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Design of active disassembly snap-fit based on electrothermal stimulation method

Zhu Yuefeng[1,2]

[1]Hefei University of Technology, Hefei, (CHINA)

[2]Kaifeng University, Kaifeng, He Nan, (CHINA)

ABSTRACT

Active disassembly product which applies active disassembly using smart materials (ADSM) method uses active disassembly structure as connecting piece of parts, and traditional heating stimulated method is heating the whole product. Electro thermal stimulation method is local heating stimulated method. Because of centralized energy, short heating time and less energy consumption, heat-damage of other parts for the product is very small. Introducing the principle of electro thermal stimulation method, design method of active disassembly snap-fit based on electro thermal stimulation method is elicited. The feasibility of design method is verified by electro thermal stimulation experiment.

KEYWORDS

Active disassembly using smart materials (ADSM); Electrothermal stimulation method; Heating wire; Active disassembly snap-fit; Design method.

INTRODUCTION

Active disassembly structure is made of shape memory materials, for instance, active disassembly snap-fit, and active disassembly of product is achieved when ambienttemperature is changed. Active disassembly snap-fit which is made of shape memory polymer is used as fastenings of electronic products, then active disassembly of electronic products is achieved by improving original connection structure, so disassembly efficiency of products is increased by a larger margin, and reclamation cost is reduced to the maximum level[3-5]. Many research institutes and universities have done a series of research and experiments on ADSM (Active disassembly using smart materials, ADSM), such as, the institute of cleaning electronic products in Brunel University, Nokia R&D Center, Helsinki University of Technology, University of Art and Design Helsinkinian, the Sharp company in Japanese and so on, many research achievements are acquired, such as, LCD display stents which are made of shape memory polymer are achieved automatic and non destructive disassembly by adopting water-bath heating mode, and process of mobile phone disassembly and recycling are simplified by developing a heat stimulation mechanical structure. Some active disassembly products are manufactured, The economic and environmental characters for active disassembly product have been assessed. If the conventional heat stimulated way is adopted, such as water bath and air bath, the whole of product is heated, and the heating time is longer, and more energy is consumed, and parts of the product is probably destroyed when heating. If the conventional heat stimulated method is applied to multi-step active disassembly structure, disassembly efficiency is much lower, and cost of processing gets higher.

Electrothermal stimulation method belongs to local heating stimulated method, as a result of its intensive energy, and time of heating is short, needs of energy is lower when stimulated, temperature damages of other part is much smaller, disassembly efficiency is the higher, and active disassembly time can be controlled. Active disassembly which is achieved by electrothermal stimulation method has been studied abroad, such as, cleaning electronic institute of Brunel University in England made fasteners which are made from thermoplastic adhesive materials. Heating wire is embedded in adhesive, then adhesive materials will be melted after heating wire is energized, connection of products will become invalid[1]. If fasteners made from adhesive materials are used in connection of products, joint strength of products can be reduced, and structure of connection is more complex, this method can be only applied in some electronic products of simple structure. Based on the conventional electrothermal stimulation method, active disassembly structure which has higher disassembly efficiency, stronger joint strength and controlled disassembly time is researched, there will be important guiding significance to perfect active disassembly theory and research on multi-step active disassembly which depends on electrothermal stimulation method.

ACTIVE DISASSEMBLY THEORY BASED ON ELECTROTHERMAL STIMULATION METHOD

Electrothermal stimulation method is that electric heater bands or heating wire is arranged on the root segment of active disassembly snap-fit, then active disassembly snap-fit is stimulated directly after electric heater bands or heating wire is energized. Electric heater bands with certain power is pasted into the root segment of shape memory polymer (SMP) snap-fit, and quantity of heat generated after electric heater bands is energized carries on conduction of heat for shape memory polymer snap-fit, then shape memory polymer snap-fit is stimulated to deform, shown in Figure 1, moreover, the connection of products will become invalid. Or heating wire is embedded in the root segment of shape memory polymer snap-fit, and then shape memory polymer snap-fit is stimulated to deform by energizing to heating wire, In the same way, active disassembly of parts is achieved, but power of heating wire is asked to be lower so that other part is not damaged. Or heating wire with certain power is embedded in the root segment of common thermoplastic snap-fit, quantity of heat generated after heating wire is energized fuses the root segment of snap-fit, shown in Figure 2, and then the connection of products will become invalid, purpose of active disassembly is achieved. The time of stimulated deformation or melting time of snap-fit can be adjusted through controlling the power of heating wire. Active disassembly time based on electrothermal stimulation method can be controlled, and the intensity of active disassembly structure can meet the requirement of connection. Design of structure is easier, in particularly, the purpose of multi-step active disassembly can be achieved by using electrothermal stimulation method, and the disassembly efficiency is improved obviously.

