FABRICATION OF AL/STEEL COMPOSITES BY VACUUM ASSISTED BLOCK MOULD INVESTMENT CASTING TECHNIQUE

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Abstract: *Metal/metal composites are a group of promising composite materials with high developing and service potential. Especially in many fields they can be a powerful low cost alternative to metal/ceramic composites. The most commonly encountered type of these composites is steel reinforced aluminium matrix composites which stand out with high wear and abrasion resistance. Significant fabrication processes of metal/metal composites are based on liquid metal techniques. In this study, Al/steel composite specimens were produced by using vacuum assisted solid mould investment casting technique. A380 aluminium casting alloy were infiltrated into steel preforms, which were produced with H13 hot-work tool steel turnings, in the plaster based solid investment casting moulds. Micro structure observations, HB hardness measurements and XRD, EDS analysis were carried out for characterization.*

Keywords: METAL/METAL COMPOSITE, AL/STEEL COMPOSITE, INVESTMENT CASTING

1. Introduction

The ultimate mechanical and physical properties can be obtained with metal matrix composites (MMCs) like specific modulus, strength, wear resistance and thermal stability. [1] Aluminium matrix composite applications largely take place in aerospace, automotive, transportation and manufacturing industries. [2] As a result of increasing demand for lightweight structures, aluminium matrix composites can find much more application fields. [3] In MMC production with any process ceramic reinforcement usage is widespread. Ceramic based reinforcements have some advantages against to metallic ones. They offer greater increases in strength and modulus, and they are commonly less dense than metallic reinforcements. However metallic reinforcements provide unique composite properties; for instance they may not decrease ductility or toughness of the matrix and they can be achieved at much lower cost. [4] For production of aluminium MMCs with steel reinforcements reported common liquid-solid methods are stir-casting and squeeze casting processes. [5, 6] In this study, vacuum assisted block mould investment casting technique was used for aluminium-steel composite fabrication as an alternative method. Vacuum assisted is utilized for liquid aluminium infiltration into steel preforms made by turnings.

2. Experimental Procedure

H13 tool steel turnings, which were used as reinforcement, were provided from a local machining workshop. The chemical compositions of steel turnings are given in Table 1. Shortened turnings were filled into a cylindrical steel mould with 20 mm in diameter and 40 mm in height and 125 MPa pressure was applied by using a mechanical press to fabricate a steel preform. A photograph of steel preforms is shown in Figure 1.

Table 1: *Chemical composition of H13 tool steel turnings (wt %)*

C	Si	Mn	Cr	Ni	Mo	V	Fe
0.50	0.20	0.25	4.50	-	3.0	0.15	Bal.

Fig 1. *Photographs of H13 tool steel preforms*

The block investment casting mould, which was used for vacuum infiltration, was prepared with a cylindrical wax pattern with 21 mm in diameter and 50 mm in height. The wax pattern was fastened to a rubber flask base and a stainless steel perforated flask was place on the base. Holes of the perforated flask were covered with an adhesive band. Plaster bonded (plaster/silica) commercial investment powder were mixed with water in the ratio of 0.40 then the slurry was filled into the flask under vibration. After 2h holding, the flask was placed into an electrical furnace for dewaxing and burnout process. According to a certain burnout regime the mould was heated up to 650 °C gradually. The steel preform was placed into mould just ten minutes before the casting; in this way preheating of the preform was provided without excessive oxidizing. The flash mould was taken out from the furnace at 650 °C and was placed into the vacuum casting machine. -105 Pa pressure was applied during the casting process. A380 alloy was melted at 730°C in an electric resistance furnace using a clay/graphite crucible, and then was cast into the mould as shown in Figure 2. Chemical composition of the A380 alloy is given in Table 2. After solidification, the mould was dipped into the water for decomposition and the cast part was taken out.

Table 2: *Chemical composition of A380 aluminium alloy (wt %)*

Fe	Si	Cu	Mn	Mg	Zn	Ni	Ti	Pb	Al
1.0	7.5-9.0	3.0-4.0	0.5	0.30	1.0	0.2	0.2	0.1	Bal.

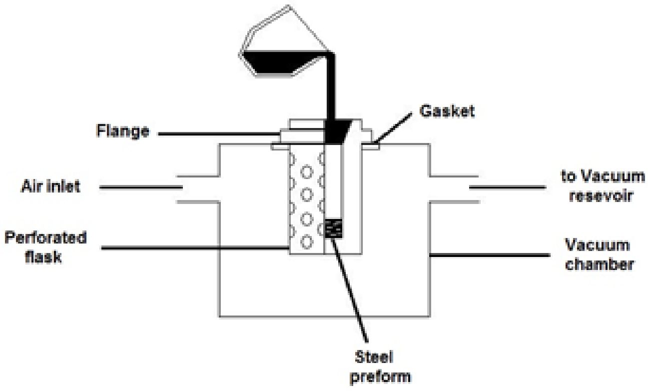


Fig2. *Schematic illustration of casting process*

Post casting, T6 heat treatment process was carried out. First, specimens were heated up to 490 °C and held 30 min. for solutioning then quenched in water and held 8 hours at 165 °C for artificial ageing. After that specimens sectioned for metallographic preparing.

