TECHNIKA TRANSPORTU SZYNOWEGO

Irena NOWOTYŃSKA, Krzysztof TERESZKIEWICZ

HYBRID AND INTELLIGENT MATERIALS IN TRANSPORT

Abstract

The paper presents the possibility of using a new generation of hybrid materials and intelligent materials in transport. Hybrid materials are mainly used in the aerospace industry. They have properties of the inhibition and blockings of the development of cracks at the cyclical load, very good characteristics of the load and the impact resistance and the low density. Smart materials Thanks to the exceptional properties can be integrated with other materials in order to obtain properties unattainable by any other method. This can be a shape memory alloys, piezoelectric materials, electrochromic, electroluminescent, magnetorheological or electrorheological. In transport means they are not only the simple devices, but also complicated constructions.

INTRODUCTION

Cargo and passenger transport plays an important role in the economy and our everyday life. Due to the rapidly growing road transport is necessary to use modern information and communication technologies to increase the efficiency, safety, and minimize the negative impact of transport on the environment. For a new generation of materials are metal-composite laminate (FML). These are laminates consisting of a thin metal layer and a polymer-fiber composite, ceramic or polymer. Such laminates are characterized by excellent properties of both metal and polymer composite fiber. This combination results in a new generation of hybrid materials inhibit and blocking the development of cracks under cyclic loading, very good characteristics of load and impact resistance and low density. Another new class of materials are smart materials with controlled properties, obtained by using the shape memory alloys, or embed special systems such as systems piezoelectric or optical fiber. The development of smart materials is subordinated to create opportunities specific practical objectives in areas such as aerospace, automotive, robotics, medicine. In the practical application of intelligent materials is frequent as a component of design or functional structure called an intelligent structure [11].Smart materials are currently used mainly in the aerospace and automotive industries. They are used in advanced safety systems, the construction elements such as suspension, engine, electronic devices, wings, rotor blades [12].

The paper presents the possibilities of using modern materials in transport, taking into account their advantages.

1. FIBRE-METAL LAMINATES

FMLs are fiber-metal laminates consisting of alternating layers of thin metal sheets and polymer/ceramic fiber or polymer/ polymer fibre composite. Laminates are characterized by the excellent properties of both metal and polymer composite. This combination gives a new generation of hybrid materials with brake and block the development of cracks under cyclic loading, very good characteristics load and impact strength and low density. make it easy production structures and their repair. Can be adapted to different needs by: combining different fiber systems /resin, the use of various types of metal alloys, the different sheet thickness, the various layers of the laminate stacking sequence, orientation of fibers, surface pretreatment, etc. The first group of laminates FML, prepared for laminates were ARALL aviation (Aramid Laminate Aluminium) in which the fibrous component is made of fiber Aramid (Kevlar). Used them in the 80's Twentieth century, the cargo doors on the plane C17 military. Unfortunately, despite the very good operating results were replaced again due to metal construction the very high cost of production at the time. Research is also conducted on other connections but not all of the material combinations of materials are possible. The combination of alloys aluminum with carbon fibers seemed very attractive but may not be used due to corrosion galvanic. Another forward-looking laminate from the group FML is a combination of titanium and ECT fiber composite graphite / polymer (TIGR). the problem for solutions in applications conductivity of air is electric carbon fiber. Compared to metal FML achieve very high tolerance damage including fatigue, corrosion, impact strength, residual stress. Compared to the material composite resulting in a higher strength, toughness, fracture toughness. An advantage in the manufacturing process is the ability to conventional manufacturing processes (preparation techniques preliminary, some forming, cutting) the production of skin panels, the leading edge and small structural elements. As a result, the investment cost of the change technology FML metal is relatively low. Other advantages include: fire resistance, discharge atmospheric corrosion resistance. These materials are characterized by very good corrosion resistance because the layer of the constitute a barrier to moisture that could attack inner metal layer, and the metal layer protect against "standing up" when exposed to moisture [12].

