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Editorial: Acoustic and mechanical metamaterials for various applications - volume II

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Editorial on the Research Topic
Acoustic and mechanical metamaterials for various applications - volume II

Metamaterials are homogenization wave-manipulation materials composed of artificial microstructures designed from natural materials, which could realize extraordinary physical and mechanical properties those natural materials do not possess. Composite materials, metamaterials, and smart materials are three important advanced functional materials. The essence is to use finely designed artificial microstructures to replace continuously distributed uniform materials in traditional equipment and structures, resulting in devices and components with more diverse functions and superior performance. From this perspective, the development of functional materials is equivalent to upgrading and expanding traditional equipment design. By fully leveraging the advantages of microstructure design, equipment design would be developed towards refinement, integration, and personalization. Due to the sub-wavelength structural characteristics of metamaterials and their excellent wave regulation ability, they have important application value in the regulation of acoustic and elastic waves (Ma et al., 2021). With the continuous development of metamaterials and the advancement of advanced processing techniques such as 3D-printing, metamaterials have shown important application value in many fields such as aviation, aerospace, ships, rail vehicles, automobiles, home appliances, and architecture. Therefore, in order to promote the development of metamaterials in applications, we have organized two special issues, attracted the attention of many scholars and received nearly 30 submissions.

In the Volume I, a total of 13 papers were published, including 4 papers on airbone sound absorption, 2 papers on ultrasound medical applications, 2 papers on waterbone sound wave regulation, 1 paper on seismic wave regulation, 1 paper on vibration attenuation, 1 paper on nano-device application, 1 paper on vibration energy harvesting, and 1 paper on energy regulation in atomic chains. Airbone sound absorption and insulation are of great concern and are the most mature. Scholars from Chongqing University have investigated the impedance matching of composite acoustic metamaterials composed of micro-perforated plates and subsequent Fabry-Pérot (FP) channels. Broadband sound absorption has been realized through a design with thickness of only 50 mm, the average sound absorption coefficient reached 0.88 with an absorption frequency bandwidth from 490 to 4,000 Hz (Wu et al., 2022). Scholars from Northwestern Polytechnical University have proposed a sub-wavelength porous meta-liner with sound absorption from 900 to 1,200 Hz. The propeller with the meta-liner duct can reduce the noise level of the ducted propeller between 3.6 and

5.5 dB in the design frequency range (Xiao et al., 2022). The team from Xi'an Jiaotong University have designed metamaterials with excellent sound absorption performance in the range of 600–900 Hz, and applied them to noise control in substations (Yang et al., 2022). The team from Jiangsu University have reduced the thickness of the sound absorbing metasurface to an extremely thin range of approximately 1/90 wavelength (Guan et al., 2021).

The regulation of sound waves in biological tissues and aqueous media has also been a hot Research Topic in recent years. The application of metamaterials in biomedical imaging can improve the transmission ability and resolution. In addition, applying metamaterials to aqueous media can achieve noise reduction, reduce sound radiation and sonar echoes. The attenuation and harvesting of vibration energy is also a Research Topic that we pay attention to. It can attenuate vibration energy or increase energy density through resonance, or through bandgap to block the propagation of mechanical waves. In addition to mechanical equipment, the application object also includes the isolation of seismic waves in buildings. In addition, metamaterials can also be used to construct various functional devices, achieving sensing and detection (Ma et al., 2022).

The Volume II included a total of 7 papers, including 1 review on bionic metamaterials, 1 review on tunable, reconfigurable, and programmable acoustic metasurfaces, 1 paper on isolation of underwater sound waves, 1 paper on shock and vibration resistance, 1 paper on acoustic energy attenuation based on acoustic black holes, 1 paper on acoustic beam splitting, and 1 paper on ultrasonic damage localization. The combination of various materials in complex composites is also a common feature of biological systems, which have been shaped in the course of evolution to achieve excellent properties in various requisites, both static and dynamic, thus suggesting that bioinspired concepts may present useful opportunities to design artificial systems with superior dynamic properties (Ma et al., 2014). So the scholar from University of Trento have reviewed a set of biological systems (nacre composites, spider webs, fractals, cochlear structures, and moth wings) and corresponding bioinspired metamaterials, highlighted their main features and applications (Dal Poggetto). In recent years, acoustic metasurface has extended to the regime of tunable, reconfigurable, and programmable control to further expand the capacity of AMs. The scholars from Rowan University have reviewed the recent development of AMs and summarizes the fundamental approaches to achieve tunable control, namely, mechanical tuning, active control, and the use of field-responsive materials (Zabihi et al., 2023). The Research Topic selection of these two reviews belongs to two very hot development trends in this field and has also received high attention from researchers.

