The Performance Improvement of the Spring Fastener for the Medical CPU Cooling Plate

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Abstract: This study focused on the locking performance evaluation of the medical CPU cooling plate spring fastener and its environmental durability after the modification of the fastener body dimension and the improvement of spring materials. Springs used to evaluate environmental durability are made of stainless steel wire and piano wire. The main purpose of the fastener body dimensional modification is to improve fastener locking performance. Study results suggested that the effect of thermal aging has little effect to the free length and compression loading of both piano wire spring and stainless wire spring. The salt spray has little effect on the free length of either piano wire or stainless steel wire spring, however, it significantly affects the compression load, especially for the case of piano wire spring; the change is up to 50.52% after 1200 hours salt spray test. Overall, the heat resistance and weather resistance capabilities of stainless steel wire spring is much better than that of piano wire. By the modification of the fastener plastic main body chamfer and two-protruding-side sizes, it significantly improved the IZOD impact values and fastener pullout force; also, via thermal shock test, it effectively improved the fasteners loosen, flaked and tripped problems.

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1 Introduction

Recently, the rapidly development of human technology has increased the demand for the medical electronic apparatus as well as the computing speed. Central Processing Unit (CPU) is the main unit that is used to process various and large amount of calculation. CPU requires stable, quick and fast transport speed. High computing speed requires high voltage and results in high temperature generation. To maintain the stable computing performance, CPU needs to equip with sufficient heat dissipating capability. It is custom to install various types of cooling plate to ensure good heat dissipation results. The method to secure cooling plate and CPU on the mother board is one of the core technologies.

Due to the limited space inside the desktop computer chamber, the fastener used to secure cooling plate has to be small, lightweight, not easy to loose and durable. Therefore, the type of fastener chosen is spring-type fastener. Plastic material is used for main body as its lightweight, low cost, beautiful color, short forming period and good corrosion resistivity. The material chosen for the main body is Polyamide 66 (Nylon 66) as its good wear resistance, self-lubricant, corrosion resistance and mold ability [1].

Fastener is a mechanism that is used when system required some degree of flexibility. Spring is used to apply torque to a mechanism or is used to absorb abruptly increased energy. Depending on the application, spring has various kinds of shape, diameter, no. of coil and material. Spring materials have large effect on spring fastener main body support, vibration absorption and degree of locking. Spring mechanical properties various with environment conditions have been studied by several researches [2~4]. Li, etc [5] used resistance strain gauge to analyze the loading of effective coils of spring under high stress action, then used electronic microscope to observe the crack to find out what caused the spring surface fracture. Ku., etc.[6] analyzed the causes of spring fatigue fracture and suggested that effective space, load and deformation are the parameters that can solve spring facture problem. They concluded that the proper choice of the materials can increase spring lifespan. Hu, etc. [7] have studied hole-corrosion effect of 304 stainless steel in NaCl solution under different cold working methods. Zhang [8] studied corrosion speed of carbon steel under salt water, and found out that effect of the salt-water concentration, temperature and PH value on carbon steel corrosion speed. Qiu [9] analyzed the causes of cylindrical spiral spring hydrogen brittle fracture failure, and explained that the attached hydrogen atom attached on the spring surface due to daily use or manufacturing is the reason that causes the spring to delay failure. Galvanization can be used to prevent hydrogen brittle failure from happening.

Environmental affect is always the major factor on the quality of medical products, several studies have been focused on this field, Abdel-Hakim, etc. [10] studied the thermal stability of the prepared polymer composites, Metwali [11] studied the performance of the polymerase chain reaction on some barley genotypes with a thermal cycle (Perkin Elmer), the thermal stability of purified dextran has been evaluated through the thermogravimetric analysis by Tarek, etc. [12], Bahobil [13] optimized the incubation temperature and thermal-stability for the purified protease.

This study is the join-industrial-academic project. The purpose of this project is to evaluate and analyze the performance and environment resistivity of the medical CPU cooling plate spring fastener after the change of the dimension and spring materials. Spring fastener consists of three portions as shown in Fig. 1. It includes main body, pin and spring. The material of main body and pin is Nylon 66. The purpose of fastener main body is to secure round slot on motherboard. Pin is used to deform the main body fixed end to fasten motherboard and cooling plate. Spring is used to provide support of main body and absorb vibration energy.

