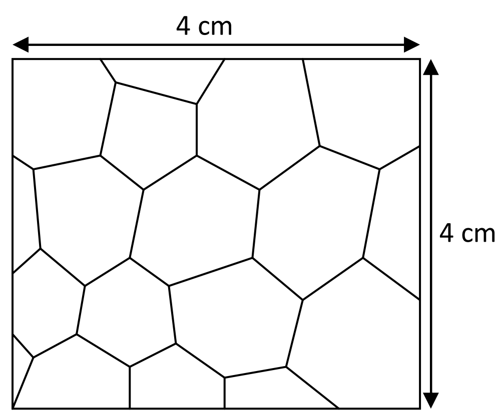
Lecture 27-28:

Metal working: deformation processing: Cold working & annealing: recovery, re-crystallization & grain growth, phenomenological & mechanistic approaches

Questions:

1. List a few advantages & limitation of hot working.
2. List a few advantages and limitations of cold working.
3. Estimate energy required to extrude 250mm diameter billet of aluminium to 25mm diameter rod. Given flow stress of aluminium = 10MPa and therefore find out the amount of force needed. Process efficency = 70%. Neglet work hardening.
4. If the maximum strain per pass in a wire drwing operation is 0.65 how many drawing passes will be rquired to draw wire of 0.25mm dia from 5mm wire rod?
5. While designing rolling process discuss whether large reduction in a single pass is prefrerable to smaller reductions in successive passes?
6. The following figure gives a typical microstructure of a pure metal. Magnification is 100X. Find out its grain size in terms of ASTM number (N) which is given by: $n = 2^{N-1}$. Where n represents number of grains



7. Count the number of grains (F), number of edges (E) and number of points (P) in the microstructure given above. State the type of relationship these must follow.
8. Describe how by cold work & annealing the following microstuctures can be developed in a single phase alloy (a) fine grain structure (b) coarse grain structure
9. Suggest at least two methods to know if steel sheet has preferred orientation.

Answers:

1. Advatages: Hotworking is done above recrystallisation temperature where flow stress is very low therefore it is possible to give large deformation with minimum effort (energy rquired is less). No futher heat treatment is required. Product is in annealed / normalised state. Limitation: Metal tends to oxidise. Scaling leads to loss of material. Tool life is shortened because of abrasive scale, high temperature and lack of lubrication. Poor surface finish & difficulty in precise guage control. It is quite common to pickle hot rolled sheets before cold rolling.

2. Advantages: Good surface finish & precise guage control. Gives higher strength. Limitation: needs intermediate annealing because of work hardening, deformation / pass is limited by flow stress which increases with deformation, more energy intensive, needs more powerful equipment, Makes the material anisotropic.

3. Work done per unit volume = $\frac{1}{\mu}\int \sigma d\varepsilon = \frac{\sigma}{\mu} ln\left(\frac{A_0}{A_f}\right) = \frac{\sigma}{\mu} 2ln\left(\frac{d_0}{d_f}\right) = \frac{10}{0.7} 2ln\left(\frac{250}{25}\right) \approx 66MJ/m^3$ where μ is efficiency. Stress required = 66MPa. Force = stress x area = $66 \times \frac{\pi}{4} \times 0.25^2 = 3.24\ MN$

4. Strain in a single pass is = $\varepsilon = ln\left(\frac{A_0}{A}\right) = 2ln\left(\frac{d_0}{d}\right)$. Using this it can be shown that diameter after n^{th} pass is given by $d_n = d_0 exp\left(-\frac{n\varepsilon}{2}\right)$. Therefore number of pass = $\frac{2}{\varepsilon} ln\left(\frac{d_0}{d_n}\right) = \frac{2}{0.65} ln\left(\frac{5}{0.25}\right) = 9.3$. This means successive dies sholud be so chosen that in 10 passes the wire could be drawn.

5. During rolling contact length with roll surface is a function of reduction per pass. Let this be l and plate thichness be t. The ratio Δ = l/t gives an idea about the deformation zone. If Δ >> 1 deformation will be inhomogeneous. This would result in residual stresses and may lead to cracking. On the other hand if D << 1 there will be too much of friction between work piece and the roll. For a given plate thickness the former represents large deformation where as the latter represents small deformation. The optimum rolling schedule is some where in between.

6. Note that a large number indicates fine grain structure where as a small number denotes coarse grain structure. The above stucture appears to be coarse. Measurement shows following result.

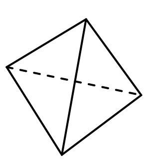
   Count the number of grains assuming contribution of corner grain as ¼ & grains at edge as ½. Thus n= (6+3/4+9/2)/A = 11.25/A

   A = 16/2.54/2.54 = 2.48 in^2

   n = 2^{N-1} = 11.25/2.48 = 4.54

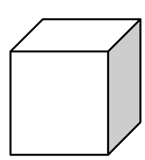
   N = 3.2

7. Number of grains F = 18, E = 39 & P = 22: It follows the relation P+F = E+1. This is a 2-D form of Euler rule in Topology (There is a striking similarity with phase rule). If you count the number of corners, faces & edges of the following 3D shapes you get the Euler's rule (a) Tetrahedron (b) Cube (c) Octahedron



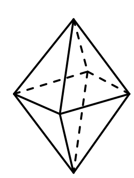
P = 4, F = 4, E=6

P+F = E + 2



P = 8, F =6, E=12

P+F = E + 2



P =6, F =8, E=12

P+F = E + 2

8. Critical neuclus is inversely proportional to amount of cold work. If before annealing if the metal is given small amount of cold wok and then annealed at a relatively higher temperature it is likely to have coarse grain structure. On the other hand high amount of cold followed by annealing just above its recrystallisation temperature would give fine grain structure.

9. Preferred orientation would give different properties along different direction. Measurement of elastic modulus along diffent direction is a common method to determine anisotropy. It can also be established by direct measurement of crystal orientation by X-Ray diffraction technique or SEM using EBSD (Electron Back Scattered Diffraction) .