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Editorial

Microstructure: Where Do We Stand?

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Editorial

The word 'microstructure' has created a tremendous interest in the science and engineering domain. In general context, microstructure means structure of a material as determined by using microscopic techniques including optical microscopy, electron microscopy and force microscopy. History indicates that understanding and application of microstructural concepts is important in the innovation, improvement and design of materials. At the same time, demand for increased microstructural details has lead to the development of the advanced microscopic techniques. Modern microscopes can reveal information from a region as small as an atom. Then there are aberration corrected microscopes to present such fine details. Now, it is well accepted that microstructural information is very important in the domain of research, development, quality control and reverse engineering. The analysis and understanding of microstructural features is very important in the development of materials.

Microstructures are created due to a variety of causes. Microstructures are generated due to a change in temperature or pressure (phase change occurring during phase transformations), deformation (forging, rolling, etc.) and processing (welding). Microstructures are also created due to a combination of processing (like casting and extrusion, deformation and heating, etc.). Also, microstructures could be created or modified locally, during manufacturing processes, like, machining and grinding.

Microstructures can be at different scales. They are hierarchical in nature. It can be of nanoscale, sub-microscale, microscale, mesoscale and macroscale. In reality, in a microstructure, a combination of length scales are observed. In general, they will be in the form of a microstructure statistics involving size, shape, volume fraction, distribution and alignment. The microstructure gives unusual macroscopic properties, like the shape memory effect. Microstructure affects ductility and fracture. They affect damage of the materials during service. They affect damage mechanisms and damage rates during creep, fatigue, oxidation, corrosion, etc. It is also highly relevant in the remaining life analysis of the industrial components and systems.

Microstructures at different length scales have drawn the attention of both academicians and industrialists. With the improved understanding of the materials microstructure, the materials engineer is able to use it as a predictive tool in the design, processing and applications. It is also true that materials with microstructures at different length scales have different properties. For example, materials at micrometer scale exhibit Hall-Petch relation whereas materials with nanometer length scale present inverse Hall-Petch relation.

Materials engineers always look to tailor the microstructures in the materials to get the maximum returns from them. A group of aluminium alloys classified as precipitation hardened aluminium alloys are extensively used in the airframe of the aircraft structures. They are strengthened by the formation of extremely small and randomly arranged clusters or particles. Microstructural engineering in steels had been for a long time. Great Cyril Stanley Smith brought the microstructural engineering involved in Damascus steel to the notice of the materials community. We can say that the modern materials engineer has a classic foundation in this marvellous piece of steel. Based on the knowledge, a prominent domain called as thermomechanical processing is being used to generate high strength materials from eutectoid, high carbon and microalloyed steels.

Scientists and engineers have manipulated microstructures to create new and better materials. Insight from one investigation has accelerated the microstructural science in another system. This growth will continue and it will be useful to improved utilization of the limited resources we do have and all of us will hope that this be accelerated and let it be a healthy growth for everyone involved.

Microstructure developing due to plastic deformation contains a large number of defects, like, dislocations and other point defects. These defects are influenced by stress, temperature and time. As a result, correlations are formulated which link the parameters describing microstructures to deformation processes. These correlations increase understanding of the microstructural evolution during processing and to obtain parameters dictating final properties. Use of image processing techniques is in the developing stage. Techniques, like pattern recognition are used to extract information at the faster scale. Use of finite element analysis grids with adaptive grid network enables simulation with relevant length scales. The literature indicates that the detailed structural information which could be computed using advanced computational methods. These calculations are done with the limit of viable computation. But the analysis dimensions are limited by a small number and this details need to be upgraded to a global scale to extend to real life problems.

Structure –properties are correlated by Hall-Petch relation (strength to grain size). This leads to two important conclusions, i.e. existence of microstructure and its implications for materials properties. Second one is development of scaling laws for characterizing materials response. An attempt to understand the materials behaviour demands that we understand a hierarchy of structures, starting with atomic scale factors like crystal structures/ lattice, increasing in scale to the level of the isolated defects that exist within the material affecting the bulk properties.

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Critical role for a materials engineer is to decide and control a number of microstructure scales affecting materials properties. As a challenge future lies in our ability to tailor the microstructure to yield desired properties.

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