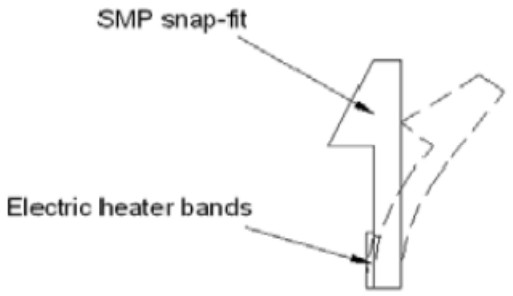

Figure 1: Electrothermal stimulation effect of SMP snap-fit

Root segment of common thermoplastic snap-fit is melted by heating wire, schematic is shown in Figure 2.

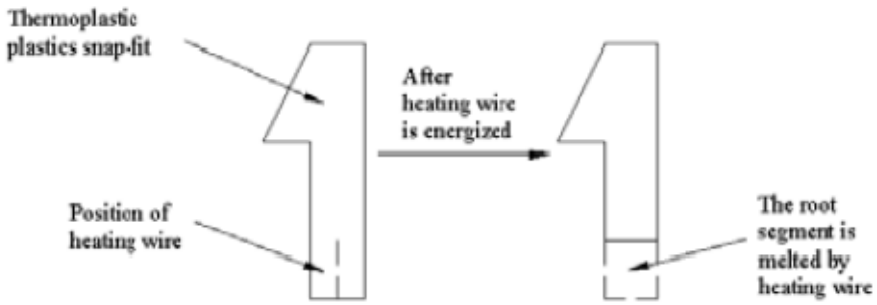

Figure 2: Electrothermal stimulation effect of common thermoplastic plastics snap-fit

Shape memory polymer is stimulated by electric heater bands, and the effect is shown in Figure 3.

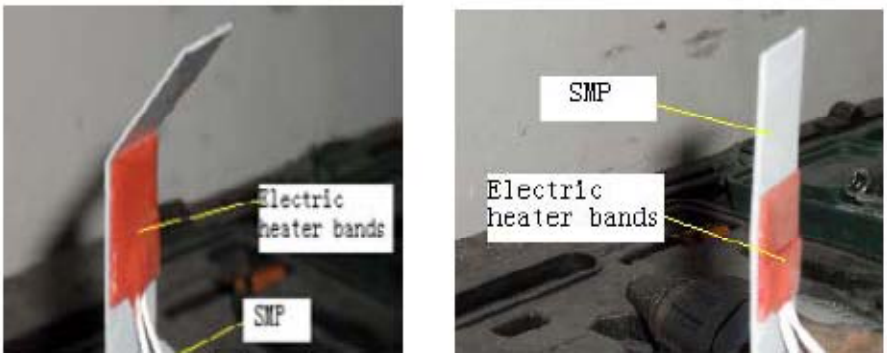

Figure 3: Shape memory ploymer before and after electrothermal stimulation

Common thermoplastic plastic is melted by heating wire, and the effect is shown in Figure 4.

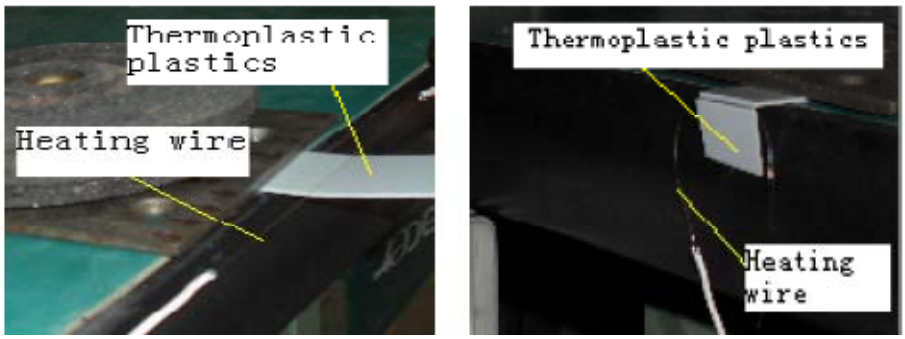

Figure 4: Common thermoplastic plastic before and after electrothermal stimulation

DESIGN OF ACTIVE DISASSEMBLY SNAP-FIT BASED ON ELECTROTHERMAL STIMULATION METHOD

Shape memory polymer snap-fit does not rely on mechanical force to provide work, when SMP snap-fit is used as connecting piece of products, connection of products becomes invalid by relying on shape deformation and reducing of structural strength for SMP snap-fit, the shape recover deformation of SMP is very large[2]. Connecting piece of products is made of SMP snap-fit, and electric heater bands are pasted into the root segment of snap-fit. The power of electric heater bands is chosen by stimulated temperature and time of SMP snap-fit. Connecting piece of products is made of common thermoplastic snap-fit, and heating wire is embedded in the root segment of snap-fit. The power of the heating wire is chosen by the melting point of common thermoplastic snap-fit and melting time of the root segment. This text adopts finite element analysis software ABAQUS to simulate temperature field of snap-fit. Within a certain extent of power, reasonable heat flow (power of heating wire) is finally determined by many times of loading test.

