Fatigue Analysis of Al/Fly Ash Composite from Coal Waste using Hot Isostatic Pressing

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ABSTRACT

Hot isostatic pressing is one of the method applied in powder technology to produce high density material. This research aims to investigate physical and mechanical properties of aluminium-fly ash composite made by hot isostatic pressing. Material uses was aluminium powder ($\leq$ 53 µm)as matrix and fly ash powder as filler ($\leq$ 53 µm). Fly ash powder was calcined at 800^o C for 3 hours. Aluminium and fly ash composition were 95%, 100%, and 5%, 0 % weight fraction. Mixtures were stirred for 5 hours and pressed using 50 MPa and 100 MPa pressure to obtain green compacts. Te green compacts were hot isostatically pressed by 120 MPa pressure at temperature variation of 520^o C, 540 ^{o}C, and 570 ^{o}C using 1 hours holding time. Fatigue analysis showed that optimum fatigue resistance was obtained at composition of aluminium95%-5% fly ash composite made by hot isostatic pressing at 540 ^{o}C, 120 MPa pressure, and 1 hours holding time. This composite produced minimum fatigue rate of 0,005 mm^3/Nm. The specimen experienced in situ reaction caused by aluminium oxidation during sintering process.

Keywords: *Hot isostatic pressing*, aluminium- *fly ash* composite, mechanical properties

INTRODUCTION

Composite is widely developed for various purposes such as airplanes, motor vehicles, and other areas that required high strength material, but light in weight. Composite is a combination of two or more materials that unequal in shape and chemical compositions both microscopically and macroscopically

Metal composites can be fabricated by molding or powder methods. However, molding methods have drawback in producing homogeneity. Reinforced particles are tending to float or precipitate due to density differences. Meanwhile, powder methods can produce homogeneity by appropriate mixing between metals and reinforced particles. The mixtures are pressed and sintered at certain temperature to obtain homogeneity

Aluminium is a frequently used material in machines components, particularly in form of alloy. Superiority of aluminium compared to other metals is in high corrosion resistance, electrical conductivity, heat conductivity and decorative property.

Fly ash is formed at temperature of 920-1200 ^{o}C and collected as ash precipitator and cenosphere. Cenosphere has low density 0.6 g.cm^{-3} and can be utilized as ultra-light material composite. Meanwhile, the density of ash precipitator is 2,0-2,5 g.cm^{-3} (Bienas, et al, 2003). According to Landman (2003) and Bienas et al (2003), the main composition of fly ash is silica and alumina with magnesium oxide and calcium oxide as minority.

Metal composite using aluminium matrix as reinforced material such as SiC, SiO_2, Al_20_3, aluminosilicates, graphite, and *fly ash* produce better mechanical properties (Ejiofor et al., 1997). Volume fraction affects fatigue property and material strength linearly (Kobayashi et al.,1998). This phenomena will be investigated in the production of Al-fly ash composite using powder method.

METHODS

Materials

Powder of AK12 ($AlSi_{12}CuNiMg$) used as base matrix. Microstructure photograph of material can be seen in Fig. 1

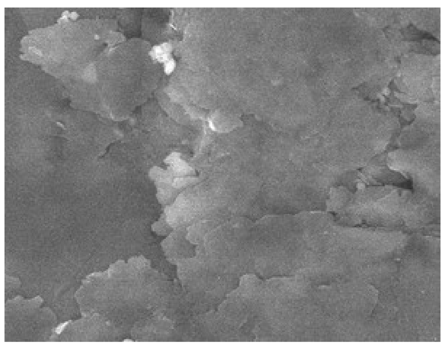

Fig.1. Aluminium powder under SEM.

Powder fly ash with particle size of 53-100 nm used as reinforced material as shown in Fig 2.

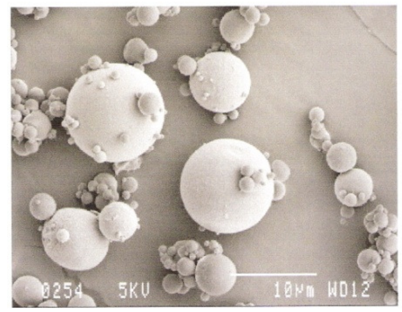

Fig. 2. Fly ash particles under SEM

Composite Production

Composite production using hot isostatic pressing method was conducted according to the following steps (Fig 3).

