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Dyanamic and Post –Dyanamic Recrystallization under Hot, Cold and Severe Plastic Deformation Conditions

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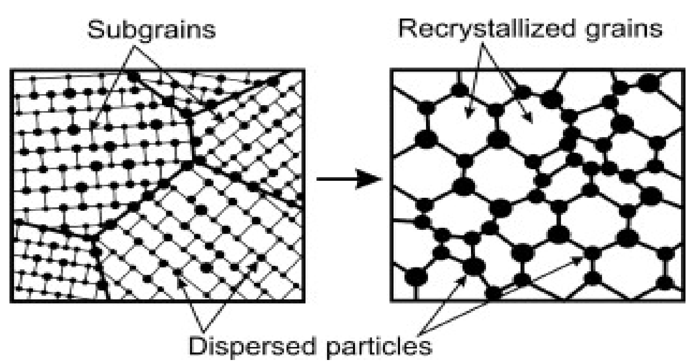
***Abstract:** The control of microstructure as well as of green refinement through thermo mechanical processing has been developed extensively since around 1970 and has been recognized as being both of technical importance as well as of scientific interest. The term Recrystallization is commonly used to describe the replacement of a deformation microstructure by new grains during annealing. The micro structural changes taking place under these conditions and the associated mechanical behavior are described. During the conventional discontinuous dynamic recrystallization that take place at elevated temperatures, the new grains evolve by nucleation and growth in materials with low to medium stacking fault energies. On the other hand, new ultrafine grains can be produced at low temperatures. During annealing, the microstructure is characterized by mixture of increasing amount of recrystallized grains and decreasing amount of strain hardened grains. Schematic representation of the discontinuous static recrystallization taking place during the annealing of strain, hardened materials.*

These result from the gradual transformation of the dislocation sub-boundaries produced at low strains into ultrafine grains with high angle boundaries at large strains. These process, termed in situ or continuous dynamic recrystallization, is still not perfectly understood. By contrast, multidirectional forging provides both types of data currently concerning the micro structural changes. Recent studies of the deformation material of the behavior of metals and alloys under SPD conditions carried out using MDF as well as other SPD methods are synthesized and the links between the micro structural and mechanical observations are examined carefully.

1. INTRODUCTION

The Control of Microstructure as well as grain refinement through thermo mechanical processing has been developed extensively since around 1970 and has been recognized as being both of technical importance as well as of scientific interest. The most developed method of grain refinement is based on plastic deformation at ambient temperatures followed by annealing at elevated temperatures. Dynamic Recrystallization is one of the processes by which a crystalline aggregate can lower its free energy during deformation. When recrystallization is synchronous with deformation, it is called Dynamic or Syntectonic Recrystallization. In the absence of concurrent deformation it is called static recrystallization or post-tectonic recrystallization. The nature of dynamic recrystallization depends on the type of material under consideration. Continuous dynamic recrystallization proceeds by the creation of sub grains from dislocation cells. The plastic deformation of metals below recrystallization temperature is known as cold working whereas the plastic deformation of metal above recrystallization temperature is known as hot working. In hot working process, the metal has a reduced yield strength no strain hardening occurs between the materials as it is plastically deformed. Shaping the metal at hot working temperature range requires much less force and power than in cold working. It also has greater ductility which allows for massive shape changes that would not be possible in cold worked parts. During hot deformation, the shape of the curve can be restricted or work hardening rates counter balance by dynamic recovery or by dynamic recrystallization. During Dynamic recovery, original grains get increasingly strained, but the sub-boundaries remain more or less equiaxed.

Over the past two decades, another method of new grain formation has been studied extensively; this takes place under conditions of severe plastic deformation. In this case, the ultrafine grain structures are developed at relatively low temperature.



Schematic Representation of the continuous static recrystallization.

2. FACTORS AFFECTING THE STRUCTURE FORMATION DURING SEVERE PLASTIC DEFORMATION

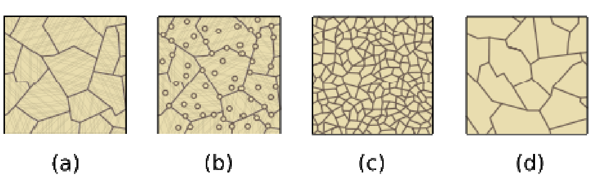
- Temperature- The hot deformation can cause grain refinement due to the occurrence of dynamic recrystallization. The lower is the temperature, the finer are the grains, but at the same time the higher is the degree of deformation required for the beginning of dynamic recrystallization.
- Strain Rate- An increase in the strain rate leads to the grain refinement. However, it is unreasonable to increase the strain rate in the case of SPD at room temperature. First, upon cold deformation, an increase in strain rate insignificantly decreases grain size. Second an increase in strain rate causes the formation of surface cracks and the premature failure of the sample.
- Chemical composition-During severe deformation at room temperature, the alloying facilitates grain refinement by slowing down the diffusion.
- Pressure-Structure and, correspondingly, strengthening depends on the pressure applied upon SPD. For example the low carbon 0.1% C-Mn-Si steel.

Example-Structure and Properties of Steel after SPD-It induces a martensitic transformation. Marten site contains 0.08% carbon.

3. ROLE OF GRAIN BOUNDARY IN NUCLEATION OF DISCONTINOUS DYNAMIC RECRYSTALLIZATION-

- It can be divided into two stages;
- Nucleation of new strain free grains

Grain growth during which the new grains replaced the deformed
Historically it was assumed that the nucleation rate of new recrystallized grains would be determined by the thermal fluctuations model successfully used for solidification and precipitation phenomenon.



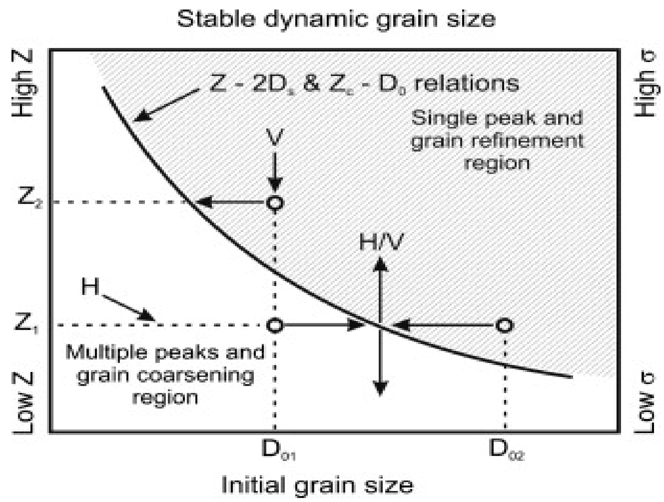
Recrystallization of a metallic material (a→b) and crystal grains growth (b→c→d).

It is assumed that as a result of the natural movement of atoms small nuclei would spontaneously arise in the matrix. The formation of these nuclei would be associated with an energy requirement due to the formation of a new interface at and energy liberation due to the formation of a new volume of load energy material.

4. DISCONTINUOUS DYNAMIC RECRYSTALLIZATION MODELS-

A simple me so scale model was developed and the material is described on a grain scale as a set of N spherical grains. Each grain is characterized by its diameter and dislocation density. The model includes

- A grain boundary migration equation driving the evolution of grain size via the mobility of grain boundaries.
- A dislocation density evolution equation, involving strain hardening and dynamic recovery.



Microstructure Mechanism map for distinguishing between two types of dDRX

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