OVERVIEW OF COMPOSITE MATERIAL TECHNOLOGY WITH Si-C PARTICLES REINFORCEMENT

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Abstract: Manufacturing technology of metal matrix composites reinforced with particles are still in the attention of researchers worldwide because of interest shown in the modernization and optimization of current technologies and improving the properties of composite materials and their effectiveness in use. Using a Taguchi experimental plane, applied manufacturing technology which has the objective function of the composite mechanical properties have been identified optimal values of the factors with significant influence. The experimental results on mechanical properties were analyzed by further investigations on the structure of composites, fracture and defects identifiable by ultrasonic testing of composite material particles ranfort Si-C.
Key words: composite, particles, traction, structure, ultrasonic, fractured-surface.

1. INTRODUCTION

Composite materials are defined as materials consisting of two or more components with individual characteristics and whose combination leading to synergistic effects that lead to new applications in different phases of the components considered separately.
The definitions itself are general in nature and not necessarily cover all types of composite materials. Rohatgi (Rohatgi, 1988) in his shows that "the term implies that the composite material is macroscopically identifiable, meaning that materials are not only differentiated at the molecular level, but also have distinct properties and this is generally mechanically separated".
Reinforcing elements are inorganic materials (graphite, oxides, carbides etc.) or metallic form of fibers or particles and matrix by use may be polymeric, ceramic or metal.
Using reinforcement material particles to produce metal matrix composites have some important advantages:
-compared to fiber, the particles are much cheaper;
-there is the possibility of obtaining materials with a heterogeneous isotropic or controlled;
-can use simple technologies to embed and dispersion in the matrix.
SiC particles, of different configurations, is used in particular for producing composites with high wear, ensuring product achieved an increase of density, dimensional stability and high specific properties.
In terms of theory, the particles used must meet the following conditions:
-microscopic size, which vary from a few microns to several hundred microns;
-be wetted by the liquid alloy;
-not react with the elements of speed metal bath.
For each combination of matrix-ranfort is a distinct value of the time after which the strength of the interface layer reaches maximum value.
-density is close to that of the metal melt to avoid gravity segregation. There are a variety of particles produced from graphite, silicon carbide, alumina, silicon nitride, glass, steel, iron, lead, etc., with sizes ranging from less than one micron up to 500μm or even more.
Metal composite particles can be classified in (Carcea, 2008; Ibrahim et.al.,1991):
• composite with small particles, which average particle diameter is between 10 and 100 nanometers, approaching the size of the crystal structure of metals and alloys;
• composite with large particles are composed of a matrix metal, ceramic or carbon particles are incorporated into various types of materials. The properties of composites with particles depend on quantity, size, shape and distribution of supplementary material (Carcea, 2008). So if reinforcement SiC particles in titanium matrix main properties refer to high ductility and high mechanical resistance and in case of using the matrix of Al-Mg superplasticity speak of a composite material obtained.

Mechanical loads are transmitted when the matrix composites for reinforcement material. Pregnancy transferred particles depends on the intensity of the request. If blood shear, which occurs at the interface is higher than the local resistance, it is possible to show a crack tends to propagate (Laramee & Thiokol, 1987).

The particles are used, in particular, to produce composites with high wear. The presence of particles leads to a decrease but the elongation and hence the tenacity of the material, resulting in a limitation when used only to produce composites which no excessive mechanical and thermal shock.The particles used to produce composite materials are produced by various chemical or physical processes, the preferred methods to assure quality and purity particle surface.

Composites with nanoparticles can be composites with random orientation and microparticles can have both preferred orientation and random orientation. The particles can be metallic or nonmetallic, just as the matrix can be metallic or non-metallic (Ureña et.al., 2004):

-*metal particles in nonmetallic matrices*: one such composite material is solid rocket fuel, composed of aluminum oxide powder in a flexible organic link, as that of polyurethane or rubber polisulfid. Another example is the material obtained from a metal powder is suspended in a resin termoreactive. Composite material product is durable, tough, good conductor of heat and electricity and is used for cold bonding;

-*matrix-particles nonmetallic minerals*: an example of this category is the material consists of particles of sand and rock in a mixture of cement with water, that react chemically hardens;

-*metallic particles in metal matrices*: a great alloy, composite material is obtained from metal particles contained in a metal matrix, but not "dissolve". Lead particles are commonly used in copper alloys and steel. Some metals are brittle at ordinary temperatures, particles of these metals, such as tungsten (tungsten), chromium, molybdenum, may be included in a matrix ductile. Resulting composite material as matrix ductile and resistant to high temperature, as fragile constituents;

-*non-metallic particles in metal-matrix*: non-metallic particles, such as ceramic, may be embedded in a metal matrix. Resulting composite material is called - cermet.

