Extrusion of CP Grade Titanium Powders Eliminating the need for Hot Pre-compaction via Hot Isostatic Pressing

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Abstract

Chemically pure, hydride/dehydride titanium powders were cold pre-compacted then extruded at 850°C and ~450MPa under argon. The extrusions were 100% dense with a narrow band of surface porosity and equiaxed microstructure of similar magnitude to the starting material. The tensile properties of the bars were better than conventionally extruded CP titanium bar product. Outcomes from this study have assisted in the identification of a number of key characteristics important to the extrusion of titanium from pre-compacted CP titanium powders, allowing the elimination of canning and hot isostatic pressing (HIPping) of billets prior to extrusion as per conventional PM processes.

Keywords : CP titanium, hydride/dehydride powders, extrusion, lubrication

1. Introduction

The hot extrusion of cold compacted powders has advantages over extrusion of cast billet by offering the potential of fine grain size in a single pass and the possibility of using lower density starting billets as extrusion feedstock [1]. However, challenges exist with the selection of lubricants [2], unless canning or HIPping is used to densify the titanium powder billets. This extended abstract describes the quality of extruded bar produced from cold compacted billets of hydride/dehydride (H/HD) titanium powders with no canning.

2. Experimental and Results

Titanium rod was extruded using a laboratory direct extrusion apparatus from green billets of CP grade 3 (CP3) H/HD titanium powders at 850°C under an argon atmosphere. Green billets were fabricated from TP-325-1 and TP-100-1 powders of angular morphology. TP-325-1 was a -45μm (-325#) powder with a D_{50} of 23μm and TP-100-1 a -140μm (-100#) powder with a D_{50} of 27μm. Samples of 80g of powder were uniaxially pressed in air to approximately 54% and 57% (TP-325-1 and TP-100-1) of theoretical density and subsequently cold isostatically pressed (CIPped) to approximately 72% and 73% (TP-325-1 and TP-100-1) of theoretical density to form green billets. The green billets were then upset at 850°C to approximately 100% theoretical density and extruded. Small sized tensile specimens were made from the extruded rods manufactured from TP-325-1 powder according to ASTM Standard A370 [3] and tested to failure.

Extrusion did not occur when BN was the sole lubricating agent but did so when used in combination with graphite and MoS_2 bearing grease. The application of these lubricants was sufficient to ensure the successful extrusion of 9 mm diameter Ti rod at an extrusion stress of 450MPa and an extrusion ratio (initial area/final area) of 7.0. However, further refinements to the lubrication system are considered necessary.

The extrudates produced from both powders had 100% theoretical density and oxygen and nitrogen levels close to the starting powders

Porosity was fairly constant at about 0.1% through the centre of the extrudates in the extrusion direction. Slightly higher levels of porosity were observed close to the external surface of the extrudates, but the overall porosity level was acceptably low in all directions. The edge porosity was normally below 1% and never exceeded 2%.

Fig. 1 shows equiaxed grains in TP-100-1 and TP-325-1 extrudates after extrusion and 825°C anneal for 30 minutes. The grain size was similar to the starting powders, Fig. 1. The porous layer at the surface of the TP-325-1 extrudates was much finer than that in TP-100-1 extrudates due to the finer starting powder, but was of similar depth, Fig. 1.

Some trace lubrication remained on the surface of the extrudates, which required removal during subsequent processing. There did not appear to be any major penetration into or contamination of the bulk material of the extrudate from the lubricates, however, there were some minor peak traces due to boron contamination confined to within the porous band at the surface.

