INVESTIGATION OF THE OBTAINING OF THE MMC WITH METAL MATRIX Al AND Fe REINFORCEMENT PHASE

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Abstract: *The aim of the present paper is to test the synthesis of moulded metal composites (MMCs) with a metal matrix Al and a strengthening metal phase Fe of type „in vitro" and „hybrid". There was a test done for the preparation of composites using a method similar to "capillary forming", such as the metal matrix (melt of aluminium) was infiltrated in the space between the iron blasting grit which is the inversely option of solving similar problem in which problems the blasting grit (the strengthening phase) are forcibly implemented into the melts (the metal matrix). In this way the problem which needs to be solved, in which the melt is infiltrated between the space of the iron blasting grit, allows for the maximum reduction of the volume of the metal matrix on account of the strengthening phase. The experiments were conducted with laboratory equipment elaborated on the base of another equipment for "capillary forming" with extra vacuum, patent protected developed by the department "Materials Science and Technology". From the received moulded metal composites (MMCs) were establish areas of reaction between aluminium and the iron powder. The experiment produced significant results as received alloying between iron and aluminium at a relatively low temperature of melting of the iron in which there were received metal-composites structures of the type „in vitro" and „hybrid", which were tested by metallography and micro-hardness analysis.*

Keywords: MMCs, IRON-BASED ALLOYS, ALUMINIUM POWDER, IRON POWDER, CAPILLARY FORMING, VACUUM

1. Introduction

The formation of moulded metal composites (MMCs) is one of the most modern trends in the development of materials technology. In general, the metal composites are a heterogeneous system consisting of a relatively homogeneous metal base (matrix), which through various technologies is imported and distributed differing in kind, form, content, and certain characteristics, called the phase of strengthening (reinforcement) [4].

Manufacturers and engineers increasingly find opportunities that composite materials offer to produce high quality sustainable and cheaper products.

MMCs are classified on the basis of the state of the intensifying phase: "in vitro|- the intensifying phase is in solid form throughout the whole production cycle; "in situ"-when the intensifying phase is a result of the crystallization process or chemical reactions; "hybrid"-occurring as a result of a more complex interaction involving elements of both. Methods and technologies for the production of metallic composites are different in origin and are numerous. Some of the most frequently used methods and techniques are gravity casting, moulding under pressure, centrifugal casting, squeeze casting, forging or vacuum infiltration of the molten metal etc[3,5,6].

In the conducted studies the received metal composites can be conditionally assigned to composites "in vitro". An interaction of the intensifying phase with the metal matrix is observed as well - a complex interaction referred to in literature as a "hybrid"[1].

Research concerning the methods of formation of MMCs in the present paper are brought to the usage of various schemas of vacuumization of the space for the synthesis of the composites, using the concept of the "Capillary forming" [1,2]

2. Experimental Procedure

The purpose of the conducted studies was related to the preparation of moulded composites from metallic type "in vitro" and composites, in which the presence of a reaction of the reinforcing phase with the matrix metal can be observed, i.e. composite type "hybrid".

The classical method of preparing a moulded composite is "in vitro" administers a mechanism of forcible insertion of the reinforcing phase into the prepared melt and subsequent homogenization of the composite structure [5,6]. In our case mixing the matrix with the reinforcement phase itself was carried out on the principle of "capillary forming" [2]. Initially, the reinforcing phase is emptied into the form (Fe-metallic blasting grit), then the matrix metal (Al) in the form of a melt is infiltrated forcibly in the spaces between the metallic blasting grit. Thus following the created scheme of mixing the metal matrix and the reinforcement phase additional firmness is added to the composite with force being produced.

$$P = Pa - Pk \qquad (1)$$

$$Pa = p_a.Fa, \qquad (2)$$

$$Pk = p_k.Fk \qquad (3)$$

P_a- atmospheric pressure;

p_k– pressure of the melt in the space between the metal particles, i.e. in the metal matrix; p_k approximately equal to the vacuum gauge readings;

Fa - area under atmospheric pressure;

Fk - area of the melt in the composite;

$Fa \approx F\kappa$.

As mentioned above, in the present studies – pure aluminium has been used for the metal matrix, and blasting grit from pure iron for the reinforcing phase.

To complete the assigned task there has been developed a laboratory system schematic diagram that is shown on Fig.1.

As it is shown in Fig.1, the source of heat is a gas burner (10) and the flame it produces envelopes the area in which the flux is positioned (1), the metal matrix (aluminum powder) (2) and the reinforcement phase (iron powder)(3).

