In situ forging experiments at HARWI II with advanced TiAl alloys

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Thermo-mechanical treatments as hot rolling or forging are well established metallurgical processes to improve mechanical properties and to homogenize the microstructure as well as for near net-shape production. Several microstructure parameters e.g. phase fractions, grain size or crystallographic texture, change during hot forming. However, conventional analysis methods can only infer the changing mechanisms from post-process metallographic studies. We used a conventional deformation dilatometer (DIL 805A/D) modified for working in the HZG synchrotron beamlines HARWI II and HEMS at DESY [1] for hot deformation experiments. This setup enables the continuous monitoring of the interaction and evolution of different microstructure parameters in situ, i.e. during processing, while simultaneously recording the process parameters (temperature, force and length change).

First in situ forging experiments were done with intermetallic γ-TiAl based alloys. These alloys exhibit excellent high-temperature strength combined with low weight, making them ideal candidates for replacing the twice as dense Ni base super-alloys currently used in the medium temperature range (~700 °C) of industrial and aviation gas turbines. In recent years, research activities are focused on TiAl alloys containing additional amounts of ductile bcc high-temperature β phase in order to improve their formability at elevated temperatures (e.g. for forging).

A series of forging experiments varying in process temperature and process speed (Fig. 1) was performed with an as-cast and HIPed Ti-43Al-4Nb-1Mo-0.1B (in at.%) alloy. Specimens with a diameter of 5 mm and a length of 10 mm were deformed at three different temperatures each with two strain rates up to a total reduction in length of about 45 % (Fig. 1a). Immediately after the deformation the specimens were quenched in order to study the deformed microstructure. During the experiments X-ray diffraction was performed in transmission geometry with a photon energy of 100 keV (λ = 0.124 Å) and a beam size of 1·1 mm^2. The diffraction rings were continuously recorded on a mar555 flat panel detector with a frame rate of 0.25 Hz.

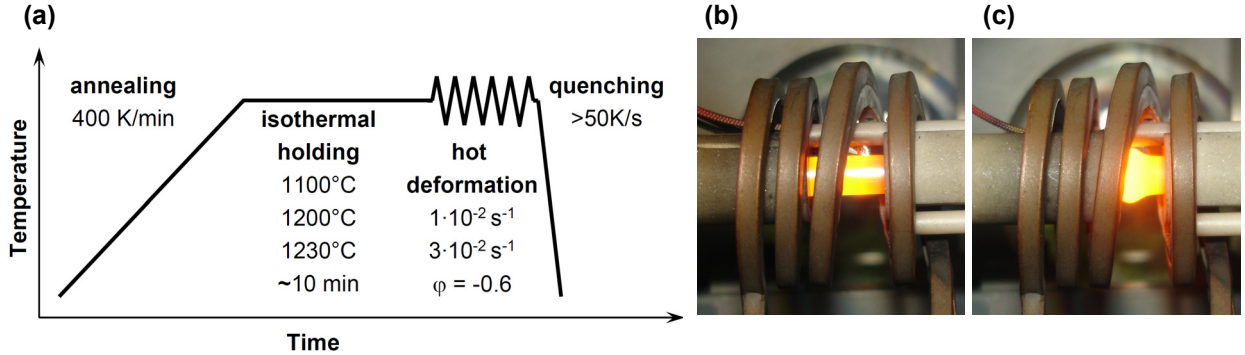

Figure 1: (a) Sketch of the forging experiments with processing parameters. Annealed specimen (b) before and (c) during deformation.

In order to study the interaction between different phases and the evolution of grain size and crystallographic texture during deformation the diffraction ring of a specific reflection was unrolled. The unrolled rings of consecutive images were combined to azimuth angle vs. time diagrams. Single reflection spots on the diffraction ring occur as ‘time-lines’ in the diagram. This