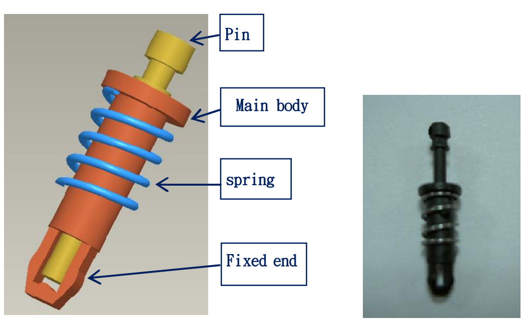

Fig. 1 Spring fastener assembly schematics and actual appearance

2 Study methods

The purpose of this study is to evaluate the effect of the environment conditions such as thermal aging and salt spray on the spring fastener free length, compress load and spring constant under various designs and sizes, then, use the modification of the dimension to improve its IZOD impact value and fastening performance. Use thermal shock test to verify its weather resistivity and build up spring constant K numerical analysis model then compare the analytical data to test results. Research flow chart is shown in Fig. 2 and discussed in the following paragraph.

2.1 The spring selection

There are various types of spring. Cylindrical helical spring was used in this study. Depending on its use, the material chosen for the spring is different. Details information was list in Oguri Fujio[14]. Materials chosen in this study are stainless steel wire (SUS 304) and piano wire (SWP): stainless steel wire has better anti-ecorrosion and thermal resistivity characteristic; Piano wire has better anti-fatigue characteristic. Three types of spring were evaluated in this research, as shown in Table 1.

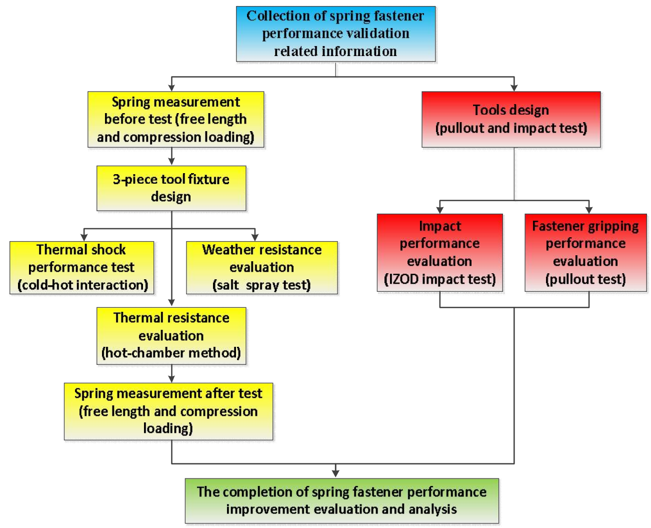

Fig. 2 Research flow chart

Table 1. Spring dimensions

Type of Spring	Wire Dia. (inch)	Spring O.D. (inch)	No. of Coil (coil)	Free Length (inch)
Piano Wire Spring	0.020	4.650	4.25	0.250
Stainless Steel Wire Spring	0.022	4.650	4.75	0.250
	0.020	4.650	5.25	0.260

2.2 Fixture design and specimen preparation

A three-piece special fixture, as shown in Fig. 3, was designed to simulate the fixation of fastener and motherboard, CPU and the cooling plate. The amount of compression occurred from these fixtures is identical to that of the real cases. This special fixture was formed by three steel plates, plates surface were galvanized to avoid the effect of the oxidation. Each fixture has 20 holes; 20 set of spring fastener can be installed at the same time. Twenty set of fixtures were used in this study, among them, 10 sets were used to evaluate piano wire spring, and the rest were used to evaluate stainless wire spring. Four hundred pieces of spring fastener were studied. Initial free length was measured for each specimen before it was installed. ALGOL force gage was used to measure initial load when spring was compressed 0.18 inch. Then, plastic pin was used to clip spring on the fixture tightly. Fig. 4 shows the complete set of the springs installed. To evaluate the effect of the fastener main body after size was modified on impact and fasten properties, another set of fixture required for impact experiment and pullout experiment was designed and manufactured, as shown in Fig. 5 and Fig. 6.

