# PRELIMINARY MICROSTRUCTURE AND HARDNESS STUDIES OF A356/STAINLESS STEEL COMPOSITE VIA GRAVITY DIE CASTING TECHNIQUE

M.N. Mazlee, J.B. Shamsul, K. Hussin, S.S. Rizam, K. Ismail*
*School of Materials Engineering, Universiti Malaysia Perlis (UniMAP). 02600 Arau, Perlis, Malaysia*
*e-mail: mazlee@unimap.edu.my*
*Department of Applied Sciences, Universiti Teknologi MARA (UiTM), Perlis Branch, Arau Campus, 02600 Arau, Perlis, Malaysia*

**Abstract**
The microstructure and hardness of A356/stainless steel composite via gravity die casting technique were evaluated. Both nearly completed bonding and incomplete bonding was seen at the stainless steel wire-A356 matrix interface (abbreviated as interface). The variation of microhardness readings across the interface demonstrated the decreasing trend from the centre of stainless steel wire to the A356 matrix alloy. The microhardness at the interface showed the intermediate reading between the stainless steel wire and A356 matrix alloy. Heavily concentrated of needle-like structure at single stainless steel wire as compared to that of double stainless steel wires. Globular structure can be seen in a larger size around single stainless steel wire compared to double stainless steel wires.

*Keywords:* A356 matrix alloy, stainless steel wire, gravity die casting.

## Introduction
The unique properties of the fibre reinforced composite materials are to a great extent dependent on the unique nature on the fibre-matrix interface which can be defined as the region of significantly changed chemical composition constituting the bond between the matrix and the reinforcement for transfer of loads between these members of the composite structure [1]. Fabrication technique and optimum fabrication parameters play the crucial roles in determining the resulted fibre-matrix interface. Major fabrication methods used for aluminium metal matrix composites are stir casting, squeeze casting, compocasting, liquid infiltration, spray deposition, direct melt oxidation process and powder metallurgy [2]. Recently, aluminium-stainless steel composites have gained the attention due to the low cost of fabrication, the sustainability issue of the stainless steel and the potential to be used particularly for wear applications. Only few research regarding microstructure have been conducted on the aluminium-stainless steel composites system via die casting technique [3] and liquid infiltration technique [4]. The microstructural changes in the matrix alloy was induced by the fabrication parameters and thus gave the impact to the interface bonding between the matrix and the reinforcement. Interfacial bonding of aluminium-stainless steel is more ductile and is desirable in metal matrix composites relatively [2]. Eventhough the strong interface bonding is preferable for the improved mechanical properties, the poor interfacial bonding has a better damping capacity at the expense of strength as compared with the strong interfacial bonding [5]. No attempt so far was made to study the microstructure and hardness of the A356/stainless steel composite. This research presents on the study of microstructure and hardness of A356/stainless steel composite via gravity die casting technique.

## Experimental Procedure
*Materials*
The matrix alloy used in this present work were primary cast ingot A356 (Al-7%Si-0.3%Mg) alloy and stainless steel wires of 500 µm diameter were used as the reinforcement.

*Procedure*
Stainless steel wires were aligned at the uniform distance and fixed on a stainless steel mould of 30 mm height and 90 mm diameter. The matrix alloy was melted in a muffle furnace using a clay crucible. Matrix alloy was heated up to 850°C within 2 hours before poured into the preheated stainless steel mould. Optical micrographs were captured using Image Analyzer equipment. Hardness readings were obtained using Vickers microhardness equipment to measure the hardness variation from the centre of the stainless steel wire to the A356 matrix alloy.

## Results and Discussion
Figure 1 shows the microstructure of the A356/stainless steel composite with the majority of the globular structure and the minority of the needle-like structure. It can be seen the porosities (irregular black areas)

in the A356 matrix alloy and incomplete bonding at the interface as denoted by I. However, nearly completed bonding was achieved at the interface as denoted by C.

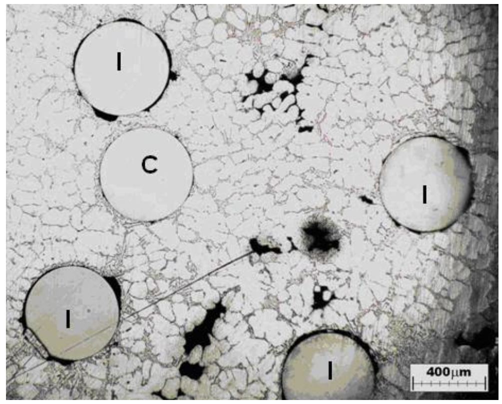


**Figure 1** : Optical micrograph shows stainless steel wires in A356 matrix alloy. Nearly completed bonding interface and incomplete bonding interface were denoted by C and I respectively.

Referring to the Figures 2a and 2b, it shows the variation of Vickers microhardness from the centre of the stainless steel wire to the A356 matrix alloy. The variation of microhardness readings across the interface demonstrated the decreasing trend from the centre of stainless steel wire to the A356 matrix alloy. The microhardness at the interface showed the intermediate reading between the stainless steel wire and A356 matrix alloy. This result was contradicted to the h by Yee-Her Hwang et. al (1997) which indicated that the hardness at the interface were much higher comparatively. They found that the composite degradation after exposure at elevated temperature was due to the formation of irregular, ternary (Fe,Cr)Al intermetalic compound at the interface. The intermediate hardness at the interface in this study was due to the insufficient exposure time during heat treatment process.