Surface hardening can be achieved through the integration in an aluminum metal matrix of hard particles of alumina, silicon carbide, titanium carbide, boron carbide etc. In this case the lift is provided by the dispersed phase and metal table base is designed to retain particles embedded in the surface friction, not to be displaced and torn.

Graphite particles placed in aluminum matrix matrix improve tribological properties (coefficient of friction, abrasion losses) and placed in proportion to (1..5)% (in sizes at 10-100μm) in the liquid alloy, graphite particles have a strong tendency to segregation by flotation, because they have low density and are not wetted by metal melt (Neagu & Ştefănescu, 2007).

2. MATERIALS AND METHODS

2.1. Materials

For the production of composite materials were used as matrix two aluminum alloys (ENACAlSi5Cu3Mg and ENACAlSi7Cu2Mg) and the silicon carbide particles ranfort two grain (Table 1). The main properties of SiC particles used to obtain composites are: density [g/cm3]: 3.21, coefficient of expansion [10-6/oC]: 5.40; modulus of elasticity [GPa] [temperature oC]: 324 (1090) (Ştefănescu et.al, 2002).

2.2. Planning experiment

Planning of experiments methodology is used by Taguchi (Pillet, 1997). The proposed method seeks to meet certain criteria, such as measurement facility, minimizing the number of tests and then testing the price, providing the best possible accuracy. Taguchi has developed an original method that allows, based on some standard tables, easily solving most industrial problems plans on experience. While techniques orthogonal planes of experience in the public domain, Taguchi's originality lies in implementation strategies, providing a subset of the standard arrangements enough in current practice. Determining the parameters presented three original aspects:

-reducing effects by leaving unchanged the possible causes of low or very low cost;

-main quality criterion of a process is its performance relative dispersion;

-Taguchi has developed linear graphic is a graphical representation of the damage factors in columns orthogonal arrangement. These charts have to factor in the simplification of these arrangements orthogonal.

Easy to study is the model proposed by Viger and Sisson (Dusa, 1996; Nedelcu & Prutenu, 2000) matrix model system consisting of "and" factors: F1, F2 ... Fi each factor having some levels is presented in relation (1).

$$Z_t = M + \left\lfloor E_{F_1^1} E_{F_1^2} \dots E_{F_1^{n_1}} \right\rfloor \cdot [F_1] + \left\lfloor E_{F_2^1} E_{F_2^2} \dots E_{F_2^{n2}} \right\rfloor \cdot [F_2] + \dots + \left\lfloor E_{F_i^1} E_{F_i^2} \dots E_{F_i^{n_i}} \right\rfloor \cdot [F_i] + \\ +^t [F_1] \cdot \begin{vmatrix} I_{F_1^1 F_2^1} & I_{F_1^1 F_2^2} & \dots & I_{F_1^1 F_2^{n2}} \\ I_{F_1^2 F_2^1} & I_{F_1^2 F_2^2} & \dots & I_{F_1^2 F_2^{n2}} \\ \dots & \dots & \dots & \dots \\ I_{F_1^{n_1} F_2^1} & I_{F_1^{n_1} F_2^2} & \dots & I_{F_1^{n_1} F_2^{n2}} \end{vmatrix} \cdot [F_2] +^t [F_1] \begin{vmatrix} I_{F_1^1 F_3^1} & I_{F_1^1 F_3^2} & \dots & I_{F_1^1 F_3^{n3}} \\ I_{F_1^2 F_3^1} & I_{F_1^2 F_3^2} & \dots & I_{F_1^2 F_i^{n3}} \\ \dots & \dots & \dots & \dots \\ I_{F_1^{n_1} F_3^1} & I_{F_1^{n_1} F_3^2} & \dots & I_{F_1^{n_1} F_i^{n3}} \end{vmatrix} \cdot [F_3] + \dots \\ \dots +^t [F_1] \cdot \begin{vmatrix} I_{F_1^1 F_i^1} & I_{F_1^1 F_i^2} & \dots & I_{F_1^1 F_i^{n_i}} \\ I_{F_1^2 F_i^1} & I_{F_1^2 F_i^2} & \dots & I_{F_1^2 F_i^{n_i}} \\ \dots & \dots & \dots & \dots \\ I_{F_1^{n_1} F_i^1} & I_{F_1^{n_1} F_i^2} & \dots & I_{F_1^{n_1} F_i^{n_i}} \end{vmatrix} \cdot [F_i] + \dots +^t [F_{i-1}] \cdot \begin{vmatrix} I_{F_{i-1}^1 F_i^1} & I_{F_{i-1}^1 F_i^2} & \dots & I_{F_{i-1}^1 F_i^{n_i}} \\ I_{F_{i-1}^2 F_i^1} & I_{F_{i-1}^2 F_i^2} & \dots & I_{F_{i-1}^2 F_i^{n_i}} \\ \dots & \dots & \dots & \dots \\ I_{F_{i-1}^{n_i-1} F_i^1} & I_{F_{i-1}^{n_i-1} F_i^2} & \dots & I_{F_{i-1}^{n_i-1} F_i^{n_i}} \end{vmatrix} \cdot [F_i] \quad (1)$$

