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Improving surface finish and wear resistance of additive manufactured nickel-titanium by ultrasonic nano-crystal surface modification

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Abstract

Nickel-titanium (NiTi) alloys have great potential to be used as biomedical implants or devices due to their unique functional properties (i.e., shape memory properties and superelastic behavior). The machining difficulty associated with NiTi alloys is impeding their wide application. Additive manufacturing (AM), however, provides an alternative method to manufacture NiTi structures. One major concern associated with NiTi devices fabricated in this route is the potential for release of toxic Ni ions due to the poor surface finish as well as high surface porosity. In this study, NiTi samples were produced using selective laser melting, the most common AM techniques. Then, an innovative surface processing technique, ultrasonic nano-crystal surface modification (UNSM), was used to mitigate the potential for the Ni ions release. By simultaneous ultrasonic striking and burnishing, UNSM can significantly improve surface finish and decrease surface porosity. In addition, UNSM induces a plastic strain which in turn hardens the surface layer. The synergistic effect of better surface finish, lower subsurface porosity, and a hardened surface layer resulted in higher wear and corrosion resistance. It is therefore expected that UNSM can be potentially used to treat biomedical devices.

Keywords: Additive manufacturing; NiTi; Ultrasonic nanocrystal surface modification; Surface finish; Porosity; Wear Resistance; Corrosion resistance.

1. Introduction

In recent years, nickel-titanium (NiTi) alloys, also known as nitinol, have attracted the attention of many researchers due to their two distinct features, i.e., superelasticity (SE) behavior and shape memory (SM) effect (Bansiddhi et al., 2008). Both SE and SM behaviors are due to a solid-solid phase transformation between austenite (higher temperature and stronger phase) and martensite (lower temperatures and softer phase). SE is the ability of a material to return to its original shape after a large deformation (Up to 8% for NiTi) without any temperature changes. On the other hand, SM NiTi requires subsequent heating (more than the austenitic finish temperature) after applied deformation in order to return the material to its memorized shape. SE NiTi mostly is commonly used for biomedical