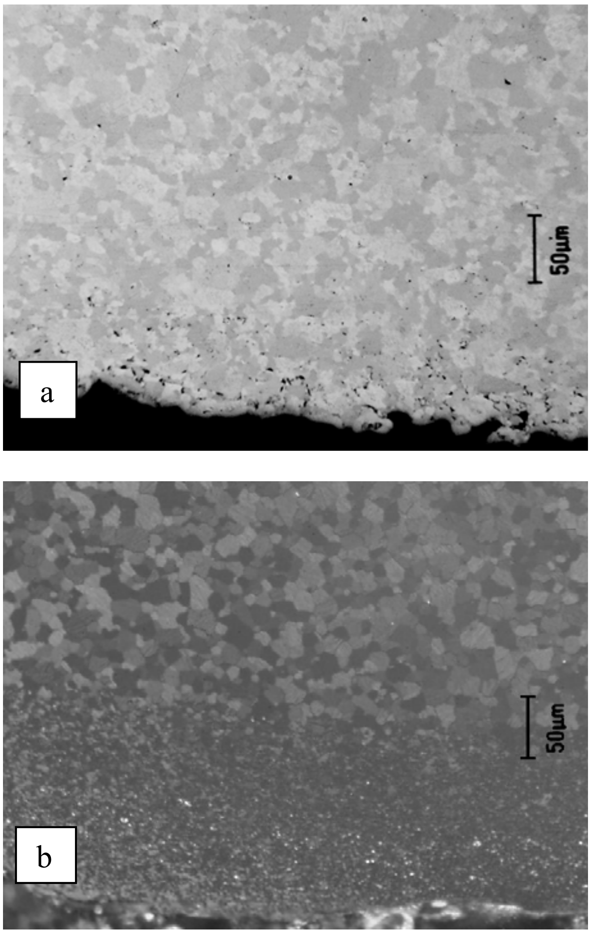

Fig. 1. Reflected light micrographs of (a) TP-100-1 and (b) TP-325-1 extrudates in the surface region in the plane normal to the extrusion direction.

There was also subgrain structure within the extrudates that consisted of a needle phase within grains and an inter-granular phase, Fig. 2. Both phases contained hydrogen probably due to the presence of 0.03wt% hydrogen levels present in the source powders.

The extrudates had an elongation response equivalent to CP1 and CP2 grade titanium extrusions with much higher strength properties, Table 1, possibly due to the fine grain microstructure that was retained from the TP-325-1 powder and the titanium hydride particles in the subgrain structure. The TP-325-1 extrudate properties were better than CP3 properties that may be expected from TP-325-1 powder.

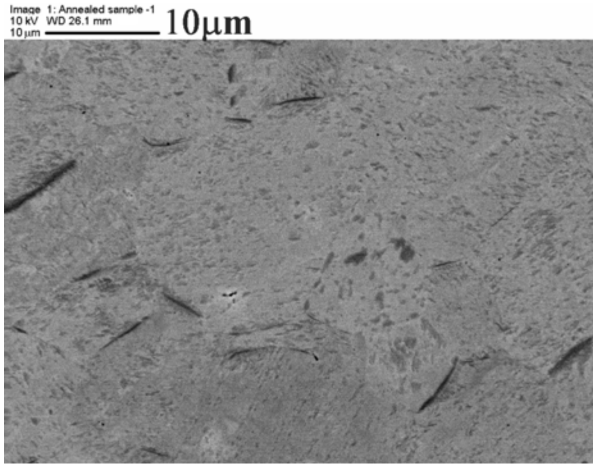

Fig. 2. Backscatter electron micrograph of TP-325-1 extrudate after annealing at 825^{o}C for 30 minutes showing low atomic number element contrast from needles and intergranular particles.

Table 1. TP-325-1 extrudate tensile properties compared to standard titanium extrusions [4].

	TP-325-1 Extrudate*	CP1	CP2	CP3
UTS	745±11	276	345	448
Yield	483±30	207	276	379
% Elongation	23±4	25	20	18

* Three samples only.

3. Summary

Extruded rod with an equiaxed grain structure and minimal process contamination was produced by extrusion of cold compacted powder billets without canning. The extrudates were fully dense with a ~98% dense skin at the surfaces. The tensile properties of the extrudates were substantially better than conventionally extruded titanium of similar chemistry.

4. References

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