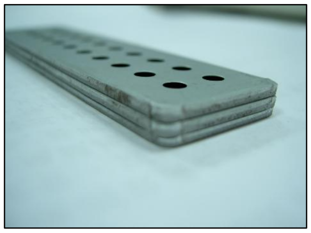

Fig. 3 Three-piece fixture

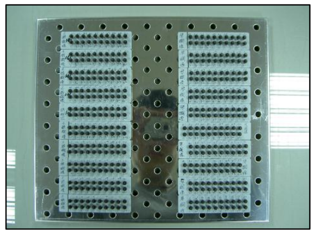

Fig. 4 Installed specimen

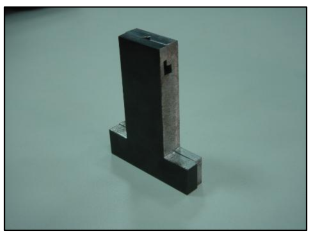

Fig. 5 Impact test fixture

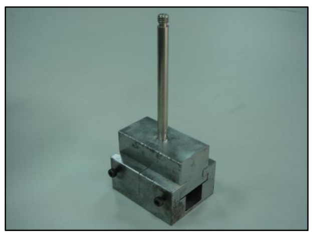

Fig. 6 Pullout test fixture

2.3 Environmental evaluation

Since the material (Nylon 66) used for CPU cooling plate spring fastener main body and pin is highly environmental sensitive, it is necessary to understand the long-term environment effect on its property. This study has evaluated the thermal resistivity, weather property and thermal shock characteristics under long-term environmental effect. Evaluation results are list as follow:

2.3.1 Thermal resistivity verification (thermal aging)

The purpose of this validation is to compare the effect of thermal aging, under constant compression, to the compression load and free length for piano wire spring and stainless steel wire spring at 80℃ for long duration time. The testing apparatus used here was T-Machine TMJ-9713 thermal channel, its temperature was controlled at 80±2℃, duration time for validation was 2000 hours.

2.3.2 Weather resistance verification (salt spray)

The goal of this verification is to compare the weather resistance capability of piano wire spring and stainless steel wire spring. Neutral salt spray test was used to accelerate the degree of materials surface oxidation to evaluate the compression load variation and free length variation (recovery) under constant compression. THERCON SST-7NL salt spray tester was used in this verification process. Salt water PH value is 6.5~7.2, water temperature: 25±2℃, validation period: 2000 hours.

2.3.3 Thermal shock verification

The purpose of this test is to compare the piano wire spring and stainless steel wire spring used to lock the CPU cooling plate on the motherboard and evaluate the fastener performance under the thermal shock testing condition (85℃ to -40℃). Thermal shock cycle graph is shown in Fig. 7. Each cycle was completed in one minute. Number of cycles is 500. T-Machine TMJ-9713 thermal chamber and Frigor GLE40 super low temperature freezer were used in this test.

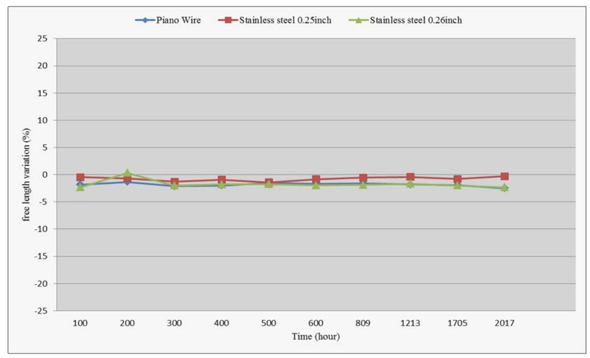

Fig. 7 Schematic diagram for thermal shock cycle

2.4 The Evaluation of fastener body dimension to fastening performance

The portion of this study was focused on the modification of the main body of plastic spring fastener to improve fastener performance. Impact test and pullout test were used to verify the effect of dimensional modification to the fastening performance.

2.4.1 Impact test

Impact test was used to evaluate the effect of plastic fastener main body, before and after dimensional modification, on the impact energy. Fig. 5 shows the special fixture designed for the purpose of the secure of the plastic fastener main body. First, fasten the plastic fastener low body on the tool, then, IZOD impact tester was used to do the impact test. The apparatus used here is Hung-Ta IZOD impact tester. The maximum impact energy is 30 kgf-cm.

2.4.2 Pullout test

Pullout test was used to evaluate the effect of plastic fastener main body, before and after dimensional modification, on the gripping performance. Fig. 6 shows the special fixture designed for the purpose of the pullout test. First, fasten the plastic fastener low body on the three-layer fixture, then, desktop tensile strength tester was used to do the pullout test. The apparatus used here is Hung-Ta HT-8115B desktop tensile strength tester The maximum loading is 50 kgf.

