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Effect of TiNi in dry sliding wear of laser melt deposited Ti_2Ni/TiNi alloys

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ABSTRACT

Wear resistant TiNi-based intermetallic alloys reinforced by isolated irregular Ti_2Ni particles were fabricated by a laser melt deposition process. The alloy Ti50Ni50 included Ti_2Ni and B2 TiNi, while the alloy Ti53.8Ni46.2 consisted of Ti_2Ni and martensitic TiNi. Wear resistance of the alloys was evaluated on a block-on-wheel dry sliding wear tester at room temperature under loads of 98 N, 147 N and 196 N. The Ti_2Ni/TiNi intermetallic alloys exhibited high wear resistance. The intermetallic alloy Ti50Ni50 showed less plastic deformation than Ti53.8Ni46.2 owing to the pseudoelasticity of Ti50Ni50, while wear mass loss of Ti53.8Ni46.2 was slightly higher than Ti50Ni50 because Ti53.8Ni46.2 had more Ti_2Ni reinforcing phase that enhanced the Ti_2Ni/TiNi intermetallic alloys wear resistance at high contact stress.

1. Introduction

TiNi is well-known for its shape memory effect, pseudoelasticity, toughness, ductility and biocompatibility. The shape memory TiNi alloys are widely used in mechanical, aerospace, medical and biological industries. Under dry sliding wear test conditions, the TiNi intermetallic alloys with body-centered cubic (BCC) B2 type crystal structure have exhibited outstanding wear resistance due to their excellent pseudoelasticity [1–9]. Li [10] studied the wear resistance of heat-treated and the as-received TiNi under different loads. The heat-treated TiNi alloy with better pseudoelasticity, showed higher wear resistance than as-received alloy under low contact load (approximately 89 N), no significant difference existed under high contact load because heat from friction pulled TiNi alloys away from the temperature range of pseudoelasticity effect. Owing to the load-bearing capability and low hardness, the wear resistance of TiNi alloys under high contact load needs to be further enhanced [11–14].

Good toughness and ductility make TiNi-based a good candidate as a wear resistant and ductile matrix. The Ti_2Ni intermetallic compound with the face-centered-cubic crystal structure can act as a reinforcing phase in a wear resistant composite material due to its high hardness (HV700) and strong atomic bonds [15,16].

In the present work, two TiNi-based intermetallic alloys, Ti50Ni50 and Ti53.8Ni46.2, both reinforced by Ti_2Ni, were designed and fabricated by a laser melt deposition process. Wear resistance of the alloys was evaluated under room-temperature dry sliding wear test conditions. The wear behavior of B2 and martensitic TiNi during dry sliding in a wear test is discussed.

2. Experimental Procedures

Commercial purity Ti–Ni elemental powder blends in nominal chemical composition (at.%) of Ti50Ni50 (A) and Ti53.8Ni46.2

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(B) were selected as the raw material. Short cylinder-shape ingots of the Ti_2Ni/TiNi alloy with an average diameter of approximately 18 mm and height of 12 mm to 14 mm were fabricated by a laser melt deposition process in a newly patented laser melting furnace [17], as shown in Fig. 1. The alloy powder in an argon shielded water-cooled copper-mold was melted by a high-power laser beam from a 6 kW continuous-wave CO_2 laser. The laser deposition parameters are as follows: laser beam power 3 kW, laser beam diameter 14 mm, laser beam irradiation time of 30–50 s.

Metallographic sections were prepared using mechanical polishing procedures and were etched in $HF–HNO_3–H_2O$ water solution in a volume ratio of 1:6:7 for approximately 3 s. The worn surfaces of the intermetallic alloys were cleaned by 4% HNO_3 in order to remove the transferred steel material from the rotating mating wheel. Microstructure was characterized by Olympus BX51M optical microscope (OM) and KYKY-2800B scanning electron microscope (SEM). X-ray diffraction (XRD) was conducted using the Rigaku D/max 2200 pc automatic X-ray diffracto-meter with Cu target Kα radiation to identify the constitution phase. Phase chemical compositions were analyzed by energy dispersive spectroscopy (EDS) using Noran Ventage DSI spectrometer. Microhardness was measured using a HXZ-1000 semi-automatic Vickers microhardness tester with a testing load of 4.9 N and a dwelling time of 10 s.

