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Mechanical Characterization of Al-Hematite Composites Developed by P/M Technique

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***Abstract* - In this experimental study, Al-based hematite particle reinforced composite materials were manufactured by powder metallurgy. The compression strength, tensile strength and hardness at varying compaction pressures and sintering temperatures were investigated. The results of the tests revealed that hematite particles can be successfully used as a reinforcement material and it does not deteriorate the properties. The increase in hematite particle percentage and high compaction pressure resulted in high density of the compact, thereby increasing compression strength, tensile strength and hardness of the component. Sintering played a more vital role having direct effect on mechanical properties of the component with varying sintering temperatures. Highest compression Strength of 270MPa, tensile strength of 187MPa and hardness of 69BHN was attained for 8%Hematite particles at Sintering temperature 500°C and compaction Pressure 400MPa. These results indicate that Al-Hematite composites can be considered as an appropriate material where high compression strength is of major importance.**

INTRODUCTION

Composites possess high strength to weight ratio and have come a long way in replacing the conventional materials like metals, wood etc.

Aluminium Powder Metallurgy (P/M) offers components with exceptional mechanical and fatigue properties, low density, corrosion resistance, high thermal and electrical conductivity, excellent machinability, good response to a variety of finishing processes, and is competitive on a cost per unit volume basis. In addition, the primary driver for the use of Aluminium P/M is the unique properties of Aluminium coupled with the ability to produce complex net or near net shape parts which can reduce or eliminate the operational and capital costs associated with complex machining operations. Due to popularity of Aluminium P/M different reinforcing elements are being used to develop newer composites and evaluate their various properties. The variations in properties were also dependent on both sintering time and temperature. Prolonged sintering times had an adverse effect on strength of the composite [1, 2].

Compression strength, hardness and indirect tensile strength of powder metal Al-SiC composites increases with increase in the reinforcement content from 5-30 weight percent of SiC[3]. Aluminium P/M alloys can be improved without recourse to hot working or master alloy powders if their design is based on an understanding of the underlying sintering processes [4]. Mechanically milled and extruded composites show finer and better distribution of reinforcement particles that lead to better mechanical properties of obtained products. Addition of TiAl and Ti_3Al particles of the reinforcing materials to the aluminium matrix increased the hardness of the composite materials obtained [5]. The compression strength, tensile strength, hardness, and formability characteristic of Aluminum composites produced by powder metallurgy route were greatly influenced by reinforcement size, reinforcement percentage, sintering temperature and compaction pressure [6-14]. Composite materials with Al_2O_3 reinforcing phases increase the tensile properties along with the particles portion in the aluminum matrix growth [9]. Diverse efforts have been made effectively to develop the compressibility and the sintering response in different way, and for diverse series of Al alloys. To meet the requirements of today's situation, advancements of materials has been the prime focus and more and more newer materials have been developed to satisfy the present day needs. Therefore in the present investigation an Al-hematite composite has been developed for various percentages of hematite and the resulting composite has been subjected to evaluation of its mechanical properties due to different compaction and sintering values. The micrograph studies have been carried out to see the proper mixture of components.

EXPERIMENTAL DETAILS

Aluminium has played and continues to play a key role in the development of metal matrix composites. Aluminium possess combination of properties like light weight, environmental resistance, good thermal conductivity, moderate strength and low coefficient of thermal expansion. In particular, the automotive industry demands both light weight and low cost materials in order to reduce fuel emissions and improve fuel economy at affordable prices therefore, Aluminium is selected as the choice of matrix material. Aluminium powder of average grain size 30µm and density 2.78g/cc is selected as base material for the development of powder metallurgy composite.

TABLE 1: THE CHEMICAL COMPOSITION OF THE MATRIX ALLOY (WT %)

Constituents	Formula	%
Aluminium	Al	99.5
Arsenic	As	0.0005
Lead	Pb	0.03
Iron	Fe	0.5

