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SOLVING AIRCRAFT PROBLEMS WITH SMART MATERIALS

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Abstract *–There is a strong relationship among the materials and aerospace industry because materials determine the weight, strength, efficiency, cost, and difficulty of maintenance of an aircraft. The aircraft designers want to use the materials those are light, high strong and durable. The increasing of efficiency and improvement of reliability include the use of smart materials. Smart materials are those materials which can perform a special action in response to some specific conditions like high or low temp, high stress and high or low pH value. Smart materials are able to transform electric energy into desired energy. Various types of smart materials like piezoelectric, shape memory alloys, magneto stricive materials are used. These materials reduce aircraft engine noise and sound, vibration, cabin noise, flutter problems, flow separation or turbulence, and handle more heat. In the smart materials there are sensors, actuators and controllers. So the applications of smart materials are increasing rapidly.*

Keywords: Smart materials, Piezoelectric, Vibration, Noise and Actuator

1. INTRODUCTION

With the development of material science many new, high quality and expensive materials have come into the field of aviation sector. Smart materials find a vast range of applications. Smart materials are the new materials which change their properties by applying external stimuli like temp, pr, electric and magnetic fields. By changing their properties smarts materials can detect faults and cracks in the aircrafts. Smart materials, each exhibits particular properties. The materials which only exhibit shape change are known as shape memory alloys. Some alloys may show two way effect one is above the memory temp and other is below the temp. At the memory temp, the materials alloy goes a solid state phase transformation. The scope of applications of smart materials include engineering problems like vibration control, sound control, shape control, self-repair, damping aero elastic stability, and stress distribution. Smart materials increase passengers and crews comfort by reducing vibration and noise and increase systems and components structural life. They also improve aircraft performance and optimize aerodynamic and lifting surfaces.

2. DEFINITION

The materials which change their properties by external stimuli like stress, temp, electric and magnetic fields. Some smart materials are called sensual devices because they can sense their environments and supply a signal in response. Other smart materials both sense and environment and they are known as adaptive materials.

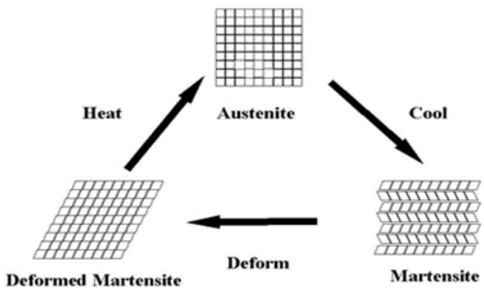

Fig.1: Smart material

3. STRUCTURE

Another important feature of smart material is smart structure. The main five elements of smart structure of smart materials are given below:

Data acquition: The main of this component is collect new data for sensing and monitoring the structure.

Data transmission: Forward row data to the central command and central unit.

Command and Control unit: Manage and control whole system by analyzing data.

Data Instructions: Transmit decisions and instructions.

Action Devices: Take action by controlling the devices.

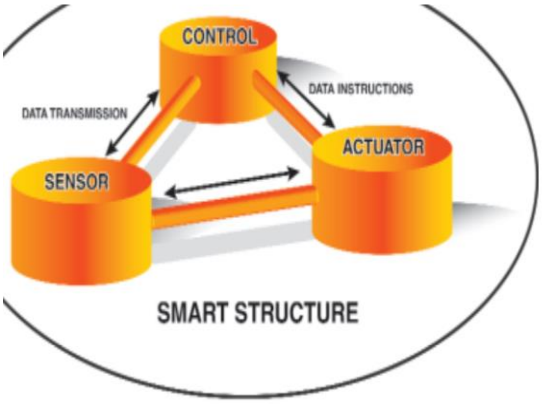

Fig.2: Smart materials structure

4. CLASSIFICATIONS

Smart materials can be classified into two categories:
(i) Active materials: they posse the capacity to modify their geometry or material properties by application of electric thermal or magnetic fields. Piezoelectric, SMAs are the examples of this material.
(ii)Passive materials: These materials are not active. Fiber optic materials is the good example.
Piezoelectric materials: Piezoelectric materials produce voltage when stress is applied and vice versa. Appropriate designed structured materials can be made from these materials.
Shape Memory Alloys: They are materials when temp is applied large deformation is occurred. The shape memory effect happens due to the change of martensitic phase and induced elasticity.
Magneto strictive materials: Exhibition of shape change under the influence of magnetic field.
Common smart materials and associated stimulus response

