Applicaiton of NiTi memory alloy dish gasket in power grid

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Abstract. Dish-shaped gasket (DSG) was prepared to use NiTi shape memory alloy (SMA) for the current study. The recovery force of the NiTi SMA based DSG increases with the rise of temperature. The DSG can supply a recovery force of 5.89 kN at 95 ºC. The NiTi SMA based DSG can effectively decrease the loop resistance of the clamps to less than 30μΩ under the heating of the clamps, and it also can continuously suppress the heating of the clamp until the height of the nut loosening exceeds the original height of the DSG.

1. Introduction

Bolt-type fixed clamp is an important connection component of diversion circuit in power transmission and distribution. However, the looseness of the bolt induced by vibration from the wind or electromagnetic effect is inevitable for the bolt-type fixed clamp, which leads to heating of the clamps or even severe ablation [1,2]. Though overheating defects of the clamps are possible to be timely eliminated via living work method, the risks of the power grid increases and a large amount of manpower and material resources are consumed.

SMA is a series of alloys which possess shape memory effect [3]. "Shape memory effect" is a phenomenon that the material recovers to its original shape after a prefabricated deformation by changing external conditions, such as temperature, properly [4,5]. NiTi SMA is one of the most widely used SMA and it was recognized to possess the most superior performance [6].

Contact resistance is a key factor for overheating of junctions in power transmission and distribution. When the temperature rises, regular spring gasket would oxidize, lose its elasticity, and lead to the looseness of the bolts. Worse more, once the bolts become loose, the contact resistance further increases, which promotes the overheating of junctions in power transmission and distribution. The above repeated vicious circle finally leads to the failure of the junctions. Comfortingly, it is possible that NiTi SMA is able to decrease the contact resistance of junctions by recovering its memory shape with the rise of temperature, resulting the re-fixing of the junction and avoiding its overheating [7-9]. However, the effect of NiTi SMA based DSG on suppressing the overheating of clamps in long-term service has not been reported. Bolts of clamps may be loosened many times during long-term service; therefore, it is necessary to study the effect of NiTi SMA based DSG on suppressing the overheating of clamps when bolts are loosened many times.

In the current study, DSG was prepared with the NiTi SMA, and the effect of NiTi SMA based DSG on suppressing the overheating of clamps when bolts are loosened many times is studied.

2. Experimental Method

2.1 Preparation of the NiTi SMA based dish-shaped gasket (DSG)

NiTi SMA was melted via vacuum medium frequency induction furnace. The composition of Ni and Ti are 51.9 at.% and 48.1at.%, respectively. The alloy was heated to 1250 °C and then held at this temperature for 30 minutes. The DSG was machined from casting ingots and the heat treatment of the DSG was described before [9].

2.2 The recovery force test

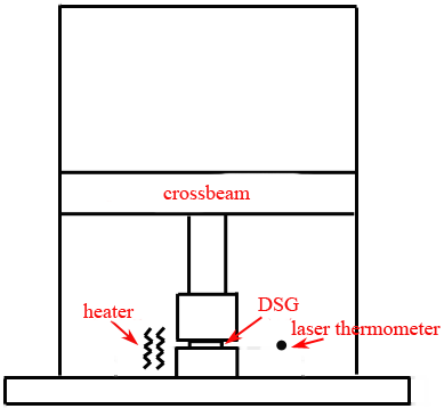

Fig. 1 the diagrammatic sketch of the recovery force test

The recovery forces were tested by an electronic universal testing machine. At the beginning of the experiment, the prepared DSG was planished by the machine, and then the loading on DSG was adjusted to zero. A heater with tunable output power was used to heat the DSG and the temperature was timely monitored and recorded by laser thermometer during the whole test. At the meantime, the value of recovery force was also recorded via the stress sensor at the machine. The diagrammatic sketch of the recovery force test was shown in Fig.1.

