Investment Casting of Cellular Structures from 60 NiTiNOL Shape Memory Alloy

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Abstract: This research attempt was to examine shape memory behavior of lightweight 60 NiTiNOL cellular structure cast by investment casting process. Acrylonitrile butadiene styrene (ABS) polymer was used as pattern materials. The 4-point bend test was conducted under loading and unloading conditions. Shape memory behavior of 60 NiTiNOL Single layer core cellular structure was confirmed.

Keywords: Investment casting, 60 NiTiNOL shape memory alloy, colloidal silica binder, Titania.

1. INTRODUCTION

Ni-Ti based shape memory alloys have attracted much attention because of their potential applications for high temperature conditions. Honeycombs have been primarily used in lightweight sandwich structures and are some of the high strength/density structures in many important loading situations such as bending [1]. An auxetic structure to airfoil shapes were also developed [2]. Constructing the cellular structures from shape memory alloys (SMAs) provides even greater potential taking the advantage of the shape memory and superelastic effects. Investment casting was employed to produce net shape lattice castings. This allows for parts with complex curvatures to be easily fabricated. Aluminum alloys [3], nickel-based superalloys [4], and titanium alloys [5] have been studied. Despite significant casting defects, good strength and damage tolerance of the lattice structures have been measured.

Investment casting differs from all other casting processes in the use of a disposable pattern to form the cavity into which the metal is poured. The complexity, detail and surface finish of the casting is directly dependent upon the integrity and dimensional stability of the original pattern [6-15]. The purpose of this investigation was to estimate the shape memory behavior of Ni-Ti alloy cast in Titania investment shell moulds. The mechanical properties with loading and unloading conditions were also investigated.

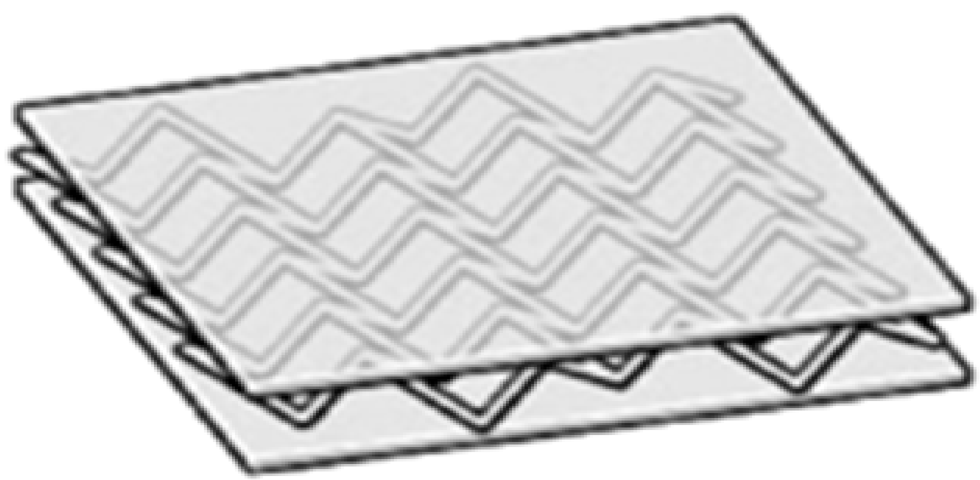

Figure 1: Single layer core cellular structure for investment casting.

2. MATERIALS METHODS

Acrylonitrile butadiene styrene (ABS) polymer was used as pattern materials. In the present work, the colloidal silica binder was used to fabricate the investment shell moulds from Titania as reinforced filler materials. The silica content in the colloidal silica binder was 30%. Two grades (primary and backup sands) of stuccoing sand were employed in the present investigation. Finer grade fused silica sand having AFS grain fineness number 140 was employed for primary coats. This sand was used for first two coats, called prime coats to get good surface finish and every detail of the ABS pattern. Coarser grade sand having AFS grain fineness number 60 was employed for back up coats. The backup sand was employed to develop more thickness to the shell walls with minimum coats [25-30]. The thickness of shell moulds were 10 mm. After all coats, the shells were air dried for 24 hours. The investment shell moulds were heated to 300^{o}C to remove ABS pattern material. Two shells of each treatment were made to get single layer core cellular structure as shown in figure 1. The Ni-Ti alloy was melted in an induction furnace under vacuum. The liquid alloy was gravity poured under vacuum into the pre-heated investment shell moulds [16-30]. The shell moulds were knocked off by hand hammer after solidification of the molten. The castings were cleaned with soft brush and visually inspected for pins and projections. The 4-point bend test was conducted on single layer core structures to estimate center point displacement during and loading and unloading as shown in figure 2.

