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Automotive application of shape memory alloys

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ABSTRACT

Shape memory alloys have drawn much attention and interest due to their unique properties such as shape memory effect and psedoelasticity. They found numerous applications in every field of engineering. The key advantage is that Shape memory alloys equipments especially actuators do not require bulky and complicated mechanical design to function, where the active element can be deformed by applying minimal external force and will retain to their previous form when subjected to certain stimuli such as thermo mechanical or magnetic changes. This paper describes the some of the applications of SMA in a vast area of automobile.

I.INTRODUCTION TO SHAPE MEMORY ALLOYS

For centuries metal have played an important role as structural materials. Since Bronze Age men are using the alloys. With advancement in technologies, people are trying to understand the material behaviour. Apart from alloys, many other material(like composite) have been introduced, but a special group of material that exhibits some typical engineering functionality like sensing, actuation etc. are called 'active materials'.

In this chain a name included is 'Shape Memory Materials' which couples thermal with electrical field. Shape Memory Materials (SMM) are featured by the ability to recover their original shape from a plastic deformation. Despite the SME (Shape Memory Effect) was found in 1932, in AuCd alloy, but the phenomenon was not so attractive till 1962 when a significant recoverable strain was observed in NiTi alloy at Naval Ordnance Laboratories, USA .

The martenstic transformation occurs in shape memory alloys due to change in temperature. Because of these phase transformation the SMA exhibits two extraordinary characteristics, which are SME and PE.

Shape Memory Effect

A material first undergoes the martensitic transformation. After deformation in martensite state the permanent strain is recovered when the specimen is heated. This occurs due to reverse transformation effect. But upon cooling it does not return to its deformed shape.

Pseudoelastic Effect

When the SMA is stressed at temperature just above transition temperature the martensite phase is induced due to stress. It shows a increasing strain at constant stress. On unloading the material reverts to austenite phase at lower stress. This effect causes the material to exhibits the extreme elastic behaviour, known as pseudoelastisity.

Automotive applications of SMAs

The demand for safer, more comfortable and enhanced performance vehicles have tremendously increased the number of sensors, actuators and microcontrollers installed in modern vehicles, which will increase the weight and volume of the vehicle, and are not preferable in vehicle design. Shape memory alloys proving a pioneer in this area.

Body Frame

In automobiles the bumper beam absorbs the accidental kinetic energy by deflection in low-speed impact and by deformation in high-speed impact. Based on the last years necessity of lighter materials and safer usage of vehicles we try to come with a new class of materials for bumper systems. Analyze of metallic materials is cheaper when the analyze take place on a computer avoiding the metallic loss or energy consume. RĂCIUN Radu Cristian et. al.[1] presented few results obtained in Catia software about the behavior of some metallic materials under external solicitations in function of the mechanical properties of metallic elements, geometry of the element, restrains and solicitation points. Shape memory alloy are smart materials that can use the external mechanical energy damping to thermal energy in bumper applications. In martensite to austenite domain they observe an increase of damping mechanical capacity with possible applications in bumper systems.

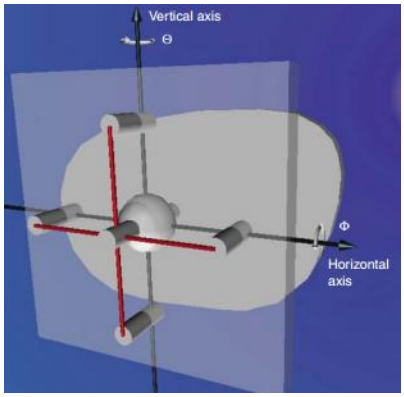


Figure1 The SMA actuated side-mirror concept. Four SMA wires when heated through Joule heating contract and provide the rotational motion about the two axes[2]

Shape memory alloys (SMAs) provide dense and effective actuation for a variety of mechanical systems. Eric Williams and Mohammad H. Elahinia [2] developed a two degree of freedom SMA to turn the position of a rearview mirror for automotive applications. To evaluate the performance of the actuator a prototype SMA actuated mirror is designed and fabricated (figure 1). Four SMA wires were used to develop an antagonistic type SMA actuator to orient an automotive side mirror. The main benefits of the new actuator are in simplifying the design and in providing cost savings. This model includes all the major subsystems of the mirror: dynamics and kinematics of the mirror, thermomechanical material behavior of the SMA wires, and heat transfer model of the

wire. Experimental evaluations as well as simulations showed the effectiveness of the new SMA actuator. Ibrahim, Muhammad Firdhaus [3] developed a wind shield wiper for automobiles (figure 2).

