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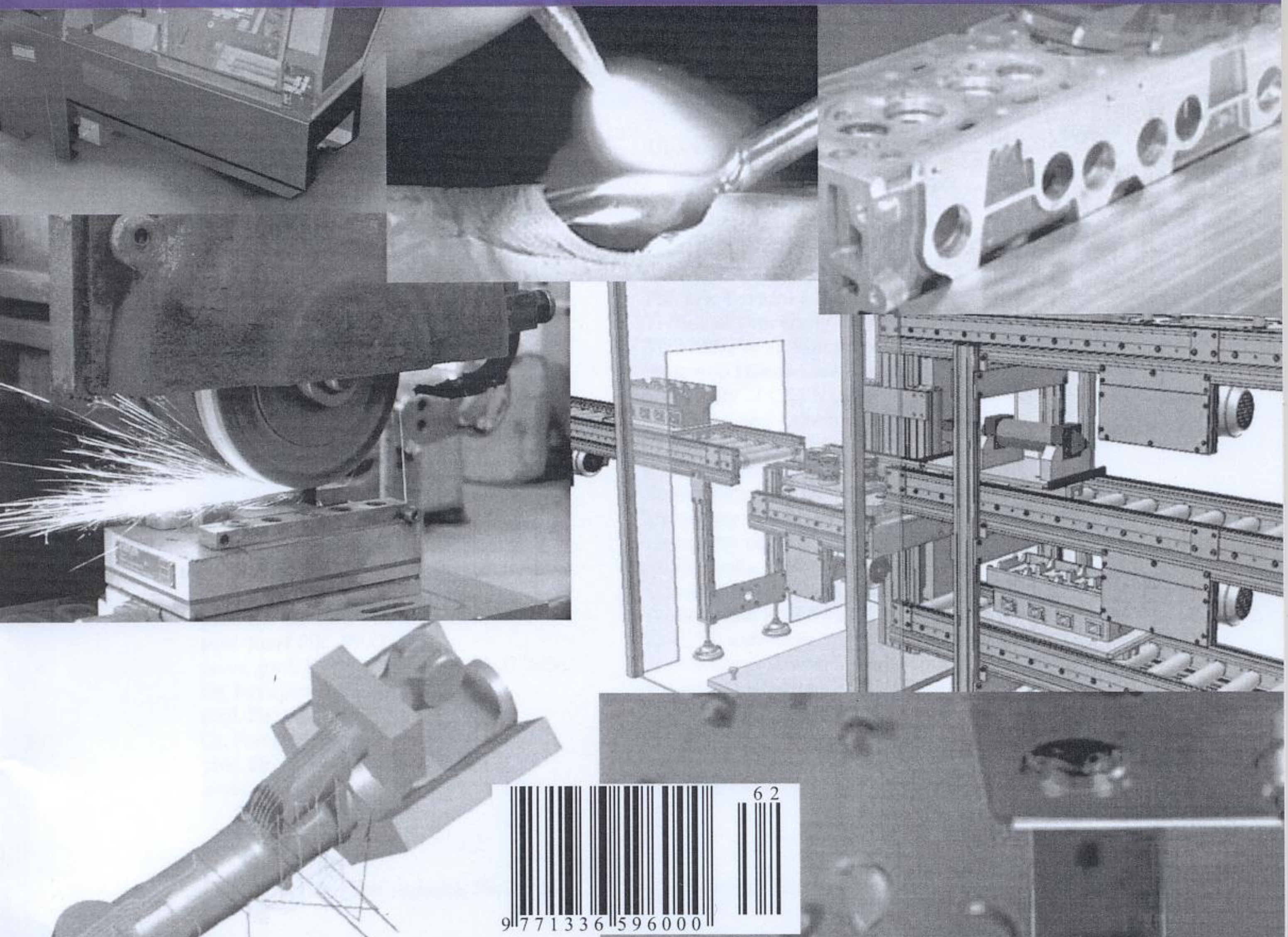

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INVESTIGATION OF ALLUMINIUM ALLOY COMPOSITION ALSI9CU3 ALLOY IN FOUNDURY PROCESS

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Abstract
In presented paper the primary melt composition of alloy AlSi9Cu3 used for production of different car body parts is investigated. The used measurement instrument was a metal analyzer ARL -3460 used for metals bases of aluminum and iron, used in combination with software ASPECT – 80. An investigation of material composition was conducted and the process and principles of selected spectrometer procedure discussed. The results are compered with calibration element for AlSi9Cu3 and main influences in accordance to selected foundry melting process of melt composition are discussed.

