Study of Super-Elastic Properties of NiTiCu by Nano-Indentation

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Abstract

Nickel titanium copper (NiTiCu), is an interesting metal alloy that shows two unique properties. The two unique properties are shape memory and superelasticity. A shape memory alloy is an alloy that returns to its original shape after undergoing some sort of deformation after heating the alloy above a certain critical temperature point, where each different alloy has its own transformation temperature. Superelasticity is similar to that of shape memory, where deformation occurs and the alloy returns to its original undeformed shape. The difference between shape-memory and superelasticity is superelasticity does not have to be heated to return to the original undeformed state. With these 2 unique properties in mind, thin ribbons of nitinol undergoes nanoindentaion for a better understanding of NiTiCu. This type of research is beneficial to get a better understanding of the materials used in the Aerospace industry. This paper will discuss the activities and results of this research project. The value of such research to undergraduate engineering education will also be addressed.

Introduction

Shape Memory Alloys (SMA) have been around the Aerospace industry since the early 1970's and are still around to this day. The ability to be around the industry for so long, speaks to the versatility and importance of SMAs. From early applications of hydraulic tubing coupling used on F-14s to being used in fixed-wing aircrafts and rotorcrafts, SMAs have been solving engineering problems in the aerospace industry [1]. The property of shape memory is extremely similar to the property of super-elasticity. Both properties allow the material to recover to its original shape after some sort of deformation or applied stress has occurred. The difference being that shape memory needs to be heated above a certain temperature and super-elasticity occurs when the material is already above that temperature threshold. This research mainly focuses on Nickel titanium copper's (NiTiCu) super elastic property. This occurs when NiTiCu undergoes a phase transformation in its crystal structure. When an external stress is applied this 'induces the transformation of parent austenite phase to a martensitic phase' [2]. Once the stress is released, the martensite phase reverts back to an austenite phase almost immediately. When this reverting phase transformation happens, the specimen recovers to its original undeformed shape. This is what the research is based on. Taking NiTiCu ribbons, putting a stress on it (in terms of applying a load from a nanoindenter), and analyzing what happens.

Experimentation

When starting the research, the first step was to determine what type of tip would be used. We chose to use a spherical nanoindenter because we believe that a shape memory alloy would respond to better to a spherical shape. Also it is noted that a spherical indenter would "avoid plastic deformation so as to concentrate on the relationship between the indentation response and the elastic and phase transformation properties of the material" [3]. Avoiding plastic deformation would be essential as are looking to study the super-elasticity of NiTi. Also looking into the variations of the thickness as a part of processing was a part of the research. When doing nanoindentaions, thin films are mostly used, but instead of thin films we used thin ribbons. The ribbons that are being tested are 40 microns thick and show super elastic properties. For the nanoindentation, a hard tip, usually diamond, is used to press an indentation in a sample. The tip penetrates the sample until the user defined force/load is reached. This is shown in Figure 1. Through this testing, the super elasticity of the ribbons as a result of processing and the variations of the thickness within 40 microns is looked into. A nanoindenter that fits the needs of this research is located form an outside source because WMU does not own one. Since research is still ongoing, there are no results to be reported

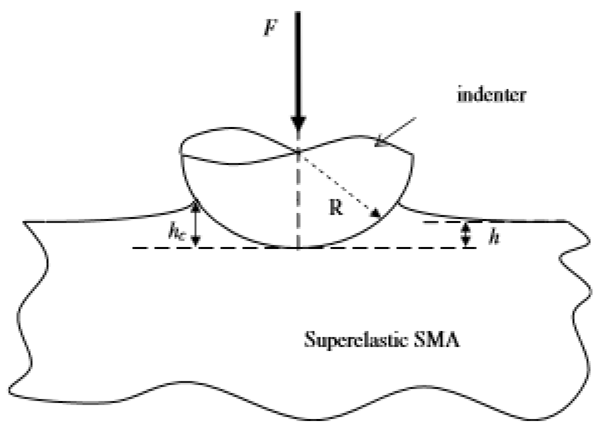

Fig. 1: Illustration of Indentation [3]

Value of Research

Research like this can be very beneficial to undergraduate students studying the Aeronautical/Aerospace field. Shape memory alloys have a lot of applications in these industries. Being able to work with a material that is widely would give the researcher an edge on the other undergraduates also trying to get their degrees in Aeronautical/Aerospace Engineering. Say for instance someone is applying for a job using shape memory alloys, or trying to do more research using nanoidentation. The researcher would have more experience with the material or the testing methods, which would give him/her an upper hand in the selection process. This research can also be beneficial in the classroom. Instead of learning about some of the things talked about in the classroom, one can actually see firsthand about these things that have been caught in class. In a usual material science class, terms such as phase transformation, the martensite phase, the austenite phase, are all talked about in this class. One comes across all of these terms as it relates to how super-elasticity works within the materials. Nanoindentation testing is usually used to determine mechanical properties of the specimen. The tester would be able to determine the hardness by taking the maximum load and dividing it by the area of the indentation. The tester could also determine Young’s modulus by finding the slope of a load- displacement graph. These properties are also discussed in lecture during classes, which gives a researcher a better understanding about the material being taught. Doing research also teaches about the hard work that is put into whatever topic is being researched. Research is not an easy thing to do because an original idea needs to be made up to research. There is no rubric, no template, or no direction to guide you through the process of what the researcher is doing. Doing research like this is not like some science lab where a teacher/professor instructs what to do. An undergraduate researcher helps out with a professor’s idea, and work as a team in a collaborative effort to figure out something that has never been done before. Even though the research is still not complete, a lot of time has gone into just doing the basics. Since Western Michigan University does not have a nanoindenter of its own, the actual nanoindentation testing needed to be outsourced to some other university or company. Because of the specific need to use a spherical tip, locating a nanoindenter with a spherical tip has proved quite the challenge.

Bibliography

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