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Advantages of Gasar-Materials for Brake Shoes and Plates

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ABSTRACT

The high thermal conductivity is one of the most important properties of materials used for brake shoes and plates manufacture. Besides these materials should have a high friction coefficient, toughness and endurance. The metal-plastic compositions are widely represented among the materials used now, however they have low heat conductivity coursed in limitation of transport driving capabilities. For the solution of this problem, we offer to apply recently created porous materials – *gasars* with monolithic metal matrix and cylindrical (or ellipsoidal) pores charged with abrasive powder. *The tests have shown, that Gasar brake components have higher thermal conductivity and combine properties of solid metal and frictional material.*

INTRODUCTION

The frictional materials are materials with a high friction coefficient. They are applied in braking or transmitting torques devices. Operation requirements of frictional materials in modern machines are very difficult. The initial braking velocity sometimes reaches 50-70 м/s at pressure 7,0 MPa and very fast friction results in surface heating up to 1000-1100 ^{0}C. For normal operation in such conditions the frictional materials should ensure smoothly braking and have:

- a high friction coefficient constant in wide temperatures range
- high wear proof
- sufficient hardness and strength
- High thermal conductivity
- Good ointment and high grip resistivity
- high corrosion resistance.

The frictional materials, which are using now, do not satisfy to these requirements in whole scale. The frictional materials on the basis of asbestos have a low thermal conductivity and cause high heating of a braking system. Moisture or oil in asbestos material results in change of a friction coefficient and cause a large wearout, especially in a combination with high temperature, when there is a carbonization of organic components.

The metal frictional materials are unsuitable for operation in heavy condition also. They have inclination to welding and grip particularly at high temperatures. Besides this the large wearout and low friction coefficient is observed under light operation requirements.

Metal-ceramics frictional materials consist of metals, oxides, carbides, asbestos and graphite powder and satisfy to many requirements. But this material has some demerits also. One of them is the insufficient strength.

Thus, the frictional materials should combine in themselves alternative properties to be reliable in the operation under heavy requirements. The design of new effective frictional materials is one of the most difficult problems of the materials technology.

It can be solve with application of new porous materials - gasars, which manufacture technology is grounded on the so named *gas-eutectic* transformation. Gas-eutectic transformation in metal-hydrogen systems is relatively recent discovery [1]. In this reaction, the liquid decomposes into a solid and a gas phases: L→S+G. The transformation may take place if the phase diagram for the metal-hydrogen system involves a gas-eutectic equilibrium as in Figure 1.

At present gas-eutectic reactions provides a scientific foundation for processes of manufacture of revolutionary gas-solid materials based on Fe, Ni, Cu, Mg, Al and their alloys. Making the material consists of two steps [2]:
- melt charging with hydrogen to reach the eutectic composition, and;
- melt solidification in a conventional or continuous casting mold.

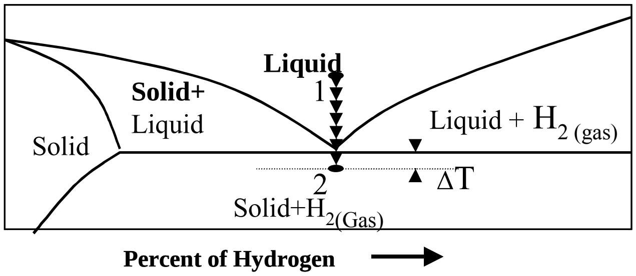

Figure 1. Metal-hydrogen system with gas-eutectic equilibrium

No melt foaming occurs because the gas is evolved as the melt freezes. The process is in many ways similar to conventional eutectic transformation, the distinction being that the liquid decomposes into a solid and a gas rather than into two solids. The main process variables that govern the amount of porosity and the size, shape, and orientation of the pores are the hydrogen level in the melt, gas pressure over the melt in solidification, direction and rate of heat removal, and alloy chemical composition. Changing these variables, one can control the pore structure over a wide range.

Materials produces by gas-eutectic solidification are so different structurally from all other porous metals [3] that a new word was coined for them-gasar, which is an abbreviation of the Russian term for “gas-reinforced.” Gasars may be manufactured in diverse structural variations depending on the process variables previously discussed.