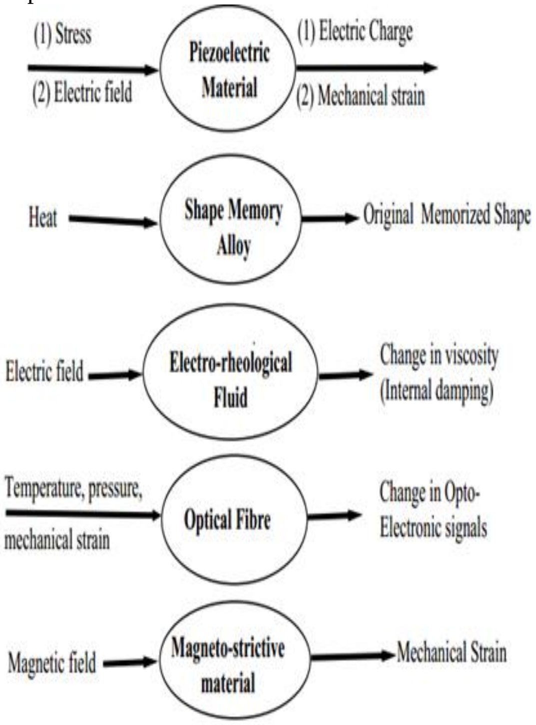

Fig.3: Response of smart materials

Table1: Comparisons among different smart materials

Active system	Shape memory alloys	Magneto strictive materials	Piezo Electric materials
Driving force	Thermal field	Magnetic field	Electric field
materials	TiNi,Tipd	Tbfe, Smfe	PZT
Advantages	(i)Large forces (ii) High frequency (iii) high strength	(i)High frqency (ii)High temp range (iii)contract less control via magnetic field	(i)High bandwidth (ii)High frequency (iii) Low power actuator

5. SOLVING VIBRATION PROBLEM

Vibration is an unwanted effect in the aircraft as it creates stress concentration, material fatigue, shortening service life, efficiency reduction and noise. So the engineers always try to minimize the vibration. By using piezoelectric material it is possible to produce the anti-resonance vibration. Vibrations are suppressed systematically. The piezoelectric sensors convert the mechanical deformation into electric signal. Then the electric signal is processed by control center which inverts the signal and amplifies it. The new signal is sent to the actuation device. Then another piezoelectric material converts electric energy into mechanical energy and thus reduce the vibration. Sensory structure are designed for controlling the aerospace structure such as acoustic noise, vibration, drag and skin friction by using advanced polymeric smart materials.

5.1 Active Suppression of Skin Panel Vibration

Skin panel vibration is produced due to engine noise and flow separation that can lead the fatigue failures. For this failure there is need more maintenance cost. The use of piezoelectric wafer reduce the aircraft skin panel vibrations. So the aircraft lifetime will increase.

6. NOISE SUPPRESSION

Comfortness is mostly preferable in most of the aircrafts. No one want to hear noise. Noise produced mainly from engines, propellers and helicopters rotor in the cabin. By proper interacting the structures with smart material noise in this case can be reduced. The actuator made with piezoelectric materials is attached to the fuselage. The fuselage may also made with smart materials.

6.1 Cabin Noise

In the passenger aircraft noise is always annoyed. The aircraft engineers try their best for solving the problem. In the aircraft usually the passive damping devices are used. But noise create in the cabin from the vibration of fuselage and it is low frequency. The passive damping devices cannot absorb the noise. In this case piezoelectric materials are used for active damping.

There is a Ultra quiet Cabin develop by Ultra quiet Technology. In this field, sensors made of smart materials are attached at different location of fuselage and actuators are made of piezoelectric ceramic which bonded to the fuselage.

Fig.4: Solution of aircraft cabin noise

6.2 Engine Noise

Turbine engine is the main source of noise. If we make variable area engine with shape memory alloys and attached to the chevron which modify the shape of exhaust. Thus control the noise from the engine. During the takeoff, the altitude and speed is low so the temp is high. The high temp forces chevron inside and the noise bypasses the flow of engine. Thus the noise can be reduced.

Fig. 5: Solution of engine noise

6.3 Helicopter Blade Noise

To eliminate the loads and vibrations in the aircraft smart materials are used. Helicopter is a rotary wingtype aircraft where noise and vibration are more. The noise and vibration are created by rotor blades.The “Blade Vortex Interaction” is also the main source of noise. If we can control the blade then the noise may be reduced 8db to 10 db. For solving the problem we can construct the blade in such a way that becomes continuous twisting. There is another solution, the use of servo aerodynamic control surfaces like flap, tab or blade tip. The piezoelectric actuator is best suitable for solving this problem. For twisting the blade the PZT is used in the blade skin. The tab actuator which uses trailing edge trim tab driven by SMAs.

Another solution in which adaptive vibration control devices are used. These devices are made of piezoelectric materials which vary the stiffness, the damping and the mass of dynamic system. A successful flight of piezoelectric actuator driven main rotor tail edge flaps was done in 2005 by Euro copter on BK 117.

Fig. 6: Solution of helicopter blade noise

7. ADAPTIVE SMART WING

Usually in the aircraft the control surfaces such as flap, rudder, and elevator are adjusted by electric motor or mechanical control system like cable or hydraulic system. Using piezoelectric actuator we can solve this problem because the control surface can change the shape itself as the result of aerodynamic features changed.

