FACTFILE:

ENGINEERING & MANUFACTURING QUALITY CONTROL

UNIT 3.2.2 – USING MATERIALS, PARTS, COMPONENTS, TOOLS, EQUIPMENT AND PROCESSES

Rewarding Learning

Heat Treatments

Introduction

Students should be able to:

- apply knowledge and understanding of the following processes:
  - annealing;
  - hardening and tempering; and
  - normalising.

The most common process that is used to improve the properties of metals and alloys is heat treatment. Important properties such as hardness, strength, ductility, toughness and resistance to wear can be modified by the use of alloying and the application of heat treatments.

The main aim of heat treatment is to change the microstructure of the material by modifying the crystalline structure of the atoms or by changing the size and alignment of the grains in the material.

Annealing

The purpose of annealing is to change the structure of the material so that it will be as easy as possible to form and cut by increasing ductility and reducing hardness and strength.

Annealing is achieved by heating the material above a specific temperature called the upper critical limit and allowing it to soak by holding it at that temperature for a period of time. The metal is then cooled slowly.

Annealing is a process that puts the material into its softest or most workable condition and may be repeated several times in the manufacture of a product.

To anneal carbon steel, low medium or high carbon, the steel must be heated above a specific temperature (known as the upper critical temperature) and allowed to cool slowly, usually in a furnace. The minimum specific temperature depends on the percentage of carbon in the steel. For example

- The annealing temperature for a carbon steel with a high carbon content is 0.83% needs to be above 738°C. This produces a large coarse grained pearlite structure.
- The annealing temperature for a carbon steel with a carbon content of 0.4% needs to be above 840°C. This produces a large coarse grained ferrite and pearlite structure. The result of annealing is to produce a large coarse grain structure in the steel. This allows it to be worked and shaped easier.

To anneal aluminium it must be heated to around 400°C and allowed to cool or quenched in water. Aluminium has a low melting point so care must be taken not to overheat it.

To anneal copper it must be heated to 700°C and quenched in water or allowed to cool in air. Copper and aluminium will quickly lose the effect of annealing in a process called age hardening.

Hardening

To harden carbon steel it must be heated above a specific temperature known as the upper critical temperature and cooled rapidly by quenching in cold water or oil. The minimum specific temperature depends on the percentage of carbon in the steel. To harden for example, high carbon steel with a carbon content of 0.83% the steel is heated above 738°C and quenched in cold water or oil.

A crystalline structure called martensite is formed in the steel which is very hard but also very brittle.

The degree of martensite and thus hardness developed depends on the amount of carbon present. Martensitic steel, though hard is very fragile and brittle so it must be tempered to introduce toughness into the steel to make it useful.

Tempering

To relieve some of the brittleness and hardness from the carbon steel a process called tempering is needed. This is a process that essentially balances the hardness and toughness of the product to suit the purpose it will be used for.

The carbon steel is heated to below the upper critical point. The exact temperature depends on the purpose for which the steel will be used for. When heated to the required temperature the carbon steel is quenched in cold water.

To temper a piece of hardened steel first the surface of the steel must be cleaned to show a bright clean surface. The steel is then heated with a blow torch until oxide films appear on the surface. As the desired colour appears the steel must be quickly quenched in cold water. The chart opposite shows a steel colour tempering guide.

Normalising

Normalising is a process similar to annealing but with a faster cooling rate that removes internal stresses and creates a uniform crystalline structure in steel work.

When a part has been bent, cut, hammered, welded etc. the material will work harden and may have residual stresses which can cause weakness in the part.

Normalising is similar to annealing in that the steel is heated above the upper critical temperature and allowed to soak for a short time then allowed to cool in air. After normalising the steel will have uniform grain structure and all the internal stresses caused by processing will be removed.

Revision questions

1. What heat treatment would be used on high carbon steel to prepare it for a series of machining processes?

2. Why is martensitic steel not suitable for the tip of a screwdriver?

3. Why must a steel surface be cleaned prior to starting the tempering process?

4. What heat treatment introduces toughness into the work piece?

Additional Resources

Steel Heat Treatment

https://www.youtube.com/watch?v=xXOtdTa2ypU

Properties and Grain Structure

https://www.youtube.com/watch?v=uG35D_euM-0&t=391s