2. SHAPE MEMORY ALLOYS

One of the new classes of materials, which drew wide spread the attention of researchers in the world are in the form of smart materials shape memory alloys. The increasing availability and outstanding physical properties make it may be successfully integrated with other materials in order to obtain properties unattainable by any other method. Shape memory materials are alloys which have the ability to remember the originally given shape and it is playing under the influence of appropriate external conditions such as changes of magnetic field or temperature [7]. The special properties of these alloys are associated with them occurring in reversible martensitic transformation. This transformation mainly steel and Al-Cu alloys. It also has a more general nature and is found in many metal alloys, some ceramics, and even in the cells of living organisms. Shape memory alloys have unique properties, among other materials related to changes in the modulus of elasticity or damping. Above all, however, have the capability to generate significant forces during the activation process, which are related to of the shape memory effect (stress recovery). Due to the these properties of shape memory alloys for active and fully controlled steering qualities such as shape, static deflection, the characters and the frequency of vibration, amplitude resonance damping. In recent years, there has been a rapid development of security systems that use of advanced materials such as shape memory alloys. An example of such a solution is the bonnet lifting of car system. This type of solution are used in more than a decade in such models as the Honda Legend car, Jaguar SX and the Citroen C6. But only use of smart materials allowed reduce the cost, size, weight, and increase the reliability of the system. The principle of operation of the safety system of pedestrians is simple: during a collision bonnet of car is being raised, allowing the absorption of energy of collision with pedestrian [8]. Applications of NiTi alloy has enabled multiple operation of the system, while the former after a single use need to be replaced.

Fog lamp mounted low in front of the cars are exposed to damage at high speeds, for example by stones. Destruction can be minimized if the lamp is protected by a special housing. It is opened and closed by an actuator mechanism equipped with shape memory alloys. When the lamp is turned on, the mechanism opens the shutter housing, and when the shutter closes off [5, 10]. Car engines used in vehicles must operate in demanding conditions such as high temperature differences (low temperature and high at a standstill while driving) that cause such a change of the oil viscosity in the hydraulic system. Car engines used in vehicles must operate in demanding conditions such as high temperature differences (low temperature and high at a standstill while driving) that cause such a change in the oil viscosity of the hydraulic system. Therefore, to control them used shape memory alloys. Natural ability to be deformed by a change in temperature causes that from these materials may form elements of the flow control valve. This type of solution applied as the first company in the Mercedes-Benz passenger car diesel engine. The use of the flow control valve allows to reduce the amount of gas emissions and improving the comfort of the engine in the early stages of its operation [9].

Aviation is a branch of industry which are used in the latest and most advanced materials and technologies. Air Force is a branch of industry which are used in the latest and most advanced materials and technologies. Wing aircraft is one of the most important components. They work on it during the flight a large force and therefore its correct operation allows increase the comfort, speed, safety and reliability. Wires made of shape memory alloys cause a change in the shape of the moving wing tip, which adapts to the conditions prevailing during the flight. The maximum deformation of the wires is 11 mm, which allows the deformation of the end of the wing angle of up to 45^{o}. The deformation of the wires causes the voltage from 2 to 5V, and return to the previous state is possible by cooling the cold air. Wires made of NiTi alloy can operate even at temperatures up to $-55^{o}C$ at a height of 2000 meters above sea level, that is, under conditions typical for small passenger aircraft [6].

Shape memory alloys are also used in helicopters. There are mounted in the rotor blades. Are designed to reduce rotor imbalance by changing their shape. Helicopters are equipped with movable flaps on the ends of the rotor, the change of position is passive. The use of shape memory alloys to make an active change, and thereby increase the comfort and flight safety [3].

Shape memory alloys used in wagons in heating systems in modern trains too. Shape memory alloys of heating systems used in wagons in modern trains. The valve contains a spring NiTi alloy controls the flow of steam produced by the generator. The valve is used in the winter, when low temperatures can lead to a freezing of condensed water vapor and eventually cause damage to the tubes [5]. Smart materials are also used in infrastructure allowing for a safe and more comfortable transport. Examples of such applications are railway crossings in elastomeric elements, which are placed inside the wire of shape memory alloys. Tie rods are made of NiTi are placed inside concrete slabs in specially hollow channels. Are mounted at the ends of the concrete slabs railway crossings. These plates are mounted on a rubber surface, which vibration isolation acts. Therefore, the action helps shape memory actuators. During the passage of the railway vehicle followed by activation of the system and change the shape of the tie rods from the SMA. This results in substantial stiffening and the result in a substantial reduction of the vibration amplitude. [1].