3. Results and Discussion

Metallographic preparing processes grinding and polishing may not be easy for bimetallic structures with huge hardness differences. So, in order to increase hardness of aluminium matrix and reduce the difference between tool steel reinforcement, T6 artificial aging heat treatment was carried out after casting. Section microstructures of the cast specimens are given in Figure 3 with increasing light microscope magnifications.

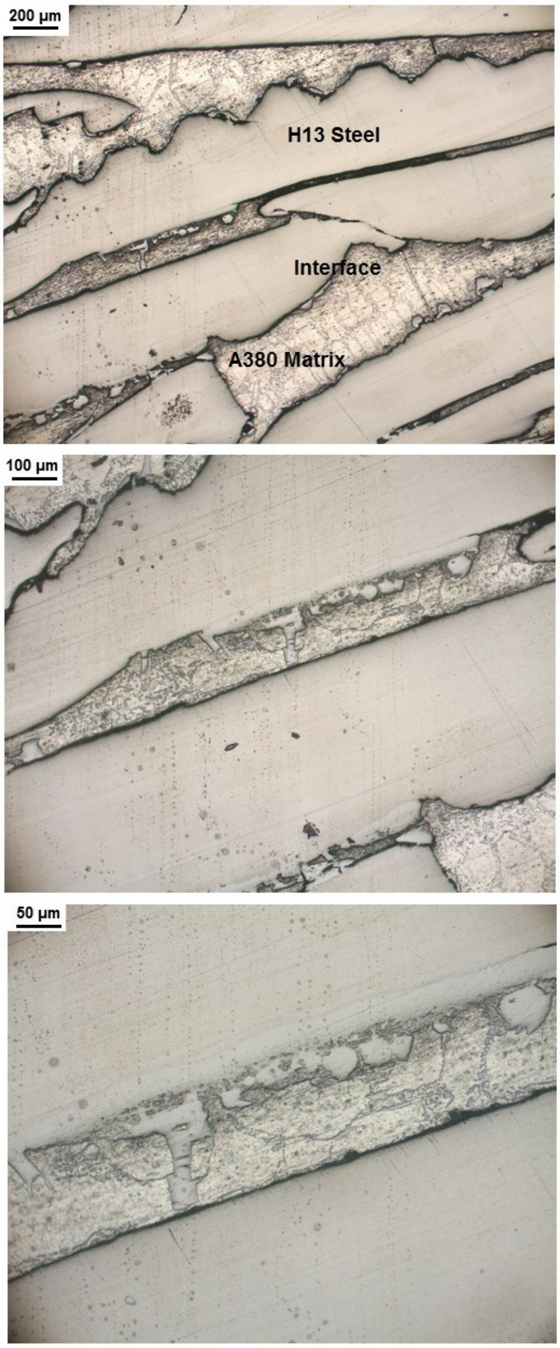


Fig 3. Light microscope micrographs of A380/H13 composite

The first observation is internal cavities of steel preforms, which were produced by pressing, were fully filled with molten aluminium A380 alloy. According to this, it can be stated that infiltration is extremely successful. During machining of the tool steel, turnings were formed as serrated and it is clearly seen on micrographs. This serration profile absolutely increases mechanical bonding ability of the steel turnings. The micrographs in higher magnifications show that, bonding between aluminium and steel is not only occurred mechanically but also metallurgical bonding transition zone which is called interface was formed. In Figure 4 SEM images of the cast specimen microstructure are seen. In lower magnification at the left side, matrix and reinforcement distribution and interface structures can be observed. In higher magnification micrograph at the right side, EDS spot analyses were carried on the transition zone as marked 1, 2 and 3. Approximate elemental content of these marked regions are given in Table 3.

