Effect of Fe and O on the beta/(alpha+beta) transus temperature in Zr2.5Nb

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CANDU pressure tubes are fabricated from Zr-2.5Nb. This is a dual phase material with alpha (hcp) and beta (bcc) phases. The principal impurities are Fe and O. While oxygen is here considered an impurity, it is in fact controlled and added to the alloy as per reactor owner specifications.

The current phase diagram suggests the transformation temperature to be around 850°C. Pressure tubes are nominally extruded at 815°C. The influence of Fe or O on the relative volume fractions of the α and β-phases at extrusion temperature is considered equivalent to increasing or decreasing the extrusion temperature as follows:

- Iron, in usual concentrations, is fully soluble in the β-phase; solubility is very low in the α-phase. Fe is viewed as a beta-phase stabilizer, and is expected to increase the volume fraction of beta phase at a given extrusion temperature.
- Oxygen is highly soluble in the α-phase and is viewed as an α-phase stabilizer, increasing the volume fraction of alpha phase at the extrusion temperature.

While some work has been done to study phase transformations, the influence of O or Fe on phase-boundary shifts and the resulting volume fraction of alpha and beta phases during extrusion has not been satisfactorily studied. Knowledge of the modified phase boundaries will lead to better understanding how Fe and O affect the final microstructure of current production CANDU pressure tubes and perhaps provide guidance for future production tubes.

In researching hypothesised accident scenarios, ballooning tests have indicated that the temperature around the time of contact between a pressure tube and the surrounding calandria tube is 800-950°C. Because increased oxygen is expected to raise this temperature, and increased iron is expected to lower this temperature, the thermal properties of the material (i.e. heat capacity) at contact temperature are affected. Quantifying the effects of iron and oxygen on this transus temperature may help to more accurately model the pressure tube temperature and the heat content within the pressure tube at the time of contact in these accident scenarios.

This study used the CNBC C2 spectrometer to map out the beta/(alpha + beta) transus temperatures for eight Zr-2.5Nb material specimens having a range of oxygen, as well as a range in iron. The samples were be heated into the beta phase and cooled to track the onset of alpha phase in order to investigate the influence of these impurities on the beta/(alpha + beta) boundary.

Data analysis is ongoing; however, shown in the top figure is an example of the patterns for one sample at eight temperatures. The bottom figure shows a close up illustrating the onset of alpha phase in the cooling process.