Keywords:
chemical composition, AlSi9Cu3 alloy, charge materials

INTRODUCTION

The usual practice of manufacturers and suppliers of charge materials (ingots) of materials is to guarantee the chemical composition for production of castings of each type of alloy. Often a guaranteed chemical composition, due to more frequent use of cheap, raw materials, does not seem to be the key to a successful production of quality castings since it is needed to take into account the interactions of many elements, [1-3] the possibilities of creating inclusions, porosity, and thus an indirect influence on many physical, mechanical and technological properties of castings. Different percent-tage of iron, bismuth also minor additions of sodium, strontium or antimony to aluminium can influence poro-sity formation in these alloys. For this reason, regular testing of the consistency for some properties of the material quality AlSi9Cu3 is conducted on the basis of norms that prescribe conditions for control and the supply of castings.

The paper describes the working principle of an optical spectrometer, which is used to quantitatively determine the concentrations of certain elements on the basis of their wavelengths and intensities.

Since it is a charge material that is designed with the aim of re-melting of alloy castings suitable quality, the absolute values of the properties were not signi-ficant, but their repeatability by segments of the sample was monitored. There was some inconsistency, the cen-tral segment of the ingot was correct, while the boundary segments showed significant deviation properties, which are largely attributed to turbulent casting and unbalanced conditions of casting cooling and solidification.

The charge material is tested for use in high pres-sure die casting cell. From [4-8] charge materials for high pressure die casting are specified. This paper investigates quality and accordance with standard for several series of charge materials.

HIGH PRESSURE DIE CASTING

Charge material is prepared for high pressure die casting and has to comply with quality requirements [4]. High pressure die casting cell from company Litostroj is used for casting of examined charge material. High start up costs is only reduced by long casting runs, this delivering low unit cost with high volume production.

In this process, the liquid metal is injected with high speed and high pressure into a metal mould. Equipment consists of two vertical plates on which the die halves are positioned. One plate is fixed and the other has a travelling path that allows the die to be opened and closed. The aluminum is poured using a ladle into a shot cylinder. After the specified amount of metal depending on the product is poured into the shot sleeve it is then introduced into the mould cavity using a hydraulically-driven piston. High pressure pushes the molten metal into the die where the solidifying process and cooling takes place, dies are often water-cooled.. During solidification depending on the quality of charge and die quality errors can occur. Once the metal has solidified, the die is opened and the casting removed. A complete die casting cycle can vary from less than one second for small components weighing less than an ounce, to two-to-three minutes for a casting of several pounds, making die casting the fastest technique available for producing precise non-ferrous metal parts. In this process, special precautions must be taken to avoid too many gas inclusions which cause blistering during subsequent heat-treatment or welding of the casting product and die. Both the machine and its dies are very expensive, and for this reason pressure die casting is economical only for high-volume production. Aluminum is used in 80 - 90 % of the high pressure die casting alloys available in the world today. In many cases aluminum high pressure die casting can replace steel, increasing strength and reducing part weight [9].

High pressure Die Casting is an ideal process for the manufacture of high volume parts (figure 1) that require high dimensional accuracy and good surface finish with a minimum of machining. Secondary operations include die trim or surface grind flash from diecasting parting lines, drilling of holes and thread or tap holes in diecasting parts. Final milling of surfaces in diecasting parts. Vibratory deburr surface finish on die-castings. Tumble deburr diecastings. Aluminum diecas-ting parts are if necesery machined to final customer specifications.

This is a repetitive process which produces high strength and allows for castings to be made with a thinner wall sections than those of the sand or gravity process e.g. 1.5 - 3mm. To be noted is that high pressure die castings cannot be heat treated, but they can be treated in order to improve dimensional and metallurgical stability.

