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Research Article

Tribological Studies of NiMnAl and NiMnSn magnetic Shape Memory Alloys

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Abstract

In this work an attempt has been made to study the tribological behavior of relatively new Ni-Mn-Al and Ni-Mn-Sn Magnetic shape memory alloys (MSMAs).These alloys were prepared by vacuum arc melting technique. The Vickers hardness values of both the samples were measured. From tribological test and alloy comparison it is found that the wear rate of the Ni-Mn-Al alloy was less than the Ni-Mn-Sn alloy for the same time span and load. The value of coefficient of friction was more in Ni-Mn-Al alloy than Ni-Mn-Sn alloy and increased with the distance or time whereas in Ni-Mn-Sn alloy it remained nearly constant over the time span. From Vickers hardness test it was observed that the hardness value of the Ni-Mn-Al alloy is more than that of Ni-Mn-Sn alloy.

Keywords: *Tribology, MSMA, NiMnAl, NiMnSn, Pin on disc, Wear, Coefficient of friction, Frictional force*

1. Introduction

Tribology covers the science and technology of surfaces in contact and relative motion. It includes friction, wear and lubrication and associated surface layers on the contacting bodies. It has great significance in all industrial sectors.

Shape memory alloys (SMAs) are a unique class of metal alloys that can recover apparent permanent strains when they are heated above a certain temperature. They display thermo-mechanical properties such as shape memory effect and superelasticity. The key characteristic of all SMAs is the occurrence of a martensitic phase transformation. In this phase transformation, the crystal structure changes from the parent martensite transformation to a high symmetry cubic austenite phase. Magnetic Shape Memory Alloys (MSMAs) are novel active materials which are receiving considerable interest among the scientific community. They are next generation to SMAs, sharing many common properties. Conventional SMAs has less potential efficiency due to slow mechanical response to temperature changes. Hence MSMAs are promising materials which show larger Magnetic Field-Induced Strain (MFIS) with quick response at low frequencies than other smart materials. Ullako etal first discovered magnetic shape memory effect on NiMnGa alloys in 1996. NiMnGa most studied MSMA due to their large field induced strain.

The interest in studying MSMAs other than NiMnGa such as NiMnSn and NiMnAl is due to high cost of pure Ga, its low melting point and brittleness.

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2. Experimental

Two MSMA alloys $Ni_{50}Mn_{30}Sn_{20}$(sample A) and $Ni_{55}Mn_{24}Al_{21}$(sample B) were prepared by vacuum arc melting under an argon atmosphere. Repeated melting was performed to improve the homogeneity of the alloy. The alloys were melted in the small crucibles. Table 1 shows the size of prepared alloy samples. These samples were cut in flat cylindrical shape on wire cutting machine. The cutting is carried out with 0.8 mm copper wire with 300 rpm. The machining time spend was of 125 sec.

Table.1 Size of alloy samples

Sample	A	B
Height (mm)	7.35	2.20
Diameter(mm)	21.16	13.29

The Vickers hardness, were performed on both the alloy samples. For the tribological testing on pin on disk apparatus pin specimens were prepared as per the requirement. Manual joining of a pin was done taking a M.S. stem of nearly 100 mm length to hold the material in jaws of the machine. The prepared specimens of $Ni_{50}Mn_{30}Sn_{20}$ alloy (sample A) and $Ni_{55}Mn_{24}Al_{21}$ alloy (sample B) were used for pin on disc wear test at room temperature.

3. Results and Discussions

The tribology results were obtained from the test using pin on disc machine. The standard experimental unit was used for this test with following parameters:

Load = 20 N
Speed = 700 rpm.
Time = 15 min.

The load was constant throughout the test on both samples. Only small value of the load is applied on the sample being tested.

