Proceedings of the
International Conference on Mechanical Engineering and Renewable Energy 2019
(ICMERE2019) 11 – 13 December, 2019, Chittagong, Bangladesh

ICMERE2019-PI-195

PRODUCTION AND ANALYSIS OF IRON METAL FOAM BY DEALLOYING PROCESS

Mostafizur Rahman[1], Md. Abu Bakkar Sikder[2*] and Sadnan Mohosin Mondol[3]

[1-3]Department of Mechanical Engineering,
Chittagong University of Engineering & Technology, Chattogram-4349, Bangladesh
Email: [1]rmostafiz31@gmail.com, [2*]emoncuet072@gmail.com, and [3]smsadnan15@gmail.com

Abstract- *Syntactic metal foams are pulling in extensive consideration lately because of their potential for weight sparing in bundling, guards, and vehicle structures. These foams are incorporated by scattering empty particles in lattice material. Syntactic foams possess adequately high mechanical properties for use as basic materials and additionally automotive as well as energy storage materials. Powder metallurgy and dealloying process are utilized for delivering iron metal foam. Hence, the porosity of foam which is found to be shifted between 6.75% to 52.6% and the density is varied from 0.91 g/cc to 2.90 g/cc. Three types of samples are prepared varying weight percentage of pure iron metal powder and aluminum as space holder. Sample of weight percentage 30:70, 70:30 and 50:50 ratios show quite similar results in terms of porosity and density ratio. It is noted that density increases with the decrement of porosity. This is not fluctuating randomly. In addition, density of sample 30:70 is much less than samples of 70:30 and 50:50.The syntactic iron foam produced in this process is observed to be a viable procedure for permeable material manufacture. This iron metal foam can be utilized as useful and auxiliary material for making inserts as this structure gives bringing down youthful modulus and gives better cell connection. This paper represents production and analysis of iron metal foam by dealloying process.*

Keywords: Powder metallurgy, Dealloying process, Metal foam, Mechanical properties, Porosity and Density Ratio

1. INTRODUCTION

Recently, nanoporous materials are getting to be appealing in both automotive and mechanical applications. In addition, utilization of such kind of permeable porous materials is being expanded to electrical, automotive industry, biomedical, and energy storage system. Porous materials are used in modern energy storage system such as lithium-ion batteries, lithium-air batteries etc. as this kind of batteries achieve great use in electric vehicles. It is noted that one of the most current type of porous materials is by metal foam. Metal foam can be manufactured by two diverse processes. One is immediate foaming strategy which is readied with liquid metal containing consistently scattered non-metallic particles as balancing out operators to which gas is passed to shape rises to make foam and another is circuitous foaming techniques which begins from a strong forerunner consisting of metallic network containing consistently scattered blowing specialist particles [1]. As indicated by physical condition of beginning, metal foam creation is isolated into four gatherings which are framed from the vapor stage, foam from strong state, fluid state handling, electrodepositing of foam from watery arrangement [2]. Permeable metals or metallic foams are another kind of material and fall under subgroup of cell metals [3]. Pores in the metallic materials of permeable metals are being interconnected. Metallic foams have numerous alluring mixes of mechanical and physical properties such as: high vitality assimilation abilities with low densities, high strength, high load bearing capability and high temperature resistance etc. [4]. It is worthy to mention that metal foam can be characterized by cell or permeable structure of metal [5]. Researchers are carrying out several investigations on production technique of porous materials, characterization of porous materials and development of mechanical properties. Reindel et al. [6] investigated Ti6Al4 V foam with 60% porosity and pore measure ranging from 315 to 500 µm, and found that bio-modular molecule dispersion gives higher quality and firmness as thought about 25 monomodal molecule appropriations. Authors concluded that quality and firmness of porous materials is increased with increment in sintering temperature. Gibson et al. [7] studied microstructural and mechanical characteristics of porous materials prepared by powder metallurgy method. Authors made a comparative study on use of normal materials and porous materials in different applications. In contrast, Mondal et al. [8] carried out experiment on some great metal foam, did not discover its way into genuine mechanical application. Fuji et al. [9] made some samples of porous materials varying weight percentage and investigated compressive test on those materials. Authors showed greater load bearing capacity of porous materials compared with others. Niebylski et al. [10] carried out experimental comparison between upsetting characteristics of porous components prepared by Fe-based sintering technology. This paper represents production and analysis of syntactic iron metal foam by dealloying process.

