Study on Miura Folding Technology and Its Application in Sound Insultation

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Abstract. Based on the wings of dragonflies, Japanese astrophysicist Koryo Miura invented a new folding technology called Miura folding. The core principles of Miura folding include symmetry, periodicity, and compactness. The structure of Miura folding is arranged alternately by multiple parallel creases, which can remain stable when unfolding and folding. The Miura folding has the advantages of compactness, speed, structural stability, mathematical controllability, and multi-field application. Compared with traditional methods, the Miura folding provides more efficient, flexible, and more controllable solutions for a variety of application scenarios, from space technology to practical tools in daily life. This article reviews the origin and advantages of Miura folding and discusses its applications, focusing on the design and innovation of Miura folding sound insulation walls. The progress in design, the challenges related to the control of sound insulation, and the sound insulation of Miura folding are discussed. In addition, this article also discusses the application of Miura folding in other fields, the application of Miura folding technology in the era of globalization, and the prospect of future Miura folding technology in the emerging technology field. This article may offer a reference for the development of folding technology.

Keywords: Miura folding; sound insulation; satellite antenna.

1. Introduction

In biological terms, folding is often depicted as an insect's wings, leaves and flowers. The wings must be attached to the insect's body, generally below the elytra, so that it can be hoisted up while flying. Both are related to the folded and expanded condition of the insect's wings. The movement of the body demands a compact relative to the great amount of space required for lifting the insect in flight [1].

By observing the wings of dragonflies, the peculiar lines on the wings suggest that the storage method of the wings is a kind of regular folding. Based on these phenomena, Japanese astrophysicist Koryo Miura invented a new folding technology. This technology can fold and unfold the object by pushing and pulling the object with opposite angles, and it can greatly reduce the volume of the object and increase its strength. It can also greatly reduce the loss in the folding process at the same time. This folding technology has been applied to many fields after its invention, such as satellite antennas, laparoscopic surgery, sound insulation walls, and so on.

The core principles of Miura folding include symmetry, periodicity, and compactness. This structure is arranged alternately by multiple parallel creases, which can remain stable when unfolding and folding. This principle is not only fascinating but also provides infinite possibilities for innovation in various fields. The design of Miura folding requires a number of factors, including material selection, structural parameters, expansion and folding mechanisms, and acoustic optimization. Together, these factors determine the performance and applicability of Miura folding. With the development of advanced digital design and manufacturing technology, customization and precise control have become more feasible, creating conditions for the expansion of its application field.

This article reviews the origin and advantages of Miura folding and discusses its applications. This article focuses on the design and innovation of Miura folding sound insulation walls and the advantages compared with traditional sound insulation walls. The progress in design, the challenges related to the control of sound insulation, and the sound insulation of Miura folding are discussed. In addition, this article also discusses the application of Miura folding in other fields, the application of

Miura folding technology in the era of globalization, and the prospect of future Miura folding technology in the emerging technology field.

2. Application of Muria Folding

2.1. Advantages of Muria Folding

Due to the special structure of Miura folding, it has a stronger energy density and can carry heavier weights. As it is a folding structure that requires less material than other non-folding structures, it also has a smaller weight, which will reduce its own mass in many aspects of the structure. In addition, this highly symmetrical and infinitely consistent feature makes this structure highly flexible, meaning that this structure can flexibly play different roles in different structures. The Miura folding has several obvious advantages over traditional methods, especially in spatial optimization and structural design. It is highly compact and space-saving. Traditional flat materials or structures usually require a lot of space when storing and transporting. The Miura folding can fold these materials into a compact three-dimensional structure, saving valuable space. This is very useful for space exploration, fieldwork, emergencies, and carrying equipment. At the same time, it can be expanded and folded quickly, saving time and energy compared with traditional methods, which is very beneficial for applications that need to be quickly set up or recycled. In addition, the expansion structure of Miura folding is very stable and can withstand certain loads and pressures, which makes it very useful in applications that require robustness and stability, such as the use of solar panels in space. The Miura folding pattern plate can be used as the core of the sandwich structure. Because of its high strength to mass ratio and adjustable energy-absorbing properties, sandwich structures have been extensively applied in airplane and automobile sectors. [2, 3] Nevertheless, the disadvantages of traditional honeycombs, such as accumulated moisture, complex production procedures and vulnerable to shock loads, restrict the use of sandwich structures. Compared to this, Miura Foldboard has many merits, for example, its open-air passage, its continuous production technology, its excellent energy-absorbing and impact-resistance performance [4]. It also has mathematical controllability, and the folding and unfolding process is controlled by accurate mathematical models, so the designer can accurately predict and control the behavior of the structure. This is very valuable in engineering and design because it is able to accurately meet specific needs. The Miura folding can be customized to meet the requirements of a special situation. The Miura folding can also be applied in many fields, not only limited to space exploration but also has potential applications in many fields, including maps, medical equipment, building structures, environmental facilities, and so on. This makes it a multi-functional tool.