Through more than 20 years of development, acoustic and mechanical metamaterials have successfully achieved various engineering applications. Among them, the application of sound absorption is the most mature, including broadband absorption of airborne and underwater sound. For airbone sound, many institutions such as the Hong Kong University of Science and Technology, Tongji University, Xi'an Jiaotong University, National University of Singapore, and Nanjing University have made significant breakthroughs. As early as 2019, our team used multi-order sound-absorbing metamaterials to build a fully anechoic chamber (Figure 1A), realizing large-scale low-cost high-speed machining of metamaterial structures. The thickness of the sound-absorbing structure is only about 1/4 of that of the traditional sharp wedge. The team of Li Yong from Tongji University has built a large-size low-temperature wind tunnel using sound absorbing metasurface, which is an application that traditional porous materials cannot achieve. The team of Ping Sheng from the Hong Kong University of Science and Technology, the team of Minghui Lu from Nanjing University, and the team of Jiu Hui Wu from Xi'an Jiaotong University have established specialized companies to promote the engineering application and technical services of acoustic metamaterials. In addition, many applications have been made in sound insulation, vibration absorption and isolation. For example, we have applied thin plate-type sound insulation metamaterials to car engine sound insulation covers (Figure 1B), and acoustic black hole insulation metamaterials to sound barriers (Figure 1C).

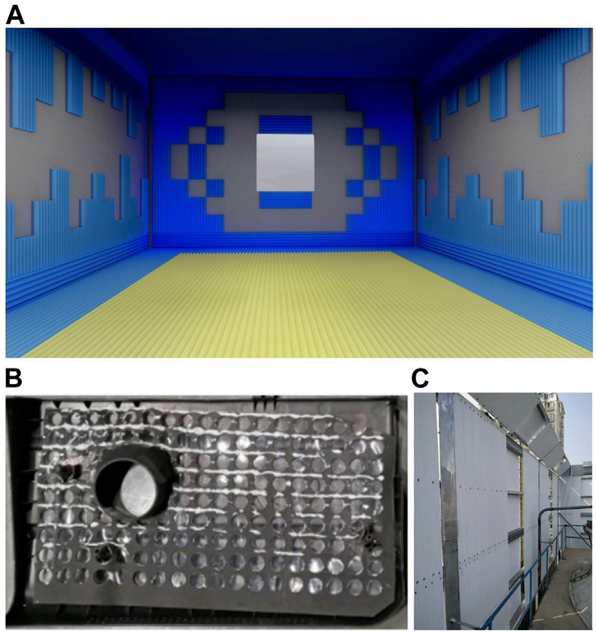

FIGURE 1
Engineering applications of acoustic metamaterials. **(A)** Metamaterial-based fully anechoic chamber; **(B)** metamaterial-based automotive engine sound insulation cover; **(C)** acoustic black hole type sound barrier.

At present, acoustic and mechanical metamaterials have sparked interest in the application of various industries, and we look forward to introducing metamaterials to solve technical bottlenecks in various fields, presenting a thriving scene. Although many gratifying achievements have been made, there are still many challenges to be faced. Firstly, many metamaterials with excellent performance in laboratory conditions often experience poor performance or even disappearance of advantages in practical engineering applications. Secondly, metamaterials are difficult to prepare through low-cost rapid processing solutions due to their relatively complex structures, which makes it difficult to accept cost-effective solutions with excellent performance. In addition, in practical applications, there are various requirements and constraints. Although metamaterials have excellent performance in some aspects, they may not perform well in other aspects, which leads to the need for a large number of compromises in practical applications, ultimately losing the performance advantages of metamaterials. However, we believe that with the continuous efforts of scholars, the application range of metamaterials will continue to expand.

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