The Applications of Shape Memory Alloy

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Abstract. With the rapid development of the aerospace industry, more stringent new requirements have been put forward for new materials. A large number of intelligent materials have emerged. The most noteworthy among them are shape memory alloys (SMAs). Therefore, the number of SMAs used for aerospace research has increased significantly. It is very necessary to analyze these works. This article focuses a specific kind of active materials called SMAs, especially for the applications of this material in the aerospace field. SMAs are able to 'memorise' or restore their previous form when facing thermal, thermomechanical or magnetic changes. Because of its superior performance and diverse uses, it is widely used in various engineering fields. A brief introduction of SMAs is provided in this work. Their outstanding properties and extraordinary working principle can also be seen in this article. Before and nowadays aerospace applications are introduced. The applications of SMAs in wing morphing, lifting body, and variable geometry chevron, were also introduced. This work will promote the application of SMAs in the aerospace field.

Keywords: Shape memory alloy, application, property.

1. Introduction

A shape-memory alloy (SMA) is a material that is able to change the shape as temperature is low, while convert back into its original shape when being heated. It has a lot of aliases such as memory alloy, memory metal, smart metal, muscle wire and so on. The "memorized geometry" has the ability to modified by immobilizing the desired geometry and applying heat treatment to items. To give an example a wire can memorize the shape of a helical spring through teaching. Assembly units made of shape-memory alloys are considered as solid, lightweight substitute o traditional actuators like pneumatic, hydraulic, and motor-based systems. They are also able to be applied in the production of hermetic joints in metal tubing, and it can become a substitute for sensor-actuator closed cycle to command the temperate of water by adjusting the flow of ratio of hot and cold water. Copper aluminum nickel and nickel titanium are the two most usually seen shape memory alloys, but SMAs also can be made from other materials such as alloying iron, gold, zinc and copper [1, 2].

Casting, induction melting or vacuum arc melting are the most usually seen methods of making SMAs. These special technologies are used to keep the alloy remaining highest level of purity and to make sure all the metals are combined with each other well. Then the ingot is rolled when heated, becoming longer sections and then stretched into wire. Although SMA can be manufactured through single crystal form but most of the applications of it prefer to use polycrystalline components.

Shape memory effects were first discovered in the 1930s. Based on the information given by Otsuka and Wayman, Arne Ölander was the one who discovered Au-Cd alloy's pseudoelastic behavior in 1932 [3]. The fundamental phenomenon of the memory effect which is controlled by the thermoelastic behavior of martensite phase was reported widely ten years later by Khandros.

2. Shape Memory Effect

There are many diverse shape-memory effects of SMAs. The two most usually seen effects are one-way SMA and two-way SMA as it is shown in Fig.1. Their procedures are very similar: beginning with martensite, increasing the deformation, heating the sample and then chilling it once more [4].

2.1. One-way SMA

As a shape-memory alloy is at a low temperature (below M_f), the metal's shape can be changed by bending or stretching and will remain those shapes until its temperature is higher than the transition temperature [5]. The shape returns to its previous shape at the time it is being heated. When the metal's temperature goes down again, it will keep that shape, up till it is deformed once more.

2.2. Two-way SMA

The definition of two-way shape-memory is it is a material that can remember two different shapes: one when it is cool, and one after it being heated. When a shape-memory effect at not only high and also low temperature is shown, that material is considered to have two-way shape memory. The application of an outward force (intrinsic two-way effect) is not necessary for this to achieve. The reason why the material has such different behavior in these situations is because training. Training gives shape memory alloy a chance to "learn" how to act in a certain routine. In general causes, a shape-memory alloy "remembers" its shape at low temperature, but after being heated and returning its shape at high temperature, it "forgets" its shape at low temperature immediately.

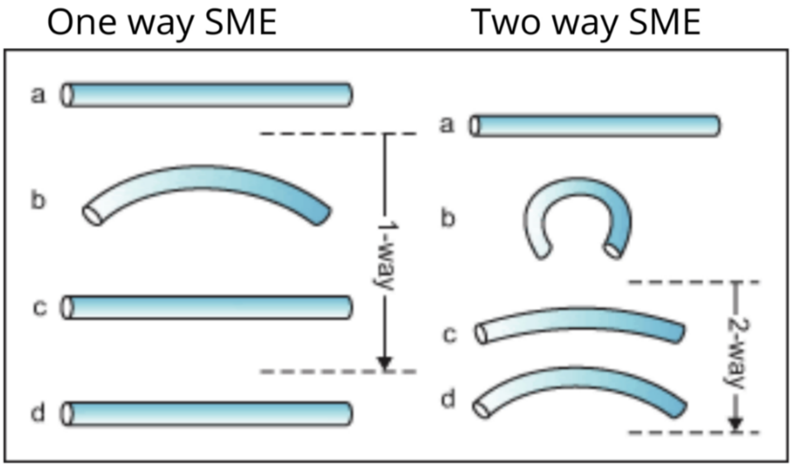

Figure 1. One- and two-way shape memory effect [4]

3. Principle

At a same composition, a lot of metals own several different crystal structures, but most of them do not have the appearance of shape-memory effect. This extraordinary property gives shape-memory alloys the power to recover to their original shape after temperature change is that there has fully reversible crystal transition process [6]. In majority crystal transitions, diffusion is the main method atoms travel through the metal in the structure, locally altering the composition, even though the same atoms build up the whole metal. This diffusion of atoms does not have a reversible transformation involved, instead all the atoms moving simultaneously, forming a new structure, just as a square can become a parallelogram by pushing two opposing sides. Diverse structures are wanted at different temperature and when the temperature of the structure below the transition temperature, the martensitic structure is formed by austenitic phase [4].

