FACTFILE:
GCSE
Engineering and Manufacturing
3.3.1 Alloying and Cold Working

Rewarding Learning

Alloying and Cold Working

Learning outcomes

Students should be able to:

- apply knowledge and understanding of how the properties of materials can be changed by:
  - alloying; and
  - cold working; and
- discuss the reasons for changing the properties of materials.

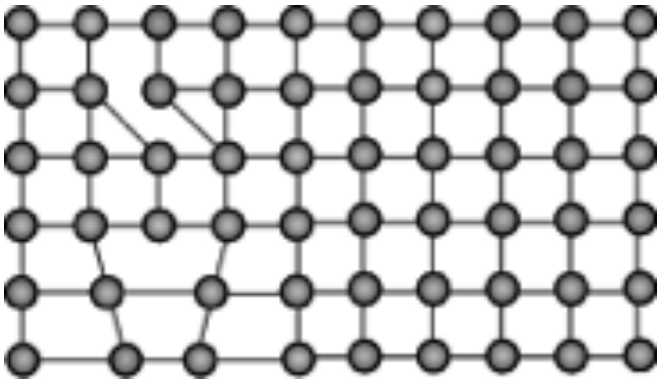
Materials and their properties

The physical and mechanical properties of materials influence their selection in the design and manufacture of products. A material is selected for a given application not only because it possesses the required properties and characteristics for the intended function, but also for its ease of manufacture at a low cost.

Alloying

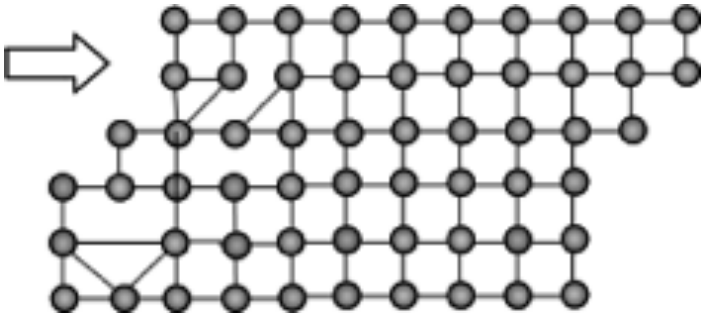
Many pure metals have limited mechanical properties and are suitable only for some specific applications. Pure aluminium is easy to form and has high electrical conductivity but has low strength and hardness so is used to make foils and for specialised conductor cables. The properties of pure metals can be enhanced by the addition of different elements.

The atoms in a pure metal are arranged in a crystalline lattice structure, the atoms are arranged in an orderly configuration; however there are often irregularities and defects within the crystalline structure such as misaligned bonds and missing atoms. These misalignments are called dislocations.

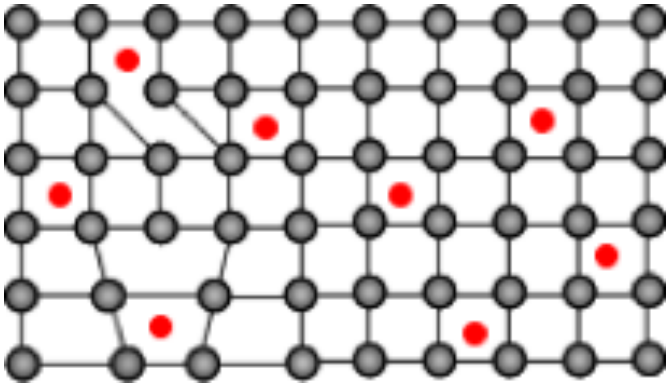


These dislocations can enable the atoms to slip past each other causing deformation of the material. When force is applied to a metal a slip plane will form allowing the atoms to shift position causing plastic deformation.

Alloying a pure metal with a small amount of another suitable element is a method used to strengthen pure metals by blocking the dislocation movement of the atoms in the metal. Aluminium when alloyed with a small amount of copper can approach the strength of steel.