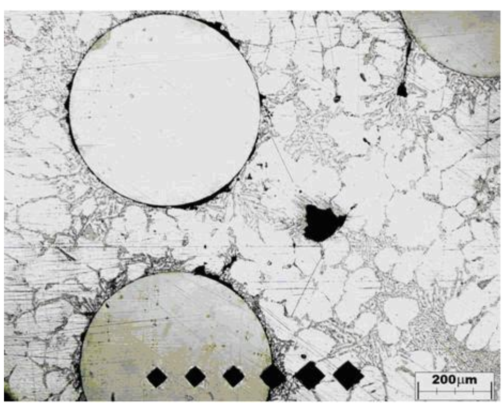


**Figure 2a** : Optical micrograph of the double stainless steel wires.

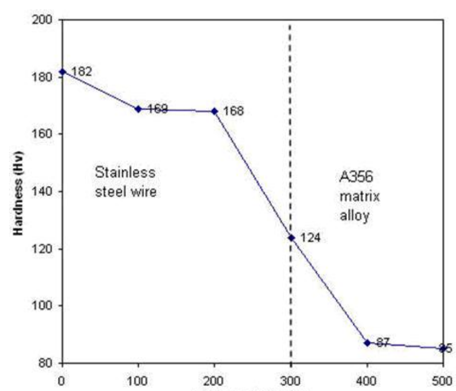


**Figure 2b** : Variation of Vickers microhardness from the centre of the stainless steel wire to the A356 matrix alloy.

Heavily concentrated of needle-like structure at single stainless steel wire was observed in Figure 3 as compared to that of double stainless steel wires in Figure 2a. Meanwhile, globular structure can be seen in a larger size around single stainless steel wire compared to that of double stainless steel wires. These features may be due to the faster solidification rate around the single stainless steel wires compared to double stainless steel wire. A finer needle-like structure can be seen clearly around the single stainless steel wire as shown in Figure 4.

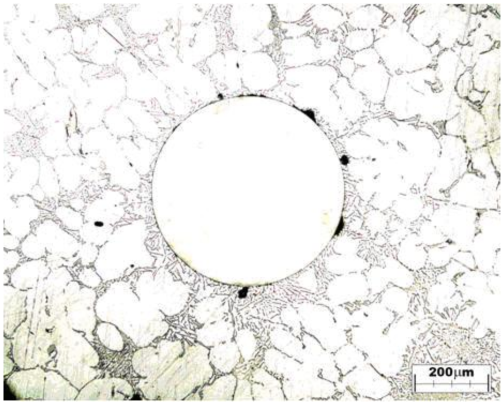


**Figure 3** : Optical micrograph of single stainless steel wire.

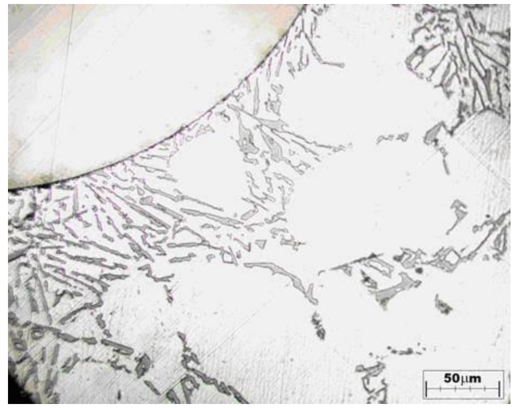


**Figure 4** : Closed up of single stainless steel wire interface.

**Conclusions**

1) Both nearly completed bonding and incomplete bonding were seen at the stainless steel wire-A356 matrix interface.
2) The variation of microhardness readings across the interface demonstrated the decreasing trend from the centre of stainless steel wire to the A356 matrix alloy.
3) Heavily concentrated of needle-like structure at single stainless steel wire as compared to that of double stainless steel wires.
4) Globular structure can be seen in a larger size around single stainless steel wire compared to double stainless steel wires.

**Acknowledgement**

The authors are grateful to UniMAP for financial support under Short Term Grant (Acc. No: 9003-00021).

**References**

[1] A.G. Metcalfe, Introduction and Review in "Composite Materials", **1**, "Interfaces in Metal Matrix Composites", Academic, New York (1974).
[2] T.P.D. Rajan, R.M. Pillai & B.C. Pai, Review: Reinforcement Coatings and Interfaces in Aluminium Metal Matrix Composites, *J. Mater. Sci.*, **33**, (1998), 3491-3503.
[3] S.N. Tiwari, A.N. Tiwari & V. Gopinathan, High Temperature Interfacial Studies in Aluminium-Stainless Steel Composites, *J. Mater. Sci.*, **22**, (1987), 2680-2684.
[4] R.B. Bhagat, Growth Kinetics of Interface Intermetallic Compounds in Stainless Steel Fibre Reinforced Aluminium Matrix Composites, *J. Mater. Sci.*, **24**, (1989), 1496-1502.
[5] Jinhai Gu, Xiaonong Zhang, Mingyuan Gu, Zhenyi Kiu & Guoding Zhang, The Damping Capacity of Aluminium Matrix Composites Reinforced with Coated Carbon Fibres, *Mat. Lett.*, **58**, (2004), 3170-3174.
[6] Yee-Her Hwang, Ching-Fu Horng, Su-Jien Lin & Kuo-Shung Liu, Interface Study for Stainless Steel Fibre-Reinforced Aluminium Matrix Composite, *J. Mater. Sci.*, **32**, (1997), 719-725.