2. MATERIALS AND METHODOLOGY

Firstly, aluminum as space holder is mixed thoroughly with pure iron powder for producing syntactic iron foam in powder metallurgy. A die punch assembly is used for compaction of iron powder and aluminum mixture. The die is 50mm×50mm square in size with a hole of 15mm through it. In addition, plunger size has become in cylindrical shape of 70mm length and 15mm dia. Iron powder and aluminum mixture is poured into the die cavity more specifically at the bottom of die cavity having a coin of 5mm thickness and 15mm dia. In addition, another coin of same dimension is used in upper surface of the mixture.

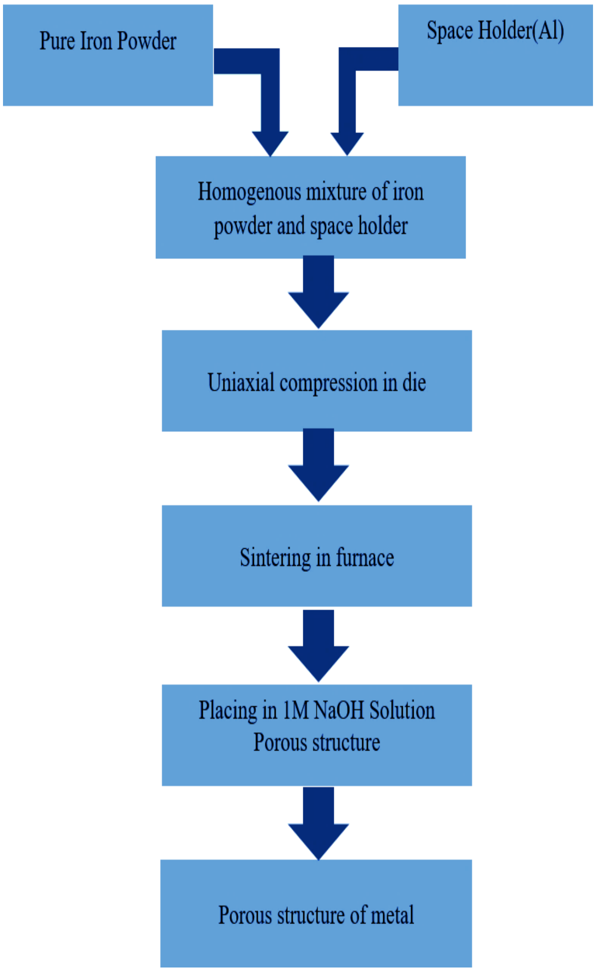

Fig. 1: Flow chart of methodology of iron foam Production

It is worthy to mention that purpose of using coin at top and bottom surface is to give a uniform contact area. Pressure force is being applied by universal testing machine pushing the plunger through die cavity. It is noted that maximum 20KN pressure force is required to obtain sufficient green strength of the mixture. A dense product of iron powder with space holder is embedded in and it is obtained by this uniaxial compression. The mixture is sintered in a furnace at 650°C temperature after compression. After that, the dense product is placed in 1M dense NaOH solution. It is noted that sodium aluminate is formed by reaction of sodium hydroxide on elemental aluminum which is an amphoteric metal. The reaction is highly exothermic once established and is accompanied by the rapid evolution of hydrogen gas. The reaction is written as:

$$2\ Al + 2\ NaOH + 2\ H_2O \rightarrow 2\ NaAlO_2 + 3\ H_2$$

After completing this reaction, Al comes to solution for reacting with NaOH putting the pore trace at the rest of iron finished product, which is our required. It is known to all that amount of pores increases with the amount of space holder. Hence, sample of 30%, 50% and 70% iron metal mixed with space holder Al are prepared for testing of mechanical properties. Compression test is done on iron foam sample produced by powder metallurgy method. It is noted that compression test is performed in tablet hardness tester of Monsanto type.

