EFFECT OF ULTRA SHOT PEENING ON CASTING SHAPE MEMORY ALLOY

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ABSTRACT
In order to overcome difficulties that have hindered precision casting of shape memory alloys, we made a ingots created with Self Propagating High Temperature Synthetic Method (SHS) which eventually led us to the success of precision casting utilizing lost wax process. Also we have succeeded in creating functional products that are treated with the ultrasonic shot peening process, improving the resiliency against deformation and fatigue strength. Although the common casting products are created using many different kinds of metals and alloys, casting products utilizing shape memory alloys have not been widely adopted due to a lack of successfully produced products. The reasons for this are that there was much difficulty in developing equal property structures that does not allow gravity segregation of Ni-Ti. Also its essential characteristics (being the shape memory and super elasticity), the makeup of component had to overcome the structural weaknesses in order to withstand from possible deformation.

SUBJECT INDEX
Ultrasonic Shot Peening, Shape Memory Alloy (SMA), Gravity Segregation, Self-Propagating High Temperature Synthesis (SHS)

INTRODUCTION
Because Ti-Ni Shape Memory Alloy (SMA) have quite difficult machinability, only rounded wire shape were available for production and the complicated shape parts are impossible to be made so far. On the other hand, we have succeeded in casting manufacture of SMA by using our original Ti alloy technology. However, there was a big problem to solve in case of using the casting method. Titanium is the metal that is light in comparison with Nickel. When this alloy is occurred gravity segregation on the earth for casting, Titanium and Nickel separate like two things that do not mix well, like oil and waters by gravity. Because of this nature, the shape-memory characteristic is lost, even if the aimed shape can be achieved by casting. In this situation, we develop Self Propagating High temperature Synthesis (SHS)[(1)-(4)]. By using ingot of this SHS technique, the casting alloy has no gravity segregation. So, the specific characteristics of SMA casting do not disappear.
In addition, because the strength of the casting product is low, it is necessary to enhance the durability for repeatable use. So, we apply the Ultrasonic Shot Peening

(USP) technology in order to enhance the durability. Here, USP, named Stressonic® technology [5], was developed by SONATS, France. The main characteristic of Stressonic® could give the smooth surface after operation, compared to the conventional shot peening, because of using polished bearing ball. So, specimens peened by Ultrasonic technology would be expected to be induced deeper compressive residual stress without the surface-coarse. Each indispensable and fundamental technology is collaborating to realize this new technology. In this study, we conducted the tensile strength tests showing the mechanical properties and further fatigue tests were conducted to confirm the effect of USP on Casting Shape Memory Alloy.

EXPERIMENTAL PROCEDURE

Base ingot used in this study is Ti-Ni SHS material whose composition are Ti-50.8at%Ni and Ti-50.0at%Ni. Here, the farmer composition would show the super elasticity and the other one shows shape memory characteristics. The first step of producing the ingot is precisely mixing Ti and Ni powders in accordance with the targeted compound-ratio. Next, the Ti-Ni mixture is filled into a crucible and packed. After placing this packed mixture inside a chamber, the inside chamber is vacuumed and filled with argon gas in order to fire up the end of powder by ignition. Chemical reaction starts at the ignition point, and generates heat of formation. This heat of formation starts off a chain reaction and propagating on the surrounding T-Ni mixture and as a result the mixture turns into alloy in a short time. Here, since the mixture is melted at a temperature far higher than the normal shape memory alloy's dissolution temperature, and followed by a rapid cooling at the end of the Ti-Ni chemical reaction to create the compound, the melting time is much faster than that of when producing an ingot by melting method. Figure 1 and Figure 2 show the above process graphically and this processing is Self-Propagating High Temperature Synthesis (SHS), which is epoch-making method, developed by Yoshimi. By using this developed ingot, the casting alloy has no gravity segregation. So the specific characteristics of shape memory alloy do not disappear.