2.3 loop resistance test

The loop resistance test was conducted with the DSG was installed on the bolt-type fixing clamps. In the installation process, the DSG deformed and became a flat gasket when the screw nuts were tightened by a torque wrench. The screw nuts were slightly loosened to simulate the lossness of the bolt at the clamps in the power grid to detect self-suppression heating effect of DSG. In order to observe the long term self-suppression heating effect of DSG, the loop resistance tests of DSG after partial deformation were carried out, and the height of the gasket was measured after loop resistance test at 25 °C.

3. Results and discussion

The relationship between the recovery force of DSG and the temperature is shown in Fig.2. The recovery force increases with the rise in temperature. The curve can be divided into two stages, and each stage can be approximately fitted as a straight line. The recovery force started to record at about 30 °C. When the temperature rises to 40 °C, the recovery force for the DSG is 1.08kN. When the temperature reached at 95 °C, the recovery force for the DSG becomes 5.89kN.

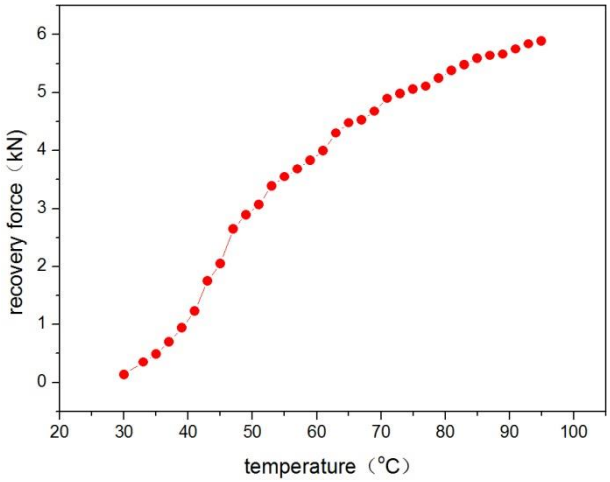

Fig. 2 The relationship between the recovery force of the NiTi SMA based DSG and the temperature

It is worth to notice that the recovery force of the DSG continued to increase when the temperature is over 40°C. The position of the crossbeam is fixed throughout tests, which means the DSG does not suffer any macro-scopical deformation at the vertical direction, as a result, the deformation of DSG was confined throughout the test even when temperature is higher than the ending deformation temperature (40 °C) of SMA, which lead to the increase of recovery force with the rise of temperature accordingly.

During the heating of the test, the temperature of the fixture, which was used to fix the DSG, also increased leading to the thermal expansion of the fixture being non-negligible. Therefore, it is necessary to have a contrast experiment for insuring the accuracy of the test. The output force versus temperature of gasket made by galvanized steel is shown in Fig. 3. Similarly, the force value of gasket made by galvanized steel increases gradually with the increase of temperature, and the output force is 0.198 kN at 95°C. As no phase transformation occurring in the range of the test temperature, the gasket made by galvanized steel wouldn't deform. Furthermore, the height of gasket made by galvanized steel is only 2.3 mm, which made its thermal expansion insignificant. Hence, the only source of this recorded force comes from the thermal expansion of the fixture.

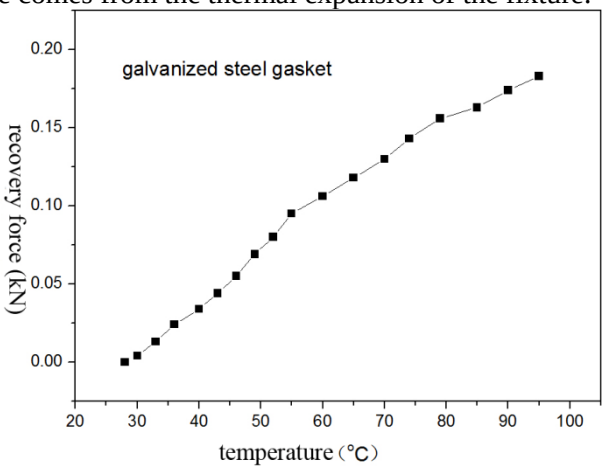

Fig. 3 the output force due to the thermal expansion of the fixture

The relationship between the loop resistance and temperature of the clamp fixed DSG with different initial loop resistance are shown in Fig. 4. , the loop resistance of the two clamps tightly fixed with bolts and screw nuts was usually measured to be less than 30 μΩ. A rapid loop resistances decrease is observed until the temperature reach 35°C. After that, the loop resistances decrease slowly. At the temperature of 35 °C, the recovery force for DSG is just 0.48kN which is relatively low, revealing that only a small recovery force is needed to decrease the contact resistance between two