3. FABRICATION PROCESS

3.1 Mixing of Pure Iron Powder with Space Holder

Making of iron foam is required mixing of pure iron powder with space holder in powder metallurgy method. It is noted that aluminum of average particle size of 5μm is mixed with high purity iron powder (purity 99.5%). Iron powder of 70 wt% and aluminum 30 wt% are weighted in an electronic balance then mixed together. In addition, 50 wt% of iron powder and 50 wt% of aluminum, 30 wt% of iron and 70 wt % of aluminum are mixed in the similar manner.

3.2 Ball Milling of Powder Mixture

The aluminum and iron powder is blended properly and uniformly together by ball milling process. A vertical type ball miller used, consists of a cylindrical shell shaped mixing chamber and a 12V DC motor. The cylindrical shell made of stainless steel is 13cm in length and 7.5cm in diameter. In addition, inner surface of cylindrical shell is made of rubber. 70g iron powder and 30g aluminum (space holder) are weighted in electronic balance and then poured into the cylindrical shell of ball miller. The shell is filled by 15-20 stainless steel ball of 5mm and rotated at 100rpm by the 12V DC motor. After ball milling, mixture of iron and aluminum powder obtained where the ratio of weight of iron powder and space holder is 70:30. In the similar manner, mixture of 50:50 and 30:70 are made.

3.3 Green Compaction of Powder Mixture

It is aforementioned that a die punch assembly is used for compaction of mixture. Pressure force is applied by universal testing machine. It is noted that 7 gram of powder mixture of iron and space holder is taken for compaction process which is previously prepared by ball milling. The weight ratio of iron powder and space holder was 70(wt %):30(wt %). It is worthy to mention that compaction is done for 5 minutes at 113MPa. After that, a dense semi-finished product of cylindrical shape is obtained. Weight ratio of iron powder and space holder is 70:30 in this dense product. Similarly, dense product with weight ratio of iron powder to space holder 50:50 and 30:70 are made.

3.4 Sintering

The semi-finished dense product is subjected to sintering after green compaction process. It is noted that sintering process is carried out to achieve enough mechanical strength and decomposition of space holder. The sintering process is carried out in an electric furnace at 650°C for 90 minutes. At this temperature, the aluminum (space holder) and iron are strongly bounded. The furnace took a very long time to reduce its temperatures. Crucibles are used to keep samples into the furnace.

3.5. Putting Finished Product in NaOH Solution

This finished product taken from furnace is put in 1M NaOH solution. This NaOH solution immediately reacts with aluminum making sodium aluminate ($NaAlO_2$) which precipitates. Sodium aluminate is also formed by the action of sodium hydroxide on elemental aluminum which is an amphoteric metal. The reaction is highly exothermic once established and is accompanied by the rapid evolution of hydrogen gas. The entire process from section 3.1 to 3.5 is shown in the Fig. 3.