The Reinforcement material selected is Hematite with average grain size 70µm and density 5.30gm/cc for the development of composite by powder metallurgy route. Hematite is the mineral form of iron oxide (Fe_2O_3), one of the several iron oxides. It possesses high hardness, good melting point and huge deposits are found in banded iron formation. The Aluminium powder with varying percentages of Hematite and a small quantity of Acrawax (lubricant) was thoroughly mixed in a ceramic bowl manually. The blended powder was shifted to the die and compacted by the punch at different pressures. The compaction was carried on a 40 Ton Universal Testing Machine. The prepared green compacts were separated from the die and were sintered in a heating furnace in the presence of nitrogen. Sintering was carried at different temperatures. Compression test was conducted on a Universal Testing Machine (UTM) of 40 ton capacity. Tests were carried out according to ASTM standard E9 at room temperature. The load was applied gradually. Compressive load was noted from the scale at breakage of the test specimen to determine the compressive strength. The composite specimen under consideration was placed on the anvil of Brinell Hardness Testing machine. The anvil was rotated until test piece comes in contact with the hardened steel ball indenter of 10mm diameter. Load of 10 kgf was applied on the specimen to make the indentation. The indentation depth was measured from the microscope and BHN was calculated from the standard formula. The tensile test was carried on a Universal Testing Machine (UTM) of 40 Ton capacity. The specimen was prepared according to the ASTM standard E8. The load was applied gradually and tensile load was noted from the scale at breakage of the test specimen to determine the tensile strength.

RESULTS AND DISCUSSIONS

Compression test

The increase in the percentage of hematite particulates as reinforcement has increased the overall compression strength of the composite. The maximum compression strength obtained was for 8% reinforcement at max compaction pressure and maximum sintering temperature. The compression strength for the composite at high compaction pressure is found to be low as compared to the composite obtained at much lower compaction pressure for the same percentage of reinforcement and this may be due to the increase in the sintering temperature that would have enhanced the interaction between the constituents as the temperature increases.