where Z_T is the theoretical response of the system, M is the overall mean responses and is calculated as the ratio of the sum values and number of experiments conducted responses, $[F_i]$ is a vector indicating the factor F_i is a column matrix with elements equal to zero less than one 1 and is in "i" corresponding to the factor considered, $E_{F_i^j}$ is the effect of environmental factor response system be located at j, and is calculated by subtracting the average response system overall average M, $\lfloor I_{F_i^j F_k^t} \rfloor$ are the interactions between factors F_i and F_k and calculated by subtracting the average response system (the factors F_i are at j level and F_k factors are at t level) the overall average (M) - $E_{F_i^j}$.

It will apply using Taguchi's matrix modeling for six technological parameters with two levels (table 1) and write the model as Viger and Sisson. Can be traced to determine the coefficients of a model type (2):

$$Z_t = M + G_r + A + P + T_{emp} + T_{imp} + V_a + G_r \cdot A + G_r \cdot P + G_r \cdot T_{emp} + G_r \cdot T_{imp} + A \cdot P \quad (2)$$

where:
M is the general average;
G_r is grit particles, [μm];
T_{emp} is the temperature of casting, [^oC];
T_{imp} is the time of mixing, [min];
A is the type of alloy used;
P the percentage mass of particles [%];
V_a is the speed stirring the mixture, [rpm].

Table 1. Levels of variation of input parameters

Input parameters *Levels*	Gr [μm]	T [^oC]	Time [min]	Alloy type, (European Standard)	P [%]	V, [rot/ min]
Level 1	40	650	1	ENACAlSi5 Cu3Mg	2	250
Level 2	200	750	3	ENACAlSi7 Cu2Mg	6	720

With the planning by Taguchi resulted in a total of 16 experimental tests. The best mechanical properties of composites were obtained from experimental tests 1, 4, 7 and 16.

Levels of variation for the factors considered are presented in Table 2.

Table 2. Factors for experience levels 1,4,7,16

Factors Tests numbers	Gr [μm]	T [^oC]	Time [min]	Alloy type, (European Standard)	P [%]	V, [rot/ min]
1	1	1	1	1	1	1
4	2	2	2	2	1	2
7	2	2	2	2	2	1
16	1	2	1	2	1	2

2.3. Experimental technique

The methodology for obtaining composite materials reinforced with particles is the key next steps (figure 1):
-introduction of Si-C particles in liquid aluminum matrix;
-mixing with a palette mix driven by belt;
-overheat entire mixture;
-cooling the entire mixture in crystalline;
-phase solidification of the mixture;
-mining-phase composite material obtained.