In short, the Miura folding has the advantages of compactness, speed, structural stability, mathematical controllability, and multi-field application. Compared with traditional methods, it provides more efficient, flexible, and more controllable solutions for a variety of application scenarios, from space technology to practical tools in daily life.

2.2. Applications of Miura Folding

Thanks to the advantages of Miura folding’s own structure, it has a wide application potential and plays a role in many fields:

(1) Space exploration and satellite technology:

The Miura folding's compactness and expandability make it very useful in space exploration. Solar panels can be designed with Miura folding to unfold in space to collect solar energy, and then take less space when folded. Through the unfolded and folded panel, the angle of the panel can be automatically adjusted according to the position of the sun and lighting conditions, so as to improve energy efficiency. Satellite antennas can also benefit from this structure and can be expanded for communication when needed.

(2) Buildings and structures:

The Miura folding can be applied to the construction field to design expandable and foldable building parts. For example, expandable sunshades, soundproof walls, or roofs can be automatically expanded or folded as needed to adjust lighting, sound insulation or save energy. In addition, the Miura-folding structure can also be used to build stable buildings and bridges to improve its wind and earthquake resistance. At the same time, it can also be used as a part of the sandwich structure to play the role of sound insulation and cushioning. The Miura-type fold core is made up of a rigid foldable origami pattern with repeated inlay [5, 6], which provides better ventilation and heat dissipation than the closed honeycomb foldcore [7]. The performance of Miura-type foldcore sandwich beams in terms of explosion resistance has also been studied [8]

(3) Medical equipment:

In the field of medical equipment, the Miura folding can be used to design foldable medical equipment, such as surgical screens, patient isolation screens, portable medical instruments, and so on. These devices can be quickly expanded when needed, providing necessary functions, and then get folded when not in use for easy storage and carrying.

(4) Map and floor plan:

The Miura folding can be applied to the design of maps and floor plans. The map can be folded into a smaller size, which is easy to carry and store, and then expanded to view details when needed. This is very useful for outdoor exploration, travel, and emergencies.

(5) Nanotechnology and materials science:

In nanotechnology and materials science, the principle of Miura folding can be used to design nanoscale structures and nanodevices. This is very useful for the preparation of nanowires, nanotubes, nanoarrays, and other materials with special functions, and can be used in the fields of electronics, sensors, and biomedicine.

(6) Emergency response and fieldwork:

In case of emergency, the Miura folding can be used to quickly build emergency shelters, field workstations, or medical stations. These structures can be quickly expanded to provide basic shelter and support.

3. Miura Folding Sound Insulation Wall

Along with the rapid development of urban areas and the rapid development of transport, the noise pollution caused by various sources including industry machinery, civilian buildings, various types of cars and other air resources has emerged as one of the biggest environmental issues worldwide [9]. Prolonged exposure to loud noise can harm the nerve system of the person and cause all sorts of illnesses, including high blood pressure, heart attack, and stroke. In order to decrease the noise pollution and to remove the effects of noise on people, a large number of sound-absorbing materials have been developed. At present, there is a great deal of study on acoustic absorbing, especially in the case of foam and fiber sound-absorbing materials, which have a low cost, a good absorbing factor, and a reduced weight, as well as being an ideal material for controlling noise in construction and transport. The traditional sound insulation uses the sound-absorbing tube. When the sound wave encounters the sound-absorbing tube, it will pass through different materials in the sound-absorbing tube and be refracted many times. Each time the refraction energy will be weakened.[10] However, this kind of sound-absorbing tube not only has a complex structure and high production cost but also can reduce the noise of specific frequencies. That is to say, when encountering sounds in other frequency ranges, the sound absorption tube can do nothing.

