Hybrid Microstructure and Mechanical Properties of HRS Processed SUS316L and Titanium Materials

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Abstract

SUS316L stainless steel, commercial pure Titanium and Ti-6Al-4V alloy powders applied by Mechanical Milling (MM) process are sintered by Hot Roll Sintering (HRS) process. Microstructure and mechanical properties of those HRS materials is investigated. The microstructures of materials produced by HRS process consist of fine grains and work-hardened structure, that is, the hybrid microstructure. Tensile test of the HRS material demonstrated the good mechanical propertie s. These results show that the HRS process is very effective to the improvement of mechanical properties in the SUS316L stainless steel, commercial pure Titanium and Ti-6Al-4V alloy.

Keywords : hybrid microstructure, nano grain structure, hot roll sintering, mechanical milling

1. Introduction

Grain refinement is very effective for improving the mechanical properties as well as workability of materials. Recently the grain refinement by the severe plastic deformation process in powder metallurgy (PM) field has received much attention[1,2)]. The PM process is one of new processes combining mechanical milling (MM) or alloying (MA), heat treatment and sintering processes. The milling treatment of powder at near room temperature gives a huge deformation and leads to a nano grain structure very easily. In the present study, sintering by means of hot rolling, i.e., Hot Roll Sintering (HRS), has proposed as a novel sintering method for the MM powders[3)]. In this method, a high density sintered compact can be made in short period. Therefore, combination of PM and HRS processes enables one to produce a compact in which the microstructure has kept finer even after sintering at elevated temperatures. The HRS process is applied to an SUS316L, pure Titanium and a Ti-6Al-4V alloy powders. In the present study, the HRS process was applied to the SUS316L, pure Titanium and Ti-6Al-4V powders. The objective of the present study is to clarify the relationship between the microstructure and mechanical properties of the HRS materials.

2. Experimental Procedure

The MM treatment of an SUS316L powder (C: 0.018, Si: 0.90, Mn: 1.07, P: 0.032, S: 0.017, Ni: 12.44, Cr: 17.31, Mo: 2.11, Fe: bal. (mass%)) with average grain size of 100 μm was performed by Simoloyer CM01 horizontal ball mill with an SUS304 stainless steel vial and balls in the Ar atmosphere. The milling intensity adopted a ball to powder weight ratio of 10:1 for 180 ks. On the other hand, in case of pure Titanium powder and a Ti-6Al-4V powder (Fe: 0.183, O: 0.198, C: 0.010, N: 0.010, H: 0.008, Al: 6.55, V: 4.26, Ti: bal. (mass%)), the particle size of less than 150 μm was used. A Fritsch P-5 planetary ball mill with a tungsten carbide vial and bearing steel balls were used for MM treatment in the Ar atmosphere. The milling intensity was a ball to powder weight ratio of 1.8:1 for 180 ks. The MM powders were provided for the HRS process[3)]. The mild steel or the pure titanium pipe was used for the MM powder, and they were sealed with the vacuum. Hot roll process was repeated for 5 times to produce a sheet material at 1173 K or 1273 K, and the final reduction in thickness was 90 %. Subsequently, the mild steel or the titanium of the pipe was removed from the HRS material. The HRS material was characterized by means of the optical microscope (OM), SEM and TEM/EDS. The tensile test was carried out by Shimadzu AGS-10kND.

3. Results and Discussion

Figure 1 indicates the cross section of SUS316L produced by HRS process. This microstructure consists of two regions, i.e., bright and dark contrast regions. Bright contrast region in the vicinity of the MM powder surface has nano grain structure. Dark contrast region has work-hardened structure with the meso grain size.

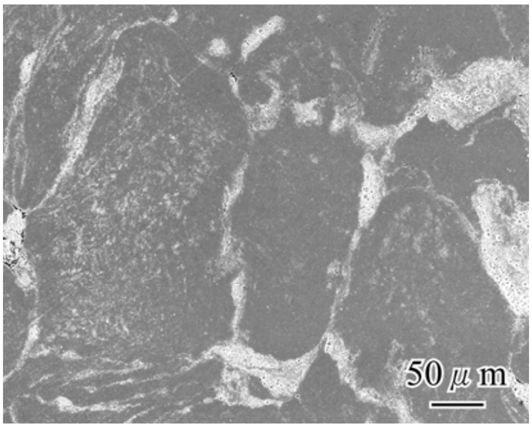

Fig. 1. OM micrograph of SUS316L HRS material.