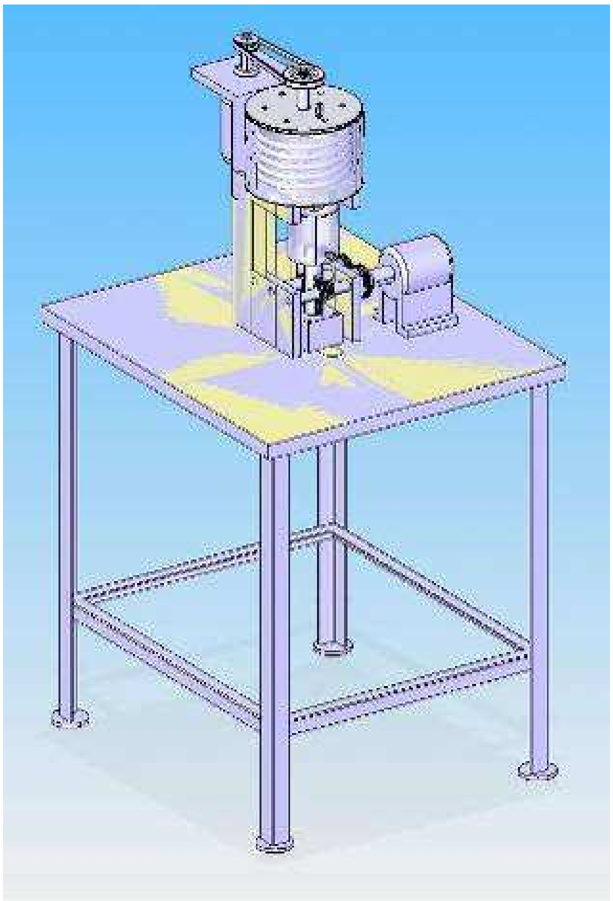

Fig. 1. The equipment for obtaining the composite material with mettalic matrix and particles reinforcement which is using the Vortex and semi continue casting

2.4. Tensile testing

Tensile testing was performed on standardized tests (EN10002-1) with the dimensions shown in table 3 (figure 2) using a tensile testing machine for INSTRON 3382 equipped with data acquisition system and specialized software Bluehill Series IXTM. Were taken into account: the speed sleeper [mm / min] and temperature [^oC]. For each composite combinations of table corresponding experiment planning have made three specimens which were tensile tested.

Table 3. Dimensions of test pieces tested

Calibrated diameter (d)	4 mm
Length between landmarks (L_{0})	20 mm
The total length (L_t)	70 mm
Length calibrated (Lc)*	30 mm

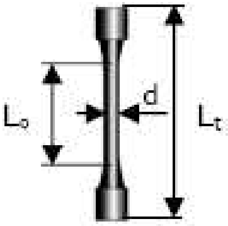

Fig. 2. Standard test-piece for tensile testing

For the base alloy (90.12% Al, 3.46% Cu, 4.8% and 0.24% Mn, 0.22% Mg, 0.4% Fe) tensile testing is shown in figure 3 and in figure 4 is presented for the test characteristic curve number 1. It can be concluded that with increasing concentration of SiC particles increased traction resistance.

