Deformation behavior and microstructure evolution of steel during the entire thixoforging process for improving the process controlling

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ABSTRACT

Today, the metallurgical industry needs to produce complex parts with high mechanical properties, low cost and high production rates. An innovative forming process, the thixoforming, is very interesting since it is possible to make some parts in fewer forming steps and with a decreased forming force. The microstructural evolution and the material flow during each step of the process must be studied to well understand the mechanisms occurring in the parts and the influence on their final mechanical properties.
The objective of this work is to characterize the microstructure of a high speed tool steel grade (M2) at each step of the thixoforging process in order to better understand the influence of the process parameters and the mechanisms of deformation. As the microstructure of the material in the semi-solid state, especially the volume fraction of liquid, is very important, several 2D and 3D techniques (SEM-EDS analyses, CLSM, X-ray microtomography) have been used to characterize the microstructure, such as liquid fraction estimation, liquid phase distribution etc. The CLSM technique is used to observe the microstructure directly at high temperature, with the apparition of liquid and the solidification. It has been found that the liquid phase of M2 could be preserved even by a low cooling rate. Thus, the microstructure could be characterized on the quenched parts. By comparing the 2D SEM - EDS and 3D X-ray microtomography observations on quenched M2, the good agreement proves that both techniques are efficient in characterizing high-alloyed steels in the semi-solid state. Thixoforging experiments are finally performed in order to study the influence of the process parameters on the microstructure, final part geometry, material flow etc. After analyzing the microstructure of the thixoforged parts, some mechanisms of material flow are proposed. Moreover, by comparing the results between the thixoforging experiments and the hot forging simulations, it is found that the material flow is very different from that of hot forging process, which results from the material behavior. The latter is very sensitive to the process parameters; an accurate process control is necessary.

Keywords: steel, thixoforging, SEM-EDS, CSLM, X-ray microtomography, material flows.