CORPUS PUBLISHERS

Journal of Mineral and Material Science (JMMS)

Volume 1 Issue 4, 2020

Article Information

Received date : July 30, 2020

Published date: December 26, 2020

*Corresponding author

Zhiyong Liu, School of Mechanical and Electrical Engineering, Heze University, Heze, Shandong 274015, China

Keywords

Closed-Cell Aluminum Foam; Special Shape; Forming Process; Solid-Liquid-Gas; Coexisting State

Mini Review

Development Status of Porous Aluminum Foam and Development of Special-Shaped Closed Cell Aluminum Foam

Zhiyong Liu[1*] and Tan Wan[2]

[1]School of Mechanical and Electrical Engineering, Heze University, Heze, Shandong 274015, China

[2]School of Materials Science and Engineering, University of Tsinghua Beijing, Beijing 100084, China

Abstract

This paper mainly talked about the development status and trend of the closed-cell aluminum foam. The development status of the closed-cell aluminum foam and the research and development significance of the forming technology for the special-shaped closed-cell aluminum foam was discussed. Meanwhile, the research ideas and directions of the forming processing for the special-shaped closed cell aluminum foam were emphatically discussed.

Introduction

At present, the energy, information and materials are the three pillar industries of social development. A large number of the high-performance functional materials have been developed continuously with the development of metal materials science and technology, the progress of material design, technology and performance test. Among them, porous structure materials have the characteristics of low relative density, large specific stiffness, damping energy absorption and sound absorption and noise reduction [1-3], therefore, it is considered to be the most potential functional material in twenty-first century by researchers. The interdisciplinary penetration of structural materials and functional materials is reflected in porous structures materials, which shows a wide far-reaching significance in the academic field and has a broad application prospect in field of the high technology and general industry. Therefore, porous structure material has become a one of the research hotspots for researchers to study [4-7].

Development Status of Porous Aluminum Foam

Aluminum, magnesium, copper, titanium, iron, and other metals and their alloys have been used to prepared the porous structures [8-11]. However, because aluminum has the advantages of abundant reserves, low density, good ductility and strong corrosion resistance, resulting in it being the most commonly used to fabricate the porous structure materials [12]. In general, the porous structure materials are categorized into two types. The first is metallic foams, which is commonly characterized by closed-cell aluminum foam [13], and the other is called porous metals, which is mostly characterized by open-cell aluminum foam [14]. The unique mechanical properties and mature processing technique of the aluminum foam made it had been used widely in the fields of national defense military, rail Transit, construction decorate, automobile traffic, warship manufacturing and aeronautic and aerospace engineering [15-17]. The closed-cell aluminum foam was first prepared at the end of 1940s. In 1948, A.Sosnick fabricated the first closed cell aluminum foam by means of gasification of the mercury in aluminum melt [18]. However, since then, the development of closed-cell aluminum foam has been relatively slow. The rapid development of closed-cell aluminum foam began in the late 80s of last century, which is mainly attributed the success to the finding of the increasing viscosity effect of the calcium particles on aluminum melt by researchers [19]. Until now, the main preparation methods of closed-cell aluminum foams are the melt foaming method [20,21], gas injection method [22,23] and powder compact melting technique [24], moreover, the fabrication technology of closed-cell aluminum foam, foaming mechanisms and cell structure control methods have been studied extensively and mastered basically. The first open-cell aluminum foam was manufactured by Ethly in 1956 [25]. So far, the preparation technology of open-cell aluminum foam mainly included investment casting, space holder infiltration, and powder metallurgy [26-28]. The open-cell aluminum foams prepared by the above method have good inheritance to the porous structure of the parent material and depends on the porous structure of the parent material. In addition, 3D printing technology can also be used in the preparation of open-cell aluminum foam [8].

The demand of high technology and general industry fields for special-shaped foam aluminum is becoming increasing with the wide application of the aluminum foam and the continuous improvement of industry requirements for lightweight [29]. However, the existing closed-cell foam preparation technology is only suitable for preparing block, plate-like closed-cell aluminum foam and aluminum foam sandwich panels [30,31]. On the one hand, it is necessary to add certain particles into the aluminum melt to increase the viscosity of the melt when the melt foaming method, gas injection method are used to prepare closed cell aluminum foam [32], which made the closed-cell aluminum foam had poor mold filling ability and cell stability in liquid state, as shown in Figure 1(a). On the other hand, the closed-cell aluminum foam will collapse layer-by-layer when it deform in solid state because of the cell wall defect [33], as shown in Figure1(a). As a result, the forming technologies of solid metal materials(casting, pressure working) are difficult to be used to manufacture special-shaped closed-cell aluminum foam. Therefore, the closed-cell aluminum foam can only be cut into small size blocks and plates or the special-shaped products by mechanical cold machining (cutting, grinding, drilling), resulting in a single type of closed-cell aluminum foam product or a low utilization rate of closed-cell aluminum foam. Although investment casting, space holder infiltration, and powder metallurgy can prepare special-shaped open-cell aluminum foam, there are problems such as small size, low porosity, incomplete removing of the space holding particles and corrosion of matrix. As a result, the effect of open-cell aluminum foam in industrial application is not good, and its application degree is also low. Therefore, the quality and preparation technology of open-cell aluminum foam need to be further improved. Based on the above analysis, it is urgent to research and develop the forming process of special-shaped closed-cell aluminum foam, so as to meet the industrial demand for special-shaped aluminum foam.

