The 25th Conference of the Mechanical Engineering Network of Thailand
October 19 – 21, 2011, Krabi

Preparation of PM Fe-FeAl and Fe-Fe_2Al_5 Composites

Pitakrattanayothin S[1], Naknaka S[1], Sumol P[2], Morakotjinda M[3], Yodkaew T[3], Vetayanugul B[3], Krataitong R[3], Torsangthum N[3] and Tongsri R[3*]

[1]Department of Chemistry, Faculty of Science, King Mongkut's Institute of Technology Ladkrabang, Chalongkrung Rd. Ladkrabang, Bangkok 10520 Thailand
[2]Department of Material Engineering, Faculty of Engineering, Prince of Songklanakarin Unversity, 15 Karnjanavanit Road Hat Yai Songkhla 90110 Thailand
[3]Powder Metallurgy Research and Development Unit, National Metal and Materials Technology Center, 114 Paholyothin Road, Klong 1, Klong Luang, Pathum Thani 12120 Thailand
*Email: ruangdt@mtec.or.th, Tel.: 02 564 6500 Ext. 4702, Fax: 02 564 6403

Abstract

Intermetallic iron aluminides are promising for high temperature engineering applications due to their excellent elavated temperature strengths and high corrosion resistance. Iron alumides prepared by pressureless sintering of blended Fe and Al powders, however, cannot be used for structural applications directly as the materials contain crack and porosity. In this paper, the pressureless sintered FeAl and Fe_2Al_5 powders were used as reinforcements in Fe-base composites. They were mixed with pure Fe powders with varied iron aluminide contents of 10, 20 and 30 wt.%. The compacts of mixed iron aluminide and Fe powders were sintered under controlled atmosphere at 1150 °C for 45 minutes. Compared to non-reinforced sintered Fe specimens, the sintered Fe composites with 10 wt.% iron aluminde reinforcement showed improved tensile strengths and hardness. Density of the aluminide-reinforced Fe composites were lower than that of the non-reinforced sintered Fe specimens. This suggests that the aluminide-reinforced Fe composites have better strength to weight ratio.

Keywords: Iron aluminides, sintering, composites

1. Introduction

Powder metallurgy (PM) is considered as a promising processing method for producing particulate-reinforced metal matrix composites (MMCs) as it provides benefits including microstructural homogeniety, materials saving and near net shape characters. Our attempt to produce this type of materials started with the 316L-ceramics system [1]. In our first work, three ceramics including Al_2O_3, SiC and TiC powders with particle sizes of less than 20 micron were used as reinforcements for the 316L matrix. The mixtures of ceramics and 316L powders were compacted and sintered using a conventional P/M process. The sintered Al_2O_3-reinforced 316L material exhibited inferior sintered density, strengths and ductility but superior hardness to those of the sintered 316L material. Strength decrease in the sintered Al_2O_3-reinforced 316L material was attributed to bad wettability of 316L matrix on Al_2O_3 particles. Addition of SiC particles to 316L powders seemed to improve sintered density and mechanical properties. This was attributed to wetting of boundaries between 316L grains and reinforcement SiC particles caused by melting materials during sintering process. Addition of up to 1.5 wt. % TiC improved the sintered TiC-reinforced 316L material properties. In contrast, addition of too high TiC particle contents resulted in that some coarse TiC particles occupied in boundaries between 316L grains. This caused detrimental effect on mechanical properties of the sintered TiC-reinforced 316L material. Experimental works had been carried out to understand deeply on particulate-reinforced MMCs by using Fe as a matrix, Al_2O_3 as an inert ceramic and SiC as a reactive ceramic reinforcement [2, 3]. The reactive SiC particle decomposed and reacted with Fe at temperatures higher than 1200 °C. Because of the reaction, different kinds of carbide-reinforced Fe composites were studied [4-7]. It was found that stability of carbide contacting with Fe at elevated temperatures was the key factor controlling reaction between carbide particles and Fe matrix.