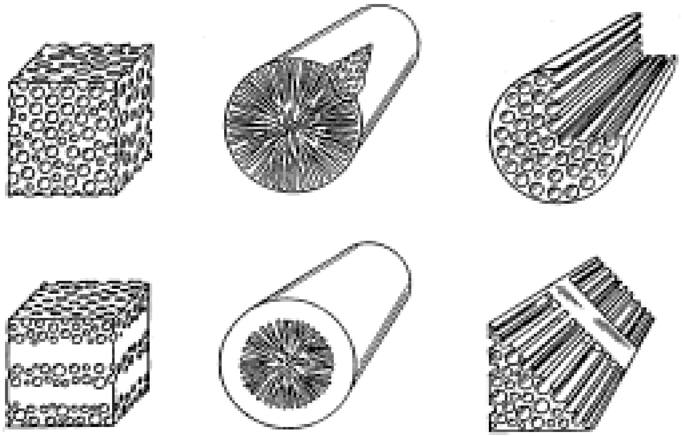

Figure 2. Gas-solid structure formed in gasars under various conditions of gas-eutectic reaction.

Figure 2 illustrates the main structural types embodied in gasars. Gasar pore size may be varied between 10μm and 10mm as desired, and the amount of porosity may reach 75%. They differ from known porous metals by large variety of structure and parameters of a pore space, concerning the low cost, high strength and special physical properties [4].

The pore wall surface is always entirely clean. In most cases it has high luster but is sometimes not so smooth due to the exposure of grown-old dendrites. The interpore walls are poreless and free of any secondary porosity or undesirable inclusions.

The relationship between the average pore diameter and the amount of porosity is an important structural characteristic of porous materials. A summary of these data for various porous metals, including gasars, is presented in Figure 3. No method is presently available for making porous metals that combine fine pore size with high void fraction. Clearly, the existing technologies are complementary in that any of them is applicable to a specific are of engineering problems. The metallic basis of gasars can be iron, nickel, magnesium, aluminium, copper, beryllium and alloys.

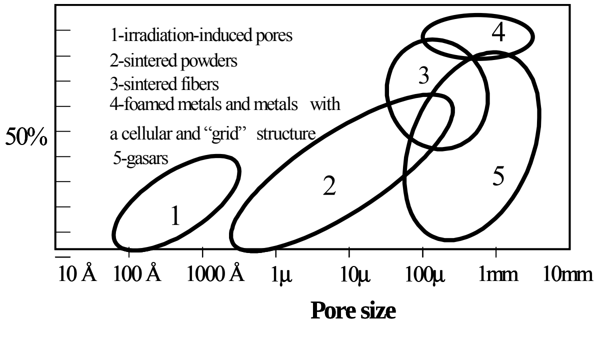

Figure 3. Relationship between the pore sizes and the amount of porosity in various porous metals.

GASAR MATERIALS INVESTIGATION

EXPERIMENT

Samples were prepared in a special furnace, by melting the metal in an atmosphere of hydrogen at present pressure, holding the melt and finally carrying out directional solidification at specified values of pressure and solidification rate [5].

American and Ukrainian scientists have designed the furnace for solidification of pure metals and their alloys in a hydrogen atmosphere. The furnace was fabricated in 1996 in the USA and is located at Sandia National Laboratories in Albuquerque, NM. In the same year, the first scientific and technological experiments were conducted.

The furnace enables thermal processing during both melting and solidification under conditions of vacuum (1-10 millitorr), or pressurized gas up to 5 MPa. Gases used in the melting process can either be inert gases, hydrogen or mixtures of gases. Melting is performed with a 175 kW coreless induction system capable of achieving metal temperatures of 1700^{0}C. Temperature is controlled by thermocouples and an optical pyrometer. Molds can be heated within the furnace with 40 kW resistive elements. The melting and solidification processes can be monitored within the furnace via two videocameras. One videocamera is mounted externally on a view port and the second camera is mounted internally.

Directional solidification or solidification with minimal thermal gradients is achieved by the design of the water-cooled copper platens and by heating the casting molds. Shapes can be cast from various alloys in either vacuum or in the above gases at high pressures. During preparation of these materials, the metal is melted in a bottom-pour crucible located in the top part of the furnace, then saturated to a given partial pressure of gas. The melt is then cast onto the water-cooled copper mold located in the bottom part of the furnace. The crucible capacity is 6 liters. Based on the alloy system, hydride formation is also possible in the furnace. The furnace is constructed to comply with A.S.M.E. Pressure Vessel codes and has many safety features within its design. The vessel is isolated in a blast room and operated remotely from a control room.