After the temperature in the area of the flux interaction have been reached around 1000 °C (thus high castability is attained), the molten aluminium powder (2) infiltrates into the space between the iron pellets. By opening the stopcock 12, dilution (sub pressure) is generated in the space around the reinforcement particles through the buffer system and the filter and it is the melt above them that ensures the pressurization of the entire system. Such infiltration is possible owing to the difference in the pressure above the aluminium melt and under it. Over the melt acts the atmospheric pressure, and under it the pressure is lower because the space in this area is connected to the vacuum system. The aforesaid makes it clear that in the system of heating and vacuuming chosen, the flux melts first and as a surface-active substance it wets the aluminium and iron pellets. Then the aluminium pellets melt and because of the difference in the pressure above and under the aluminium melt, the aluminium melt forcibly infiltrates into the space between the pellets of the reinforcing phase. As a result, the matrix and the metal pellets are soldered. This process takes place very fast and after it is completed the vacuum system is switched off and the quartz tube is removed. After the crystallization and solidification of the melt filling up the space around the particles, a metal composite structure is obtained.

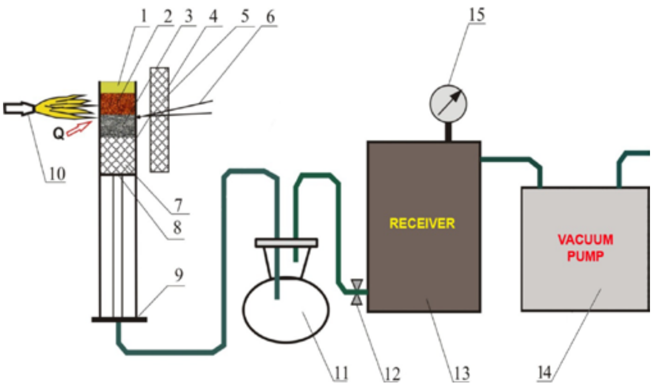

Fig.1 *A general view of a laboratory system of obtaining cast composites by a metal matrix of pure aluminium and reinforcement phase pellets of pure iron.*

1- Flux;	9- packing;
2- aluminium powder;	10- a burner;
3- iron powder;	11- an intermediate vessel;
4- a quartz tube ;	12-a stopcock;
5- a fireproof plate (screen);	13- a receiver;
6- a thermocouple;	14 –vacuum pump;
7- refractory wool;	15- vacuum meter;
8- an underthrust;	

The preliminary experiments have proved that in the absence of any flux no interaction occurs between the two metal phases and it is obvious that there is not any wetting of the reinforcement phase by the metal matrix. That is why the experiments covered in this paper were conducted after the metal matrix and the reinforcing phase were first wetted with some molten flux for aluminium alloys welding.

With the laboratory system described, series of experiments have been carried out in order to obtain cast metal composites by a aluminium matrix and a reinforcing phase of pure iron. **Table 1** illustrates the material used and contains some of its main characteristics.

The experimental samples obtained are used to prepare some samples for a microstructural analysis. The prepared metallographic polished sections were examined under a Neophot32 metallographic microscope. In addition, the microhardness of the structural composites obtained was determined.

Table1. The material used and some of its main characteristics.

Material		Main characteristics			
		Density γ [g/sm^3]	Hardness	T_m [°C]	Size [μm]
Metal matrix	Aluminium (Al)	8,86	25HV	660,3	20
Reinfor -cement phase	Iron (Fe)	7,87	60HV	1539	50-100

3. Results and Discussions

The experimental studies conducted confirm to a large extend the possibility of obtaining cast metal composites by a metal matrix of pure aluminium and a reinforcing phase pure iron.

By the elaborated experimental system, samples of composites of the type “in vitro” and “hybrid” were obtained.

Fig.2 illustrates microstructures before etching of the samples by a metal matrix aluminium and a reinforcement phase pure iron.

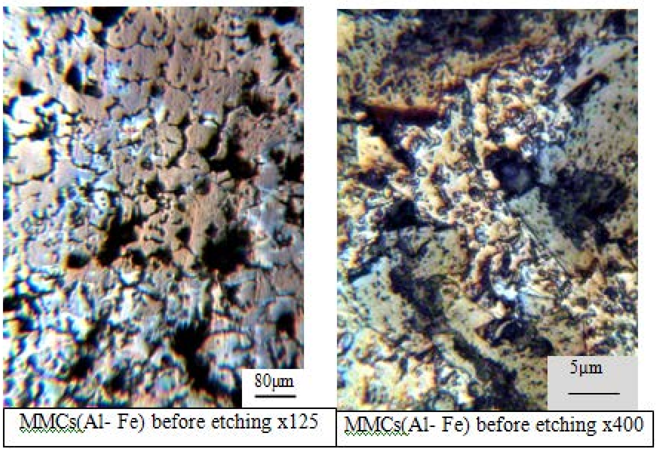

Fig.2 *Microstructures before etching of the samples by a metal matrix aluminium and a reinforcement phase pure iron.*

Among the microstructures in Fig.2, there are some closed micro-volumes (pores), in which practically no infiltration of the melt (aluminium) has taken place. One of the reasons for that may be the insufficient quantity of liquid metal (aluminium), that in its turn leads to the premature depressurizing of the system. That is why it is not possible to fill up all the space with some melt around the reinforcement phase. Other factors, such as the extent of dilution during vacuuming, the cooling rate during and after crystallization, the extent of thickening, may also be the cause of the presence of such defects. The clarification of these factors may be a subject of future studies.