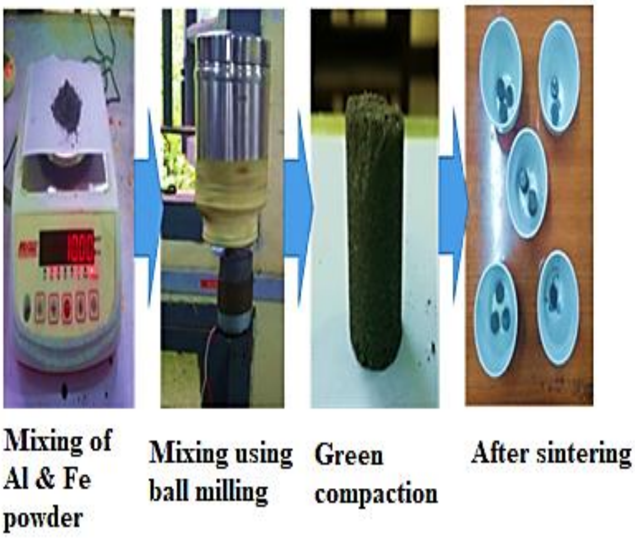

Fig. 2: Process involved in production of metal foam

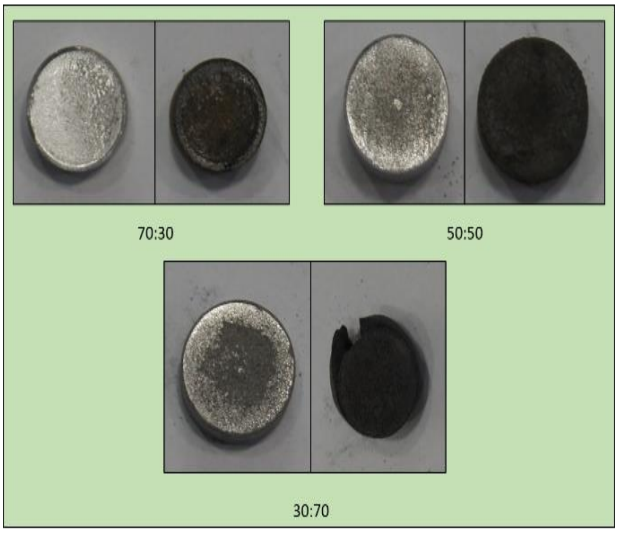

Fig. 3: Finished product varying weight percentage

4. RESULTS AND DISCUSSIONS

The 70:30 and 50:50 ratio sample gives quite similar results in terms of porosity and density ratio as shown in Fig. 4. Figure 4 shows variation of density vs. porosity graph in 70:30 and 50:50 ratio samples. It is noted that density increases with the decrement of porosity. This is not fluctuating randomly. In addition, porosity changes with density with proper manner. Figure 5 shows variation of porosity with density of 30:70 samples. It is seen that porosity changes with respect to density properly. In addition, density of the foam is much less than samples of 70:30 and 50:50. Hence, a smooth change between density and porosity is obtained from 30:70.

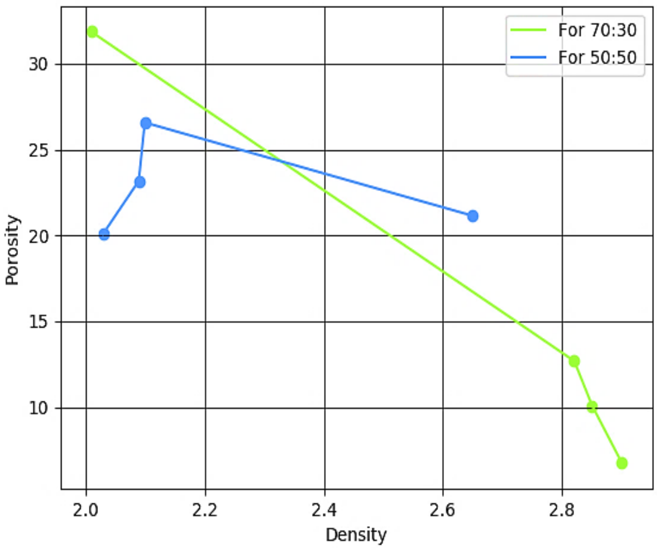

Fig. 4: Variation of porosity with density of 70:30 and 50:50 samples

It is seen that porosity of iron foam varied between the ranges 6.75% to 52.6%. In addition, density is varied from 0.12 g/cc to 2.9g/cc. It is noted that pore size control and uniform distribution of pores is found to be difficult. From hardness test, it is found that with increases of porosity the crushing load decreases. Another crucial point in fabricating iron foam via powder metallurgy method using aluminum is that iron which is a noble metal chemically does not react with oxygen at the time of sintering at around 650°C and formed light black color synthetic foam with present of aluminum as spacer.

