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INFLUENCING PARAMETERS ON HOMOGENEITY OF ALUMINIUM METAL FOAM AlSi12

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The development of metal foams results in an increasing need for the industrial application of such materials. Metal foams are shaped by the pouring technology which differs depending on which mechanism of pore production is used. This paper presents some of the basic parameters which influence the homogeneity of the metal foam structure.

Key words: *aluminium metal foams, pouring, homogeneity*

Utjecajni parametri na homogenost aluminijske metalne pjene AlSi12. Razvojem metalnih pjena javlja se sve veća potreba za industrijskom primjenom ovih materijala. Metalne pjene oblikuju se tehnologijom lijevanja koje se razlikuju, zavisno koji mehanizam nastanka pora se koristi. U ovom radu biti će spomenuti neki od osnovnih parametara koji utječu na homogenost strukture metalne pjene.

Ključne riječi: *aluminijske metalne pjene, lijevanje, homogenost*

INTRODUCTION

The three states of matter are well defined by soil, water and air. Very few materials in nature are found in pure state. They are usually found as combinations of solid, liquid and gaseous phases. In the past, in their application, the metals were mainly of homogeneous structure. However, metals can exist also in the form of foams.

Metals in the form of foams have existed since 1943 when Benjamin Sosnick tried to make metal foam by alloying aluminium and mercury, which he melted under high pressure. During 1950s the first open-cell metal foams were produced. The procedure meant pouring of the molten aluminium into a perform made of rock salt. Rock salt would dissolve and the open-cell aluminium structure would remain. This procedure yielded a more reliable structure than had been obtained by the Sosnick procedure, but metal foams continued to be regarded as an interesting but not actually useful phenomenon.

In 1959 a completely different approach was applied. A procedure was developed in which powdered metal was mixed with the gas-generating powder. The gas-generating powder had to be carefully selected since a large amount of gas is obtained during the disintegration procedure, which should have been at the metal powder melting temperature. The powder mixture was mixed in cold condition and extruded. When the obtained metal was heated the gas-generating powder would disintegrate and release gas into the molten metal, which then resulted in the formation of metal foam. The problem in this procedure was the cooling. Due to the impossibility of fast cooling, the metal foam would collapse.

Several years later, a method was developed in which gas-generating powder was added directly to the molten metal. The novelty consisted in the fact that also silicon materials were added to the molten metal in order to increase its viscosity and to retain better the generated bubbles. The procedure of obtaining metal plates that were used to obtain the presented specimens meant that instead of adding titan hydride (TiH_2) directly into the molten metal, it was heated before adding in order to form a thin layer of oxide on the surface. When titan hydride in this state is mixed with the molten metal, the oxide layer postpones fast disintegration of titan hydride. This allows that, instead of foaming, the mixture is cooled in order to obtain solid plate (precursor). The plates are then placed into moulds of desired shapes and heated to aluminium melting temperature. The hydride is melted thus releasing gas, which foams the molten aluminium in the mould.

At the end of the 80s the Japanese engineers from Shinko Wire Co. developed a procedure, which is today

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known as Alporas. In 1990 the German scientists led by the physicist Joachim Baumeister perfected the procedure of obtaining the aluminium-titan hydride mixture by mixing the powder of both components and then extruding it by forming thus simple metal profiles. The powder extruded in this way is foamed in the mould by being subsequently heated to the temperature of activation.

Today, the properties of metal foams as well as their industrial application are actively studied. Small mass, and very good mechanical, thermal and acoustic properties, provide metal foams with high advantage over the homogeneous materials. The pouring technology is used for production and forming of metal foams. There are different pouring techniques of metal foams within the pouring technology. Each of the pouring techniques is very demanding from the aspect of foaming process regulation [1 - 6].

EXPERIMENTAL PART

Activation of Aluminium metal foam (AlSi12) was performed at the Foundry Laboratory (Laboratorij za ljevarstvo), Faculty of Mechanical Engineering and Naval Architecture, University of Zagreb. The aim of the research was to determine the temperature and time necessary for the precursor activation, in order to obtain the homogeneous structure of Aluminium metal foam.

Equipment

The equipment used for the generation of the metal foam consists of electric resistance furnace LINDBERG type CR-5, measuring central unit HEWLETT-PACKARD type 3852A, two measuring sensors, and computers for storing and processing of data. The scheme presentation of the measurements is presented in Figure 1.