All the reinforcements investigated as given above failed to provide integrity with Fe matrix. In this work, new reinforcements of iron aluminides were chosen to prepare sintered Fe base composites, not only because of iron aluminide potential set of physical, chemical and mechanical properties [8, 9] but also their low cost, low density, ease of fabrication, good wear resistance and resistance to oxidation and corrosion [10, 11]. The aluminides (FeAl and Al_2Al_5) were synthesized using pressureless sintering [12]. The as-synthesized aluminides were ground and mixed with Fe powders and processed via a 'press and sinter' method.

2. Experimental procedure

Syntheses of Fe-Al and Fe_2Al_5 intermetallics were given in [12]. The as-synthesized materials were ground into powdered forms with particle sizes < 75 μm. The FeAl and Fe_2Al_5 powders were mixed with pure Fe powders with varied iron aluminide contents of 10, 20 and 30 wt.% as shown in Table 1. The compacts of mixed powders were sintered under control atmosphere at 1150 °C for 45 minutes. Microstructures and mechanical properties of the aluminide-reinforced composites were observed and tested, respectively.

Table 1 Nominal composition of the iron aluminide-reinforced Fe composites

Composite	Iron aluminde	
	FeAl	Fe_2Al_5
1	Fe+ 10% FeAl	Fe+ 10% Fe_2Al_5
2	Fe+ 20% FeAl	Fe+ 20% Fe_2Al_5
3	Fe+ 30% FeAl	Fe+ 30% Fe_2Al_5

3. Results and Discussion

3.1 Density change

All sintered composites showed density increase from green to sintered specimens. This indicates that all powder compacts gain densification by sintering. Addition of higher iron aluminide contents resulted in lower sintered materials density (Fig. 1). This is attributed to low density of iron aluminides. Decrease of sintered density due to iron aluminide addition is similar to the case of Al_2O_3 addition to Fe base composite [2, 3].

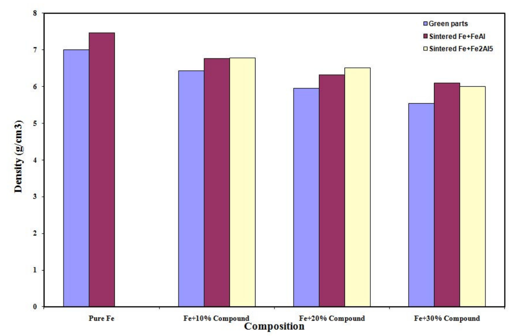


Fig. 1 Density change from green to sintered parts

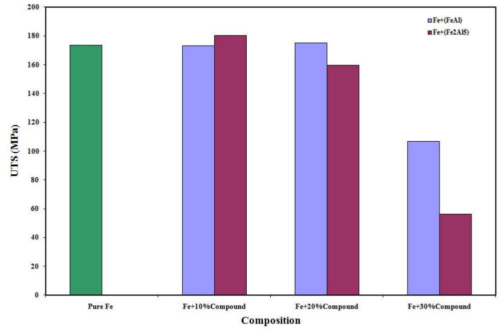
3.2 Mechanical properties

Only the 10 wt. % iron aluminide-reinforced Fe composite showed tensile properties (Fig. 2). Compared to the sintered pure Fe material, the iron aluminide-reinforced Fe composite exhibited higher tensile strengths but lower ductility although its microsructures showed that the reinforcement distribution was not uniform (Fig. 3). Increase of tensile strengths in the iron aluminide-reinforced Fe composite indicates benefit of aluminide addition to Fe matrix. Compared to the Al_2O_3-reinforced Fe composite [2], the iron-aluminide-reinforced Fe composite showed positive improvement of tensile strengths. Experimental results indicated that the iron aluminide content added for preparation of the Fe base composite was limited at a certain value. Poor tensile properties of the iron aluminide-reinforced composites with 20 and 30 wt. % iron aluminide additions were evidences of the limitation. Inferior mechanical properties of the iron aluminide-reinforced composites with too high contents of reinforcement were clearly related to the composite materials microstructures (Fig 3). Distribution of aluminide powder particles was not uniform in the cases of the composites with too high aluminide contents. Agglomerated iron aluminide particles occupying the boundaries between sintered Fe particles were clearly seen in the microstructures. The iron aluminide agglomeration along the boundaries inhibited sintering between the Fe particles to form Fe matrix.