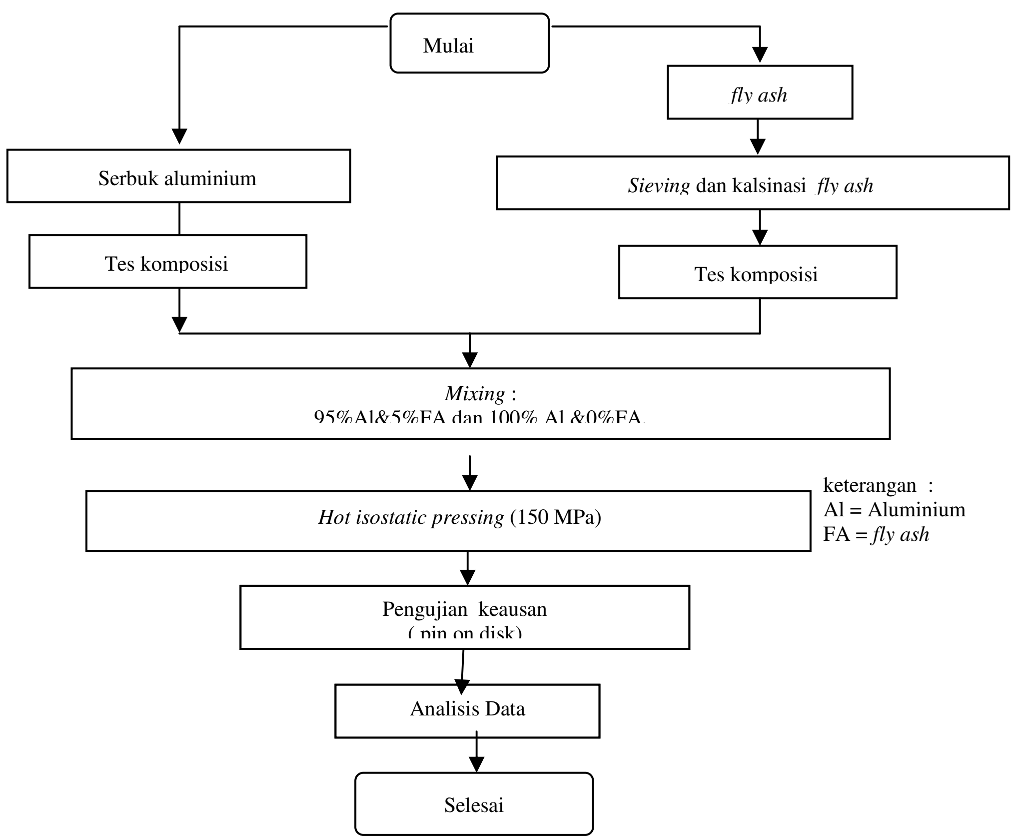

Fig 3. Composite fabrication steps

RESULTS AND DICUSSIONS

Fatigue analysis was conducted using pin on abrasive disc method on cylindrical specimen that previously sanded according to ASTM standard (ASTM G 99-95a, 2003). Relative fatigue was calculated based on loss of specimen weigh (pin) by abrasion using 1,4 µm surface roughness disc rotated at 80 rpm and 1.7 kg load. Rate of fatigue was measured by abrasion volume per load and abrasion distance.