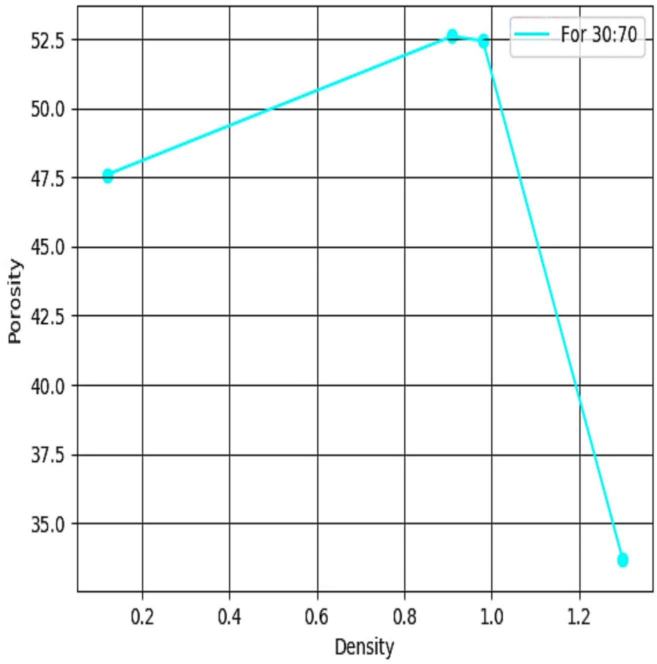

Fig. 5: Variation of porosity with density of 30:70

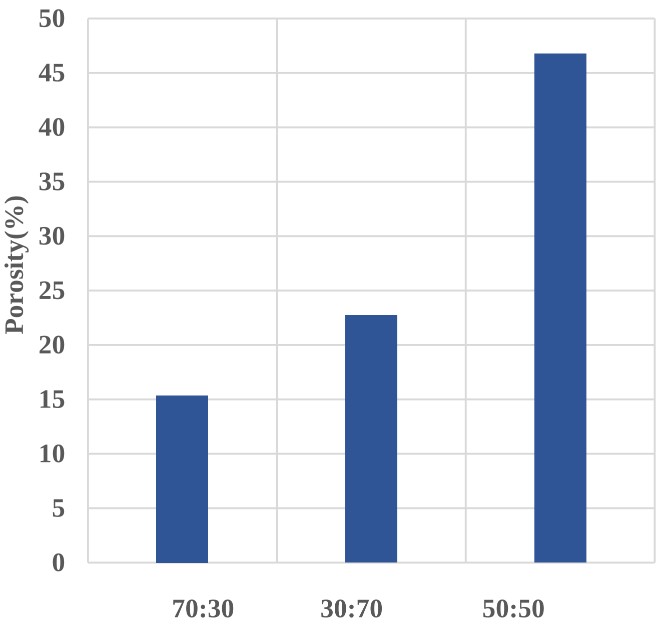

Fig. 6: Variation of average porosity of samples

XRF information demonstrates the ordinary type of the sharp fluorescent ghastly lines is gotten in this strategy. This is the outflow of trademark "auxiliary" (or fluorescent) X-beams from a material that has been energized by barraging with high-vitality X-beams or gamma beams. The wonder is generally utilized for essential investigation and compound examination. In the most foam production method the properties can be varied over a wide range by controlling the production parameters.

