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Selection of a Ni-Ti Alloy and Designed of a Heat Treatment to Optimize a PDA Corrective Devices

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Abstract – Three Ni-Ti alloys have been characterize to optimize a stem dispositive used to correct a congenital heart diseases called Patent Ductus Arteriosus (PDA). Chemical analysis (XRF), metallographic analysis (SEM) and tension test were carried out to select the most suitable alloy. Additionally, a heat treatment was designed in order to achieve higher mechanical properties without losing an important memory property known as superelasticity. As a result, Young's module and percentage elongation were improved in an 18%, and in a 100% respectively. In other hand, plateaus strength was not significantly changed; indicating super-elasticity has been held on a adequate range.

The PDA represents 12% of total cases related to heart congenital diseases. At local level, statistics developed by the Cardioinfantil Hospital showed that around 9% of consultations within a mount are children with PDA, being the cardiopathy with more incidences that requires a corrective procedure.

Shape memory alloys are characterized for being able of recovering their original shape after the application of a drastic deformation process. The nickel-titanium (Ni-Ti) alloys, commercially known as Nitinol, are the most used shape memory alloys due to its high mechanical strength, and in the specific case of medicine, because its biocompatibility.

During the last years the Biomedical Engineering group of Universidad de Los Andes has developed a PDA corrective device manufacture with Nitinol springs. Unfortunately, it has not reached the desired rigidity which is the goal of the present research.

The methodology followed to develop this investigation was divided into two stages: first one related to characterization and selection of the Ni-Ti alloys with best mechanical properties for the device; and the second one was about the design of a heat treatment to improve even more the rigidity of the selected alloy.

The stage of characterization and selection of the Ni-Ti alloy was based in chemical composition analysis trough X rays fluorescence (XRF), metallographic analysis trough scanning electron microscopy (SEM), and tension test based on the ASTM standard F2516-07e2. As a result, N type alloy was selected. This alloy was characterized for a chemical composition of 55.31%wt of Ni and 44.69%wt of Ti, a Young's Modulus of 25GPa, plateaus strength of 330MPa, percentage elongation of 35%. Due to the greater amount of nickel, the metastable phase Ti_3Ni_4 was largely precipitated which warranties the superelastic behavior of the material (Fig.1).

Second stage was developed trough two approximation, first one to define specific ranges of the variables of the ageing heat treatment and the second one to define concrete specific values to ensure maximum rigidity. All treatments were carried out in a convectional resistance furnace. The different heat treatments were compared trough scanning electron microcopy analysis and tension tests. As a result, a temperature of 600°C and a time of 1350 seconds were selected as the optimization parameters for the aging treatment. After the process Young's Modulus was increased in 20% and plateaus strength was decreased in 8% indicating an improvement of rigidity but without compromising superelastic properties. From the microstructure point of view, it was found concentration of metastable phase Ti_3Ni_4 was significantly reduced after the heat treatment (Fig.2). These facts allowed concluding there is an inverse relationship in nickel rich Ni-Ti shape memory alloys between Young's modulus and precipitation of metastable fase Ti_3Ni_4. Then an optimal balance of that phase has to be reached to ensure maximum rigidity keeping superelastic behavior of the material.

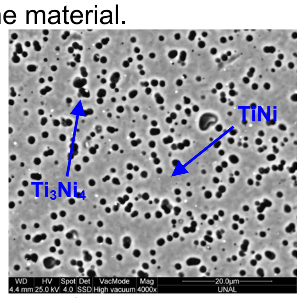

Figure 1: SEM image of the characteristic microestruture of type N alloy.

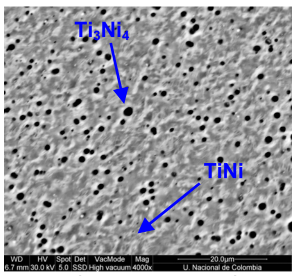

Figure 2: SEM Image of type N alloy after heat treatment was carried out.