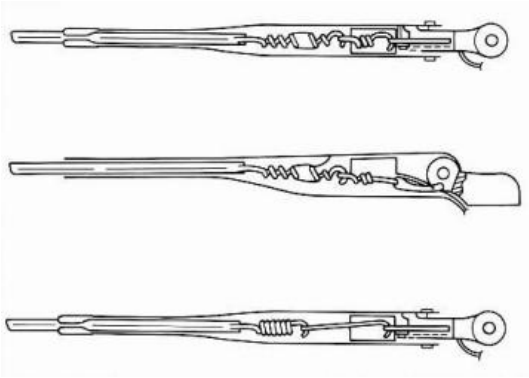


Figure 2: Wind shield wiper using SMA

Automobiles often include child locks for preventing doors, especially rear doors, from being opened from within the passenger compartment. This sometimes creates a problem for adult who is sitting there because then another adult have to open it for them. Also the cost of installation is high so it is preferable to reduce the cost without compromising the safety and convenience and SMA locking system does it [4].

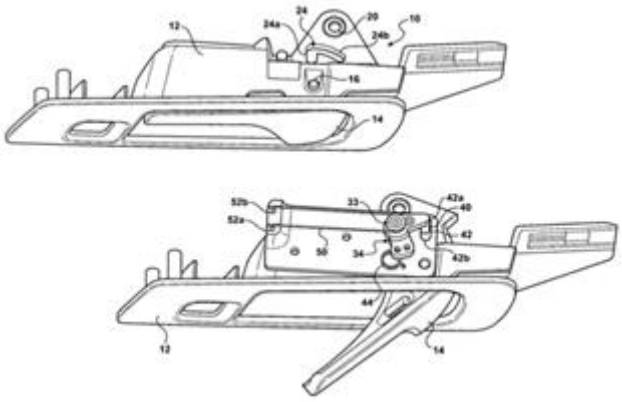


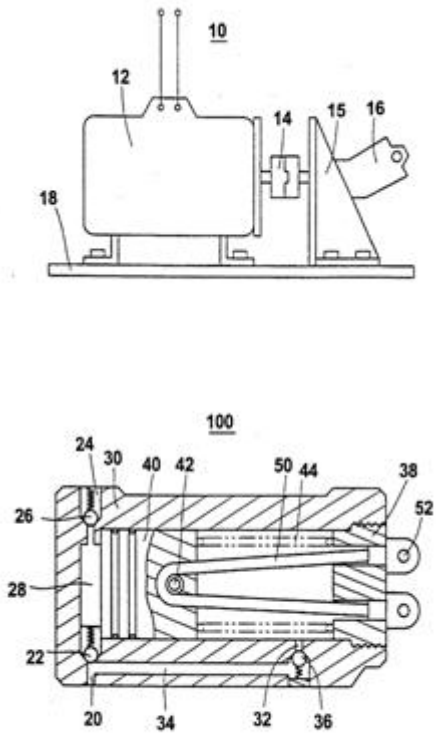
Figure3: Door handle and child lock assembly [4]

One aspect of the invention provides a handle assembly which functions to enable or disable the door handle from actuating a latch rather than installing a lock assembly on the latch itself. In order to reduce packaging requirements and still keep costs low, the actuating mechanism preferably employs a wire, formed from a shape memory alloy, which is able to contract and expand in order to activate the locking function.

Engine

Hong-Jae Lee [5] invented a hydraulic pump using shape memory alloy in 1995. Pump is connected to electric terminals to be contracted by the supply of electric power for lowering a piston, the piston mounted to move within a cylinder to thereby introduce a fluid into the cylinder is raised by a biasing force of a bias spring to

externally discharge the fluid introduced in the cylinder. The pump had a simple structure which is light and easily repaired and maintained.



