Study on Impact Properties of New Composite Metal Porous Materials Based on Data Analysis

Xiran Yang*
School of civil engineering, Central South University, Changsha City, Hunan Province, 410075 China
*Corresponding author e-mail: 3084363189@csu.edu.cn

Abstract. The new composite metal porous materials are widely used in sophisticated structure based systems as for their great influence on properties. While, it is endowed with potential in its role of decreasing the weight of products, costs of material as well as recycling. The new composite metal porous materials with customized mechanical and impact properties have also attracted the attention of researchers in industrial structural applications. Hybrid technology is one of the important and effective methods to enhance the properties of composite metal materials. In this paper, the influencing functions of properties of composite porous metal materials are investigated in order to improve their structural characteristics, especially the research on the enhanced impact resistance of composite porous metal materials.

Keywords: Metal, Porous Materials, Impact Properties

1. Introduction
In industrial fields where composite porous metal materials are applied, such as civil engineering, reinforced composite porous metal materials made from long and continuous new metals fail to reduce weight, and cost on life maintenance is not reduced due to their resistance to corrosion and resistance to fatigue [1-3]. Reinforced metal composites can be produced to a larger extent, and they are more used in sustainable manner, and are stronger and lighter than other common materials such as steel. The industry that uses metal compositions refers to the automobile field. In this industry, the majority of automobiles are produced by steel [4]. But, composite metal materials were initially adopted by manufactures instead of steel to make the cars lighter. It is estimated that the reduction of 25% in weight of vehicles could save the use of crude oil of 250 million barrels. The new reinforced metal based composition is characterized with different physical property and chemical property on micro and macro scales [5]. This has sparked interest of people in various engineering and structural industries, which serves as a way to increase ratio of weight. New metal-reinforced composite materials are universally adopted in fields such as military, marine, aerospace and civil engineering, benefiting modern industry a lot [6]. However, when exposed to impact damage, composite metal materials are expensive and difficult to repair.

In engineering applications, people are more and more interested in replacing single metal with new composite metal porous materials. The main objective is to reduce the use of metals by using new
metallic porous materials. New metallic porous materials provide the advantage of composite materials. The mechanical properties of new composite metal porous materials are determined by the structure of the metal. The new composite metal porous materials have excellent thermal and acoustic performance. Due to the porous structure and low concentration, composite metal porous materials need the best performance in cost effectiveness, maintenance and durability compared with single metal materials, which is critical for sustainable development. One of the obstacles in evaluation of the properties of strengthened metallic porous materials is to establish the resistance to impact. The impact property of the composite metal porous material was determined to enhance its own property. Therefore, composite metal porous materials can not only reduce the weak links of a single metal, but also have the advantages in environmental protection, impact absorption energy and better bearing capacity.

2. Composite Metal Porous Materials

The combination of two or more metals in the matrix of a single composite metallic porous material produces greater stiffness and strength than a single metal-reinforced porous material [7]. In general, a composite metal porous material has a lower cost of one material and a higher cost of the other metal. Low modulus and cheap metals make the composite metal porous material more resistant to damage and the total cost can be reduced, while exorbitant metals with high modulus provide the carrying capacity and composite stiffness. Therefore, composite metallic porous materials can offer high stiffness and strength so as to improve resistance to impact and fatigue, and thus high toughness of fracture can be achieved, and weight or total cost can be reduced [7]. Mixed composite porous materials can be classified as matrix composite porous materials. Thermoplastic metals are dissolved into thermosetting matrix during curing, which is called matrix composite porous material. Therefore, when a thermoplastic metal retains its metallic features after cured, it can be regarded as a metal composite porous material. Concerning thermoplastic metals, plastic deformation serves as a significant factor to improve absorption of energy of composite metallic porous materials. The aggregate energy consumed by the thermoplastic metal that is fused into the thermosetting matrix is similar to that of ordinary metal composite porous material. It is proved that the effect of metal properties on the aggregate energy consumed by the composite porous material is greater than that of the matrix.

2.1. Carbon Based Materials Reinforced Composite Metal Porous Materials

Compared with the structure of carbon-based materials, composite metal porous materials have special material properties and can reduce the structural weight, so they are widely used in structural applications [8]. By combining metals with expensive carbon/graphite metals, the composite porous material becomes more economically sustainable. Carbon/graphite is chosen for its high level of strength, low concentration and high modulus. The mechanical properties of composite porous materials are expected to reach the same level as single metals. In this field, composite metallic porous materials composed of different metals prove to be with effectiveness and practicality.