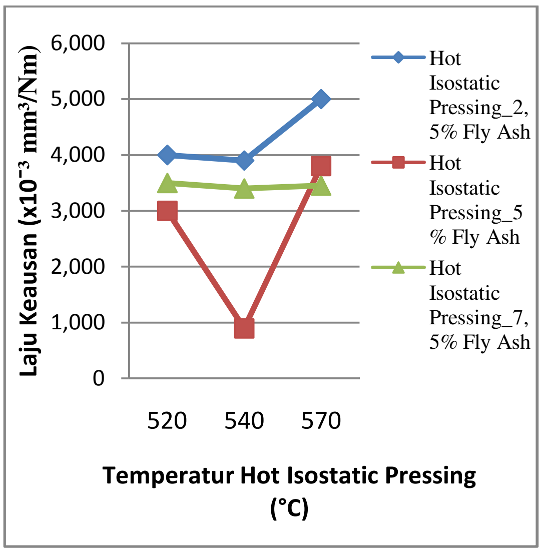

Fig 4. Effect of sintering temperature on fatigue rate

Result of fatigue analysis is shown in fig 4. The lowest rate was obtained at 540 °C that produced fatigue rate 0,016±0,0057 mm³/Nm indicating the high resistance of material. On other hand, the highest rate was produced at 520 °C with fatigue rate of 0,034±0,0007 mm³/Nm in accordance with the results of hardness test and density measurement. Both material density and hardness are the lowest.

Fly ash addition at pecentage of 5% was reduced fatigue rate to 0,016±0,0057 mm³/Nm compared to fatigue rate at 100% aluminium , i.e. 0,188±0,016 mm³/Nm. This result indicates an increase in fatigue resistance due to fly ash addition in accordance with Miyajima (2003). Smaller fly ash particles with hard and round shape can fill the aluminium matrix well. Higher density will produce higher fatigue resistance, therefore will decrease fatigue rate.

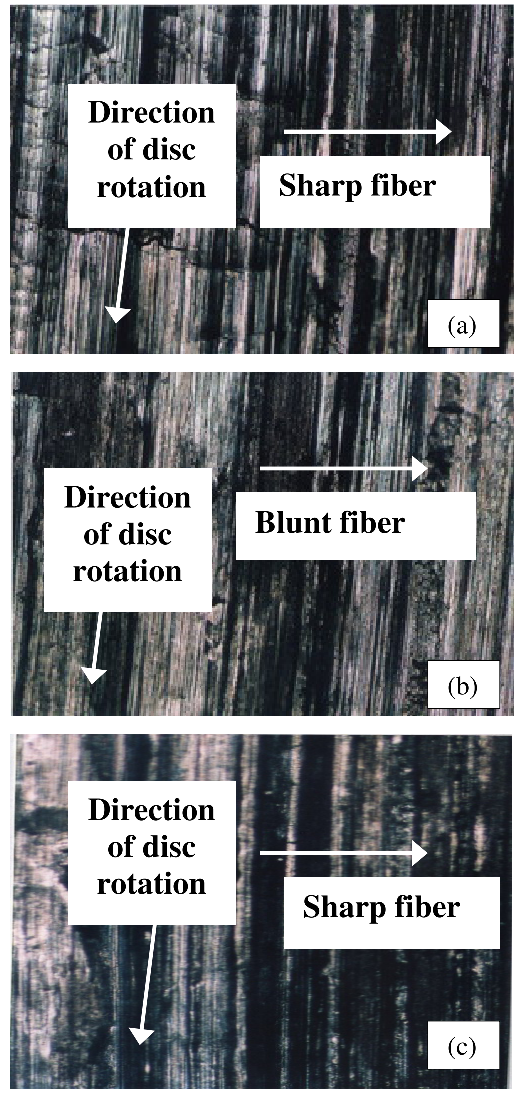

Fig 5. Surfaces of composites consist of aluminium/5% *fly ash* at sintering temperatures (a). 520°C, (b) 540°C dan (c) 570°C.

Observation of material surfaces in Fig 5. shown the formation of blunt fibers on highly fatigue material (5a) compared to sharp fibers of low fatigue material (5c).

REFERENCES

ASTM., 2003, *"Annual book of ASTM Standards"*, Section 3, Volume 03.01, pp. 234-235, Baltimore, MD, U.S.A.

ASTM., 2003, *"Annual book of ASTM Standards",* Section 3, Volume 03.02, pp. 429-433, Baltimore, MD, U.S.A.

Bienias, J., Walczak, M., Surowska, B., dan Sobezak, J., 2003, *"Microstructure and corrosion behaviour of aluminum fly ash composites",* Journal of Optoelectronics and Advanced Materials, Vol.5, No.2, June 2003, pp. 493-502.

