

AN APPLICATION OF A HIGH-TEMPERATURE AND HIGH-PRESSURE REACTOR

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Preliminary Note - Prethodno priopćenje

A prototype of a high-temperature and high-pressure reactor on oxygen-hydrogen flame used for gravity separation of multiple mineral components mixture is already in its second year of development. This equipment, applied in a high temperature range, is able to treat the waste of some industrial technologies, which are of multiple component nature.

Key words: *oxygen-hydrogen reactor, high-pressure, high-temperature, power unit, high-pressure chamber, oxygen-hydrogen generator*

Primjena visoko-temperaturnog i visoko-tlačnog reaktora. Već se dvije godine razvija prototip visokotemperaturnog i visokotlačnog reaktora koji koristi plamen kisika i vodika, a primjenjuje se za gravitacijsku separaciju višekomponentnih mineralnih smjesa. Ova oprema, primjenjena u opsegu visokih temperature, omogućit će obradu višekomponentnih otpada nekih industrijskih tehnologija.

Ključne riječi: *reaktor na kisik-vodik, visokotlačni, visokotemperaturni, energetska jedinica, visokotlačna komora, generator kisika i vodika*

INTRODUCTION

The high-temperature and high-pressure oxygen-hydrogen reactor currently under development is dedicated to gravity separation of multiple mineral components of rocks [1]. Existing dressing technologies can not treat multiple mineral components of rocks accurately because the rocks can be crushed or ground only to a specific limit of fineness. Individual minerals, especially noble metals and rare elements, are distributed in fine particles within the rock and are very often intergrown by each other. Physical methods can not effectively separate these elements. The exposure of the rock to high temperatures (up to 2700 °C) and high pressures (up to 2MPa) effects their collapse. A comparison of some rock's properties before and after its exposure to extreme conditions in an enclosed space of the high-temperature and high-pressure oxygen-hydrogen reactor with a presented vapour phase enables testing of changes in the physical-chemical properties of rock samples. The result of processing of some industrial waste of different kinds of rocks, mostly silicate, with special thermal and mechanical properties will be given. A real possi-

bility is a production of pure and subsequently ultra-pure materials to be used in production of ceramic materials. Plasma reactors for gravity separation purposes have recently been developed in some countries, but they are not widespread due to the energy costs. The results of the project by the end of 2001 are listed in this article.

MAIN OBJECTIVES

The high-temperature and high-pressure oxygen-hydrogen reactor, in which the process of gravity separation of multiple mineral components takes place is composed of two parts:

1. Rock samples or some industrial waste are be melted under extreme high-temperature and high-pressure conditions in the reactor. The molten material is kept under these conditions in the presence of vapour phase until the entire degradation of the prime structure of the rock samples is finished.
2. After the entire degradation of the prime rock samples or the industrial waste the process of the loss of status parameters (pressure and temperature) in the reactor space will be controlled so that the required individual components are selected from the molten material.

P. Rybár, T. Lazar, H. Hamrák, M. Demčák, D. Domaradský, BERG Faculty, Technical University of Košice, Slovakia

The assigned amount of funds for the project influenced the development of the power unit. In order to build a functional prototype of the oxygen-hydrogen reactor, an expensive surface finish was replaced by a very effective cooling system. In addition the automatic process control monitoring system of the melting process inside the reactor had to be changed by manual operating mode. The new power unit was finished and tested outside of the pressure chamber at the end of the year 2001. In the series of experiments the oxygen-hydrogen flame ignition, the output of the power unit and the operating of the cooling system, in which the nitrogen was used as a cooling medium, were verified. The cooling system and the amount of delivered nitrogen influence the shape of the oxygen-hydrogen flame as well.

MODIFICATIONS TO THE PRESSURE CHAMBER IN ORDER TO MAINTAIN REQUIRED TEMPERATURE AND PRESSURE FOR EXTENDED PERIODS OF TIME

The pressure chamber is the main component unit of the oxygen- hydrogen reactor where the rock sample changes into molten material. The energy for this phase change process is supplied by the power unit. The pressure chamber cooperates in the melting process and at the same time provides relatively long-time maintenance of the high-temperature and pressure with the possibility of their controlled reduction.

