Gasification of Jordanian oil shale by using nitrogen non-thermal plasma
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Abstract
Research conducted at Institute of Fluid Mechanics (LSTM) in Erlangen, Germany, investigated the potential of oil shale gasification at low temperatures using nitrogen atmospheric plasma. Oil shale samples containing average moisture of 2.5%, volatile 18%, fixed carbon 20% and ash 59.5%, were exposed to ion bombardment. This process converts fixed carbon and hydrogen atoms into the gas phase. The benefit of this method is that gasification of the oil shale is performed without water and at low power of 300 W. The basic requirements for oil shale gasification include generating plasma at low temperatures (200-550°C), using a pulsating high voltage (f=20 kHz). Additional rotation of the samples during the process increases the surface exposed to the plasma. Experimental study was conducted to investigate the influence of main process parameters such as nitrogen gas mass flow rate (in the range of 7-10 l/min), mean diameter (d) of oil shale particles (in the range of 4.5-10 mm) and distance of the plasma nozzle from the oil shale (5-15 mm). It has been found that the maximum gasification percentage is 23.0% of the original oil shale weight, in the case of using 10 l/min nitrogen flow rate.

Introduction
The aim of this study, conducted at Institute of Fluid Mechanics (LSTM) in Erlangen, Germany, was to investigate gasification of the oil shale samples using plasma jet. Tested samples originate from El-Lajjun, located in west-central part of Jordan. A non-thermal nitrogen plasma jet was used to convert the organic matter (kerogen) within the oil shale, into a gas. Electron temperature in the non thermal plasma is several times higher than the temperature of heavy particles, which induces plasma chemistry.

Experimental setup
Atmospheric plasma jet, used in the current research, was generated by a low power plasma beam system. The high voltage AC generator used is equipped with a voltage rectifier that converts the line voltage 230 V AC 50/60 Hz into a pulsed high voltage (up to 10 kV at frequency f=20 kHz). The plasma gas must be pressurized between 5-10 bar. A mass flow controller was used to regulate the mass flow rate of nitrogen in the range of 7-10 l/min. A high torque motor was used to rotate the samples at certain rotation speed in order to expose higher sample area to the plasma jet.

Results
Processes induced in samples during exposure to the plasma jet cause visible changes in sample color. Dark color, which is coming from oil content, disappears during treatment.

Conclusions
✓ Atmospheric nitrogen non-thermal (cold) plasma jet was successfully used for selective gasification of oil shale samples.
✓ Good levels of evaporation were reached using low energy (300 W) plasma generator.
✓ Oil shale gasification using cold plasma was found to be fast, efficient and does not requires water or steam.
✓ Influences of most important system and process parameters, on the quality of gasification process were determined:
  • Gasification increases with increase of the plasma temperature and (to the certain extension) treatment time.
  • Increase of the plasma gas mass flow rate (in the test range of 7-10 l/min) does not affect oil shale gasification significantly.
  • Best gasification results were achieved with lower mean diameter of oil shale particles.