Design steps of active disassembly snap-fit based on electrothermal stimulation method can be divided into three steps : (1) SMP snap-fit or common thermoplastic snap-fit which has a certain dimensions and material attributes is designed according to designing approach of active disassembly snap-fit, joint strength of snap-fit, character of constraints, character of compatibility, character of sturdiness and so on. (2) Reasonable cross-section of power loading is determined according to

the dimensions of the snap-fit. (3) Simulation experiment is asked to make many times in finite element analysis software ABAQUS, and then comparing to temperature field distribution of snap-fit which is generated by different power of heating wire, reasonable heat flux is finally determined according to stimulated temperature of SMP snap-fit, or melting point of common thermoplastic snap-fit and the stimulated time.

Finite element analysis simulation of shape memory polymer snap-fit

There is heating wire with a very high power inside the electric heater bands which is made of polyimide electrothermal film, and heat conduction efficiency is higher. The highest temperature is 180 centigrade for long-term using and 300 centigrade for short-term using, and the highest power density can reach 7.8 watt per square centimeter. The cross sectional area of electro thermal film is equal to 7.5 square millimeters, so the highest power can reach to 0.585 watt. Because power of electrothermal film is very high, strong heat quantity will be generated after electric heater bands are energized. The temperature which is generated by heat transfer is more than stimulated temperature of the shape memory polymer snap-fit. The stimulated time is very short. Moreover, other parts of products can not be damaged during process of thermal excitation. If the power of electric heater bands is low, the time of stimulated deformation will get longer and active disassembly efficiency will be reduced.

Temperature field of the shape memory polymer snap-fit is analyzed in ABUQUS, setting analysis parameters: thermal conductivity is equal to 0.28W/ (m• k), the specific heat capacity is equal to 1900J/ (kg· K), the density is equal to 1150kg/m^3 for shape memory polymer snap-fit. The boundary condition is that the bottom surface of snap-fit is fixed. The environmental temperature is set to 20 centigrade. Element type is DC3D8, and stimulated temperature is about 84 centigrade, and stimulated time is 6 seconds, then power of electrothermal film as heat flux can be loaded into the root segment of the shape memory polymer snap-fit. The loaded cross-section is as Figure 5 showed. Thermal analysis is done for snap-fit. Through many times of loading tests, temperature field distribution of snap-fit generated by different power in a certain extent is compared. The power of electrothermal film is equal to 0.06 watt to ensure that the time of stimulated deformation is 6 seconds, and the lowest temperature of snap-fit is 84 centigrade by simulation test.

In a similar way, stimulated temperature of shape memory polymer snap-fit is reached in different of stimulated time, the power of electric heater bands and the lowest temperature in the root segment of shape memory polymer snap-fit can be reckoned out, and the result is showed in TABLE 1.

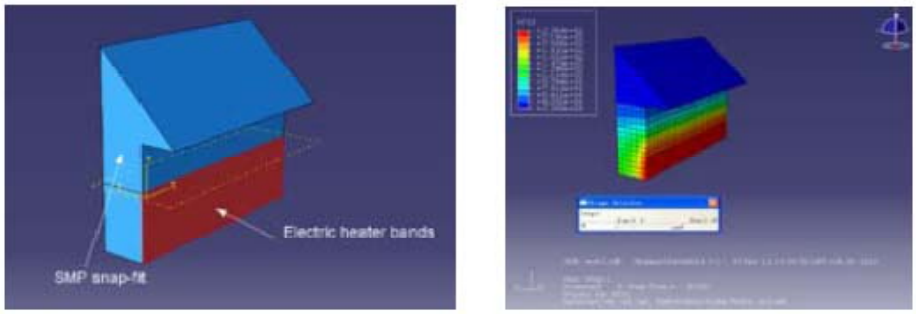

Figure 5: Temperature field distribution of snap-fit

TABLE 1: The relation among stimulated time, power of electric heater bands and lowest temperature in the root segment of shape memory polymer snap-fit