Ejiofor, J.U. dan Reddy R.G., 1997, *"Developments in the processing and properties of particulate Al-Si composites",* Journal JOM, 49 (11), pp. 31-37.

Filho, A.L., Atkinson, H., dan Jones, H., 1998, *"Hot isostatic pressing of metal reinforced metal matrix composites"*, Journal of Materials Science 33, pp. 5517-5533.

Froyen, L. dan Verlinden, B., 1994, "*Aluminium Matrix Composites Materials*", Training in Aluminium Application Technologies (TALAT) Lecture 1402, pp. 12.

German, R.M., 1994, *"Powder metallurgy science"*, 2nd Edition, pp. 318-321, Metal powder industries federation, New Jersey.

Hatch, J.E., 1999, *"Aluminum properties and physical metallurgy",* 9nd Edition, American society for metals, Metal park, Ohio.

Ismail, I., Jamasri, Wildan, M. W., 2004, *"Pengaruh komposisi fly ash dan aluminium silikat terhadap sifat fisis dan mekanis fly ash glass-ceramics"*, Prosiding Seminar Nasional Teknologi dan Aplikasi Piping Engineering, Jurusan Teknik Mesin Fakultas Teknik UGM, Yogyakarta, pp. 43-47.

Izciler, M. dan Muratoglu, M., 2003, *"Wear behaviour of SiC reinforced 2124 Al alloy composite in RWAT system"*, Journal of Materials processing Technology 132, pp. 67-72.

Kobayashi, M., Funami, K., Suzuki, S., dan Ouchi, C., 1998, *"Manufacturing process and mechanical properties of fine TiB dispersed Ti-6Al-4V alloys composites obtained by reaction sintering",* Materials Science and Engineering A 243, pp. 279-284.

Landman, A.A., 2003, "*Aspects of solid-state chemistry of fly ash and ultramarine pigments"* University of Pretoria etd.

Miyajima, T., dan Iwai, Y., 2003, *"Effects of reinforcements on sliding wear behavior of aluminum matrix composites",* Wear 255, pp. 606-616.

Nurzal, Jamasri, Wildan, M. W., 2004, *"Pengaruh komposisi fly ash dan aluminium silikat terhadap sifat fisis dan mekanis fly ash glass-ceramics"*, Prosiding Seminar Nasional Teknologi dan Aplikasi Piping Engineering, Jurusan Teknik Mesin Fakultas Teknik UGM, Yogyakarta pp. 48-52.

Rusianto, T., Wildan, M. W. dan Rochardjo, H.S.B., 2004, "*Pengaruh tekanan kompaksi dan suhu sintering terhadap densitas dan sifat mekanik aluminium",* Proceeding Seminar Nasional Perkembangan Riset dan Teknologi di bidang Industri, Yogyakarta.

Setyana, L.D. dan Wildan, M. W., 2004, "*Pengaruh tekanan kompaksi dan kandungan grafit terhadap sifat fisis dan mekanis pada komposit al/grafit",* Proceeding Seminar Nasional Perkembangan Riset dan Teknologi di bidang Industri, Yogyakarta.

Setyana, L.D. dan Tarmono, 2005, "*Pengaruh kadar* TiO_2 *terhadap Sifat Fisis dan Mekanis Komposit Matrik Logam Al-*TiO_2", Media Teknik, No.3 Th. XXVII, Edisi Agustus 2005, Fakultas Teknik Universitas Gadjah Mada, Yogyakarta.

Surappa, M.K., 2003, *"Aluminium matrix composites: Challenges and opportunities ",* Sadhana, Vol. 28, Parts 1 & 2, February/April 2003, pp. 319–334, India.

Thumler, F. dan Oberacker, R., 1993, "*An Introduction to Powder Mettalurgy",* Book 490, The Institute of Materials, London.

Verlinden, B. dan Froyen, L., 1994, "*Aluminium Matrix Composites Materials*", Training in Aluminium Application Technologies (TALAT) Lecture 1401.

Xu, Z.M., Loh, N.L. dan Zhou, M. 1997, *"Hot isostatic pressing of cast SiCp-reinforced aluminium-based composites"*, Journal of Materials Processing and Technology, USA, Vol. 67, Nos. 1-3, pp. 131-136.