists of a high pressure casing with the dimensions of 120 x 10 mm. Inside the high pressure tube there is a set of 37 tubes, each with the dimensions of 10 x 1.5 mm

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Effect of mixtures

- Binary mixtures with N_2, He, O_2, and Ar:
  - impurities in the S-CO_2 cycle
  - positive effect on the shift of the pinch point
  - negative effect on the heat transfer and the total length of cooler

- Binary mixtures with H_2, H_2S, CH_4 and CO:
  - the typical components of mixture of CO_2 from the capture technology

- Multicomponent mixtures will likely have a similar effect as the binary mixtures

- Research of multicomponent mixture is necessary for both CCS systems and the S-CO_2 cycles and will be done in the future.

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Results

- The CCS systems and the S-CO_2 cycles suffer from the same issues when impurities are mixed with the pure CO_2.
- These impurities are always present in the captured CO_2 and to some extent are present in the S-CO_2 cycles as well.
- The CCS technology - transport: consists of similar components (heat exchangers and compressors) as the S-CO_2 cycles.
- The design of compressors for the CCS system transport part is slightly different than that for the S-CO_2 cycles, the effect of mixtures on compression is similar.
- Shift of pinch point is possible, but with a negative effect on the compression near the critical point

Conclusion

- Research of the effect of mixtures on the heat exchangers and compressors is one type of the S-CO_2 cycle and the CCS system synergy.
- Other type of synergy is the use of CO_2 as a working medium in the S-CO_2 cycles in the compressor stations or other part of the CCS system as a cycle for waste heat recovery.
  - Implementation of the S-CO_2 cycles to the CCS systems is very interesting and has a good perspective for the future systems.
  - CO_2 from capture can be used as a working medium, thus reducing issues with CO_2 storage and transport.
- Synergy of research for both technologies, the CCS system and the S-CO_2 cycles, will bring new interesting findings that will help development of both the CSS system and the S-CO_2 cycles.

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Thank you for attention

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