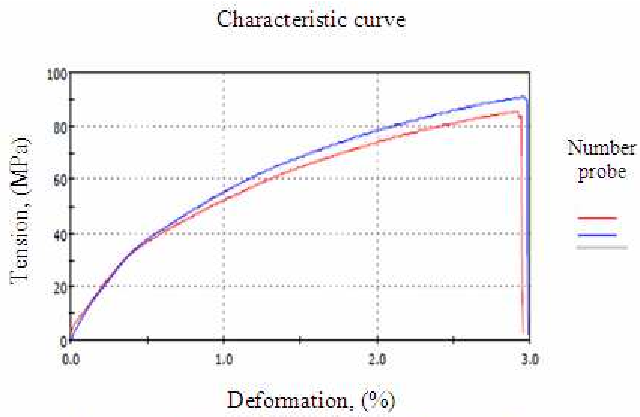

Fig. 3. Characteristic curve for the base alloy

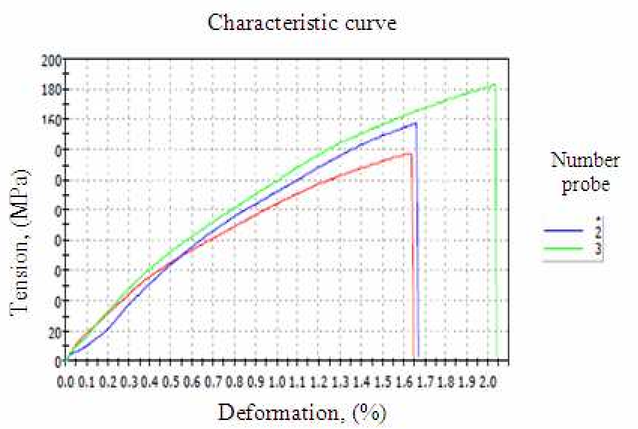

Fig.4. Characteristic curves for test number 1

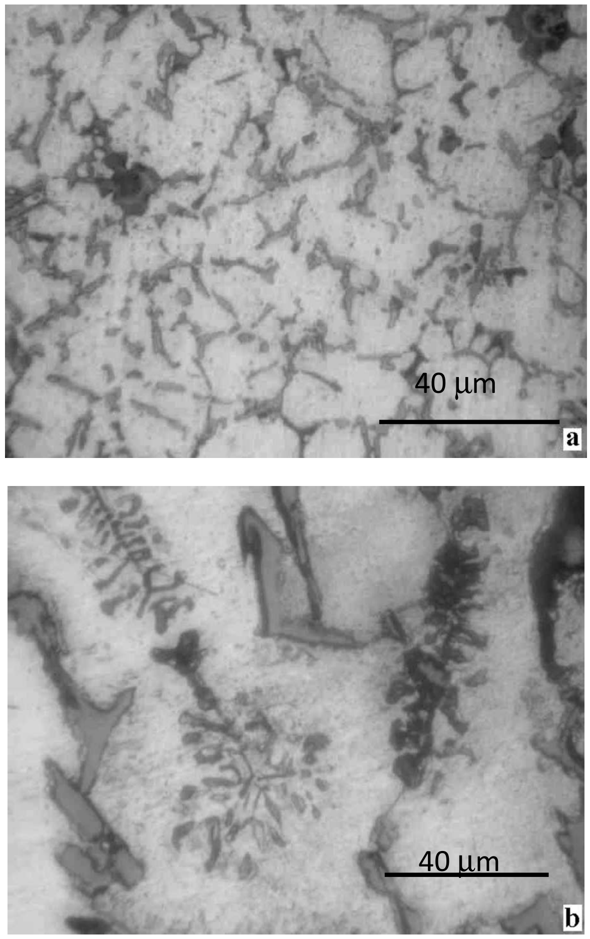

Fig. 5. The microphotos of matrix allows: a- allow ENACAlSi5Cu3; b- allow ENACAlSi7Cu2Mg

2.5. Structural Analysis

Optical microscopy and SEM microscopy were used for structural analysis matrix alloys and composites with silicon carbide particles. For optical microscopy was used an optical microscope XJP-6A equipped with image acquisition system and specialized software for metallographic image analysis (Material Plus v4.1). SEM microscopy was used for an electron microscope VEGA Tescani II LMH Detection and equipped with EDX detector for chemical analysis microareas. Working conditions were: vacuum environment (10^{-2}Pa), voltage 30kV, tungsten filament.

2.6. Fractured surface analyzing

The samples under the traction testing were exposed fracturewd surface analyzing in view of break mechanisms analyzing of composite material obtained. To fracture surface imagines acquisition electron microscope was used VEGA Tescani II LMH described above.