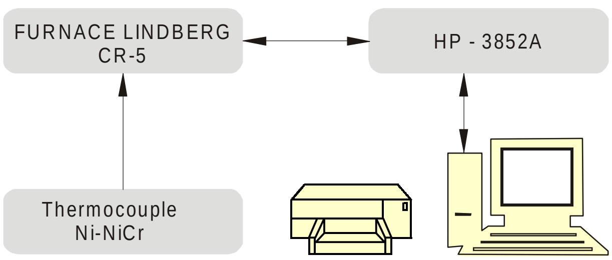

Figure 1. **Flowchart of the measuring equipment**
Slika 1. **Blok shema mjerne opreme**

Precursor

By using chemical foaming agent (in this case TiH_2) greater control over the structure is achieved than in case of other metal foam generating techniques. It is still relatively difficult to control the dispersion of the foaming agent within the melt, which means that the foam generated in this way will not have completely uniform structure.

By exposing the titan hydride to thermal treatment it is possible to generate a thin layer of titan oxide on its surface. By adding titan hydride (TiH_2) into the molten metal, the particles of silicon carbide are also added, thus increasing the alloy viscosity. The formed layer of titan oxide prevents disintegration of titan hydroxide i.e. blocks the foaming reaction long enough to disperse the titan hydride (TiH_2) as uniformly as possible within the molten metal.

Since foaming does not occur immediately, it is possible to cool the precursors and thus to stabilise their structure. The precursors produced in this way can be then stored until their usage; if necessary they are cut to the desired dimensions and placed into moulds in which they are activated (foamed). The complexity of the foaming mould can be very high.

The heating of the mould and precursor results in reaction. The titan oxide layer around the titan hydride particles is disintegrated and this results in its disintegration into titan and hydrogen. Hydrogen produces bubbles which form pores in the metal after its cooling. The control of the duration of reaction and temperature at which it occurs makes it possible to produce metal foams with the porosity of 50 to 95 %, i.e. with the pore size from 1 to 10 mm [2].

Foam generation procedure

The measuring sensors are connected to the measuring central unit, taking care of the poles and the sequence of input. After mounting the temperature measuring sensors, the measuring central unit is connected to the computer. The central unit has the role of gathering results from the measuring sensors (thermocouples). The computer communicates with the measuring central unit, accepts and interprets the results in *.txt file. One thermocouple measures the temperature of the furnace and the other one measures the temperature of the precursor. The thermocouple that measures the temperature of the furnace is attached to the cover so that it is about 30 to 40 mm below the cover inside the furnace. The second thermocouple is attached to the precursor by means of bolt and nut (Figure 2.).

Figure 2. **Thermocouple on precursor**
Slika 2. **Termopar na prekursoru**

This is followed by the preparation of the foam activation mould. The tubes of different transversal cross-sections can serve as moulds. The wall thickness of all moulds was equal. After preparation, the mould is placed into the furnace, and pre-heated for at least two hours at a temperature of 500 °C. It is very important to place the mould in the centre of the furnace so that all its sides would be at even distance from the heater (Figure 3.) and to avoid excessive heating of one side which would lead to uneven heating of the precursor and thus to its non-uniform foaming.

Figure 3. **Position of mould in the furnace**
Slika 3. **Smještaj kalupa u peći**

MEASUREMENT RESULTS

The foaming temperature for AlSi12 is about 580 °C, and depends on the precursor material (AlSi12), type of agent (TiH_2), and the precursor heating rate. In case of fast heating when the precursor is placed into the hot furnace, the foaming occurs also at a lower temperature. The foaming takes about 100 seconds, but this duration depends also on the heating rate. Every activation process needs to be carefully controlled, since a 10 °C excess in temperature or prolonged stay in the furnace can result in foam collapse.

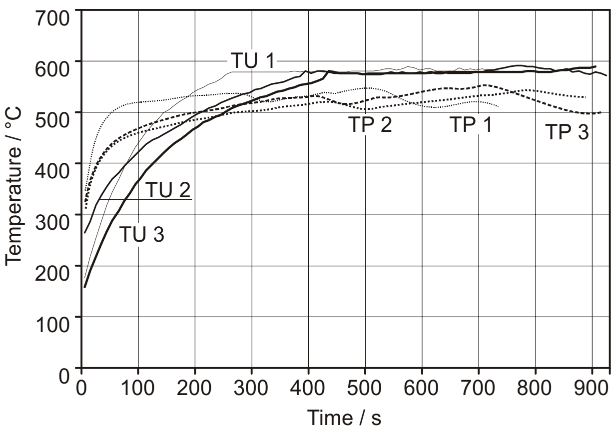

Figure 4. **Activation process of metal foam AlSi12**
Slika 4. **Proces aktivacije metalne pjene AlSi12**

After the reaction is completed the mould is removed from the furnace and cooled in order to stabilise the metal foam. After 1 to 2 minutes the mould is water-cooled to room temperature, and after that cut, and the obtained specimen of the aluminium metal foam is taken out.

Since the thermocouples are connected to the measuring central unit, and in turn connected to the computer, their readings are recorded during the whole experiment. The results are saved in a text file on the computer, which is later converted in some of the diagram plotting software which then shows graphically the obtained results (Figures 4. and 7.).