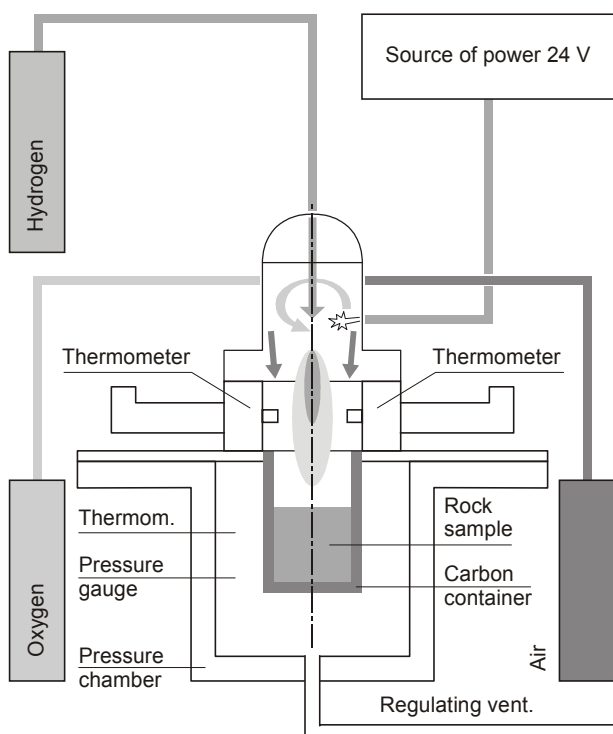


Figure 1. General scheme diagram
Slika 1. Dijagram opće sheme

The necessary modifications to the pressure chamber were based on its new function and actual information obtained as part of the Litho Jet project [2-3]. A distinction consisted in off-setting the pressure chamber with two contact thermocouples used for monitoring thermal changes inside the chamber and by fitting with a exhaust valve. The previous design enabled only jump - discreet regulation of the snort valve (position 1: released/open, position 2: shut/closed). In order to continuously control the release the products of combustion, the valve was off-set by an electromotor that enabled, through the use of mechanical transmission, to decrease the pressure inside the chamber to the required level. The pressure value in the chamber was controlled only visually using a pressure gauge that was situated in the cover of the chamber (Figure 1.).

DESIGN AND PRINCIPLE OF THE POWER UNIT

The design of the power unit was suggested as an oxygen-hydrogen flame generator with the combustion temperature of up to 3000 °K.

The main component of the flame generator is a starting cell from a jet-fighter aero plane adjusted for separate supplies of a fuel (hydrogen) and an oxidizer (oxygen) through electromagnetic regulation valves (Figure 2.). The starting cell is added a cooling system using a gaseous medium (nitrogen or compressed air) which depends on the nature of the experiment. The cell consists of two casings between which is a space used for cooling medium distribution.

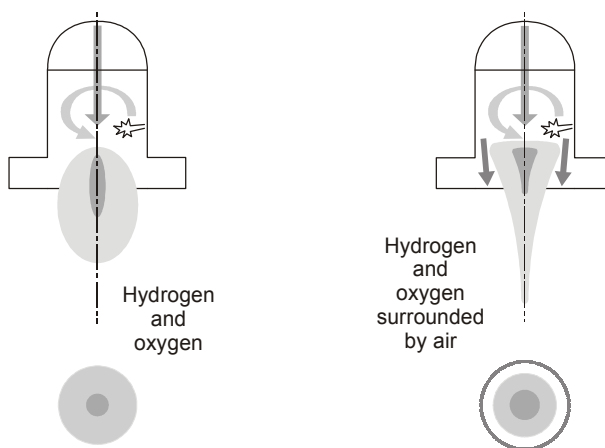


Figure 2. Flame shape regulation by nitrogen or compressed air
Slika 2. Reguliranje oblika plamena primjenom dušika ili stlačenog zraka

The flame generator works as a system with an external gases mixing that takes place inside the combustion cell. The flow of escaping fuel from a nozzle situated in the upper part of the cell is directed by the cooling medium. The supply cooling medium is directed into the combustion space by four openings which are connected to the internal cooled space. Besides cooling, this system also

enables the flame shape to be controlled (Figure 3.). The narrow flow of hydrogen formed by the cooling fluid is dragged by the oxygen that escapes through the perforated surface of an insert which has a bell-bottomed shape and is situated inside the combustion cell. In the lower part of the cell there is a low-voltage spark-plug which is used for the flame ignition.