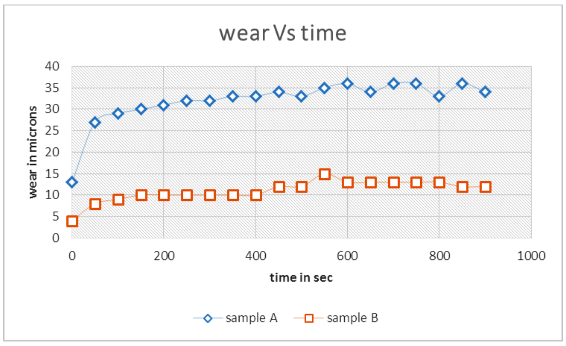

Fig.1 wear comparison graph of sample A and sample B

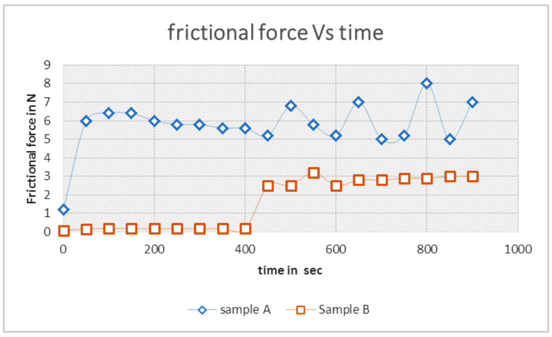

Fig.2 Frictional force comparison graph of sample A and sample B

The comparison of the sample A and sample B is done with the three different parameters wear, frictional force and coefficient of friction. The fig.1 shows wear behavior of both specimens comparatively similar in nature. It clearly shows that the wear rate of sample A is more than sample B for the respective time. The wear rate of both specimens' increases gradually as the time increases.

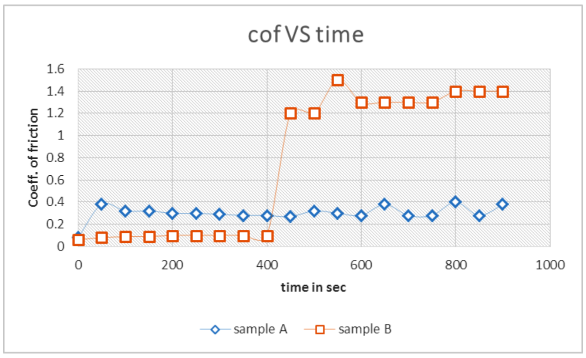

Fig.3 Coefficient of friction comparison graph of sample A and sample B

The both specimens are compared for frictional force. The fig. 2 shows that sample A has more frictional force value than the sample B for respective time. For sample B, frictional force is gradually increases and is nearly linear compared to sample A.

The graph of coefficient of friction vs time is shown in the fig. 3. It has been observed that sample B has sudden change in the value of coefficient of friction occurs at 400th second to 450 second.

Conclusion

From tribological studies of NiMnAl and NiMnSn and comparison following conclusions are drawn.

1) From tribological tests it is that wear rate of the Ni-Mn-Al alloy is less than the Ni-Mn-Sn alloy for the same time span and load. The highest wear value obtained in Ni-Mn-Al alloy is 15nm whereas in Ni-Mn-Sn it is 36nm. The wear rate of the Ni-Mn-Al sample is 0.0244 mm^3/m which is almost half of the wear rate of Ni-Mn-Sn sample i.e.0.04275mm^3/m.
2) Linear and gradual increase in frictional force occurs in Ni-Mn-Al alloy where in Ni-Mn-Sn this graph is nonlinear in nature. Ni-Mn-Al alloy has less frictional force obtained than the Ni-Mn-Sn alloy over the similar time span.
3) The value of coefficient of friction in more in Ni-Mn-Al alloy than the Ni-Mn-Sn alloy. The coefficient of friction in Ni-Mn-Al alloy goes on increasing with the distance or time whereas in Ni-Mn-Sn alloy the coefficient of friction remains in nearly constant over the time span.
4) Form wear test and alloy comparison it is observed that the Ni-Mn-Al MSMA has less wear rate, gradually increasing frictional force and coefficient of friction than the Ni-Mn-Sn MSMA.
5) It is also found that the calculated wear volume loss of Ni-Mn-Al sample 79.308 mm^3 is less than the wear volume loss of Ni-Mn-Sn sample i.e.138.537 mm^3.
6) The Vickers hardness test carried out shows that the hardness value of the Ni-Mn-Al sample is more than the hardness value of Ni-Mn-Sn sample. The value of hardness for Ni-Mn-Al sample is found between 190 HV to 193 HV for the load of 100gm to 1 kg whereas this value for Ni-Mn-Sn is between 179 HV 181 HV.

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