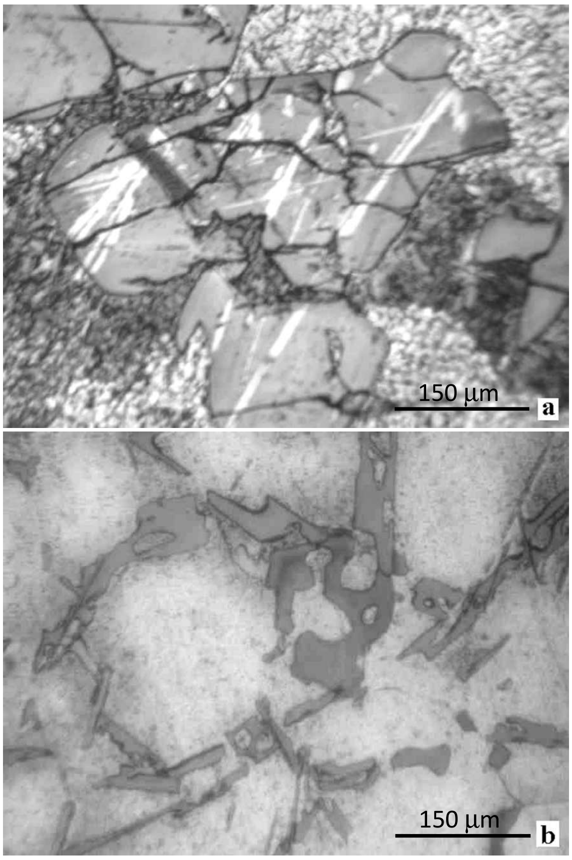

Fig. 6. The microphotos of obtained composites:
a- allow ENACAlSi5Cu3/particles SiC 200 µm;
b- allow ENACAlSi7Cu2Mg/particles SiC 40 µm.

2.7. Ultrasonic Flaw

To realize the ultrasonic testing was used with an ultrasonic transducer contact with the beam perpendicular to, or delay line:

- Dimensions (D or axb [mm]: 10
- Rated frequency [MHz]: 5
- AB Measuring range [mm]: 3-3400
- Near field length [mm]: 20
- Echo bandwidth [mm]: 1
- Reference model: G5KB-F

Device Control: USLT 2000 (Krautkramer, Germany).

3. EXPERIMENTAL RESULTS

3.1. Structural Analysis

In figure 5 are presented microphotos matrix alloys, and in figure 6 microphotos of some composites obtained experimentally.

In microphotos presented in figure 5 can be observed globular shaped dendrites, dendritic branches relatively small size, intermetallic compounds in leaf morphology network / Chinese letters or polygonal.

If microphotos composites (figure 6) is observed the existence of two components: aluminum alloy matrix and SiC particles ranfortul of.