Room-temperature dry sliding wear tests were carried out on an MM-200 block-on-wheel dry sliding wear tester as illustrated in Fig. 2, under the test loads of 98 N, 147 N and 196 N, respectively. All surfaces of the dry sliding testing samples (10 mm × 10 mm × 10 mm in size) were carefully hand-polished with 1000-grit silicon carbide paper. The coupling wheel is made of hardened 0.45%C steel (HV573). The dimension of the coupling wheel was 45 mm dia. × 10 mm wide. The test parameters are: sliding speed 0.92 m/s, wear test time 60 min and total wear sliding distance 3320 m. Each test was repeated three times. Wear mass loss was measured

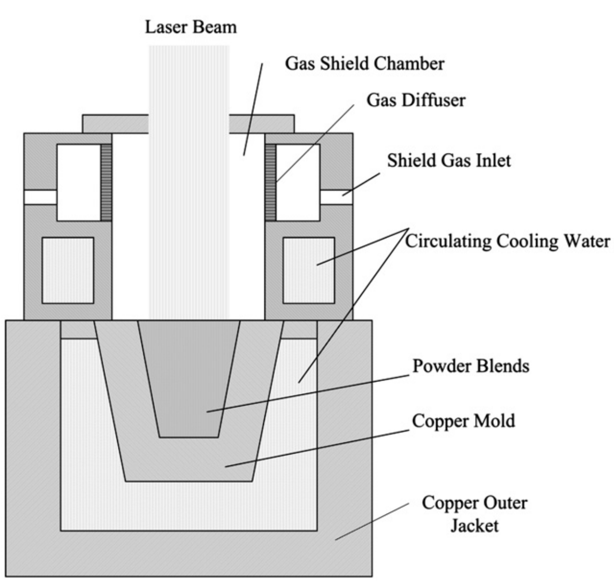

Fig. 1 – Illustration of the water-cooled copper-mold laser melting furnace.

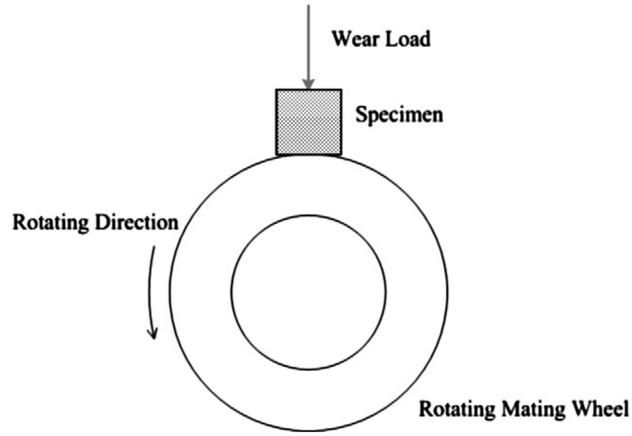

Fig. 2 – Illustration of the MM-200 block-on-wheel dry sliding wear tester.

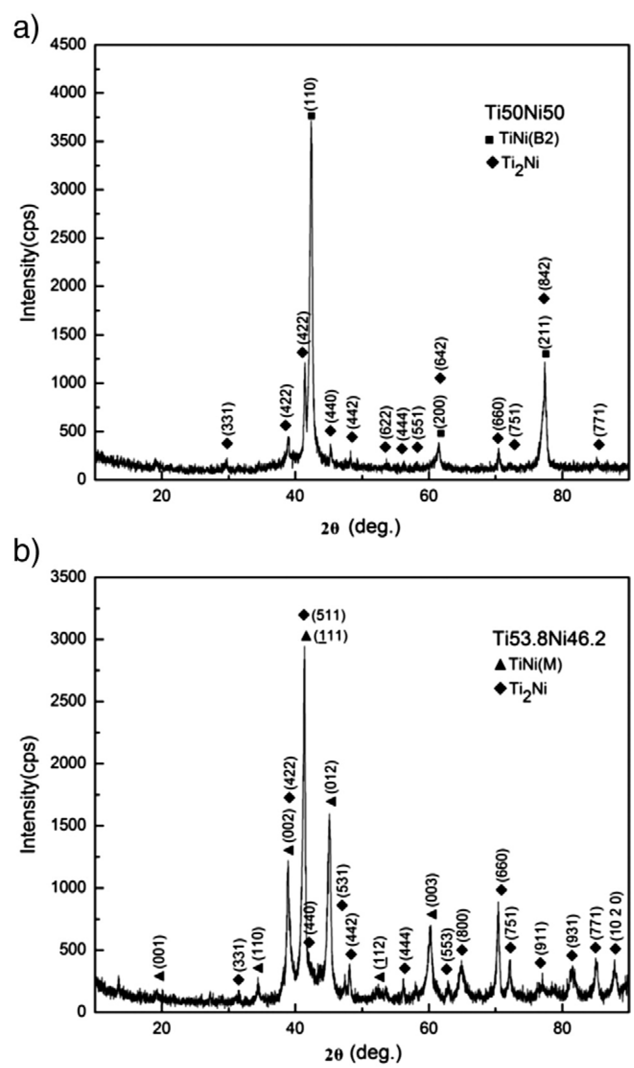

Fig. 3 – XRD pattern of the laser melting deposited Ti_2Ni/TiNi intermetallic alloys, (a) Ti50Ni50 and (b) Ti53.8Ni46.2.