3. PIEZOELECTRIC MATERIALS

As a piezoelectric ceramic materials are used both ferroelectric and non-ferroelectric. Using these materials so constructed. intelligent spring. The mechanism uses high rigidity, high throughput and low volumetric displacement of the piezoelectric actuator. In fact, a large change in the coefficient of elasticity causes a very small change in the shape of the actuator. The small size and the simple structure causes smart spring used in requiring structures such as aircraft for vibration damping [4]. This spring was also used as a silencer of pilot's seat in helicopter. This spring was also used as a silencer of helicopter pilot's seat. It is mounted on the seat support so that the force causing the vibration pass through the spring and were largely mitigated. This spring was also used as a silencer of helicopter pilot's seat. It is mounted on the seat support so that the force causing the vibration of the spring pass through it and were largely mitigated. The spring is connected to the monitoring system factors such as the weight of the crew member and flight conditions. This system is by changing the voltage actuator causes the optimal damping. Also, the helicopter rotor is mounted on four springs intelligent. Vibrations caused by the rotating blades are offset by the spring, which causes a significant drop in noise and vibration in the cabin, and can decrease the weight of the whole machine, which in turn reduces the amount of fuel burned. Piezoelectric materials are used in the monitoring of the surface made of steel and composites. Piezoelectric actuators monitoring hulls made of composites used as the first NASA space shuttles. Currently, the Accelent company offers a comprehensive structure monitoring aircraft hulls and vehicle structures (Fig.1). Piezoelectric materials are used in the monitoring of the surface made of steel and composites. Piezoelectric actuators monitoring hulls made of composites used as the first NASA space shuttles.

Fig. 1. Piezoelectric actuators

Currently, the company offers a comprehensive structure Accelent monitoring aircraft hulls and vehicle structures. Monitoring of surface mounted sensors is to use piezoelectric materials inside the hull. Under the influence of power, they are deformed and gives rise to the microwave, the possible interference inform the creation of microcracks. SMART Layers of Accelent sensor consists of laminated in an epoxy resin, which is an insulator PZT piezoelectric material [13].

4. MATERIALS MAGNETORHEOLOGICAL

Materials magnetorheological (MR) are liquids that can rapidly alter its properties viscoelastic. Liquids can vary in consistency from viscous liquid to almost solid. Reached the final state of the material depends on how strong the magnetic field is applied. This effect can be reversed as quickly as it was called (1-10ms). MR fluids have an advantage in relation to the electrorheological fluid. Among other things, they are less sensitive to the presence of impurities, and therefore can be used in devices in a more contaminated environment [7,14]. Most advanced example of such devices are shock Delphi Automotive. They are used in cars such as the Audi R8, Audi TT, Audi A8, Cadillac's 2003. They are used to achieve rapid, controlled vibration damping in a wide range of force. Shock absorbers using Magnetorheological fluid called MagneRideTM. It is a synthetic fluid containing soft particles suspended in the magnetic interaction force. He retains his properties in the temperature range from -40 to +70 °C and can operate at a stress of 80 kPa. The use of such shock absorber is to minimize movement of the vehicle, resulting in smoother ride and allows you to perform more precise maneuvering. Also reduces the car's tilt forward under braking and the rear sag under acceleration. Improving the load transfer gives better control of the vehicle during an emergency maneuvers at high speeds [2] (Fig. 2).

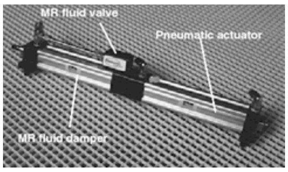

Fig. 2. Magnetorheological dampers- in pneumatic systems to control of the speed and position

Another application of magnetorheological fluid dampers are the seats vehicles especially trucks (Fig. 3). Vibration reduction system such driver's seat controlled by computer, analyzing data such as the weight of the driver, vehicle speed, surface type and then processes it and by changing the magnetic field controls the damping of choosing the optimum damper stiffness [15].

Fig. 3. Magnetorheological dampers

5. MATERIALS ELECTRORHEOLOGICAL

Materials electrorheological (ER) are liquids that change its consistency under the influence of an electric field. It is a thick suspension of microscopic particles of the order of 0.1-100 microns (dispersion), which under the influence of the electric field set up in the same position and attract each other, creating a spatially structured network that significantly impedes the movement of the solvent - and thus the liquid flow .