.Figure 4 PUMPUSING SHAPE MEMORY ALLOYS [5]

Robinson et al.[6] were invented a fuel-air system using shape memory alloy to fuel flow as function of temperature or electrical means. The shape memory alloy will change shape at a defined temperature, or in a particular temperature range, and as a result affect a control feature internal to a component in the fuel System.

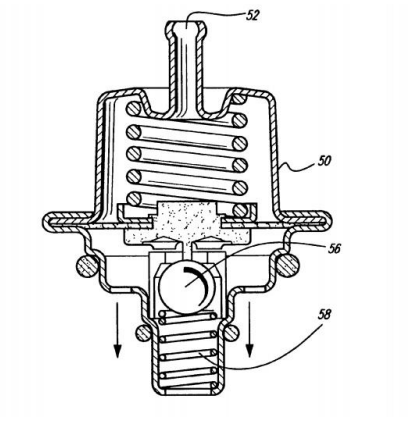


Figure 5 fuel air system containing SMA [6]

Battery Module

Abujudom, II et al[7].were invented a battery module in 1990 for engine. Module including a battery compartment, an air inlet and an air outlet, a first air flow path connecting the air inlet to the air outlet and a second air flow path around the outside of the battery compartment. The battery module has been designed to provide reductions vehicle assembly costs, number of molded parts and inventory. Use of shape memory alloy member with positional damper is used to divert the inlet air flow with change in outside temperature.

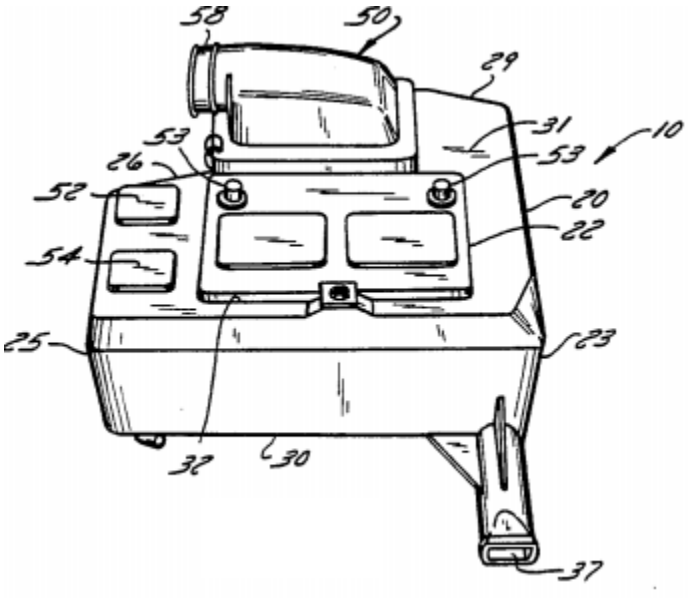
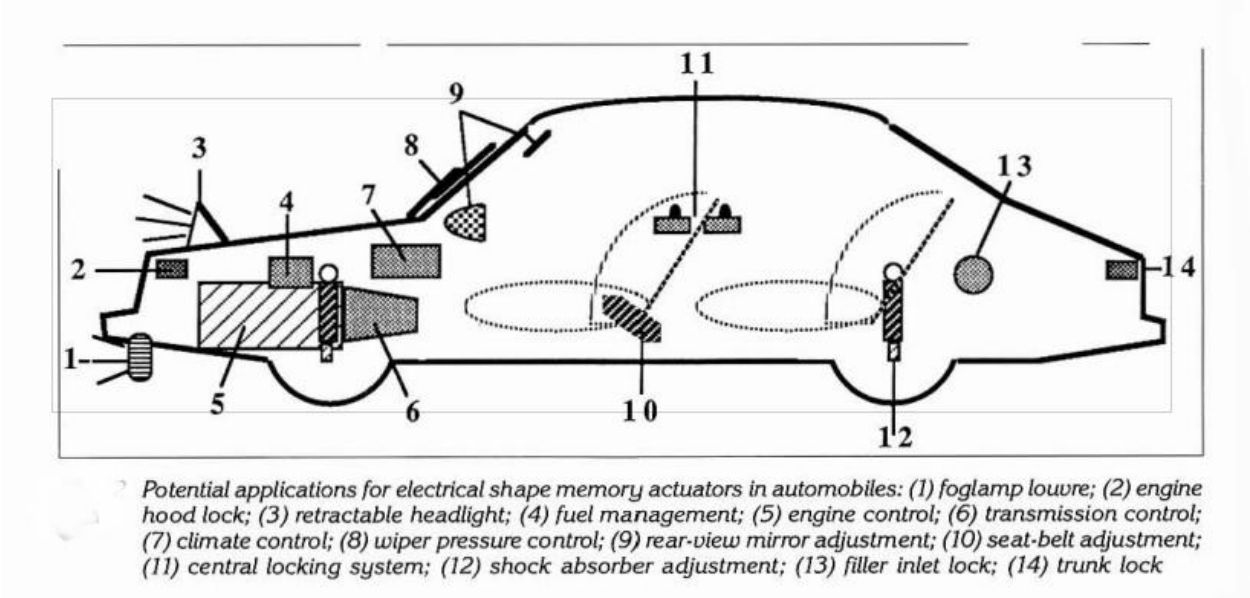