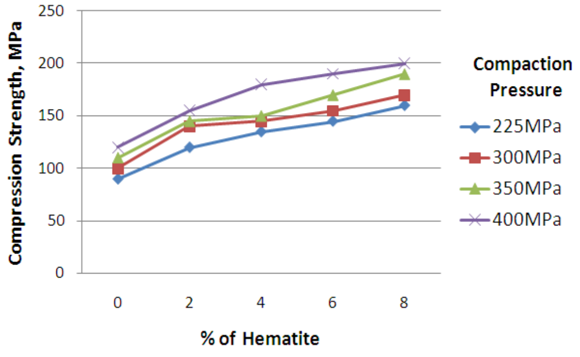

Fig 1.Compression Strength Vs % of Hematite for Sintering Temperature 400°C

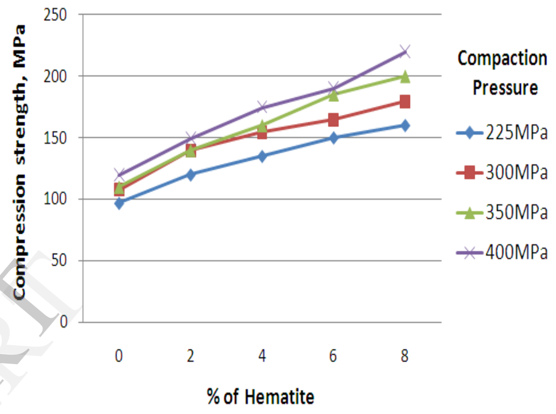

Fig 2.Compression Strength Vs % of Hematite for Sintering Temperature450°C

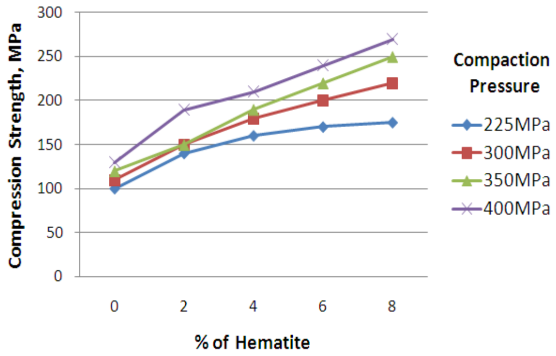

Fig 3.Compression Strength Vs % of Hematite for Sintering Temperature 500^0 C

Hardness Test

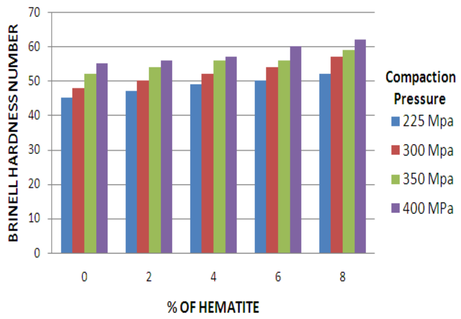

Fig 4.BHN Vs % of Hematite for sintering temperature 400°C

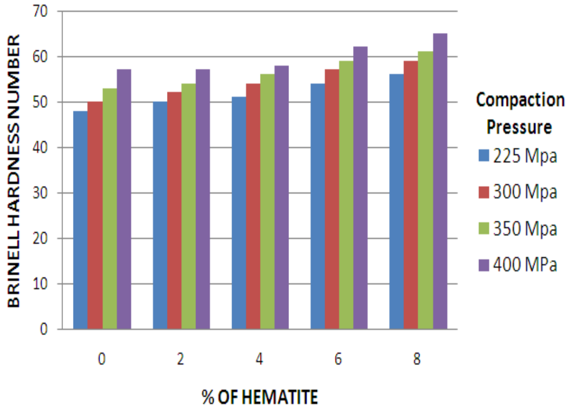

Fig 5.BHN Vs % of Hematite for sintering temperature 450°C

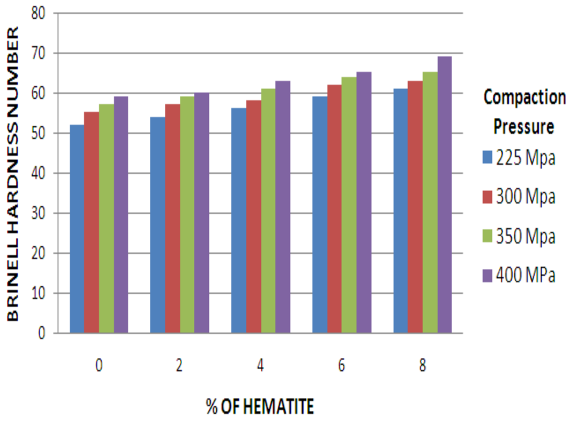

Fig 6.BHN Vs % of Hematite for sintering temperature 500°C

It is observed that Hardness of the composite being increased with the increase in the Hematite percentage. The highest Hardness of 69BHN is obtained for 8% Hematite particles at maximum sintering temperature and compaction pressure. The increase in the percentage of Hematite particles as reinforcement has directly increased the hardness of the composite and this may be due to the presence of hard particles in the matrix. The increase in the sintering temperature has attributed more in increase of hardness of the composite.

Tensile strength

The peak tensile strength is observed for the addition of 8% of hematite particles. The presence of hard particles impede in the advancing dislocation front. Maximum tensile strength of 187MPa was attained for maximum compaction pressure and maximum sintering temperature.