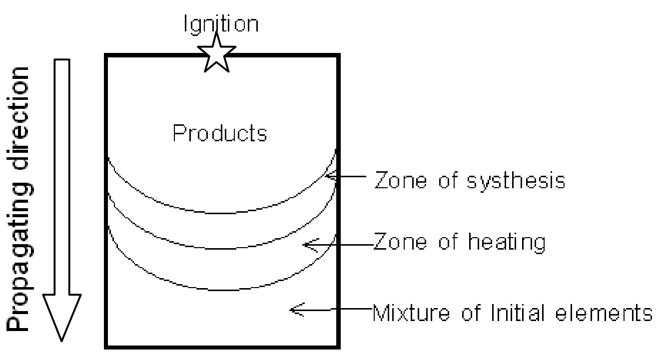
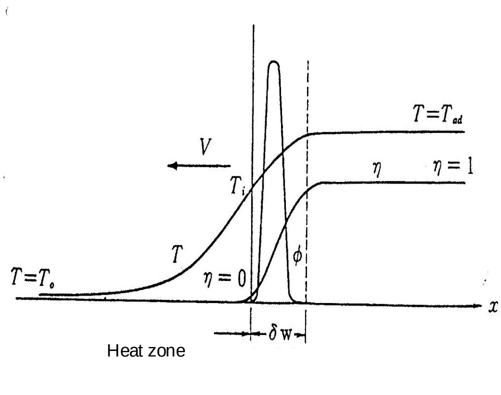


Fig. 1 Combustion process of SHS



Transmitted combustion wave temperature distribution *T*,

Fig.2 Heating process of SHS

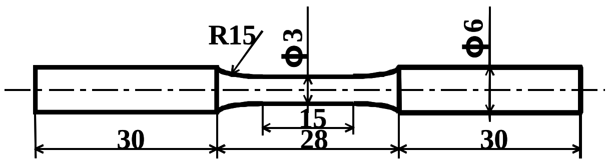


Fig. 3 The geometry of tensile specimen

Table 1 Ultrasonic shot peening conditions

Amplitude	70 micron
Dia. of sonotrode	70 mm
Injecting distance	10 mm
Shot media	0.8mm, 800HV(Bearing ball), 4g
Injecting time	8sec(100%),160sec(2,000%), 320sec(4,000%)

Tensile tests specimens were made by centrifugal precision casting method. Here, three-phase 200V 40KVA casting machine with input current of approximate 115A and mold revolution speed of 1300 rpm that is available of melting and casting ingot-weighing 1Kg at one time was used.

The geometry of tensile specimen is shown in Figure 3. Heat temperature is 753K for 40 minutes and testing was conducted at room temperature.

Shot peening was carried out by Stressonic® and conventional air peening device. Table 1 shows the shot peening conditions. In this study, we used polished bearing ball with a diameter of 0.8 mm and the hardness of HV800 for Stressonic® peening device. A 100% coverage time would be 8 seconds at this study. Because after shot peening we had to conduct the heat treatment for shape memory at 753K as mentioned above, we selected much bigger coverage time in order to keep the effective residual stress distribution even after heat treatment. So, we conducted 160 seconds and 320 seconds, which is equivalent to 2000% and 4000% coverage respectively.

The residual stresses were determined by X-ray diffractometer using the $\sin^2\psi$ -method. The residual stress distribution was obtained by repeating the X-ray measurement and electrochemical polishing.

RESULTS

RESIDUAL STRESS DISTRIBUTION

Figure 4 shows the residual stress distribution of specimen with a composition of Ti-50.8at%Ni. As shown in this figure, 2,000% and 4,000% coverage specimens could obtain the effective residual stress profile even after heat treatment. However, only 100% coverage specimens would be disappeared the residual compressive stress and almost the same as un-peened specimen. The reason of these results was considered that much longer shot treatment time affected the deeper effective layer.

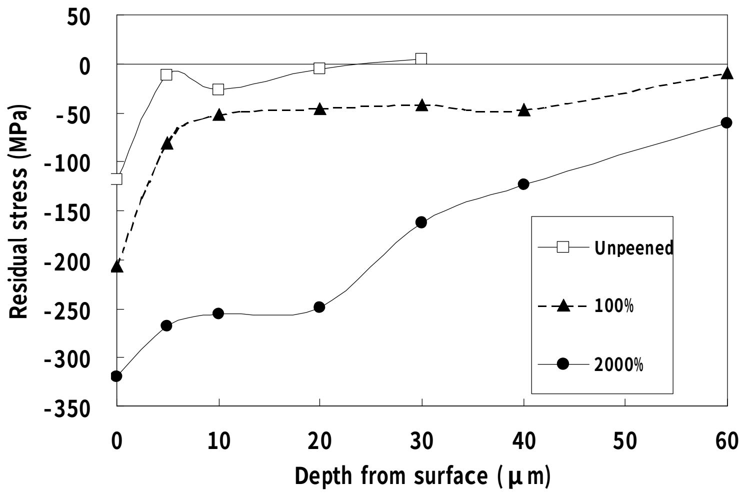


Fig. 4 Residual stress distribution

TENSILE TESTING

Figure 5 and 6 shows the results of tensile testing at each material. Figure 5 shows unpeened specimen and 8 sec shot peening specimen (100% coverage), further 160 sec (2000%). As shown in figure 5, the curve draws good super elasticity behavior. When shot peening processes are given for a long time, the stress level decreases by 2%. So, It was considered that internal residual stress of the materials helped a transformation. And as shown in Figure 6 (unpeened, 2000% and 4000% coverage), there is good shape memory behavior. However, when shot peening processes is given for a long time, the stress level increases by 2%. From these results, dislocation was occurred in the surface crystallization and surface constitution is hardened.