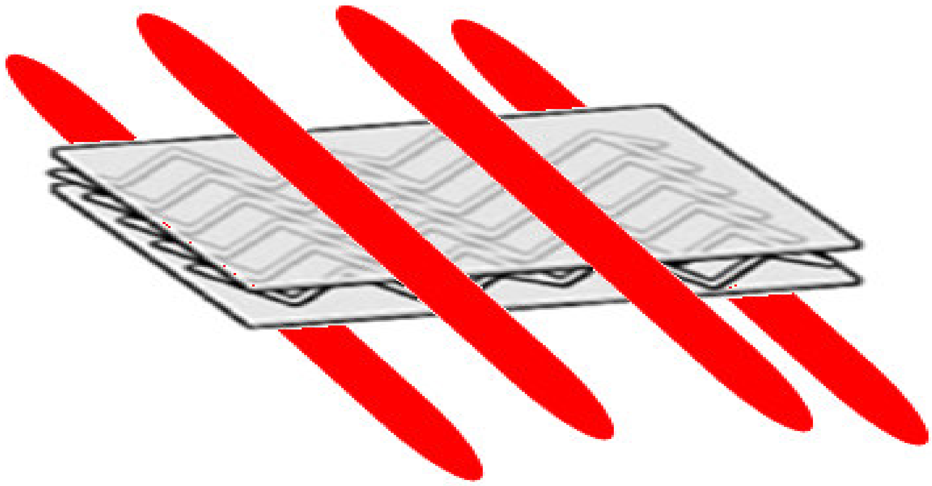

Figure 2: The 4-point bend test.

3. RESULTS AND DISCUSSION

In 60 NiTiNOL Shape Memory Alloy, TiC type carbide phases are visible in the microstructure as revealed from figure 3. Oxide phases can also be seen in microstructures of Ni-Ti alloy.

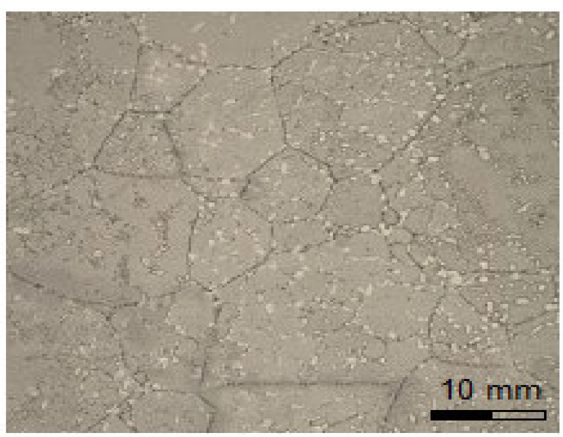

Figure 3: Optical microstructures of 60 NiTiNOL.

Figure 4 shows tensile loading- unloading curve of 60 NiTiNOL. No evidence of cracking or failure of the structure was observed. Following release of the load, the residual displacement was 1.69 mm in the cellular structure at room temperature. This value of recovery is 63.68 percent of the initial inelastic deformation after release of the load. This confirms shape memory behavior in the single layer core cellular structure.

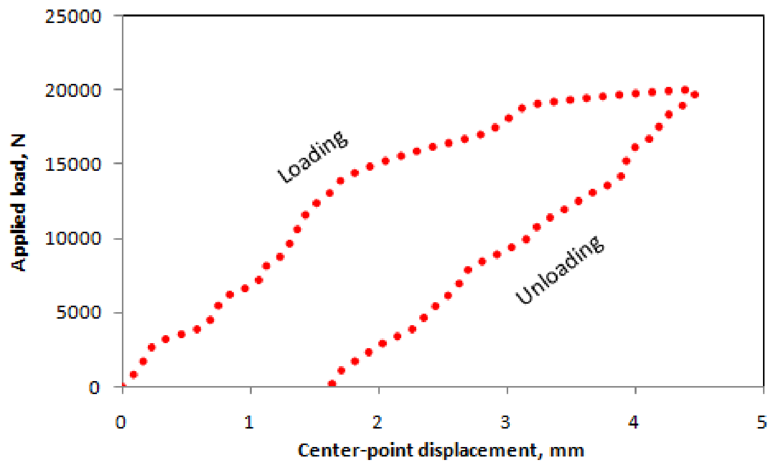

Figure 4: Loading and unloading curves.

4. CONCLUSIONS

The 60 NiTiNOL Shape Memory Alloy was cast in investment shell moulds. The shape recovery is 63.68 percent of the initial inelastic deformation after release of the load. This substantiates shape memory behavior in the single layer core cellular structure of 60 NiTiNOL.

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