How to cite this article: Zhiyong Liu and Tan Wan (2020) Development Status of Porous Aluminum Foam and Development of Special-Shaped Closed Cell Aluminum Foam. J Miner Sci Materials. 1: 1020

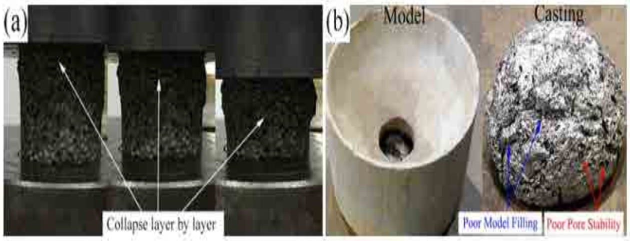

Figure 1: Deformation of closed-cell aluminum foam in different state (a)-Quasi-static compression at solid state; (b)- Gravity casting at liquid state.

Development of Special-Shaped Closed Cell Aluminum Foam

Base on the closed-cell aluminum foam can't be fabricated into special-shaped products neither in solid nor in liquid, the formability of closed-cell aluminum foam at solid-liquid-gas coexisting state was studied by researcher [34]. The flow stress of cell walls and the pressure in cells can be coordinated through controlling the solid-liquid gas-coexisting state of closed-cell aluminum foam [35]. Under the coupling effect of solid-liquid-gas, the cell walls have good thixotropism, moreover, the gas pressure in cells approximate to the thixotropic stress of the cell walls. In this case, the continuity of the cell walls and the integrity of the cells can be maintained during the closed-cell aluminum foam is effectively deformed at solid-liquid-gas coexisting, therefore, the characteristic parameters such as the structure of the cell walls and the morphology of cells unchanged basically after deformation of closed-cell aluminum foam at solid-liquid-gas coexisting state. The deformation of closed-cell aluminum foam in different solid-liquid-gas coexisting state was further investigated by researcher. Some suggestions were proposed for the preparation of closed-cell aluminum foam that is used to deform at solid-liquid-gas coexisting state, especially, the requirement of the cell size, the number and size of grains in cell walls of closed cell aluminum foam.

Summary

The deformation of closed cell aluminum foam at solid-liquid-gas coexisting is possible for the preparation of special-shaped closed cell aluminum foams with the further improvement of preparation technology of closed cell aluminum foam. Meanwhile, researchers should also focus on developing and studying the preparation technology of other special-shaped closed-cell aluminum foams to further expand the application range of closed-cell aluminum foams and promote the development of potential applications fields of the closed-cell foam.