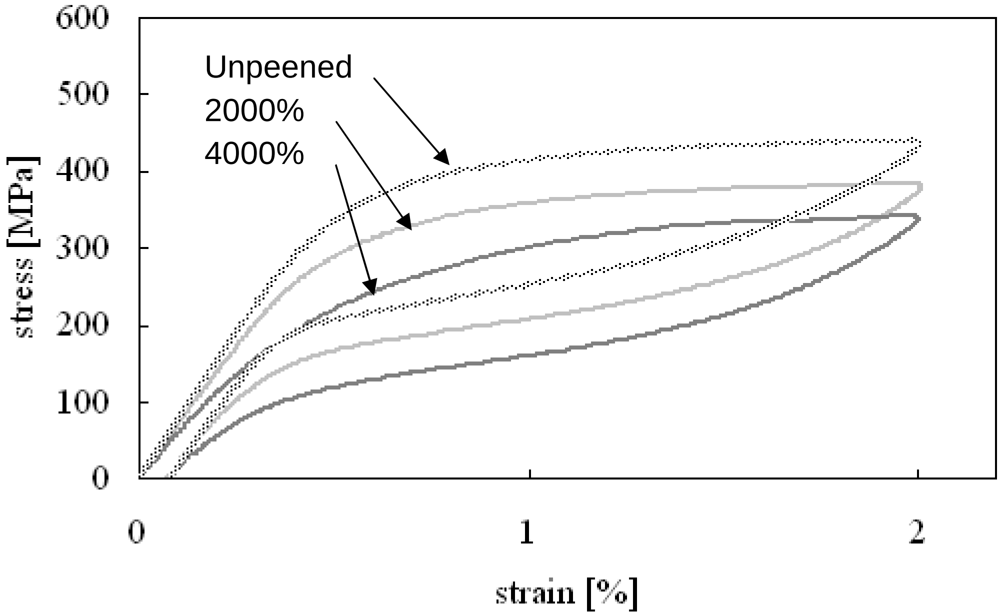


Fig.5 Stress-Strain chart at super-elasticity (Ti-50.8at%Ni)

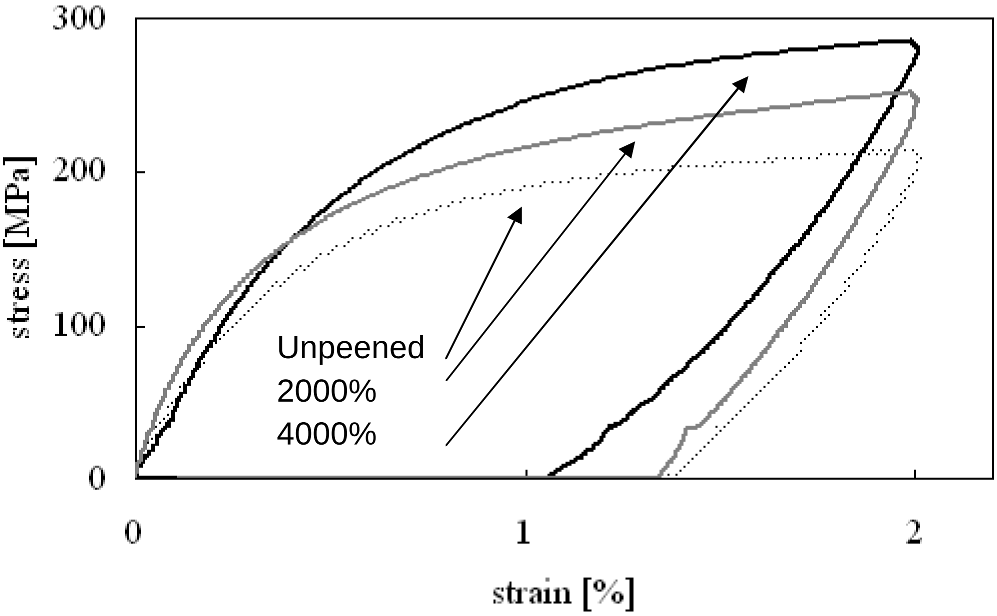


Fig.6 Stress-Strain chart at shape memory (Ti-50.0at%Ni)