clamps. When temperature is over 35 °C, the recovery force continues to increase. However, the contact resistance between two clamps only slightly decreased under the rapid increase of recovery force due to the existing of a close-touch between two clamps.

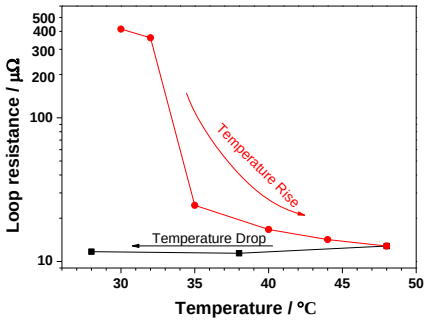

Fig. 4 The relationship between the loop resistance and the temperature of the clamp fixed DSG with different initial loop resistance

In order to verify whether the NiTi SMA based DSG could retain its ability in inhibiting heating, the loop resistance tests were repetitively conducted on DSG for three times after the former partially deformation.

The height of NiTi SMA based DSG varied during the tests, which is shown in Fig. 5 along with the illustration of the fixing mode. The original height of the NiTi SMA based DSG is 4.36mm, which becomes 2.83mm after the first installation. When the test continued from the first time to the third time, the height of the DSG after are 3.44mm, 3.98mm, and 4.30mm, respectively (shown in Fig. 5b, Fig. 5c and Fig. 5d). It is intriguing to notice that the height of the gasket increased gradually closer to its original height with the increase of test cycles.

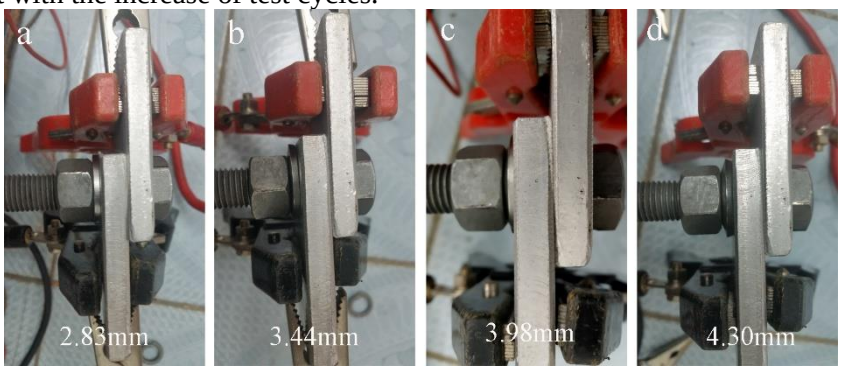

Fig. 5 The height variation of SMA based DSG in repetitive loop resistance

The loop resistance versus temperature during the repeat tests is shown in Fig. 6. The initial loop resistance value for first loop resistance test is 782μΩ (Fig. 6a). The loop resistance decreased slightly when the temperature rises to 29 °C, indicating that NiTi SMA based DSG began to deform at this temperature. With the temperature further increase to 35 °C, loop resistance has been reduced to 135μΩ, and the loop resistance remained decreasing with the increasing of temperature.

The loop resistance change in the second test is shown in Figure 6b. The initial loop resistance value is 472μΩ, and the initial temperature is still around 30 °C. The change tendency of loop resistance in the second test is similar to that of the first test, indicating that the output force of the NiTi SMA based DSG is enough to reduce the contact resistance. The height of DSG is 3.98mm after the second loop resistance test, which means that the height of the memory alloy gasket increased 0.54mm during the this test. It is worth noting that the descent rate of the loop resistance dropped down during the second test. When the temperature rises to 40 °C, the loop resistance is still as high as 136μΩ but it decreased to 38 μΩ as the temperature rises to 50 °C. In comparison, the loop resistance is 44 μΩ at 42 °C in the first loop resistance test.