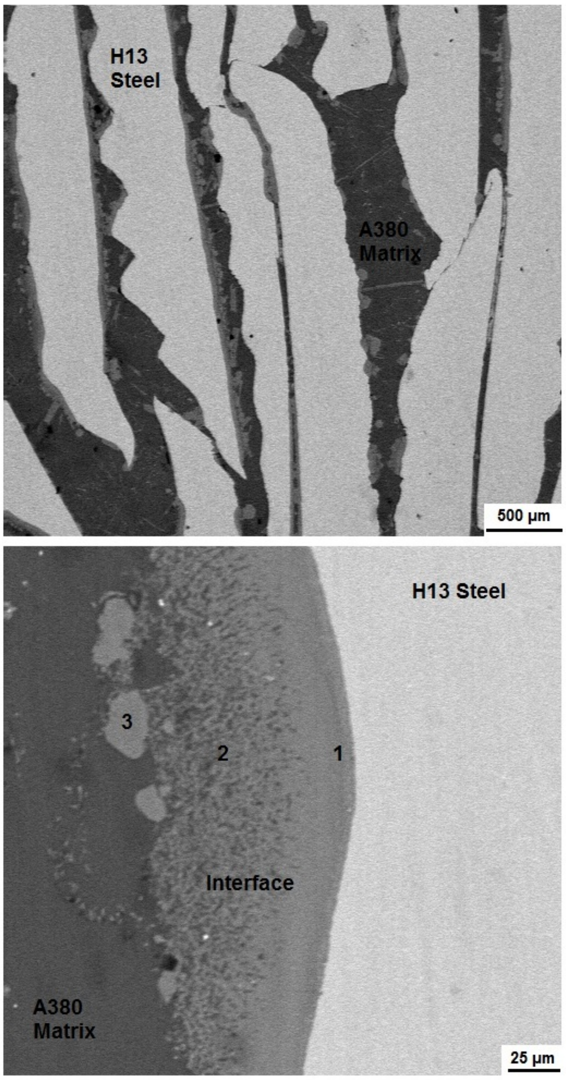
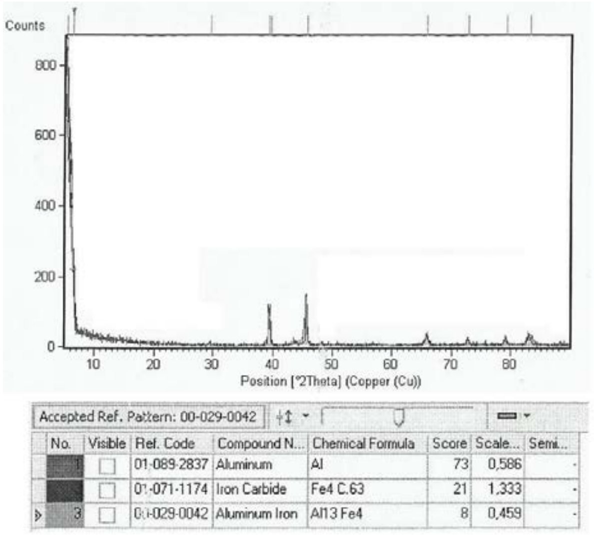


Fig 4. SEM micrographs of A380/H13 composite

Table 3: Results of EDS analysis in Figure 4

Elements (wt %)	Locations		
	Region 1	Region 2	Region 3
Al	29.128	35.763	31.763
Si	6.259	14.069	7.085
Cr	3.248	4.825	4.645
Fe	52.210	36.027	51.628
Cu	9.154	9.316	4.879

Region 1 is close to the reinforcement phase so, its iron content is higher and aluminium content is lower conversely region 2 is close to matrix phase and its aluminium content increased and iron content decreased. Region 3 is on an intermetallic precipitate in front of the interface and its iron content is higher than region 2 thus it can be said that it is a Fe-Al intermetallic formation. Also this formation is supported by XRD analyses, and its result pattern is given in Figure 5. According to this, elemental aluminium, iron carbide and Fe-Al intermetallic were determined.



Accepted Ref. Pattern: 00-029-0042

No.	Visible	Ref. Code	Compound N...	Chemical Formula	Score	Scale...	Semi...
1	☐	01-089-2837	Aluminum	Al	73	0,586	-
	☐	01-071-1174	Iron Carbide	Fe4 C.63	21	1,333	-
3	☐	00-029-0042	Aluminum Iron	Al13 Fe4	8	0,459	-

Fig 5. *XRD pattern of A380/H13 composite*

However small specimens were produced, in order to get idea about mechanical behaviours of the phases, Vickers micro hardness tests were carried out and results are given as a histogram in Figure 6.

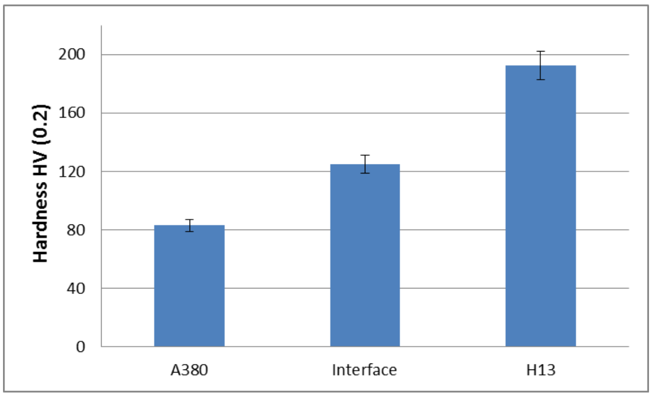


Fig 6. *Vickers hardness measurements of A380/H13 bimetal composite specimen*

4. Conclusion

The liquid aluminium alloy infiltration into tool steel preforms was performed with vacuum assisted solid mould investment casting technique and as a result bimetal composite structure was produced. Two significant features stand out in this study, first is using tool steel turnings which is a kind of waste material and second is vacuum assisted infiltration. Using turnings as reinforcement material can provide considerable cost advantage and vacuum infiltration is a strong alternative to squeeze casting which is common in literature. Vacuum assisted casting processes require simpler equipment and more controllable methods. In experimental works, block mould investment casting is preferred as an instance of vacuum assisted casting, because foundry equipment appropriate to this technique. As the last word, aluminium matrix and tool steel reinforcement bimetal composite structures would be extremely useful for high wear resistance demands.

5. References

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