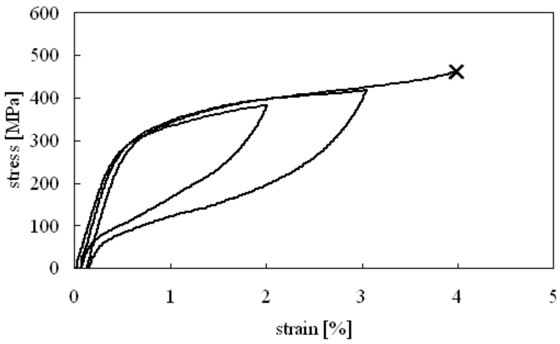


Fig. 7 Tensile test at unpeened spec. (Ti-50.8at%Ni)

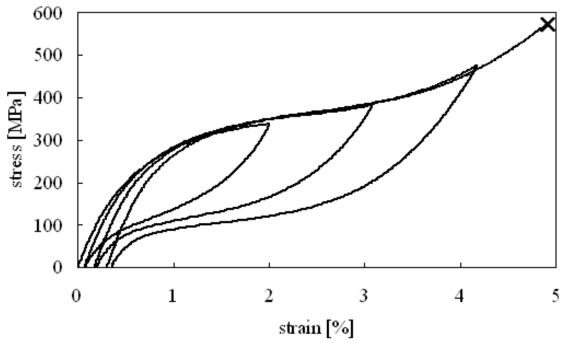


Fig. 8 Tensile test at 2,000% coverage (Ti-50.8at%Ni)

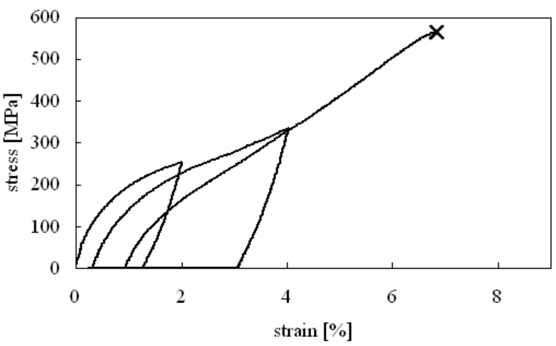


Fig. 9 Tensile test at unpeened spec. (Ti-50.0at%Ni)

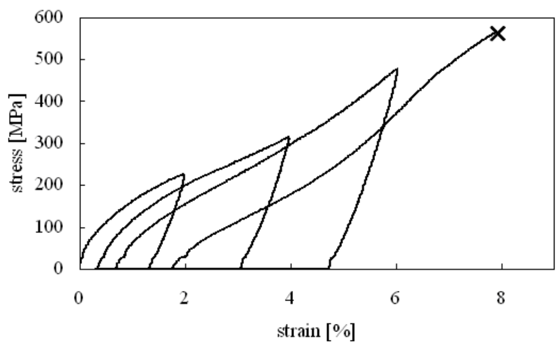


Fig.10 Tensile test at 2,000% coverage (Ti-50.0at%Ni)

Figure 7, 8, 9 and 10 show breaking tensile test result at each material. At the comparison between unpeened specimen and 2,000% peened specimen, shot peening materials are higher unpeened specimen about less than 100MPa in break stress. And also the number of test cycle at peened specimens was eventually higher than that of unpeened specimen. It was considered that the reason of this result is a significant compressive residual stress. From Figure 9 and 10, almost same result was obtained. However, the both braking stress shows almost same value.

CONCLUSION

The present study aims for confirming the effect of ultrasonic shot peening treatment, Stressonic®, on Shape Memory Alloy. Tensile tests were conducted at two types of material which shows super-elasticity and shape memory.

Following is a summary of the results obtained:

(1) The SMA produced by the SHS + centrifugal casting with Ultrasonic shot peening treatment shows good super-elasticity and shape memory behaviors in tensile tests.

(2) At super elasticity material, as shot peening treatment time increases, the stress level decreases by 2%. It was considered that internal residual stress of the materials helped a transformation.

(3) At shape memory material, as shot peening treatment time increases, the stress level increases by 2%. From these results, it was considered that the dislocation was occurred in the surface crystallization and surface constitution is hardened.

(4) From breaking tensile tests, shot peening materials are higher unpeened specimen about less than 100MPa in break stress due to the compressive residual stress.

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