The initial loop resistance value of the third is 307 μΩ, as shown in Fig. 6c. the loop resistance begins to decrease when the temperature rises to 30 °C. Different from the previous two tests, the loop resistance remained as high as 104 μΩ when the temperature increases to 50 °C. As the temperature further increases, the loop resistance stop decreased but slightly increased instead. The height of NiTi SMA based DSG after the third loop resistance test is 4.30mm, indicating that the gasket has increased to its original height. It is reasonable to predict that the height of the DSG would not increase anymore even if the temperature rises continuously. Moreover, once the DSG returned to its initial height, no further recovery force would be output and the contact resistance would maintain at 104μΩ.

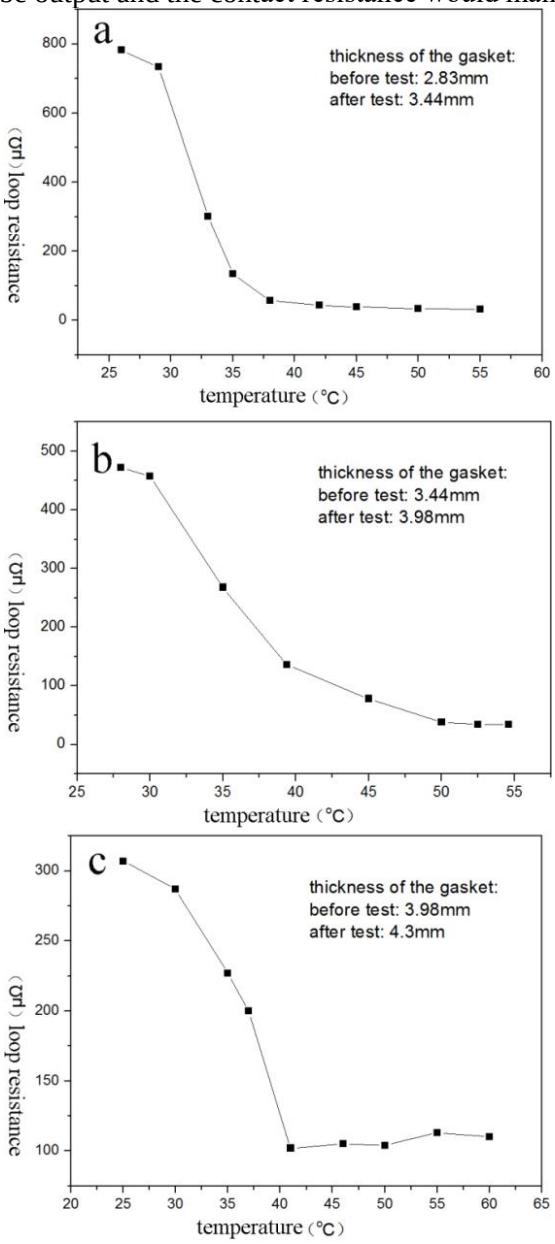

Fig. 6 The loop resistance variation in the first, second, third loop resistance test

Based on the results of the above-mentioned recovery force tests and the loop resistance experiments, the mechanism of self-suppression heating of the clamp could be deduced：when the temperature is high enough to trigger the phase transformation of NiTi SMA based DSG, the DSG output recovery force, and the contact resistance between the clamps reduced accordingly. As a result, the issues of the clamps getting overheating are effectively settled by NiTi SMA based DSG.

4. Conclusion

The recovery force of NiTi SMA based DSG increases with the rising temperature, and the recovery force of the DSG at the temperature of 95°C is 5.89 kN. The NiTi SMA based DSG can effectively decrease the loop resistance of the clamps to less than 30μΩ under the heating of the clamps, and it also can continuously suppress the heating of the clamp until the height of the nut loosening exceeds the original height of the DSG.

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