Gasar basis was made of aluminium bronze, malleable iron and eutectoid carbon steel. The gasar half-finished products, having pore-monolith structure and parallel pore orientation were received. The thickness of a monolithic layer on a cast surface was made 4-5 mm. The half-finished products were machined by cutting. The final sample shape was rectangular and with sizes 25x15x50 mm and monolithic layer thickness of 3 mm (Figure 4).

Pores were filled with metal plastic frictional material, which is manufactured in industrial scales for ground vehicle. Thermal conductivity, mechanical and frictional properties investigated on the standard equipment.

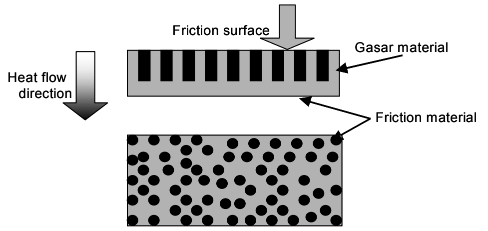

Figure 4. Structure of the sample in perpendicular of friction surface cross-section (up), and top view (below).

RESULTS

Mechanical tests of gasars have shown that directional pores below 10mm in diameter save them quite enough superior in strength (Figure 5). This ensures feasibility of unique solutions to engineering problems and provides a saving in scarce materials.

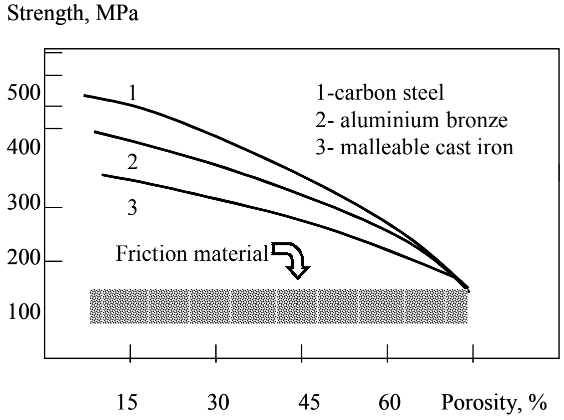

Figure 5. Gasar strength (average pore diameter 4.5 mm)

Gasars are well suited for machining and forming, allow hardening by conventional heat treatment, possess unique damping capacity, can be produced with a heat conductivity value lower or greater than the one for the monolithic material and have good capacity to absorb vibrations and sounds. In future these features may make gasars common structurals and a base for a number of composites.

The tests of a thermal conduction have shown, that the gasar material can conduct heat from a friction surface with much more high speed, than customary (Figure 6). At the same time the gasar material has enough high strength wear proof. It can serve longer and more safely than metal-plastic materials.

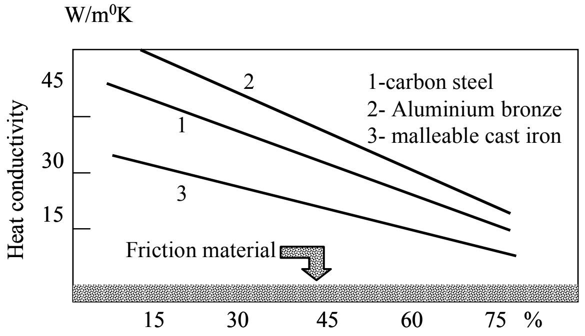

Figure 6. Effect of gasar porosity on them heat conductivity

. The results of frictional tests of a gasar material in nitrogen atmosphere without lubrication are shown in the table below. Speed of sliding on steel was 1,2 meters per one second, pressure 2,0 MPa, temperature 540 ^{0}C, time of test - one hour.

Material	Porosity, %	Friction factor	Wear, µ
Carbon steel gasar	26	0.33	2.5
	39	0.40	2.1
	55	0.45	1.8
Aluminium bronze gasar	30	0.23	1.9
	42	0.31	1.6
	56	0.38	1.2
Malleable cast iron gasar	28	0.42	3.1
	41	0.51	2.7
	51	0.62	2.1
Friction materials	6	0.55	3.9

CONCLUSION

Thus, on the basic of our researches it is possible to make a conclusion, that gasars are a perspective material for use as friction material. Unique technology allows to regulate the porous space and to product the gasars with various kinds of structure. The especially importance is that gasar material is not potentially expensive and can be made in mass quantities at presence of the appropriate equipment. They have frictional properties very close to typical materials, but higher heat conductivity and strength. The malleable cast iron gasar with porosity about 50 % and pore diameter 5 mm has most suitable combination of cost and of properties

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