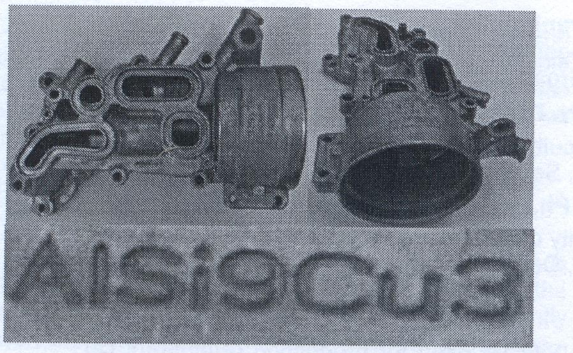

Figure 1 One of final cast products

Castings may be quenched from the side and machine size will limit casting size. Sound thick sections are difficult to cast and core configurations must be complex to enable dis-assembly. High pressure castings can suffer from porosity, although evacuated chamber and other techniques may reduce this. The charge material composition is investigated in this paper and its influence on final casting product.

3 SPECTROMETRY AND CALIBRATION

Spectrometry is a part of instrumental methods and procedures which can obtain information on the chemical composition and structure of matter based on the detection and measurement of energy changes that occur in atom. Metal analyzer 3460 (figure 2) is used to quantitatively determine the concentration of chemical elements in metal samples [5, 10] (figure 3). The instrument uses analytical software that analyzes the types of samples for elements and concentration ranges specified by the user.

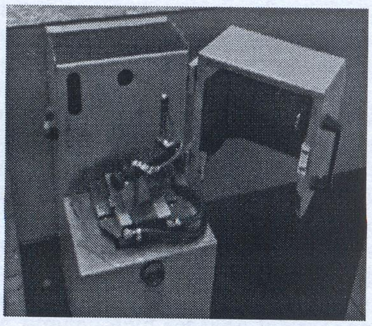

Figure 2 Chamber of metal analyzer ARL -3460

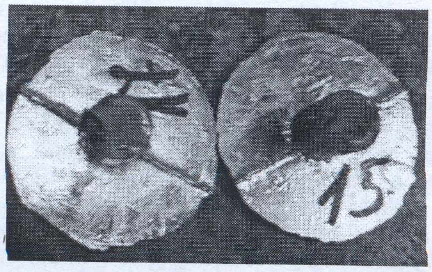

Figure 3 Test specimens of charge material alloy

When changing electron places from lower level to a higher level a photon of exact energetic state occurs /1/.

$$E = h * v = E_v - E_n. \qquad /1/$$

h - Planck constant - 6.634*10-34 Js,
E – energy of radiation,
v – frequency of electromagnetic radiation,
Ev, En – energy of higher or lower level.

The optimal chamber temperature at which the machine works is 23 ˚C, above 39 ˚C the spectrometer stops working. The electrical discharge is produced between two electrodes (the sample and the impact electrode), while the chamber is filled with argon gas. Metal analyzer 3460 calculates element concentration by using the light emitted by the discharge chamber concentration and reports its results as a percentage of concentration.

The sample should be cleaned before testing and when setting up an analysis the sample center should be avoided as the outskirts contain greater homogeneity.

The chamber analysis consists of three specific periods: prerelease of gas argon, preintegration and integration. The analysis of a sample includes the following steps: recalibration, pure state, profiling, argon cleaning filters, gap control, change the oil pumps and filters. Analytical operations include insertion of the sample and entering a few commands on the keyboard. The analysis takes 25 - 30 seconds.

3460 metal analyzer determines the concentration of elements from the measured intensity of the element. These intensities may be subject to long-term trends. Standardization or re-calibration is an operation aimed at correcting of currents by using a set of standards. The values are periodically re-measured and compared with nominal values and then performed the correction value α and β. These values are used to correct all the intensity of the sample to the next standardization.

Calibration was done with the use of a certified specimen from R&D Bonn Chemistry and surfaces, D-53014 Bonn. Certified reference material HYDRO 3048-7/1-01 for aluminium alloy Al Si9Cu3. Figure 4 shows burned marks that are remains of certified specimen testing, minimum specimen diameter is 20 mm and the burn radius is 12 mm.