3 Results and discussion

3.1 Outside environmental fffect evaluation

3.1.1 Thermal resistivity verification (thermal aging)

The free length variation for three different springs was compared based on the thermal resistivity verification (thermal aging) test results, as shown in Fig. 8. The average percentage change of piano wire spring free length varies between -1.36% to -2.49%. The average percentage change of 0.25inch stainless wire spring free length varies between -0.32% to -1.41%. The average percentage change of 0.26inch stainless wire spring free length varies between -0.16% to -0.94%. Spring load variation results are shown in Fig. 9. The piano wire spring absolute average load variation increases as thermal aging time: From -3.30% at 100 hours increases to -8.38 at 2000 hours. The average percentage change of load of 0.25inch stainless wire spring varies between 1.5% to -4.46%. The average percentage change of load of 0.26inch stainless wire spring varies between -1.45% to -8.25%.

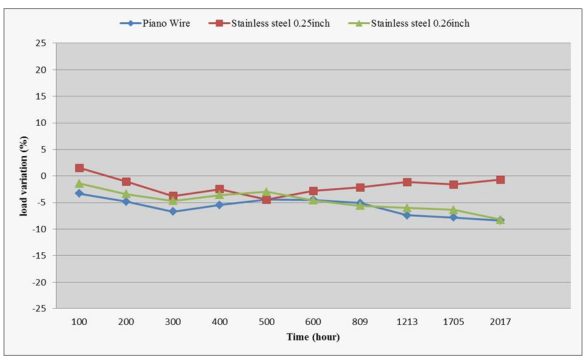

Fig. 8 The comparison of spring free length variation

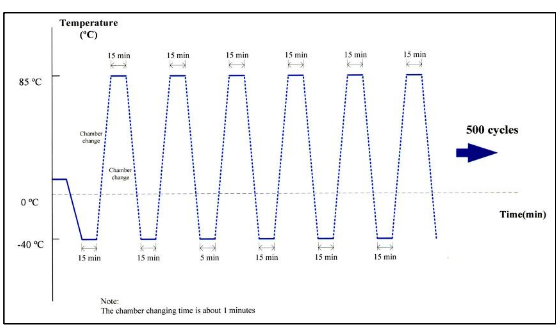

Fig. 9 Spring load variation average value comparison (thermal aging)

3.1.2 Weather resistivity verification (salt spray)

The free length variation for three different design springs was compared based on the weather resistivity verification (salt spray) test results as shown in Fig. 10. Piano wire spring test was terminated after 1200 hours salt spray test as piano wire spring was severe rusted. The average percentage change of piano wire spring free length after salt spray varies between 0.09% to -2.12%. The average percentage change of 0.25inch stainless wire spring free length after salt spray varies between 0.02% to -0.68%. The average percentage change of 0.26inch stainless wire spring free length varies between -0.16% to -1.05%. Spring load variation results are shown in Fig. 11. The piano wire spring absolute average load variation increases as thermal aging time increases: from -2.82% at 100 hours increases to -50.20% at 1200 hours. The average percentage change of load of 0.25inch stainless wire spring varies between -1.13% to -10.03%. The average percentage change of 0.26inch stainless wire spring varies between -0.88% to -12.56%. The appearance of fastener specimen after salt spray test is shown in Fig. 12 and Fig. 13. In Fig. 13, portion of piano wire spring was damaged after 1200 hours salt spray test.

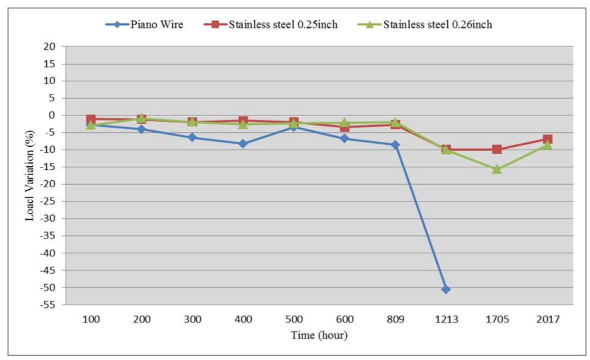

Fig. 10 Spring average free length variation comparison

Fig. 11 Spring load variation average value comparison (salt spray)