2.2. Natural Fiber Reinforced Composite Metal Porous Materials

It is well known that natural fibers have merit in low concentration, high level of strength, stiffness, which are renewable with low-cost in production [9]. However, these fibers also have some disadvantages such as low durability, good performance in absorption of moisture and low impact strength. Excessive work on mixed systems that contain natural synthetic fibers has give top priority to enhancing the mechanical and thermal properties of composite metallic porous materials. Recent studies have yielded optimistic results in blending natural fibers with synthetic metals. Compared with single metal materials, composite metal porous materials will be mixed with natural fibers to strike the balance in rational cost and optimal mechanical properties. For example, composite metallic porous materials boost the functions in higher strength and stiffness, as well as resistance to absorption of water, than natural fibers. The porous structure of natural fibers is hydrophilic, so the compositions
can swell as they swallow large amounts of water. Chemically modified natural fibers and composite metallic porous materials have been recommended as solutions, which will be used to reduce the degradation of mechanical properties to improve the resistance to moisture of the composite metal porous materials. Composite metal porous materials and natural fibers can be combined to produce hybrid composites, which will have superior mechanical properties and lower costs.

3. Test on Impact

Structure of engineering are frequently exposed to external substances, which may occur in maintenance, manufacturing and operations in services. Metal composition based porous material structure is more difficult to be damaged by impact than similar metal structure [9]. For example, tools may fall on structures during maintenance or manufacturing operations. Another example of an impact on service is when rocks and tiny debris on runway can be driven at high speed during landing and takeoff. Among such cases, the velocity of impact is lower, but the projectile mass is higher. In using the structure or composite material, stratification, matrix fracture, metal fracture and other internal damage will occur under the action of low-speed transient impact load. When these damaged specimens are used, the initiation of internal damage can lead to catastrophic failure. Therefore, the impact resistance of the composite metal porous material needs to be improved to prevent the final destruction of the structure. Ordinary inspection by naked eyes fails to be used to detect internal damage by impact in composite metal porous material structures. Such damage inside may gain momentum under load and may result in a severe reduction in strength. Therefore, we should come up with proper procedures in the design process, and taken account of the influence of foreign material on the composite porous structure. In the structural industry, due to the impact of composite porous structure performance, the limitations of composite metal porous materials have attracted people's attention. In the impact test, there are many factors that affect the impact performance of composite porous metal materials. One of the factors is the effect of the properties of metals on the composite metal porous materials. By regulating stiffness of the metal, the stress distribution of the metal under impact can be determined. In addition, the impact properties of the composite porous metal materials are also affected by the volume fraction of the metal, metal arrangement and stacking sequence. In addition, the ballistic properties of composite metal porous materials have been studied extensively. Therefore, one way to improve resistance to impact of metal composition based porous materials is through mixing treatment.