Figure 4. shows the change in the temperature of furnace and precursor (specimen) when the precursor is placed into a cold furnace. During foaming, two time intervals can be determined from the graphical presentation. The first interval is the heating of the precursor to the activation temperature (580 °C), whereas the other interval determines the isothermal process of bubble generation. The total time of precursor foaming is very long (ca. 900 s) due to the slow mould heating. In such a process it is very difficult to achieve the homogeneous structure. During foaming the specimen fills completely the mould, but the structure is not uniform and the pores are very big (Figures 5. and 6.). Big pores are the result of bonding of minor bubbles caused by slow heating. The metal foam activated in this way features very poor and extremely unrepeatable mechanical properties.

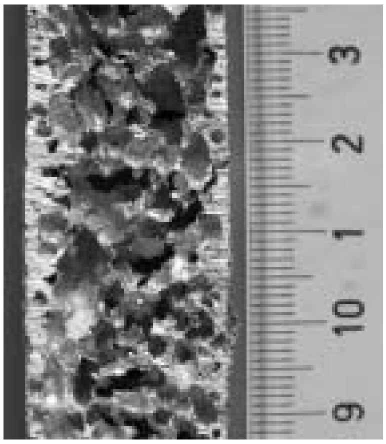

Figure 5. **Non-homogeneity of metal foam structure caused by insufficient activation process control**
Slika 5. **Nehomogenost strukture metalne pjene uzrokovana nedovoljnom kontrolom procesa aktivacije**

The second case of activating the aluminium metal foam (AlSi12) was performed by placing the metal precursor into the furnace heated at 620 °C. The measurements yielded again two intervals. The first interval of specimen heating (Figure 7.) took about 150 seconds, whereas the isothermal process of activa-

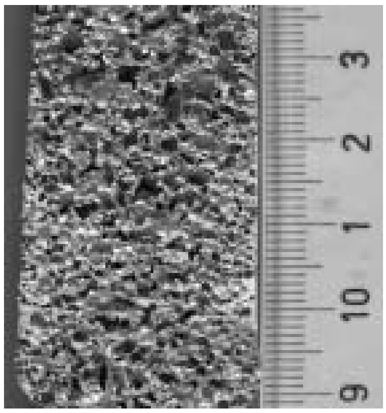

Figure 6. **Metal foam AlSi12 homogeneous structures**
Slika 6. **Metalna pjena AlSi12 homogene strukture**

tion took only 50 seconds. Within this time interval the complete metal foam activation is achieved. The homogeneous structure through the entire specimen cross-section is insured by fast heating and timely stabilisation of foam. The stabilisation of metal foam was carried out by removing the mould with the specimen from the furnace and by cooling it in the air. The metal foam specimen obtained by this procedure is presented in Figure 6.

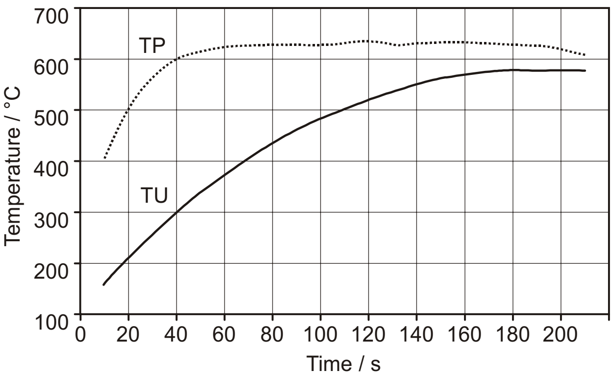

Figure 7. **Activation process of metal foam AlSi12**
Slika 7. **Proces aktivacije metalne pjene AlSi12**

CONCLUSION

The process of activating the metal foam from the precursor is very demanding regarding control of the technological process. The influencing parameters for foaming of AlSi12 precursor include the heating rate, temperature of activation and time of activation.

In order to achieve homogeneous structure of the metal foam it is necessary to control the temperature and time of activation very precisely. The gradient which leads to isothermal transformation can also be very important for the homogeneity of the casts themselves. By achieving high gradient of heat transition from the furnace to the specimen, the disintegration of the titan oxide sheath and the titan oxide activation itself occur very quickly. This is reflected in the uniform growth of bubbles in AlSi12 precursor, and after stabilisation by the homogeneous structure of the metal foam. It was determined by research that the foaming time should not be too long in order to avoid foam from collapsing. Long exposure of specimens to activation temperature causes bubble bonding and non-homogeneous structure of foam which significantly reduces the properties of metal foam.

The research of precursor foaming continues towards the pore size control and towards achieving of homogeneous structure in complex moulds.

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