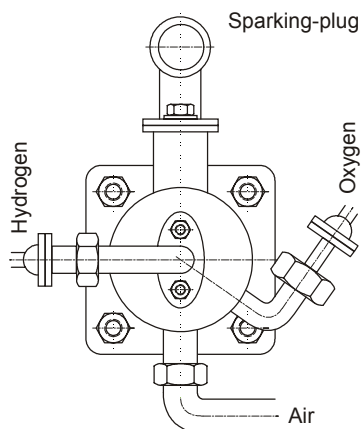


Figure 3. Power unit
Slika 3. Energetska jedinica

The combustion cell whose base is holds four contact c is connected by bolt fastening. The thermocouples are situated inside the base and overreach to the combustion space approximately 1 cm. The contact thermocouples are used to monitor the temperature along the perimeter of the flame (Figure 4.).

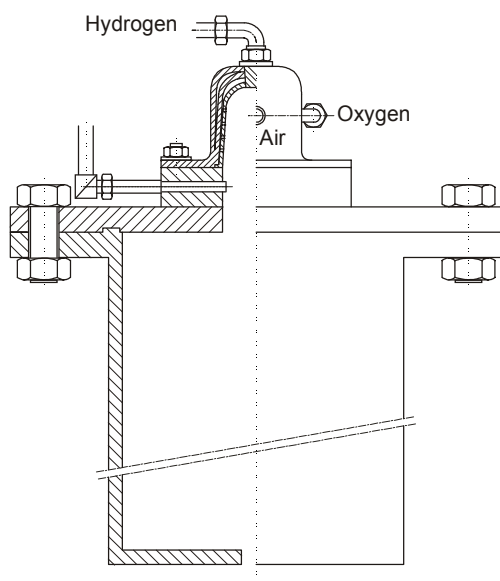


Figure 4. Head and pressure chamber with thermocouples (oxygen-hydrogen reactor)
Slika 4. Glavna i tlačna komora s termoparovima (reaktor na kisik-vodik)

OBSERVATIONS

The gas pressures were adjusted according to the temperature and the shape and color of the flame. Due to the mechanical properties of the starting cell and the material that was made from, the pressures were not increased any further. The temperature was measured at the edge of the flame (not in its center) (Figure 5.).



Figure 5. Formation of the oxygen-hydrogen flame
Slika 5. Formiranje plamena kisika i vodika

The starting amounts of the gases are: hydrogen 8.7 MPa, oxygen 18.0 MPa, and nitrogen 9.0 MPa. The final amounts of the gases are: hydrogen 4.5 MPa, oxygen 14.0 MPa, and nitrogen 8.0 MPa.

Table 1. Adjusting of gas pressure according to the temperature, shape and colour of the flame
Tablica 1. Podešavanje tlaka plina prema temperaturi, obliku i boji plamena

The number of the experiment	p_{H_2} [MPa]	p_{O_2} [MPa]	p_{N_2} [MPa]	T [°C]
1	1.0	2.3	0.5	240
2	2.0	3.0	-	570
3	3.0	4.0	0.5	440

Experiment Nô. 1

An aim of this experiment was to melt a basalt sample with a volume of 2 cm³. The carbon container on which the rock sample was situated, was placed inside the base so it was touching the sensing device of the contact thermocouples. By doing so a work space with the volume of approximately 100 cm³ was created. After igniting the flame the pressure immediately increased in the work space during which time steam escaped by leaking into the open room. Although the experiment was immediately stopped,

the basalt sample was already molten. The experiment took less than 10 seconds. One of the thermocouples was damaged during the experiment.

Experiment Nô. 2

This experiment was intended to melt a basalt sample of approximately 100 cm³. The carbon container was not engaged inside the base to avoid increasing of the pressure. The range between the container and the starting cell was 1 cm. The pressure conditions were the same as in the previous experiment. The flame burred in the electromagnetic regulation valve 25 seconds after ignition. The experiment was stopped. Approximately 10 % of the basalt sample was molten. The sample solidified in the carbon container because of the time elapse that was caused by interrupting the flame. After repairing of the electromagnetic regulation valve, the basalt sample was put under the flame in order to take it from the container.

Experiment Nô. 3

An aim of this experiment was to melt a tetrahedrite powder. The oxygen-hydrogen flame was ignited using low gases values in order to avoid blowing the fine powder out of the container. The sample was put inside the work space

and the pressures of influent mediums were slowly increased. In spite of these measures almost the whole amount of the powder was blown away. The rest was taken and kept for chemical analysis.

CONCLUSION

The high-temperature and high-pressure oxygen-hydrogen reactor currently under development is a device which can play an important role in multiple mineral components processing. It's principally based on the melting of an incoming material in the pressure chamber using high-temperatures and pressures in the presence of vapour phase. The molten material is kept under extreme conditions during relatively long-time period with an option to increase temperature and pressure in a real time.

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