was done for several reflections of different phases. Figure 2 shows such a diagram for the 002 reflection of the hexagonal α phase during forging at 1230 °C with a strain rate of $1 \cdot 10^{-2}$ s^{-1}. Before deformation starts, sharp spots indicate a relatively coarse grained microstructure with almost perfect crystals. No intensity agglomeration can be observed at preferred azimuth angles, i.e. the crystals show an almost random orientation distribution. During elastic deformation the intensity distribution does not change significantly. As plastic flow starts, the spots become more and more diffuse indicating the increasing of dislocation density, crystal defects and tilting between crystallite blocks. During further deformation, starting from about 15 % deformation, almost symmetric intensity maxima are formed at about 20°-30° distance to the load direction. Together with the information obtained from other α reflections this can be attributed to the formation of a tilted basal fiber texture which is a typical deformation texture of the hexagonal α phase [2]. After about 30 % deformation, again weak sharp spots occur in between as well as on the diffuse intensity maxima indicating the onset of dynamic recrystallization, e.g. the nucleation and growing of new defect-free crystallites. This process weakens the pure deformation texture, however the texture does not vanish during further deformation. In conclusion, it is possible to separate the effect of deformation and recrystallization on the texture in the in situ experiment, which often is difficult in post mortem investigations.

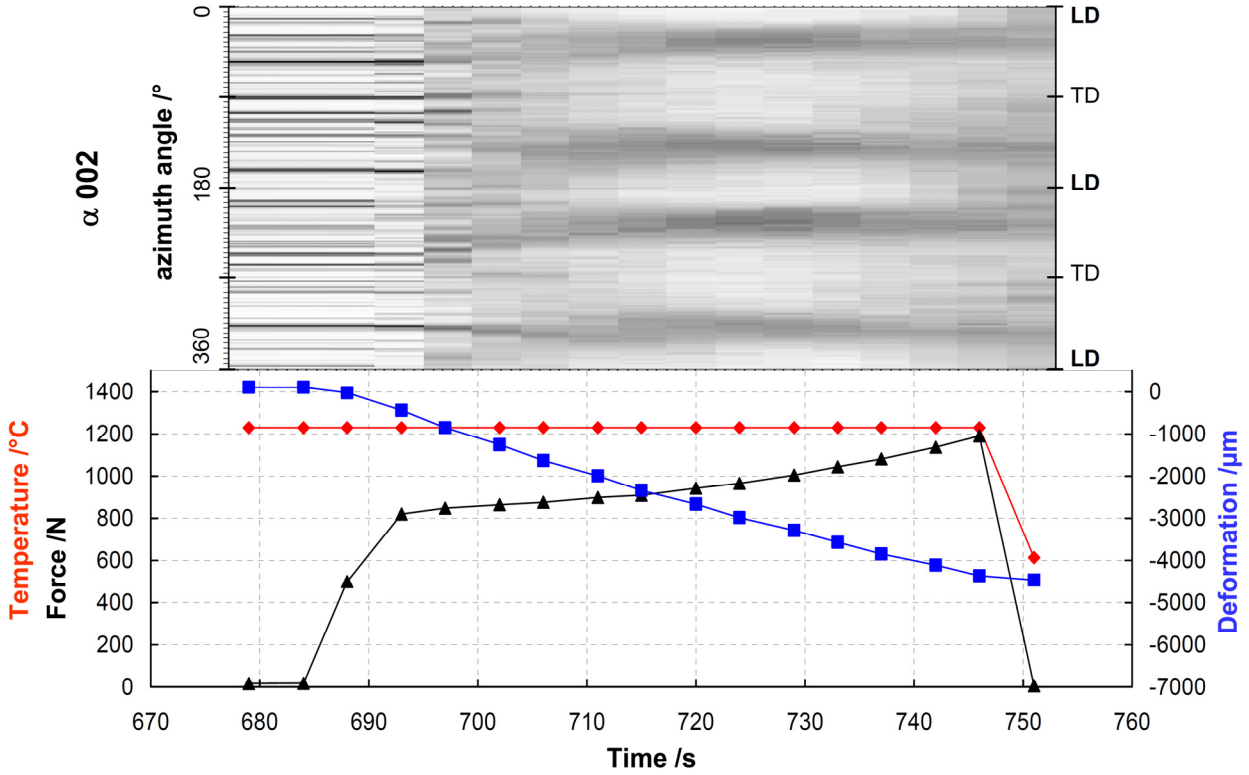

Figure 2: Azimuth angle vs. time diagram of the α 002 reflection during forging at 1230 °C with a strain rate of $1 \cdot 10^{-2}$ s^{-1}. The intensity is coded in grayscale. The process parameters are displayed below.

Depending on the process parameters qualitative differences in texture and microstructure formation can be observed. The forging experiments will be analyzed more in detail and the results will be published in an upcoming paper. Due to the obtained results, the process parameters can be optimized with regard to final alloy properties, such as grain size or texture.

References

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