Fig. 12 The appearance of stainless wire after 2000 hours salt spray test

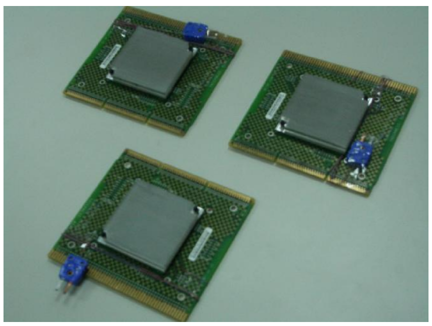

Fig. 13 The appearance of Piano wire fastener after 1200 salt spray test

3.1.3 Thermal shock verification

Thermal shock experiment is to evaluate the effect of rapid change temperature environment (500 cycles) to the fastener performance after spring fastener was secured on the CPU cooling plate, for example: whether pin loose, cooling plate off-set, fastener gripping end peels off, etc. Test results shows all three types of fasteners performance were are affected by thermal shock, there is no gripping end peels off, pin looses or cooling plate off-set. Test specimens were shown in Fig. 14. Each spring fastener has a set of special test specimen; there are three set of specimen in total. One specimen was designed for each spring fastener. The close-up picture of spring fastener, mother board and CPU cooling plate assembly is shown in both Figures 15 and 16.

3.2 The effect of temperature aging and salt spray to spring constant K

According to spring free length and fix compression load test results after temermal aging and salt spray test, it is possible to further evaluate the outside environment effectives to spring constant K. For piano wire, the change of piano wire spring constant K various is less than 5% as shown in Fig. 17. The variation for the case of 0.25 inch stainless steel spring is 5%, and for 0.26inch stainless steel is 6%. Fig. 18 shows the effect of salt spray on spring constant K. For the case of piano wire constant, after 1200 salt spray the spring constant change variation is as much as 49%. The variation value for 025inch free length stainless wire spring is within 6% and is 19% for 0.26in free length stainless wire spring.