This situation can be improved by adopting the sandwich structure and applying Miura-folding material. The material strength and flexibility of the Miura folding structure make it not only effectively absorb noise, but also improve its absorption of noise at different frequencies through some folding changes. By placing the sound-absorbing tube on an aluminum plate grille folded with Miura folding technology, the position and arrangement of the silencer are changed by controlling the angle of the grille folding, so as to absorb the noise of different frequency bands to achieve a real

perfect silence. The aluminum grille under the sound insulation wall adopts a Miura-folding structure. The Miura-folding sound insulation wall has a series of unique advantages over traditional sound insulation walls. In terms of folding and unfolding ability, the traditional sound insulation wall is usually a fixed structure, while the Miura-folding sound insulation wall has the ability to fold and expand. This allows it to unfold quickly when needed without taking extra space. When not in use, it can be folded to save space. Compared with their space efficiency, the Miura folding's compactness makes it particularly useful when the space is limited. It can provide effective sound insulation when unfolded while minimizing the space occupied when folded. This is very advantageous for the urban environment or limited indoor space. In addition, in terms of the mobility of the building, the Miura-folding soundproof wall can be designed as a movable structure, which is easy to rearrange or use in different locations. This is very practical in scenarios where the sound insulation configuration needs to be adjusted at any time, such as concert venues or temporary events.

In the face of the noise of different frequencies, the traditional sound insulation wall cannot achieve intelligent sound absorption and can only isolate most of the noise. However, the Miura-folding sound insulation wall can absorb the noise of different frequencies, and the sound insulation effect is better.

Regarding the innovative design of Miura-folding sound insulation wall, the innovative nature of Miura-folding sound insulation wall makes it a highlight in the field of architectural and acoustic design. It provides a novel way to deal with acoustic problems and can be used to create a more attractive and unique architectural appearance.

The Miura-folding structure has great potential for the design of sound insulation walls, but it still needs to be properly engineered and acoustically optimized to ensure its effectiveness in sound insulation. The Miura-folding structure can be adjusted to enhance its sound insulation performance. This may include selecting the right materials, increasing the structural hierarchy, adjusting the folding parameters, and so on. In addition, the choice of materials with good sound insulation performance is essential for the design of sound insulation walls. The structure of Miura folding can accommodate different types of materials, including sound-absorbing materials, to enhance sound absorption. The layout of the sound insulation wall also needs to consider the unfolding and folding process to ensure that it does not cause sound leakage or structural damage. In practical application, the designed Miura-folding sound insulation wall needs to be acoustically tested and optimized to ensure that it meets the expected requirements in terms of sound insulation performance. It should be emphasized that the application of Miura folding in sound insulation may require more research and engineering work to determine its applicability and effectiveness.

4. Future of Miura Folding

The Miura folding, as a traditional folding technology, contains rich cultural values, covering many fields such as art, aesthetics, education, cultural inheritance, and structural design. It is not only a clever and practical structure, but also provides a platform for cultural exchange and innovation on a global scale, with far-reaching and lasting cultural significance.

In the context of global modernization, the Miura folding faces new development opportunities and trends. It can be applied to sustainable architecture and design. As the global demand for sustainable architecture and design increases, the compactness and expandability of Miura folding make it an ideal choice for designing sustainable architectural elements.

In the process of urbanization, the Miura-folding structure can be used to improve the availability and efficiency of urban space. It can be applied to temporary activity places in cities, helping to create a more attractive and sustainable urban environment. It can also be used in the field of emergency medical equipment and portable equipment. Expandable medical equipment, temporary medical stations, or shelters can be quickly deployed in the event of a disaster or emergency to provide the required medical support. The compactness of Miura folding makes it an innovative design element of wearable technology and portable devices.

At the same time, advanced digital manufacturing technology and 3D printing technology can be used to accurately manufacture Miura-folding structures. This means that the Miura-folding element can be customized as needed to expand its application field. The Miura folding has strong artistic and cultural value, which can promote international cooperation and cultural exchange. Artists and designers can cross cultural boundaries and create unique works of art through Miura folding creation.

5. Conclusion

The Miura folding, a folding technology originating from Japan, is famous for its unique folding structure and extensive application potential. This paper discusses the basic principles, design considerations, cultural values, and potential application fields of Miura folding. The Miura folding has a wide range of potential applications. It can be used in architecture, medical care, culture and art, concert venues, and other fields, providing a variety of innovative solutions. Its space efficiency, mobility, sustainability, and aesthetic value make it popular in modern society. The Miura-folding sound insulation wall has a series of advantages that can give it a lot of room for development in the future. Although the Miura folding is still evolving and developing, it has emerged in modern society, bringing new possibilities for innovation and design in various fields. With further research and engineering development, the Miura folding will continue to attract people's attention and play an important role in future innovation.

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