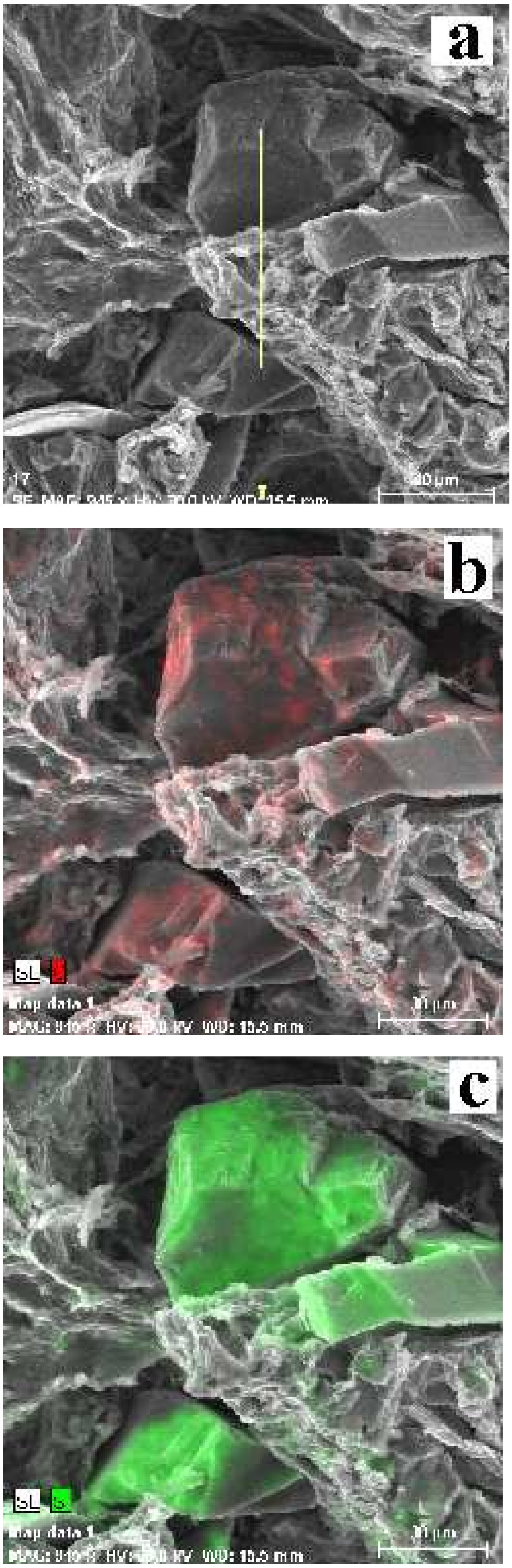

Fig. 7. The break imagines surface for ENACAlSi7Cu2Mg /particlae SiC (40 µm) surface:
a- fractured surface imagine;
b- carbon distribution;
c- Si distribution.

For larger sized particles are likely to see some fragmentation due process manufacturing technology (relatively high temperature, strong shaking of the mixture liquid alloy / SiC particles).

3.2. Fractured surface analyzing

Figure 7 presents the image of a surface breaking obtained by SEM and EDX analysis of the break surface following attempt to traction of the composite ENACAlSi7Cu2Mg/SiC particles (40µm). Note the brittle break of the composite and the existence of SiC particles in the fracture zone.

3.3. Ultrasonic Testing

Where the distance of 400 mm is presented in figure 8 the diagram of ultrasonic testing for test number 1.

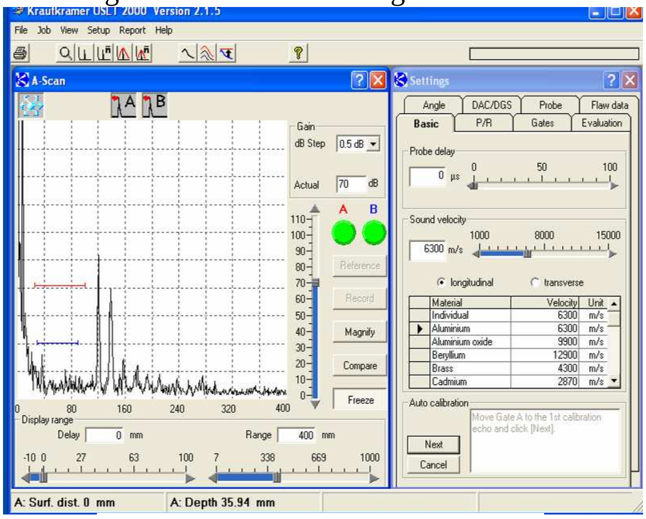

Fig. 8 Ultrasonic testing for test number 1

In this case, occurrence of very small discontinuities (porosity) which have a major influence on the tubes required to traction. Therefore we can see very clear display and an echo back.

4. CONCLUSIONS

Tensile strength compared to the base alloy used, shows an increase of about 75-114% so if reinforcement particles Si-C. Ultrasonic testing revealed the presence of very small discontinuities (porosity) which have a major influence on the tubes required to traction. Therefore we can see very clear display and an echo back.

SEM analysis of carbide particles are green (corresponding silicon) with shades of red (corresponding carbon). Distinguish between particles of metal matrix alloy used blue (corresponding to Al-Cu) with the specific nuances of alloying elements. Presence of empty spaces between particles and matrix they confirm that there is a poor wetting. Different dimensions of reinforcement particles indicate that during the process of mechanical mixing by Vortex method has been the fragmentation of particles by certain planes of cleavage.

If the distribution of aluminum metal matrix is seen as central areas and the maximum concentration of aluminum is the limit of the matrix and separated ranfort carbon are found. It is obvious that the interface formed aluminum carbide, which leads to improvement of humectability.

This carbon in silicon carbide particles is obvious and is appropriate a proportion of 30% according to the distribution of carbon in the composite material.

In the matrix is seen as a low carbon distribution confirms that during processing to form carbide Al4C3. The presence of carbides is favorable wetting process. It can be concluded that this Al4C3 carbides appeared on a poor distribution of carbon improves the wetting process.

It also noted the formation, the interface of the aluminum carbide, which leads to improvement of humectability.

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Received: 01 November 2009 / Accepted: 20 December 2009 / Abstract published online: 15 January 2010