Figure 6 Battery module

Shape memory actuators

SMA actuators have wide application in automotive industries. Generally Ni-Ti alloy are preferred due to high strength, high electrical resistivity, large recovery strains, easy workability, and excellent corrosion resistance. SMA actuators can basically be activated in two ways; thermally or electrically. shape memory alloys (SMAs) are a promising material system as they show multiple coupling effects as well as large, abrupt changes in their physical properties, e.g., of strain and magnetization, due to a first order phase transformation. Figure 7 shows some potential application for shape memory actuators in automobiles.



Potential applications for electrical shape memory actuators in automobiles: (1) foglamp louvre; (2) engine hood lock; (3) retractable headlight; (4) fuel management; (5) engine control; (6) transmission control; (7) climate control; (8) wiper pressure control; (9) rear-view mirror adjustment; (10) seat-belt adjustment; (11) central locking system; (12) shock absorber adjustment; (13) filler inlet lock; (14) trunk lock

Figure 7 potential applications for shape memory actuators

In thermal valve (fig. 8), when temperature is above optimum, Ni-Ti spring expands and pushes on steel spring which opens a secondary valve to allow more cool water to flow through the cooling system. Benefit of the use of this type of actuator is that it doesn't require additional power supply.

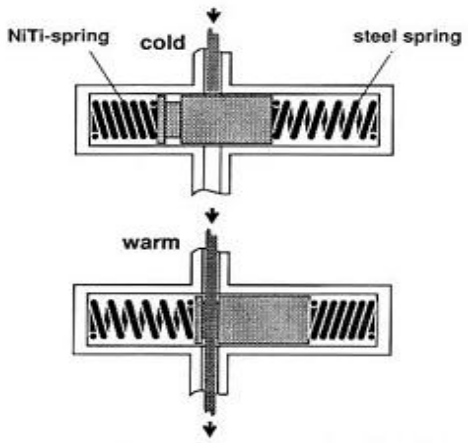


Figure 8 Thermal valves [8]

The most recent application is the heat-to-recover NiTiNb plug for sealing high-pressure fuel passage in diesel fuel injectors [9]. A typical heavy-duty diesel fuel injector comprises of a solenoid control valve, a plunger cylinder and a fuel passage linking the first two elements, as illustrated in fig. 9. Through this passage a fuel communication is established where the fuel is delivered into the plunger cylinder via control valve.

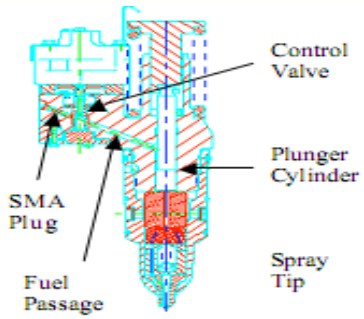


Figure 9 Typical construction of a diesel fuel injector [9]

II.CONCLUSION

Shape memory alloys having wide applications in automotive industries like actuators (thermal or electrical) which again provide better comfort, safety and control. Smart materials enhance automobile safety, performance, energy-efficiency and comfort. The many uses and applications of smart materials ensure a bright future for these metals.

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