References

1. Jeenager VK, Pancholi V (2014) Influence of cell wall microstructure on the energy absorption capability of aluminium foam. Materials & Design 56: 454-459.
2. Byakova A, Bezim YY, Gnyloskurenko S, Nakamura T (2014) Fabrication method for closed-cell aluminium foam with improved sound absorption ability. Procedia Materials Science 4: 9-14.
3. Li Y, Li Z, Han F (2014) Air flow resistance and sound absorption behavior of open-celled aluminum foams with spherical cells. Procedia Materials Science 4: 187-190.
4. Banhart J (2001) Manufacture, characterisation and application of cellular metals and metal foams. Progress in Materials Science 46: 559-632.
5. Utsunomiya H, Matsumoto R (2014) Deformation processes of porous metals and metallic foams (review). Procedia Materials Science 4: 245-249.
6. Kulkarni AA, Joshi JB (2005) Bubble formation and bubble rise velocity in gas-liquid systems: A review. Industrial & Engineering Chemistry Research 44: 5873-5931.
7. Banhart J (2006) Metal foams: Production and stability. Advanced Engineering Materials 8: 781-794.
8. He D, Zhuang C, Xu S, Ke X, Yang X, et al. (2016) 3D printing of Mg-substituted wollastonite reinforcing diopside porous bioceramics with enhanced mechanical and biological performances. Bioactive Materials 1: 85-92.
9. Li Z, Liu C, Wang B, Wang C, Wang Z, et al. (2018) Heat treatment effect on the mechanical properties, roughness and bone ingrowth capacity of 3D printing porous titanium alloy. RSC advances 8: 12471-12483.
10. He Y, Li Y, Zhang H (2017) Influence of withdrawing speed on the porous structures of gasar ingots fabricated by bridgman method. Journal of Materials Processing Technology 25: 106-114.
11. Golabgir MH, Kahrizsangi RE, Torabi O (2014) Fabrication and evaluation of oxidation resistance performance of open-celled Fe (Al) foam by space-holder technique. Advanced Powder Technology 25: 960-967.
12. Simone AE, Gibson LJ (1998) Aluminum foams produced by liquid-state processes. Acta Materialia 46: 3109-3123.
13. Jang W, Hsieh W, Miao C, Yen Y (2015) Microstructure and mechanical properties of ALPORAS closed-cell aluminium foam. Materials Characterization 107: 228-238.
14. Kim S, Lee C (2014) A review on manufacturing and application of open-cell metal foam. Procedia Materials Science 4: 305-309.
15. Chen S, Bourham M, Rabiei A (2014) Applications of open-cell and closed-cell metal foams for radiation shielding. Procedia Materials Science 4: 293-298.
16. Su L, Liu H, Yao GC, Zhang J (2019) Experimental study on the closed-cell aluminum foam shock absorption layer of a high-speed railway tunnel. Soil Dynamics and Earthquake Engineering 119: 331-345.
17. Baumeister J, Weise J, Hirtz E, Hohne K, Hohe J (2014) Applications of aluminum hybrid foam sandwiches in battery housings for electric vehicles. Procedia Materials Science 4: 317-321.
18. B. Sosnick, S. Francisco, Calif. Process for making foamlike mass of metal: 1948-1-20.
19. Davies JG, Zhen S (1983) Metallic foams: their production, properties and applications. Journal of Materials Science 18: 1899-1911.
20. Movahedi N, Mirbagheri SMH, Hoseini SR (2014) Effect of foaming temperature on the mechanical properties of produced closed-cell A356Aluminum foams with melting method. Metals and Materials International 20: 757-763.
21. Byakova A, Bezim YY, Gnyloskurenko S, Nakamura T (2014) Fabrication method for closed-cell aluminium foam with improved sound absorption ability. Procedia Materials Science 4: 9-14.
22. Moreno FG, Siegel B, Heim K, Meagher AJ, Banhart J (2015) Sub-mm sized bubbles injected into metallic melts. Colloids and Surfaces A: Physicochemical and Engineering Aspects 473: 60-67.
23. Zhou Y, Li Y, Yuan J (2015) The stability of aluminum foams at accumulation and condensation stages in gas injection foaming process. Colloids and Surfaces A: Physicochemical and Engineering Aspects 482: 468-476.
24. Ding X, Liu Y, Chen X, Zhang H, Li Y (2018) Optimization of cellular structure of aluminum foams produced by powder metallurgy method. Materials Letters 216: 38-41.
25. Pimiento SB, Hernández Rojas ME, Palomar Pardavé ME (2015) Processing and characterization of open-cell aluminum foams obtained through infiltration processes. Procedia Materials Science 9: 54-61.
26. Marchi CS, Mortensen A (2001) Deformation of open-cell aluminum foam. Acta Materialia 19: 3959-3969.
27. Wang LC, Wang F (2009) Preparation of the open pore aluminum foams using investment casting process. Acta Metallurgica Sinica (English Letters) 14: 27-32.
28. Jinnapat A, Kennedy AR (2010) The manufacture of spherical salt beads and their use as dissolvable templates for the production of cellular solids via a powder metallurgy route. Alloys and Compounds 499: 43-47.
29. Patel P, Bhingole PP, Makwana D (2018) Manufacturing, characterization and applications of lightweight metallic foams for structural applications: Review. Materials Today: Proceedings 5: 20391-20402.
30. Nesic S, Krupp U, Michels W (2014) Monotonic and cyclic loading behavior of closed-cell aluminum foams and sandwich structures. Procedia Materials Science 4: 269-273.
31. Duarte I, Vesenjak M, Opara LK (2014) Variation of quasi-static and dynamic compressive properties in single aluminium-alloy foam block. Procedia Materials Science 4: 157-162.
32. Elahi SH, Abdi H, Shahverdi HR (2013) Investigating viscosity variations of molten aluminum by calcium addition and stirring. Materials Letters 91: 376-378.
33. Peroni L, Avalle M, Peroni M (2008) The mechanical behaviour of aluminium foam structures in different loading conditions. International Journal of Impact Engineering 35: 644-658.

34. Liu ZY, Cheng Y, Li YX, Zhou X, Chen X, et al. (2018) Shape formation of closed-cell aluminum foam in solid-liquid-gas coexisting state. International Journal of Minerals, Metallurgy, and Materials 25: 974-980.

35. Liu ZY, Cheng Y, Li YX, Wang N (2020) Study on deformation of closed-cell aluminum foam in different solid-liquid-gas coexisting state. Metals and Materials International.