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Opinion

Hot Deformation of Quench Hardened Titanium Alloys As A Modern Production Method of High Strength Structural Parts?

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Opinion

Titanium alloys belong to advanced metallic materials used in hi-tech industrial branches, like aeronautics. They are considered as a hard deformable materials - usually hot worked at the temperature of 0.65-0.75 Tmelt. Quite narrow temperature range of hot working makes it difficult to form near net shape parts which do not require additional heat treatment. Industrial manufacturing processes of two-phase α + β titanium alloys – mostly used for structural elements – include usually vacuum casting, initial plastic working of ingots at the temperature range of β phase stability, recrystallization annealing at the same temperature range and again plastic working, but at the temperature range of α + β phase transformation [1].

Hot formed parts made of two-phase titanium alloys are heat treated dependently on demanded microstructure (lamellar, globular, bi-modal). High strength of structural parts is achieved by quench hardening/solutioning and following tempering/ageing. Quench hardening operation is based on martensitic transformation β→α'(α") which occurs during fast, continuous cooling (e.g. water quenching) from the temperature range of stable β phase. Final mechanical properties of heat treated parts result from effects of martensite decomposition (tempering) or metastable phase formation (ageing) [2].

New concept of titanium alloys processing is to apply hardening (water quenching) at the first stage. During hardening the stock (ingot) is heated up to the temperature of β phase and subsequently fast cooled. As a result, the alloy microstructure is fully martensitic and it is independent from initial one. The question is whether conventional tempering is necessary for obtaining sufficiently high mechanical properties? It can be assumed that martensite decomposition should occur solely during the heating up and hot deformation process. Based on previous investigation [3] it was found after hot deformation (in the conditions of superplasticity occurring) that hardened Ti-6Al-4V alloy is less sensitive to α phase grain growth deformation – more fine-grained microstructure enhances superplasticity and increase room temperature strength of material.

Recent results on Ti-6Al-4V alloy [4] - hardened (water quenched) and compressed at 600°C – indicate that martensite decomposition during hot deformation process seems to be related with fragmentation and spheroidization of α laths. It leads to high grain refinement - after deformation with cross-head velocity of 1 mm/min grain size of α phase was smaller than 200 nm Figure 1 - the range of ultrafine-grained (UFG) materials. Hardness of such material is about 440HV – significantly higher than obtained after tempering at 600°C.

It should be noticed that mentioned phenomena were observed in flow localization zone of compressed specimens –confirmed also in similar investigation [5]. The main disadvantage of presented approach seems to be inhomogeneity of final microstructure of manufactured parts – especially in case of large size ones. It needs further investigations on determining acceptable range of deformation temperature and strain – in order to obtain similar UFG microstructure, and therefore mechanical properties, in whole volume of structural part.

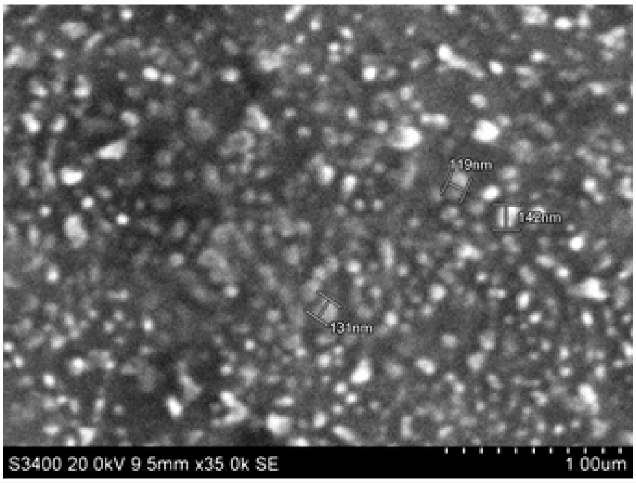

Figure 1: Microstructure (SEM) of water quenched Ti-6Al-4V alloy subsequently hot deformed at the temperature of 600°C with crosshead velocity of 1 mm/min.

Finally, the crucial for hot working process is thermomechanical characteristic of processed material. Hardened Ti-6Al-4V alloy, with martensitic microstructure, is harder deformable at the temperature of 600°C (yield stress (YS) about 700MPa [4]) comparing with lamellar microstructure (YS 500MPa [6]). However this difference should not be a big problem for devices and tools currently used in hot working process.

Conclusion

Hot deformation of quench hardened titanium could be effective method for production of high strength structural parts, without necessity of further heat treatment.

Advantages

a) only two-stage thermomechanical processing;

b) independence on initial alloy microstructure (fast quenching from β phase range);

c) final fine-grained microstructure resulting in high mechanical properties.

Disadvantages

a) microstructure heterogeneity caused by deformation inhomogeneity during hot deformation – it requires to determine optimal range of deformation temperature and strain.

Acknowledgement

None.

Conflict of Interest

No conflict of interest.

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