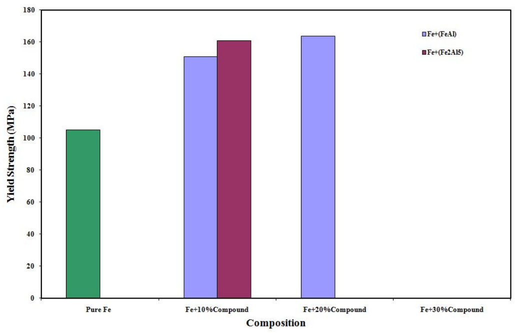
Microstructural inhomogeneity may be attributed to improper powder mixing/blending and coarse aluminide powder particle size. Improvement of powder mixing and aluminide grain reduction will be carried out in the further work.

4. Conclusions

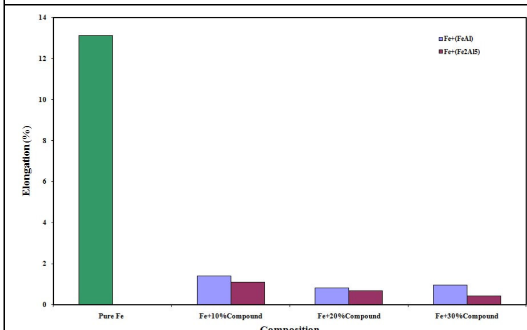
When compared to the non-reinforced sintered Fe specimens, the iron aluminide-reinforced Fe composite with 10 wt. % iron aluminide reinforcement showed improved tensile strengths and hardness although its microsructures showed that the reinforcement distribution was not uniform. Density of the composite was lower than the non-reinforced sintered Fe specimens. This suggests that the composite has better strength to weight ratio. However, this composite needs to be improved as it shows low ductility.



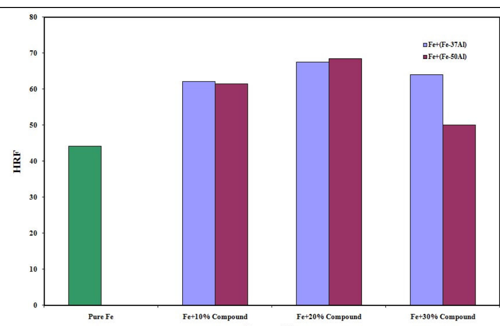
(a) UTS



(b) Yield



(c) Elongation



(d) Hardness

Fig. 2 Mechanical properties of sintered Fe-iron aluminide composites

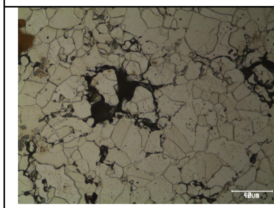
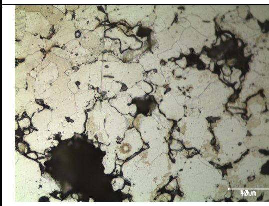
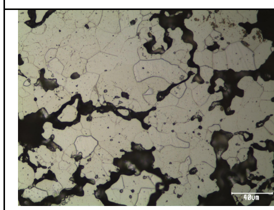
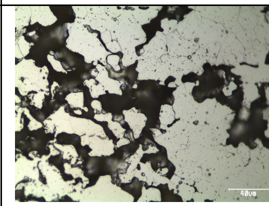
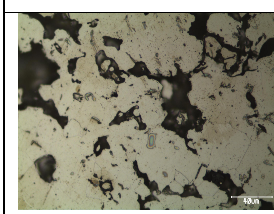
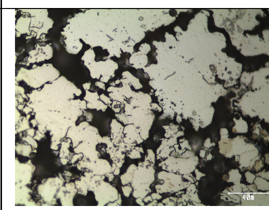
Fe-FeAl	Fe-Fe_2Al_5
	
Fe-10wt.% FeAl	Fe-10wt.% Fe_2Al_5
	
Fe-20wt.% FeAl	Fe-20wt.% Fe_2Al_5
	
Fe-30wt.% FeAl	Fe-30wt.% Fe_2Al_5

Fig. 3 Microstructures of the Fe-iron aluminide composites

5. Acknowledgement

This work is financial supported by National Metal and Materials Technology Center (MTEC). The authors would like to express their sincere gratitude to this kindly support.