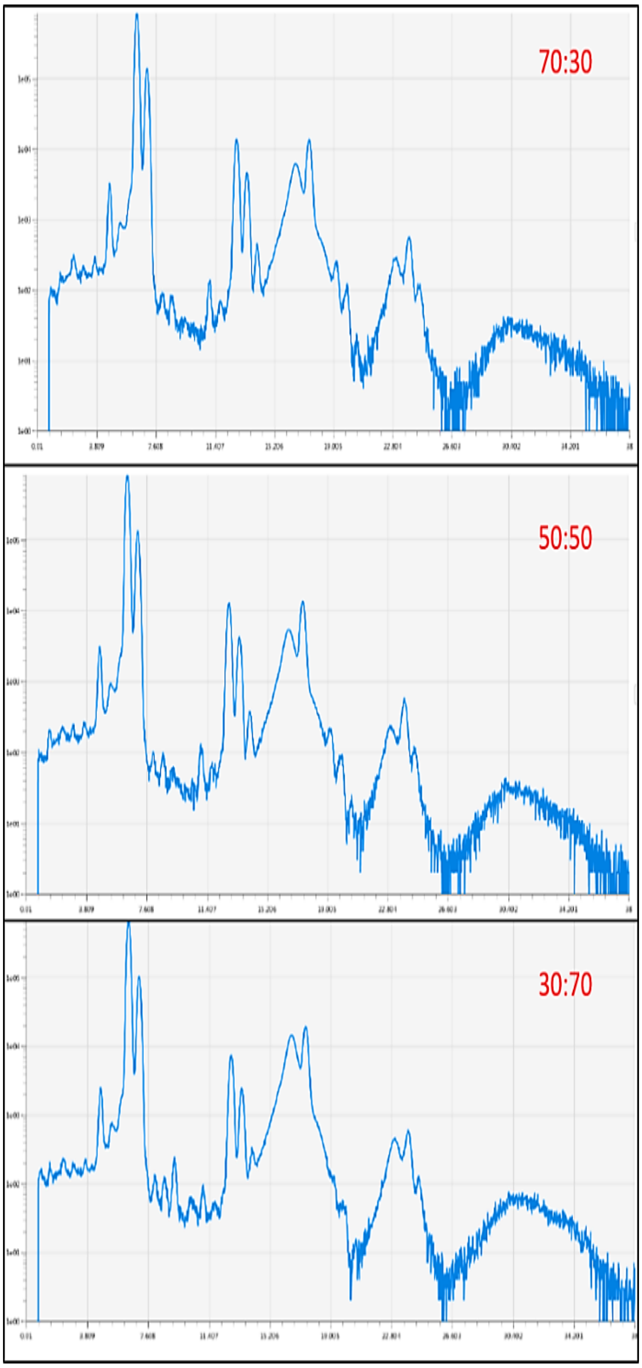

Fig. 7: XRF analysis of prepared samples

4. CONCLUSIONS

As, metal foams are used all over the globe broadly in daily regular basis and are utilized for padding, vitality retention, lightweight structure and numerous different applications. This kind of metal foams might be extremely useful to deliver a savvy material for mechanical, electrical, and chemical purposes. Exceedingly permeable materials are known to have a high firmness joined with a low explicit weight. Metallic foams offer extensive point of view because of the blending properties which are identified with metallic characterization and to permeable structure. The quality of metal foam can be expanded if sintering can be conveyed in latent air. On the off chance, it is needed a homogeneous and uniform blend of iron powder and space holder high vitality ball processing can be successful way. Again to lessen the expense much further, metallic foam can likewise be created by setting up slurry of metal powder blended with a frothing operator. Hence, for further improvement, more investigation is required on this metal foaming procedure is extremely successful as we get expected properties from our examination.

REFERENCES

[1] M. A. Hossain, N. Muhamad, and A. B. Sulong. "Processing titanium foams using tapioca starch as a space holder," *Journal of Materials Processing Technology*, vol. 212, no. 1, pp. 83-89, 2012.

[2] T. Nihan and G. Arslan. "Designing compressive properties of titanium foams." *Journal of materials science"*, vol. 44, no. 6, pp. 1477-1484, 2009.

[3] G. J. Davies and S. Zhen. "Metallic foams: their production, properties and applications." *Journal of Materials Science"*, vol. 18, no. 7, pp: 1899-1911, 2006.

[4] L. Yuhua, C. Yang, H. Zhao, S. Qu, X. Li, and Y. Li. "New developments of Ti-based alloys for biomedical applications, "*Materials Science & Engineering"*, vol.7, no. 3, pp. 1709-1719, 2014.

[5] H. Park, Y. Noh and H. Choi, "Processing, Microstructure, and Oxidation Behavior of Iron Foams," *Metallurgical and Materials Transactions*, vol.47, no.9, pp. 4760-4769, 2016.

[6] D. Reindel and K. Singer, "Porous and cellular materials for structural applications." *Proc. of MRS Symp*. vol. 521, pp. 211-218, 1998.

[7] L. J. Gibson and M. F. Ashby, "Microstructural and mechanical characteristics of porous iron prepared by powder metallurgy." *Materials Science and Engineering*, vol.43, p.494-502, 2014.

[8] D. P. Mondal, M. D. Goel, and S. Das. "Effect of strain rate and relative density on compressive deformation behavior of closed cell aluminum–fly ash composite foam." *Journal of Materials & Design*, vol. 30, no. 4, pp. 1268-1274, 2009.

[9] S. Fuji, G. V. Degischer, H. P. Clyne, "Comprehensive test on composite materials", *Elsevier Science Amsterdam*, vol. 3, pp. 20-85, 2015.

[10] L. M. Niebylski, C. P. Jarema and T.E. Lee "Experimental comparison between upsetting characteristics of porous components prepared by Fe-based sintering technology." *IOP Conference Series Materials Science and Engineering*, vol.179, pp.12-15, 2017.

[11] R. D. Payne, A. L. Moran, and R. C. Cammarata."Relating porosity and mechanical properties in spray formed tubular." *Metallurgical and materials science*, vol. 29, no. 7, pp. 907-912, 1993.