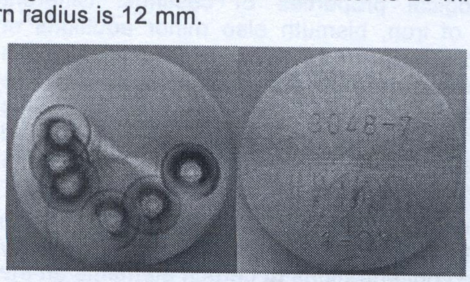

Figure 4 Calibration with certified specimen

4 SOFTWER *ASPECT - 80*

Program *ASPECT - 80* offers flexibility and overall capacity at the same time. Figure shows interface of the software.

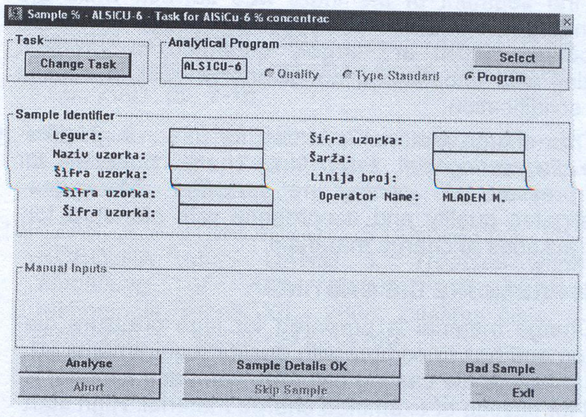

Figure 5 Interface of ASPECT - 80 software used program ALSICU-6

The main features are: Routine analysis: measures of unknown samples up to 100 elements per program. The identity of the sample: 10 fields containing up to 12 characters can be configured. Systematic configuration: complete or selective standardization can be selected at any time. Quality: allows checking the above-defined lower and upper limits. Division of Quality: allows rapid distribution of elements on the basis of product specifications Flexibility when displaying results of nine different views of results Manual entry of results: before recording the results of the possible entry of foreign analysis of optical data analysis Storing the results: the number of stored results is limited only by memory size. Statistical analysis results are stored: the calculation of average, minimum, maximum, standard deviation. Multivariable regression: an integrated package of interactive graphics for model calibration, including corrections, such as further concentration, multiple intensity correction and correction of multiple concentrations. Monitoring the status of the system: for alerts and monitoring of parameters such as vacuum, power and temperature.

5 MATERIAL

Aluminium-silicon based foundry alloys have become increasingly popular engineering materials, particularly in the transportation industry. Lightweight aluminium based castings allow designers to trim vehicle weight while maintaining performance requirements. AlSi9Cu3 is a universal alloy with very good casting properties. It is marked by less affinity to shrinkage and internal shrinkage cavities. It has very good spanabiliy, it is especially suitable for die casting. Much used universal alloy in die casting, machine and engine parts, cylinder heads, parts for electric engines, bearing blocks, casings for electric engines, bearing blocks, casings.

226D - AlSi9Cu3 (Fe) according to EN AC 46000 [6] typical analysis:
Si 8,0 % - 11,0 %, Fe 0,6 % - 1,1 %, Cu 2,0 % - 4,0 %, Mn < 0,55 %, Mg 0,15 % - 0,55 %, Cr < 0,15 %, Ni < 0,55 %, Zn < 1,2 %, Pb < 0,35 %, Sn < 0,25 %, Ti < 0,2 %.

Typical packing in 500 – 1000 kg bundles. The temperatures of the solution heat treatment [7] were 505°C, 515°C, and 525°C ± 5°C and the solution time ranged from 0 to 32 h (0, 2, 4, 8, 16, and 32 h).