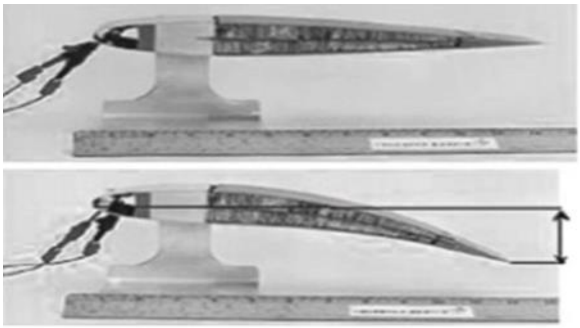

Fig.7: Smart wing

8. AERODYNAMIC FEATURES

The lift and drag of an airfoil depends on the geometry of wing and airflow over the wing and ambient temp and pr. A fixed wing is used for optimizing the lift and drag for particular flight, minimum drag cambered is used for subsonic and maximum lift is needed for maneuvers. For the Bomber aircraft mission needs both maneuvers and penetrations. For solving these problem rotary actuators and linkages to the hinge a flexible wing so that cambered can be changed. Smart materials is used for heavy slow mechanical system of actuator. Aircraft controlled surfaces are controlled indirectly and lack of flexibility. In this case, piezoelectric smart materials can increase the performance and maneuverability due to flexible and thin actuator.

9. CONTRLOL SURFACE MORPHING

In the recent years morphing wing aircraft plays an important role in the aviation sector. In this case the shape of the wing has to be rearranged for the improvement of the efficiency of the aircraft. Using the SMAs in the wing it is possible to change the shape of wing for flapping. The tailing edge is made of hinge less control surface.

10. FLOW SEPARATION

The smart wing is a continuous control surface which is made of a series of piezoelectric actuator. The continuous surface will not let the airflow separation quickly. So there is no possible to create turbulence behind the wing. As the result drag will reduce and lift will increase. So the efficiency of aircraft will increase.

11. TAIL BUFFET SUPPRESSION

Tail buffet is a vibration which is caused by the unsteady pressures on vortices. Tail buffet contributes to a high maintenance cost because frequent inspection is required. In order to keep the aircraft performance best and safe, the piezoelectric actuator is used so that vibration is controlled.

12. TURBINE TIP CLEARANCE CONTROL

The turbine is made of smart electric magnetic actuators. The tip clearance control is very important as the air leaks over the turbine tip which does not impart energy to the turbine. So the efficiency of the turbine is decreased because of fuel burns and emissions. A smart electromagnetic actuator is set up in the engine casing so that it can response the turbine blade expansion and contraction with temp. Thus the turbine blade clearance is controlled and efficiency increased.

13. FLUTTER CONTROL

Flutter boundaries improve the aircraft flight qualities, minimize vibrations and fatigue damage. In the conventional active flutter actuator depends on the use of aerodynamic control surfaces which operated by servo hydraulic actuators. But in this case there are some limitations. The active control flutter needs (i) multiple energy conversation like mechanical, hydraulic and electric. (ii) Large number of parts. (iii) High vulnerable of hydraulic pipes.(iv)Frequency bandwidth limitations. So the aircraft weight will increase. In this case active materials are directly capable of convert the electrical energy into mechanical energy. The active materials are made of piezoelectric, electro or magneto stictive materials which illuminate the need of hydraulic pipes

14. ICE PREVENTION

Icing occurs when water changes from liquid from solid phase. Ice formation and accumulation on the critical parts of the structures causes accidents and economical losses in field of aerospace. Droplets of super cooled water exist in the cumulus clouds. Aircraft flying through this clouds seed crystalize these droplets which can result in the formation of icein the aircraft wings. This ice blockages the instruments. Ice formation in the aircraft, decrease lift, thrust fall off, drag and weight increase and stall speed rises rapidly. It is sometimes cause of crash. By using a piezoelectric materials, an ice detection system is used over the surface of the wing. Inducing waves, the piezoelectric materials remove the ice. In some cases there is used a component which is made of piezo kinetic actuators, a control unit coupled to the plurity of the actuators. Thus ice can be removed.

15. CONCLUSION

The uses of smart materials is in the wide range in the aerospace industry. The uses of smart materials and structures are limited only by one’s talent and capabilities. Smart materials are very essential parts for new and existing construction of aircrafts. The smart materials solved many aircraft problems like engine vibration and noise, cabin interior noise, flow separation. Control surfaces, ice prevention, flutter control and improve the aircraft performance. Piezoelectric and magnetostrictives smart materials are very effective for high frequency applications. Shape memory alloys are very effective for low frequency vibration control. The smart materials used in the aircraft are shown:

Fig.8: Positions of smarts materials in aircraft

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17. NOMENCLATURE

Symbol	Meaning	Unit
Temp	Temperature	(K)
Pr	Pressure	(Pa)
SMAs	Smart Materials Alloys	
SMA	Smart Material	
db	Decibel	