Fig. 4. Electrorheological dampers

This effect is proportional to the electric field. The change takes place in a few milliseconds. This phenomenon is reversible - after disappearance of the electric field, MR material back to their original properties. Direction of arranging grains can be perpendicular or parallel to the acting electric field. Parallel particles provide greater strength of the material, as compared with particles arranged perpendicularly. Due to its specific characteristics, the materials used in the ER is active vibration damping devices, shock absorbers, clutches and electrically controlled valves, air applications.

SUMMARY

The use of equipment and construction solutions containing hybrid materials and smart can enhance the safety, comfort, reliability, reduction of pollution, vibration and noise. New types of smart materials and new ways to use them are usually developed by large research centers and the military. Then implemented in civil industry. The research and development of intelligent materials involved are the most developed countries. The most dynamically developing branch industry, which are widely used smart materials are the means of transport such as cars and airplanes. The development of smart materials requires multi-disciplinary knowledge from different fields of science and expertise in technical fields in which they will be implemented.

HYBRYDOWE I INTELIGENTNE MATERIAŁY W ŚRODKACH TRANSPORTU

Streszczenie

W pracy przedstawiono możliwości zastosowania nowej generacji materiałów hybrydowych oraz materiałów inteligentnych w środkach transportu. Materiały hybrydowe znajdują głównie zastosowanie w przemyśle lotniczym. Mają one właściwości hamowania i blokowania rozwoju pęknięć przy cyklicznym obciążeniu, bardzo dobrej charakterystyce obciążenia i udarności oraz niskiej gęstości. Materiały inteligentne dzięki wyjątkowym właściwościom mogą być integrowane z innymi materiałami w celu uzyskania właściwości nieosiągalnych na żadnej innej drodze. Mogą to być stopy z pamięcią kształtu, materiały piezoelektryczne, elektrochromowe, elektroluminescencyjne, magnetoreologiczne bądź elektroreologiczne. Stosowane są w środkach transportu począwszy od prostych urządzeń, aż po skomplikowane konstrukcje.

REFERENCES

1. Długosz J.: Vibroisolation railway crossings with the application of shape memory elements. Transport Problem, vol.4, issue 2, 2009.
2. Gehm R.; *Delphi improves Cadillac's ride*, Automative Engineering Online International, 2004.
3. Giurgiutiu V., Rogers C., Zuidevaart J.: *Incrementally adjustable rotor-blade tracking tab using SMA composite*. Proceeding of the 38 th AIAA/ASME/ASCE/AHS/ASC Structures, Structural Dynamics and Materials Conference and Adaptive Structures Forum 7-10, pp. 97-1387, 2000.
4. Nitzhe F., Wickramasinghe V., Zimcik D.: *Control laws for an active tunable vibration absorber blade dampen augmentation*. The aeronautical Journal, vol. 108 (1), pp. 35-42, 2004.
5. Otsuka K., Wayman C.: *Shape memory materials*. Cambridge University Press, 1998.
6. Raport Zespołu Badawczego Benoit BERTON Dassault Aviation: Shape Memory Alloys Application, Trailing Edge Shape Control, 2006.
7. Sapinska-Wcisło A.: *Mechatroniczne człony wykonawcze z zastosowaniem materiałów inteligentnych*. Akademia Górniczo-Hutnicza, Kraków, 2006.
8. Stritmatter J., Gumpel P., Zhinghang H.: *Long-time stability of shape memory actuators for pedestrian safety system*. Journal of Achievements in Materials and Manufacturing Engineering, vol.34, issue 1, 2009.
9. Stoeckel, Borden: *Actuation and fastening with shape memory alloys in the automotive industry*. Metall Wissenschaft+Technik, 46 Jahrgang, Heft 7, pp.668-67, 1998.

10. Stoeckel: *Shape memory alloys for automotive industry*. Materials and Design, vol.11, No 6, December 1991.
11. Surowska B.: *Functional and hybrid materials in air transport*, Eksploatacja i niezawodność, no, 3, 2008.
12. Trepczyńska-Łent M., Inzynierskie materialy inteligentne w srodkach transportu, Logistyka 2011, nr 3
13. www.accelent.com – materiały firmy Accelent.
14. www.fordvehicles.com – materiały firmy Ford.
15. www.lord.com – materiały firmy LORD.
16. www.martin.pl

Autorzy:
dr inż. Irena NOWOTYŃSKA– Politechnika Rzeszowska
dr hab. inż. Krzysztof Tereszkiewicz– Politechnika Rzeszowska