Table 1

Mechanical propreties [8] *of* EN AC-AlSi9Cu3

Tensile strength Rm (min)	240 ÷ 310 MPa
0,2 % Proof stress Rp0.2 (min)	140 ÷ 240 MPa
Elongation A5 (min)	0.5 ÷ 3 %
Brinell Hardness	80 ÷120 HB
Density	2.65 G/mm2
Castability	Good
Polishability	Adequate
,Machinability	Good
Weldability	Inadequate
Electrical Conductivity	13 ÷ 17 MS/m
Thermal Conductivity	110 ÷ 120 W/m · K
Heat Resistance	+ 300°C
Cold Resistance	- 100°C
Corrosion resistance	Bad

Even under optimum melting and melt-holding conditions, molten aluminium is susceptible to three types of degradation [7]. With time at temperature, adsorption of hydrogen results in increased dissolved hydrogen content up to an equilibrium value for the specific composition and temperature. With time at temperature, oxidation of the melt occurs; in alloys containing magnesium, oxidation losses and the formation of complex oxides may not be self-limiting. Transient elements characterized by low vapor pressure and high reactivity are reduced as a function of time at temperature; magnesium, sodium, calcium, and strontium, upon which mechanical properties directly or indirectly rely, are examples of elements that display transient characteristics. The mechanical properties of aluminum alloys depend on casting soundness, which is strongly influenced by hydrogen porosity and entrained nonmetallic inclusions. In order to reliably produce high quality castings from secondary alloys, it is necessary to have an understanding of the effect of impurity elements on the castability of the alloy. Iron is a major impurity element in secondary aluminium alloys such as AlSi9Cu3, and is difficult to economically remove from melts or to reduce the concentration to low levels. Iron is soluble in liquid aluminium, but segregates strongly during solidification to form various iron-containing intermetallics. Industrial experience and previous research has indicated that the β-Al_5FeSi [11] phase is associated with damaging porosity-related defects or reject castings. Bismuth may influence the morphology of the eutectic silicon phase and may also influence porosity formation in these alloys. Minor additions of sodium, strontium or antimony to aluminium-silicon alloys may increase mechanical propreties but use of these elements may also be accompanied by changes in porosity content, or morphology, in aluminium-silicon castings. Strontium-modification was found [11] to increase the porosity content in AlSi9Cu3 alloy castings, whereas sodium-modification produced significantly lower levels.

6 RESULTS

The AlSi9Cu3 aluminium alloy is recycled most often as scrap of various sizes and therefore an examination of several series (table 2) of charge material was made.

Table 2

Chemical composition of tested melts, mas. %

Elem .	Calib. spec.	Series 1	Series 2	Series 3
Si	8,87	9,1763	9,1544	9,0571
Fe	0,863	0,7725	0,7647	0,7752
Cu	2,79	3,3668	3,211	3,1958
Mn	0,338	0,207	0,2044	0,2095
Mg	0,287	0,2223	0,2097	0,2096
Cr	0,0491	0,0298	0,0295	0,03
Ni	0,1459	0,1058	0,101	0,1
Ca	0,00204	0,0007	0,0009	0,0007
Na	0,0003	0,0013	0,0013	0,001
P	0,0044	0,0015	0,0015	0,0016
Pb	0,0906	0,0786	0,0777	0,075
Sn	0,0749	0,0398	0,0376	0,0376
Al (calc.)	85,2	84,9454	85,1677	85,26

Table 2 present testing result of 3 series of AlSi9Cu3 charges done with metal analyzer 3460 and analyzed with software *ASPECT - 80*. The results are compered with a Calibration specimen. Table 2 presents the important chemical composition of tested melts of aluminium AlSi9Cu3. The testing procedure doesn't cover element in traces like Zn, Ti, B, Be, Bi, Cd, Co, Ga, Hg, Li, Sr, V, Zr, Sb. They are considered not influential in the current production casting process. Although from [12] elements like Sr, Na, Sb, and Bi in combination with diferent amount of iron can cause morphology changes and porosity and distribution of porosity in casting. Porosity in the Sr, Na, and Sb can cause compact, isolated, intergranular pores rather than sponge-type porosity, whereas Bi influences a mixture of both morphologies.

Figure 6 shows that analyzed data from table 2 are compatible with the calibration specimen. Figure 7 represents the variation of matrix done on 9 series. Composite materials technologies offer a unique opportunity to tailor the properties of aluminium in our case 226D - AlSi9Cu3. By examination on a daily basis the matrix of series 7 and 8 has been found significantly lower than expected.