3.1. Resistance to Impact and Penetration Performance

The damage of impact with low-speed of metal composition based porous materials includes intramolecular damage, matrix fracture or metal matrix debonding, metal deformation or metal fracture, and the evolution to the stratification stage. High speed impact is the impact velocity up to 2500 m/s, which will lead to metal fracture and specimen perforation. However, in the case of low-speed impact, the impact velocity is between 5 m/s ~ 15 m/s, and the impact energy is between 0 J ~ 5× 10^25 J. Damage is usually invisible on the surface of the sample, and matrix cracks and stratification usually occur on the laminates [10]. Researchers have successfully improved the impact damage resistance of composite metallic porous materials. Therefore, researchers are also engaged in the work to reduce the accumulated damage in these composition based metallic porous materials. A solution is to use hybrid technology because hybrid composite metal porous materials can combine the properties of two different metals. The impact properties of metal composition based porous materials can be categorized into two types: impact with low speed and high speed impact. The metal composition based porous material was destroyed with functions under low speed impact; however, as to events related to high speed impact is concerned, the composite metal porous material can be usually perforated or penetrated by the impactor. According to the influence of material properties, four different stages of impact damage process are given explanations. Stage 1 load increased rapidly with no visible damage. Then you have the matrix cracking in the second phase, which diffuses
rapidly and this leads to the third phase, the demetallization of the interface. Finally, in the fourth stage, the material underwent metal fracture, layering, and perforation. Many factors affect resistance to impact and performance of metal composition based porous materials, including matrix, laminate thickness, metal, boundary conditions, composite sequence as well as geometric conditions. Ballistic based impact behavior also depends on kinetic energy, shape, and the scale of the impactor. Three types of impact test results of perforation, penetration and rebound are developed. Researchers have also been studying the possible damage caused by composite metallic porous materials under working conditions and the evolution of damage to flat or cylindrical structures caused by low-speed accidental impacts, hail blows, tool drops, runway debris, etc., during fatigue loading. Despite the fact that it is the impact energy with low incident and it may not be visible by naked eye, there is still impairment to structure through thickness. The failure will exert automatic influence and the stability, durability and structure strength can be reduced. The use of quasi-static tests can be used to quantify the impact events. The advantages of quasi-static tests are that they are cheaper and easier. In low-speed collision events, dynamic effects can be ignored because the tests are regarded to be quasi-static. In events with low-speed impact, the generation of damage and propagation can be detected in a easy manner, and deflection will be achieved with high accuracy and can be directly measured, and the lateral force can be better controlled to the most extent. Impact with low speed impact produces four important events with damage: damage by contact, stratification, damage by matrix as well as metal damage. Due to the short existence of this phenomenon and numerous factors, determining the exact sequence of events will be characterized with difficulties.

4. Conclusion
In recent years, composite metal porous materials have been widely recognized by the structural industry for their excellent properties. In this paper, the research progress of composite metallic porous materials, including impact resistance and penetration properties, is reviewed. Compared with metal materials, composite metal porous materials have higher properties. Many researches are devoted to improving the performance of composite metallic porous materials under high speed and low speed impact tests. However, due to the excellent structural properties of composite metallic porous materials, further studies are needed to evaluate the impact of impact tests on their properties. At present, researchers are continuing to study the synthesis of composite metallic porous materials as structural properties with excellent performance are maintained. In general, more studies are needed in verifying the applications of structures of composite metallic porous materials.

References
[1] Liu Wenhai, Liang Yongren. Performance analysis of metallic iridium porous material in refining and filtration [J]. China Metals Bulletin, 2019(07):179+181.
[2] Duan Liuyang, Zhou Zhaoyao, Yao Bibo. Structural characterization and impact properties of sintered stainless steel mesh porous plates[J].Journal of South China University of Technology (Natural Science Edition), 2016,46(07):85-93.
[3] Zhang Yunsong, Chen Wei, Cheng Jian, Li Wei, Wang Zihan. Experimental study on heat transfer of liquid film by Jet impingement on foam metal flow [J]. Cryogenics & Superconductivity, 2016, 46(02):48-55.
[4] Zhang Wei, Yang Huiwei, Guan Wenbo, Hu Jianxing, Lu Guoyun. Research on compression deformation of thin-walled metal hollow spheres under impact action [J]. Engineering Mechanics, 2016, 33(02): 242-248.
[5] Sun Junhu. Research on mechanical properties of porous metal materials [J]. Science & Technology and Enterprise, 2015(09):215.
[6] Lv Xiangfeng, Pan Yishan, Li Zhonghua. Rigid flexible energy-absorbing structure of porous metal materials and its application in support of rockburst roadway [J].Journal of Disaster Prevention and Mitigation Engineering [3],2011,31(02):185-190.
[7] Qiao Jichao, Xi Zhengping, TANG Huiping, Wang Jianyong, Zhu Jilei. A review of the
compression behavior of porous metal materials [J]. Rare Metal Materials and Engineering, 2010, 39(03): 561-564.

[8] Qiao Jichao, Xi Zhengping, Tang Huiping, Wang Jianyong, Zhu Jilei. Research progress on mechanical properties of metallic porous materials [J]. Rare Metal Materials and Engineering, 2009, 38(S3): 267-270.

[9] Wang Yuxin, Gu Yuanxian, Sun Ming. Theoretical calculation of explosion protection of porous composite structures under impact load [J]. Acta Armamentarii, 2006(02): 375-379.

[10] Xue Tao. Research progress of porous metal material aluminum foam [J]. Light Metals, 1993(04): 53-55.