6. References

[1] Coovattanachai, O., Mima, S., Yodkaew, T., Krataitong, R., Morkotjinda, M., Daraphan, A., Tosangthum, N., Vetayanugul, B., Panumas, A., Poolthong, N. and Tongsri, R. (2006). Effect of admixed ceramic particles on properties of

sintered 316L stainless steel, paper presented in *the International Conference on Powder Metallurgy and Particulate Materials*, San Diego, USA.

[2] Yodkaew, T., Morakotjinda, M., Tosangthum, N., Coovattachai, O., Krataitong, R., Siriphol, P., Vetayanugul, B. and Tongsri, R. (2007). Effect of non-reactive hard particles on sintered Fe material, paper presented in *the International Conference on Mining, Materials and Petroleum Engineering: The Frontiers of Technology (ICFT-2007)*, Phuket, Thailand.

[3] Yodkaew, T., Morakotjinda, M., Tosangthum, N., Coovattachai, O., Krataitong, R., Siriphol, P., Vetayanugul, B., Chakthin, S., Poolthong, N. and Tongsri R. (2008). Sintered Fe-Al_2O_3 and Fe-SiC composites, *J. Met. Mater. Miner*. **18** (1), 57-61.

[4] Chakthin, S., Poolthong, N. and Tongsri R. (2008). Effect of reaction between Fe and carbide particles on mechanical properties of Fe-base composite, *Adv. Mater. Res.*, **55-57**, 361-364.

[5] Chakthin S., Morakotjinda M., Yodkaew T., Torsangtum N., Krataithong R., Siriphol P., Coovattanachai O., Vetayanugul B., Thavarungkul N., Poolthong N. and Tongsri R., (2008). Influence of carbides on properties of sintered Fe-base composites", paper presented in *the Fifth Thailand Materials Science and Technology Conference,* MSATV, Bangkok, Thailand.

[6] Chakthin S., Morakotjinda M., Yodkaew T., Torsangtum N., Krataithong R., Siriphol P., Coovattanachai O., Vetayanugul B., Thavarungkul N., Poolthong N. and Tongsri R. (2008). Properties of sintered Fe-carbide composites, paper presented in *the 22th Conference of Mechanical Engineering Network of Thailand*, Pathum Thani, Thailand.

[7] Chakthin, S., Poolthong, N., Thavarungkul N. and Tongsri, R. (2008). Iron-carbide composites prepared by P/M, paper presented in the *International Conference on Processing Materials for Properties*, Bangkok, Thailand.

[8] Godlewska, E., Szczepanik, S., Mania, R., Krawiarz, J. and Kozinski S. (2003). FeAl materials from intermetallic powders *Intermetallics*, **11**, 307-312.

[9] Gedevanishvili, S. and Deevi, S.C. (2002). Processing of iron alu- minides by pressureless sintering through Fe+Al elemental route,*Mater. Sci. Eng*., Vol. A325 (2002), pp. 163-176.

[10] Fan, R-h., Sun, J-a., Gong, H-y., Sun, K-n. and Wang, W-m. (2005). Structural evolution of mechanically alloyed nanocrystalline Fe-28Al powders, *Powder Tech*., **149**, 121-126.

[11] McKamey, C.G., Devan, J.H., Tortorelli, P.F. and Sikka, V.K. (1991). A review of recent developments in iron-aluminum alloys. *J. Mater. Res*., **6**, 1779-1805.

[12] Morakotjinda, M., Vatayanugul, B. and Tongsri, R. (2011). Synthesis of intermetallic FeAl compounds using pressureless sintering, paper presented in *the International Conference on Materials Processing Technology 2011*, Phuket, Thailand.