The SMAs unique behavior has an important relationship with phase transformation. The material is transformed between two specially appointed phases, martenite and austenite by martenite transformation. The two phases have a very different structure. Martensite with a squared or monoclinic crystal is a low temperature phase. While the other phase-austenite has characteristics of cubic crystalline structure, high temperature or parent.

4. Application

As the importance of responsibility and versatility [7] in the aerospace industry increasing day by day, shape memory alloys are attracting more and more attention of engineers around the world. SMA could be used in wing morphing, lifting body and variable geometry chevron.

4.1. Wing Morphing

New methods and applications on account of the integration of the SMAs in the real-world technologies as well as the definition and improvement of new techniques has been eagerly demanded by aerospace industry. Wing morphing of the airplane is a practical application of SMAs, including construction modifications to meet the specifications required under different condition of use. Here is some of the benefits: acceleration, decreased power dissipation, roll control, and camber alternating [8]. Morphing, from other point of view, is commonly related to defects such as not continue surface and overweight cause of the essential control structures. The employment of solution of shape memories and the mechanisms corresponding to it can help to overcome these shortcomings [8].

In a patent relating to the wing main spar, an extraordinary and fascinating structural execution of SMA drive is discovered. Placing the active abstract parts inside spars that has a shape of tubes [9]. This is going to use in extension and retraction of a telescopic part of the ultralight wing in the direction of span-wise, which uses SME again. To give another example, the morphing who has a large scale and involves geometric changing with dimensional alternations are at the equal pace with the wingspan. While in this case the selection of final morphed configuration was not intending to offer any sort of aerodynamic development explicitly, it confirmed the achieve possibility of working out the firm of the required mechanism. This kind of morphing should prove to be beneficial. In the end, scientists studied not only the theoretical and also experimental reactions using antagonistic bending unit cells to deform entire structures, in which on two sides of a simple articulated mechanism two opposite one-way SMA linear abstract parts (wires or ribbons) are mounted [9]. This subsystem (the unit cell) is then done again in direction of length, contributing to the formation of a morphing structure that is similar to a truss. This idea was shown can be realized in experiment. It can normally be applied in both airplanes and spaceships because their structural unit cells are able to be organized to adapt to the different needs.

4.2. Lifting body

Expect applying in the propulsion system, SMAs also have a wide application in adapting lifting bodies. Inserting SMA wires into an innovative recombination structure is one of the promising approaches. For the sake of making fully use of the one-way shape memory effect, 150 μm diameter NiTi alloy wires have been pre-stressed and put into a Kevlar fiber epoxy matrix [10]. There's a promised future for SMA composites in adaptive applications such as gradual strengthening of components (structure) or alternatives of the natural vibration frequencies. However, behavior of SMA is not linear and provides many other choices. In addition, there is a need to increase knowledge about the pressure traded between the metal and the polymer matrix and the fatigue behavior of such structures.

4.3. Variable Geometry Chevron

Two scientists, Hartl and Lagouda was focusing on a project which can decrease noise produced by departing planes at airports generated [9]. It has been proven, using pneumatic devices, also called chevrons, on the back edge of an exhaust nozzle (including both primary and secondary exhaust streams) can reduce the departing noise of plane. This has to thank to the proper streams mixing. Due to the installation of a secondary exhaust nozzle, the V-shaped tube plunged in the fan stream shows a decrease in thrust and an increase in things delay process when cruising. Because of all this reasons, Variable Geometry Chevron (VGC) has become the optimum solution. On account of SMA components, VGC exhibits full curvature while departing and descending with least level of deflection flow during cruisie, thus increased the efficiency and guaranteed noise reduction. The system consists of active SMA bundles wrapped in a composite shell. Thanks to the activation of the SMA beam, the Chevron structure is allowed to apply the required bending force, thus reducing noise.

5. Conclusion

Applications of SMAs in the aerospace sector have been named, invented, standardized and examined over the past two decades. The demands of SMAs alloys have experienced a dramatic and continuous increase after 1969. Many other technologies will be concerted and developed in the coming future. Proceeding with the fundamental theory and the mechanical behavior (pseudoelastic and shape memory effect), a lot of wings morphing related usages have been proposed (experimental and standardizing). Making it fit for the entrance geometry of diverse propelling systems would be the future research directions.

The industry is considering SMA designs for future applications. The new developments in SMA manufacturing and processing will be even more powerful when designing. In conclusion, in this work, the mechanism and application of SMAs were introduced. The computational model of SMA behavior is studied for further development.

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