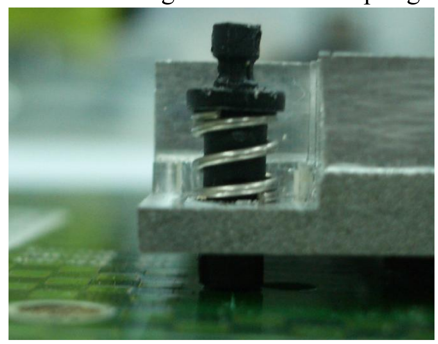

Fig. 14 Thermal shock verification test specimen

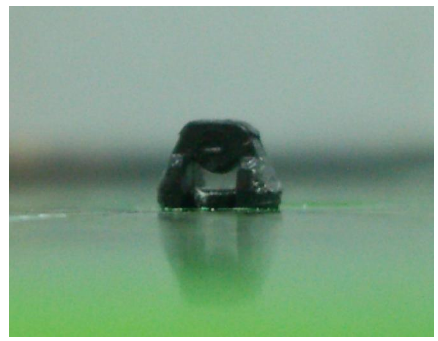

Fig. 15 The spring fastener assembly

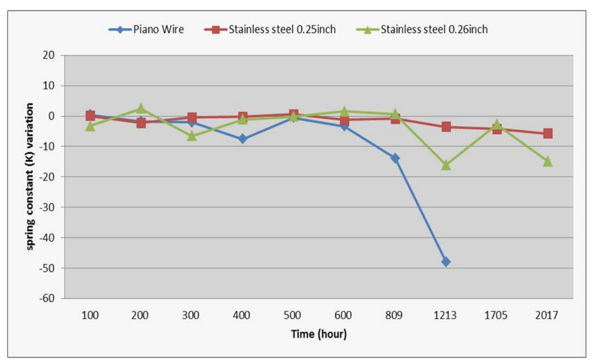

Fig. 16 Fastener fixed end assembly

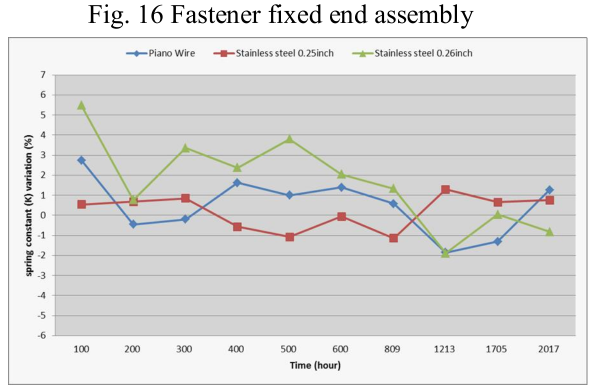

Fig. 17 Thermal aging effect on spring constant K

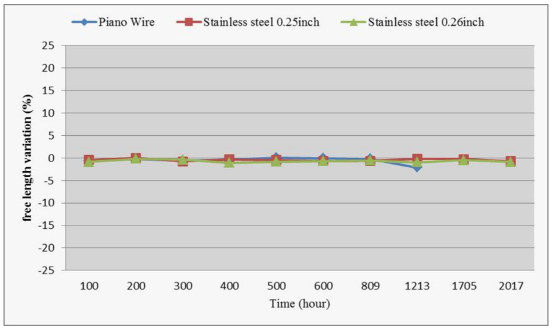

Fig. 18 Salt spray effect on spring constant K

3.3 The effectiveness of dimensional change to fastening performance

Fastening performance was evaluated using impact and pullout test; impact test is used to evaluate the impact energy that fastened plastic main body can withstand, and pullout test is to evaluate the pullout force that the intrusions from both sides of the fastening end of plastic main body can provide. The modification of the fastening main body dimension included enlarges the chamfer at fastening end and change the dimension of two protrusions. Test results show that the average impact value after dimension modification increases from 1.946 kg-cm to 2.181 kg-cm, a 12% improvement, as shown in Fig. 19. The pullout test results show that the pullout force increased by 81%, from 5 kgf before modification to 9.05 kgf after modification, as shown in Fig. 20.

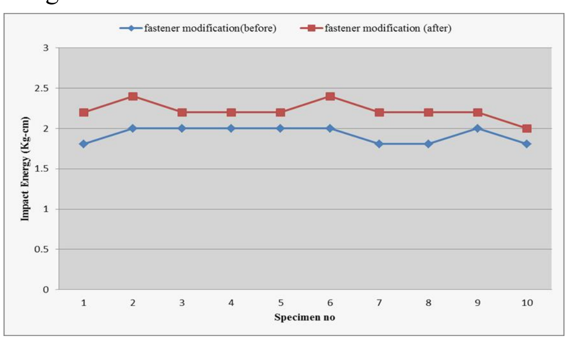

Fig. 19 Fastener main body impact value comparison

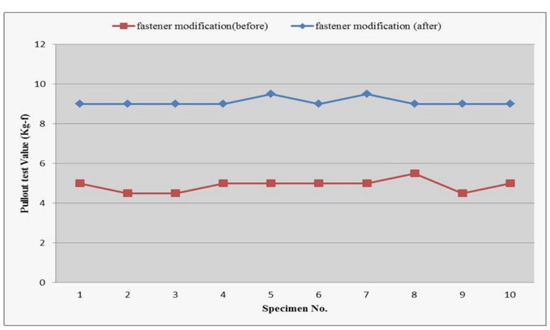

Fig. 20 Fastener main body pullout force comparison

4 Conclusions

1. According to the test results, thermal aging has little effect on piano wire spring or stainless wire spring. However the piano wire spring free length variation is about 1% larger than that of stainless wire spring wire. On the contrary, the effect to compression load variation is obvious, the maximum load variation for 0.25inch piano wire is 4.46%, and piano wire spring is 8.38%. It is concluded that stainless wire has better thermal resistivity than that of piano wire.
2. According to test results, salt spray effect to piano wire spring and stainless wire spring is not obvious. However, the piano wire free length variation is about 2% larger than that of stainless wire spring. On the contrary, the effect to compression load variation value is obvious. The maximum variation for both 0.25inch and 0.26inch stainless wire spring free length is between 10~12.5%; this value is as high as 50.52% for piano wire spring after 1200 hours. It is concluded that stainless wire has better weather resistivity that that of piano wire.
3. The effect of thermal aging on spring constant K of piano wire, and 0.25 in and 0.26 in stainless wire is not much, around 5~6%; On the contrary, salt spray effect is obvious. The spring constant variation of 0.25 inch stainless wire is 6%; 19% for 0.26inch stainless wire spring. The value for piano wire is as high as 49%.
4. The modification of the fastening main body dimension in this study included enlarges the chamfer at fastening end and change the dimension of two protrusions. The fastener impact energy increases by 12%; fastening performance increases by 81%. Therefore, dimension modification improves the performance.
5. After 500 cycles thermal shock(85℃~-40℃) test, the spring fastener-CPU cooling plate assembly was still intact; cooling plate was not loosened; fastener did not peel of or sprang away. Therefore, fastener design fulfills the environmental various resistivity requirements.
6. Based on the study results, it is recommended that the choice of stainless steel wire with free length 0.26 inch, and some modification on plastic main body dimension (such as two intrusions on fastening end, and fastening end chamber) can effectively improve CPU cooling plate spring fastener performance.normal lung tissue of the same patient.

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