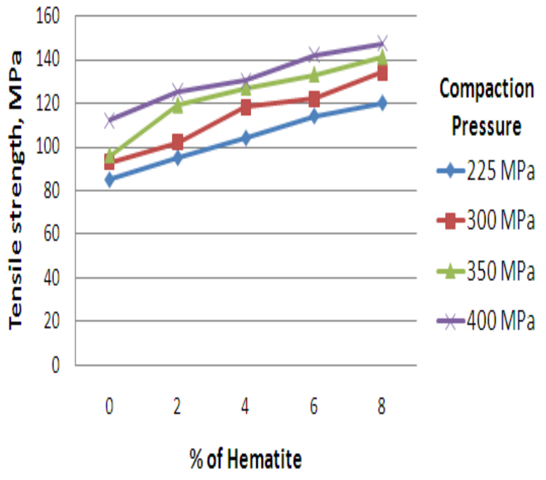

Fig 7.Tensile Strength Vs % of Hematite for Sintering Temperature 400°C

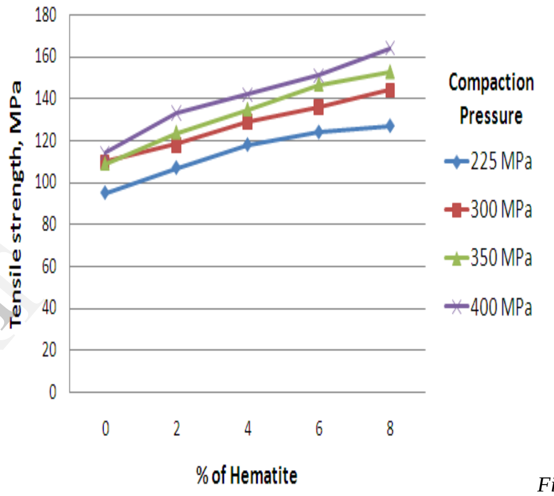

Fig 8.Tensile Strength Vs % of Hematite for Sintering Temperature 450°C

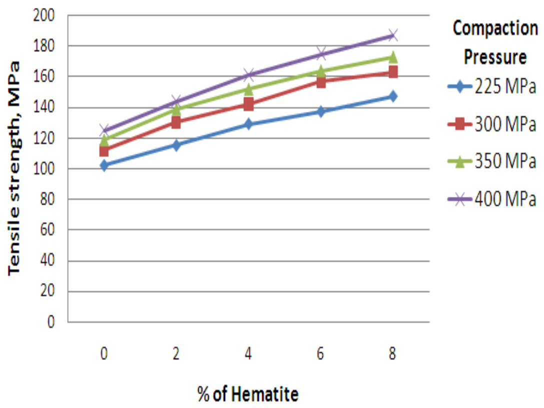

Fig 9.Tensile Strength Vs % of Hematite for Sintering temperature 500^{0}C

OPTICAL MICROPHOTOGRAPHS

The size, density, type of reinforcing particles, and its distribution have a pronounced effect on the properties of powder metallurgy composites.

The Figures(10,11and12) shows microphotographs of the polished cross-section of Al-alloy and Al-with 4 and 8%Hematite composites prepared under compaction pressure of 400MPa and sintering temperature 500^0C. As the Hematite content increases, the formation of Hematite clusters and voids are likely to occur. Anyway, when compaction pressure is gradually increased, the distribution of Hematite particles throughout the Al matrix gets more uniform. This is noticeable in composite having 8% reinforcement.

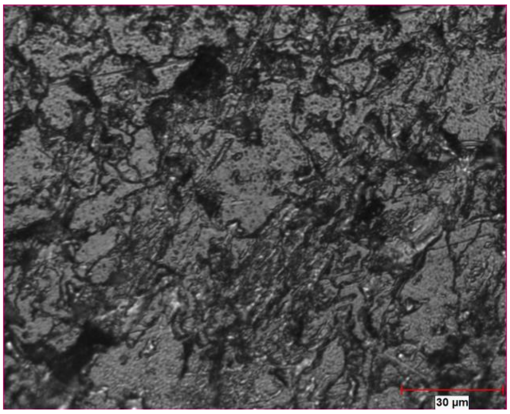

Fig 10.Al-alloy as a Base matrix at 400MPa

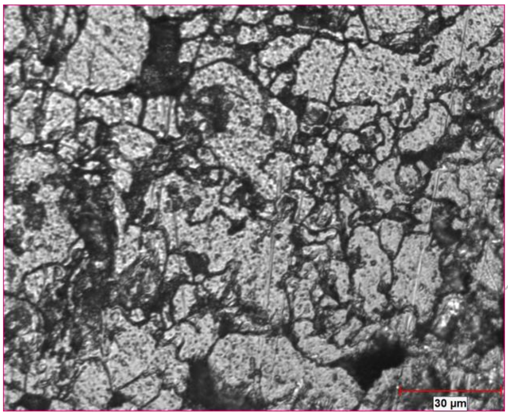

Fig 11 .400MPa, 4%Hematite

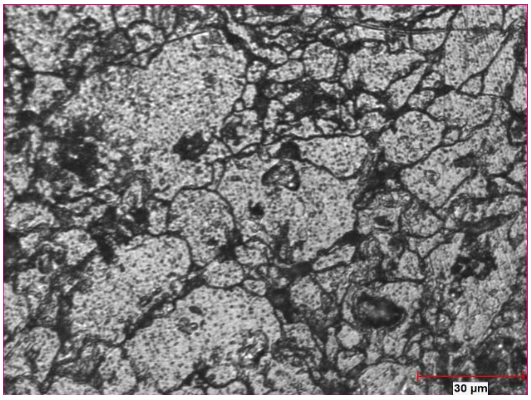

Fig 12 .400MPa, 8%Hematite

CONCLUSIONS

1. Hematite Particles can be successfully used as a reinforcement material and it does not deteriorate the properties.
2. Compression strength of the composite has increased with the increase in hematite particle percentage and high compaction pressure resulted in high density of the compact, thereby increasing both compression strength and hardness of the component.
3. Sintering plays a more vital role having direct effect on hardness and compression strength of the component.
4. Highest compression strength of 270MPa and hardness of 69BHN was attained for 8% hematite particles at sintering temperature of 500°C and compaction pressure of 400MPa.
5. Peak tensile strength of 187MPa was obtained for 8% hematite particles at sintering temperature 500°C and compaction Pressure 400MPa.
6. Optical microphotographs show better bonding between matrix and hematite particle interface.