Figure 2 illustrates the formation of hybrid microstructure as shown in Fig. 1, produced by HRS process. Such microstructure formation is attributed to the difference of deformation intensity in the shell and core region in the MM powder. The ratio of shell / core region of the hybrid microstructure can be controlled by the intensity of deformation and the heat treatment after HRS process.

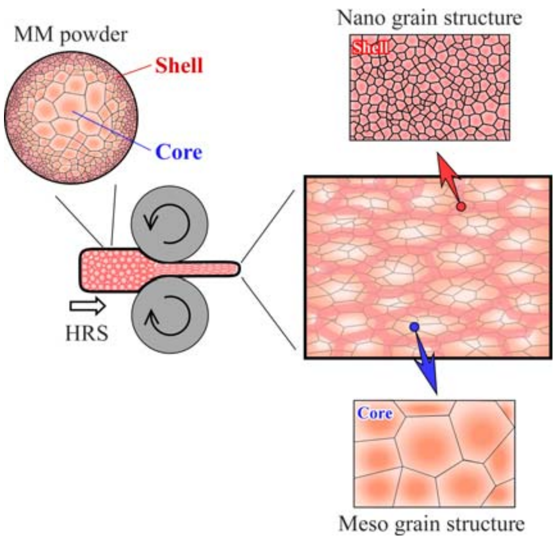

Fig. 2. Schematic illustration of hybrid microstructure produced by HRS process.

Figure 3 demonstrates a tensile test result of (a) SUS316L and (b) Titanium materials produced by HRS. These graphs show relationship of the ultimate tensile stress (UTS) and elongation. HRS material has not only high tensile strength but also good elongation compared with conventional materials. These good mechanical properties are decided by the hybrid microstructure with the two regions of nano grain and work-hardened structure. The detailed observation of the hybrid microstructure reveals the following. The UTS increases as the ratio of shell area with nano grain structure increases or the grain size in core area decreases. On the other hand, the elongation increases with increasing grain size in core area.

The material with good strength and good ductility can be expected to be produced by controlling a hybrid microstructure.

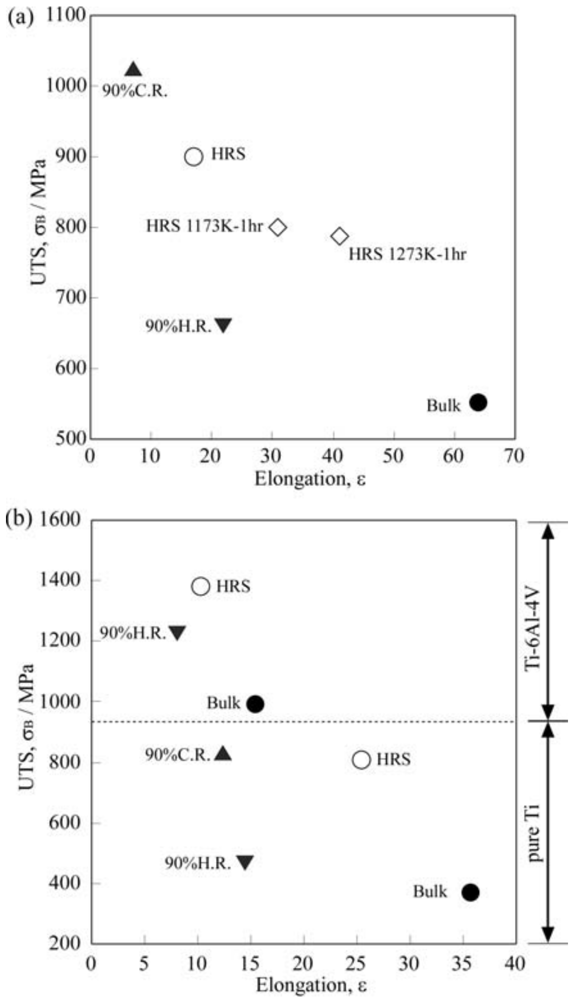

Fig. 3. Relationship between UTS and elongation of HRS material with (a) SUS316L and (b) Titanium materials.

4. References

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