Time (second)	7	11	17	35	44
Power (watt)	0.050	0.030	0.020	0.010	0.008
Lowest temperature (centigrade)	84	84	86	86	85

Finite element analysis simulation of common thermoplastic snap-fit

Heating wire with a certain power is embedded in the root segment of the thermoplastic snap-fit which is made of PVC materials (polyvinyl chloride). The melting point of the snap-fit is 212 centigrade, the thermal conductivity is equal to 0.29W/ (m· k), the specific heat capacity is 2000J/ (kg·K), and the density is $1200kg/m^3$

Heating analysis of common thermoplastic snap-fit is done in ABUQUS. The boundary condition is that bottom surface in the root segment of the snap-fit is fixed. The original temperature is set to 20 centigrade which is the normal atmospheric temperature, and element type is DC3D8. The melting point of the heating wire which is made of nichromewire is 1400 centigrade, then power of heating wire as heat flux is loaded into the root segment of the thermoplastic snap-fit. Through many times of loading tests, the power of heating wire is equal to 0.03 watt that is concluded, then ensure that melting time of the root segment in snap-fit is 8 seconds, and the lowest temperature in the root segment of the snap-fit can be reached to the melting point shown in Figure 6.

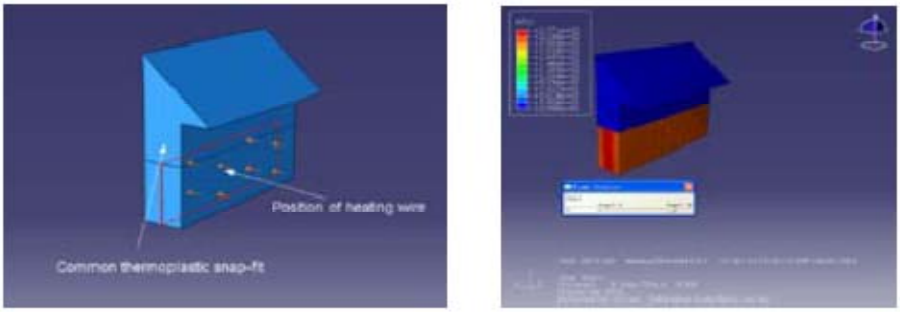

Figure 6: Temperature field distribution of snap-fit

According to above analysis, power of heating wire is 0.03 watt, then the melting point of the snap-fit is reached in 8 seconds. The lowest temperature in the root segment of snap-fit is 212 centigrade in 8 seconds, and the highest temperature which is 237 centigrade will appear in the red region near the heating wire (as Figure 6 showed). Because the heating wire is buried into the snap-fit, this temperature will not damage the other parts. Active disassemble effect will be achieved in very short time. In a similar way, under different motivate time, the relation between the lowest temperature in the root segment of the snap fits and the power of the heating wire is showed in TABLE 2.

TABLE 2: The relation among melting time, power of heating wire and lowest temperature in the root segment of common thermoplastic snap-fit

Time (second)	8	12	16	24	46
Power (watt)	0.03	0.020	0.015	0.010	0.005
Lowest temperature (centigrade)	212	214	215	217	212

For a certain type of heating wire, according to the melting point of the plastic snap-fit and the motivate melting time of the root segment, the power of the heating wire is finally determined within a certain extent of power through many times of finite-element analysis simulation. There is an important guiding significance for choosing the power of heating wire.

Shape memory polymer snap-fit is stimulated to deform by energizing to electric heater bands, and root segment of snap-fit which is made of common thermoplastic plastics is melted by heating wire. Drawing a conclusion that disassembly time of adopting these two methods is very short for electronic products, and disassembly efficiency is higher. Feasibility of active disassembly which is achieved by electrothermal stimulation method is proved through finite-element analysis simulation.

CONCLUSION

Conventional stimulated ways of active disassembly structure is changed. Electrothermal stimulation method is used as stimulation way of active disassembly structure, owing to the concentration of energy, and consumption of energy is reduced, disassembly efficiency is increased by a large margin.

(1) Shape memory polymer snap-fit or common thermoplastic plastic snap-fit based on electrothermal stimulation method, temperature field distribution of snap-fit which is generated by electric heater bands or heating wire is simulated by finite element analysis software ABAQUS. Stimulated time of snap-fit is changed by adjusting power of heating wire. Choice method of power is put forward for heating wire.

(2) Active disassembly structure based on electrothermal stimulation method, because of controlling disassembly time, there is an important guiding significance for multi-step active disassembly by using different power of heating wire.

(3) Look into the future, shape memory alloy driving part is stimulated by energizing, such as shape memory spring or shape memory foil, and then active disassembly is achieved.

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