REFERENCES

1. Mehdi Rahimian, Naser Ehsani, Nader Parvin, Hamid reza Baharvandi., 2009, The Effect of Particle Size, Sintering Temperature and Sintering Time on the Properties of Al–Al2O3 Composites, Made by Powder Metallurgy, Journal of Materials Processing Technology, Pg 5387-5393.
2. J.M.Torralba, C.EdaCosta, F.Velasco., 2003, P/M aluminum matrix composites, Journal of Materials Processing Technology, Vol. 133,Pg 203-206.
3. RajeshPurohit, R.S.Rana, C.S.Verma., 2012, Fabrication of Al-Sicp Composites Through Powder Metallurgy Process and Testing f Properties, International Journal of Engineering Research and Applications (IJERA) Vol. 2, Pg. 420-437.
4. G.B.Schaffer, 2004, Powder Processed Aluminium Alloys, Materials Forum, Institute of Materials Engineering Australasia Ltd, Volume 28, Pg. 65-74.
5. S. Muller, Th.Schubert, F.Fiedler, RStein, B.Kuieback, L.Deters., 2011, Properties of Sintered P/M Aluminium Composites, Euro PM 2011 – Metal Matrix Composites.
6. S.Scudino, G.Liu, K.G.Prashanth, B.Bartusch, K.B.Sureddi, B.S.Murthy., 2009, Mechanical properties of Al-based metal matrix composites reinforced with Zr-based glassy particles produced by powdermetallurgy, Acta Materialia, Vol.57, Pg2029-2039.
7. J.Corrochano, J.C.Walker, M.Lieblich, J.Ibanez, W.M.Rainforth., 2011, Dry sliding wear behaviour of powdermetallurgy Al–Mg–Si alloy-MoSi2composites and the relationship with the microstructure, Wear, vol 270, Pg. 658–665.
8. R.Narayanasamy, K.S.Pandey, T.Ramesh, S.K.Pandey.,2008, Effect of particle size on new constitutive relationship of aluminium–iron powder metallurgy composite during cold upsetting, Materials and Design, Vol. 29, Pg 1011-1026.
9. N.P.Cheng., 2008, Preparation, Microstructures and Deformation Behavior of SiCP/6066Al Composites Produced by PM route,Vol.202, Pg.27-40.
10. Leszek., 2006, The structure and properties of PM composite materials based on EN AW-2124 aluminum alloy reinforced with the BN or Al2O3 ceramic particles, Journal of Materials Processing Technology, Vol 175, Pg. 186–191.
11. DVojtech et.al., 2008, Structural characteristics and Thermal Stability of Al- 5.7Cr2.5Fe1.3Ti alloy produced by powder metallurgy, Journal of Alloys and Compounds, Vol 475, Pg 151-156.
12. A.H.Tavakoli, A.Simchi, S.M.Syed Raihani., 2005, Study of the compaction behavior of composite powders under monotonic and cyclic loading, Composites Science and Technology, Vol.65, Pg. 2094-2104.

13. T.Ramesh and T.Senthilvelan, 2010, Formability Characteristics Of Aluminium Based Composites, IACSIT International Journal of Engineering and Technology, Vol. 2, Pg. 1793-8236.
14. MehdiRahimian, NasirEhsani., Some aspects on strain hardening behaviour in three dimensionsof aluminium–iron powder metallurgy composite during cold upsetting, Journal of Materials Processing Technology, Vol.209, Pg. 5387-5393.
15. AnitaOlszówkaMyalska, JanuszSzala, JanSwajna., 2001, Characterization of reinforcement distribution in Al/ (Al2O3)p composites obtained from composite powder, STERMAT 2000: Stereology and Image Analysis in Materials Science, Vol. 46, Pg 189-195.
16. KatsuyoshiKondoh., 2009, Cavitation erosion of aluminum matrix sintered composite with AlN dispersoids, Wear,vol 267, Pg. 1511-1515.
17. T.Ramesh, M.Prabhakar, R.NarayanSwamy., 2010, Workability studies on Al-20% Sic powder metallurgy composite during cold upsetting advances in production Engg. and Management, APEM Journal, Volume 5, Pg. 134-144.
18. C.Srinivasa Rao, G.S. Upadhyaya., 1995, 2014 and 6061 aluminium alloy-based powder metallurgy composites containing silicon carbide particles/fibres, Materials & Design, Vol 16, Pg 359–366.
19. MFrary, S.Abkowtz, D.C.Dunaud., 2003, Microstructure and Mechanical Properties of Ti/W and Ti–6Al–4V/W Composites Fabricated by Powder-Metallurgy, Materials Science and Engineering, Vol. 344, Pg 103-112.
20. N.P.Cheng., 2008, Preparation, Microstructures and Deformation Behavior of SiCP/6066Al Composites Produced by PM route, Vol.202, Pg.27-40.