Fig.3 illustrates some microstructures after etching of the samples by metal matrix aluminium and a reinforcement phase pure iron.

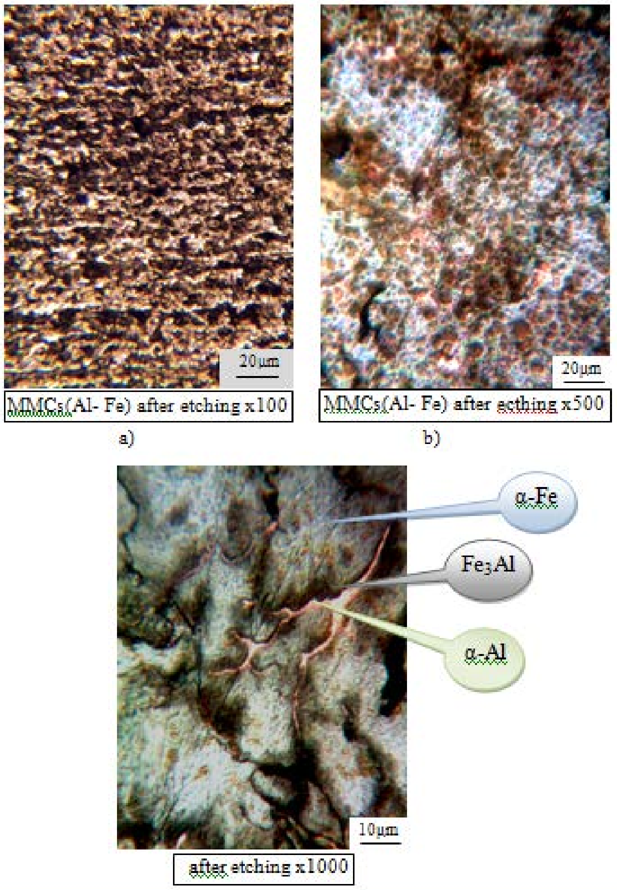

Fig.3 *Illustrates some microstructures after etching of the samples by a metal matrix aluminium and a reinforcement phase pure iron.*

As it is seen in **Fig.3**.c), iron and aluminium interact with one another because of the high temperature (1000˚C) and the diffusion processes taking place. As a result, α-Fe and α-Al are obtained. In addition, a chemical compound Fe_3Al is observed and that is indicated by the microhardness of 85HV measured in some sections **(Fig.4)**.

Fig.4*. Microstructure of the sample by a metal matrix aluminium and a reinforcement phase pure iron, which microhardness was measured.*

In the sections with molten and crystallized aluminium micro hardness of 35HV was measured, which is 10 units more than that of pure copper and is due to the solubility of iron into copper. In the sections with unmelted reinforcement phase iron the hardness measured was 75HV- 85HV, which is 15 units more than that of pure iron and it is due to the solubility of aluminium into iron. Such a result may be considered significant, because an alloy between aluminium and Fe is obtained at comparatively lower temperatures than the melting temperature of iron.

4.Conclusions

After the experiments were conducted, on the basis of the results obtained, the following major conclusions may be drawn:

1. Some methods of building cast metal composites by a matrix (pure Al) and reinforcement phase (pure Fe) are developed by applying the method of "capillary moulding" and vacuuming.

2. In the building of the composite Fe-Al it was established that, as result of the high temperature, some diffusion processes take place and solid solution of aluminium into iron α-Fe and solid solution of iron into aluminium α-Al are obtained. In addition, a chemical compound Fe_3Al is observed too.

3. The durometric analysis conducted has revealed an increase in the hardness of the phases and structural composites in the composite obtained by a matrix of aluminium and reinforcing phase of iron, in comparison with the initial components (pure aluminium and pure iron). It is due to the solubility of aluminium into iron.

4. The cause of defect generation (pores) in the structure that are due to the incomplete filling of the capillary space with melt is related to the parameters of the technological process (the extent of diluting during vacuuming, the cooling rate during and after crystallization, the extent of thickening, etc.) in the preparation of metal matrix composites. This problem may be solved in the course of further studies.

5.References

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