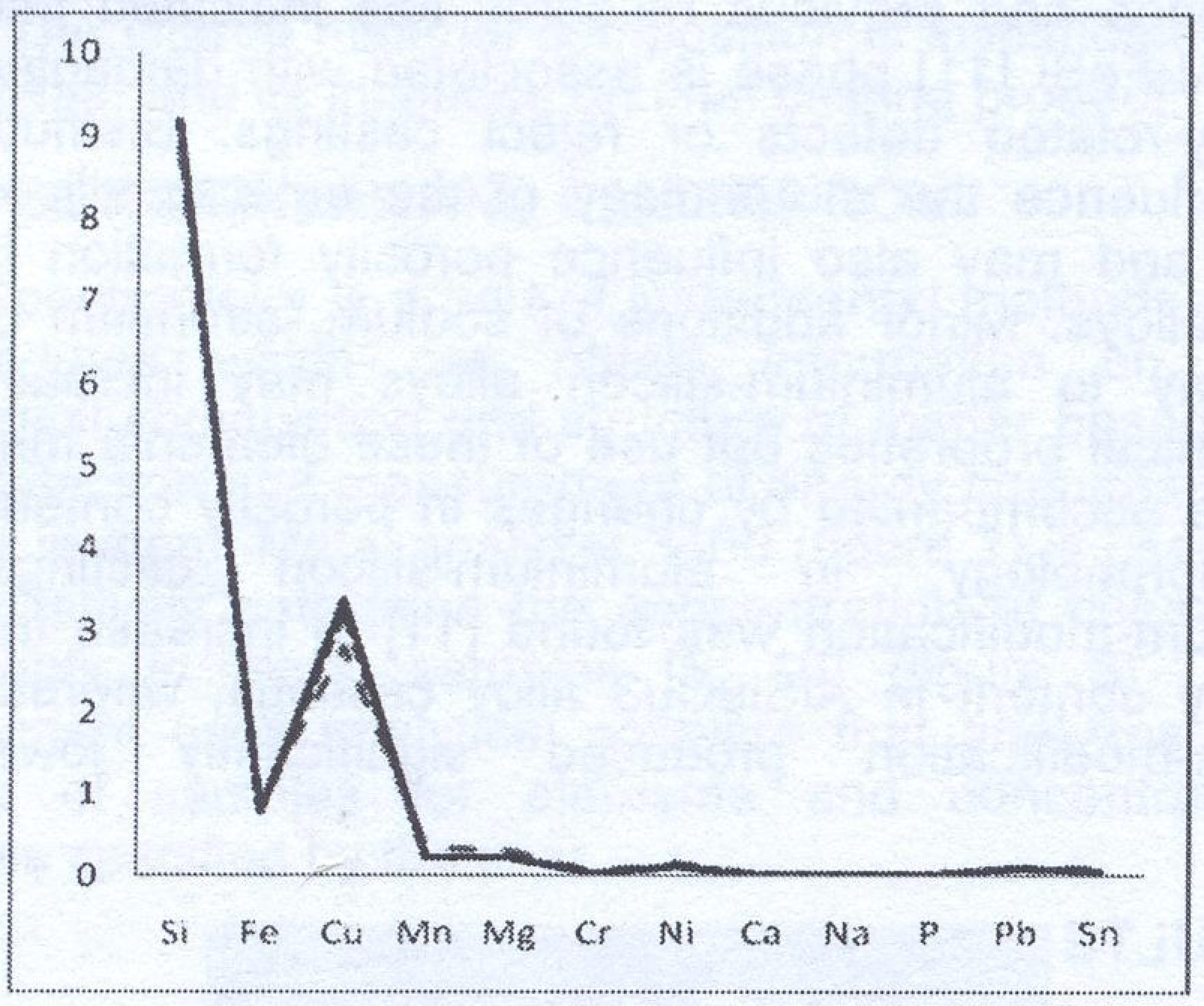

Figure 6 Comparison of series with calibration specimen

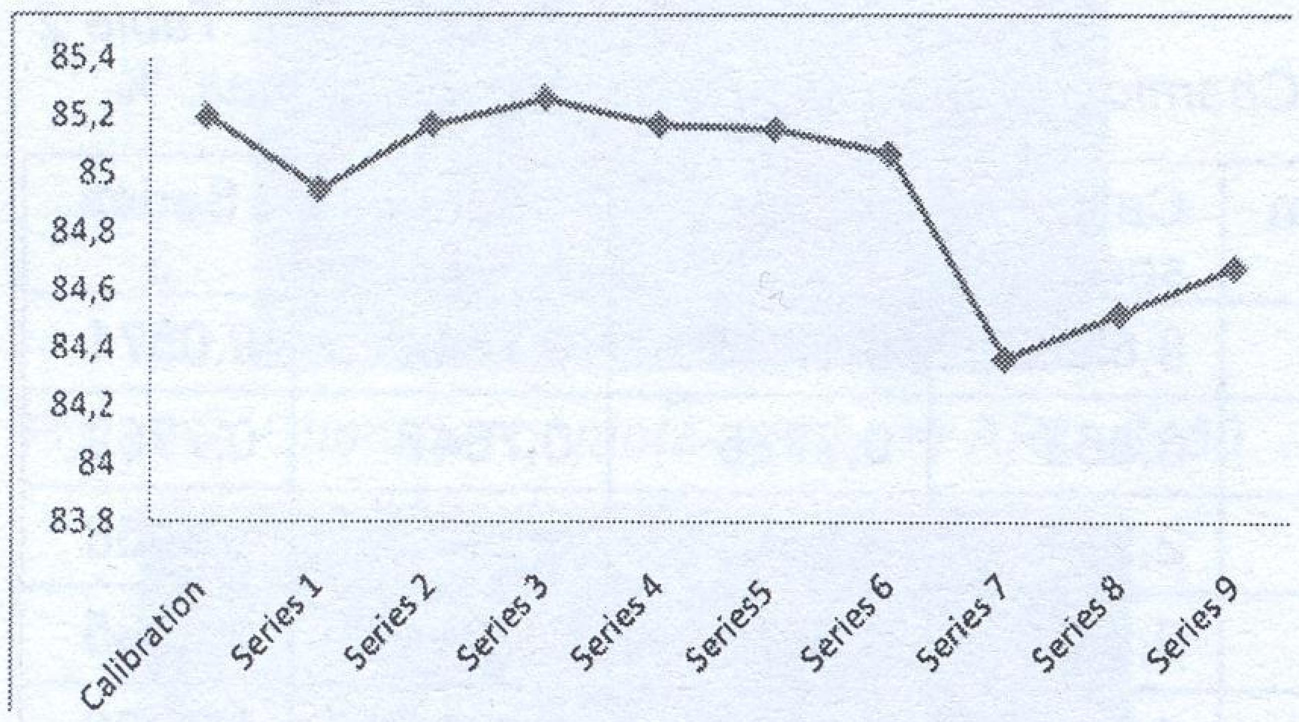

Figure 7 Variation of matrix on 9 tested series

The success of aluminium matrix composites is highly dominated by the control and the enhancement ("management") of the interfaces between the aluminium matrix and the reinforcement phase. However as the process control didn't include specifications of several elements that in combination could cause porosity. One of element combinations like TiB_2 can still be present and participate in nucleation of α-Al grains [12] even after several remelts. The cause is settling down of TiB_2 particles due to gravity and result is decrease of boron element. Iron elements can wary from ,6 to 1,1 but [11] has show that ideal amount is 0,6 therefore the amount of Fe is 0.17 higher than needed because higher amounts of iron have total greater porosity.

CONCLUSION

Testing has shown concentration of elements within given tolerances. However certain elements were not tested and the matrix examination in 9 series has shown variation in 7th series. As the scrap metal is used for remelting that can cause undesirable effects in the matrix and certain elements such as boron, titan, sodium, strontium or antimony to aluminium-silicon, bismuth should be included in further testing for beter management of final microstructure and porosity control.

Further study on porosity will be investigated in order to detect the effect of material on creation of microstructure and porosity. And effect of new element combination will be analysed for determination of changes in mechanical properties

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