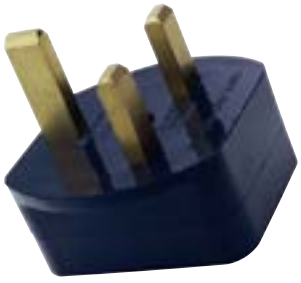


Alloying can enhance properties other than strength, alloying can be employed to increase hardness, toughness, corrosion resistance, performance at high temperatures, melting point and working properties such as machinability and fusibility. Alloys are created by mixing the components together in precise quantities when they are in a molten state.



Advantages of alloying

Copper has high electrical conductivity but in its pure form is a soft material. By adding zinc to copper we obtain brass which has high electrical conductivity and is hard and resistant to corrosion. It is easy to appreciate why brass rather than copper is used in the pins of a domestic plug.



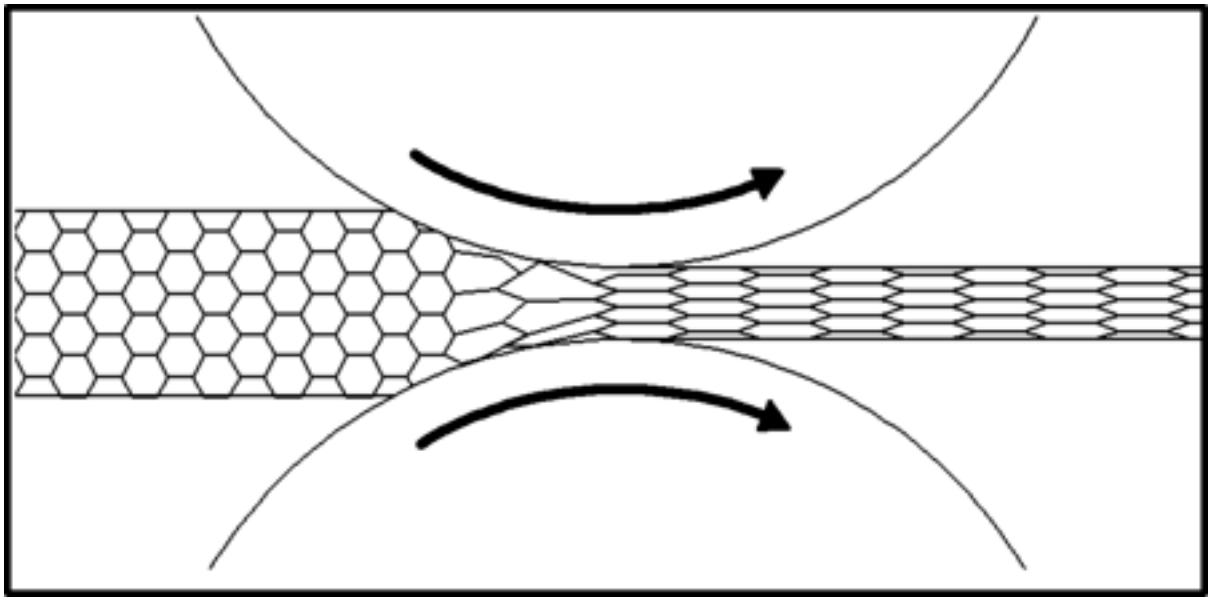
Aluminium is commonly alloyed to produce metals used in electrical wiring, aircraft structures, kitchen wares, car components and many more every day items. Aluminium is most commonly alloyed with copper but nickel, cobalt, manganese and magnesium are also added. Aluminium alloys have been formulated to suit a wide range of applications and production processes such as deep drawing, welding and casting.

Iron is a widely available metal that has good strength but is soft and has low resistance to corrosion. By alloying iron with a small amount of carbon we can obtain a very strong and hard material (Steel) that can retain its hardness even at high temperatures. Alloying steel with chromium produces a material that will not corrode (stainless steel).

Cold Working

The properties of some metals can be changed by inducing plastic deformation in the material at room temperature, this is called cold working. Cold working results in an increase in hardness and strength but a reduction in ductility.

In the production of sheet metal the steel is cold rolled in order to harden and strengthen the steel. Cold working causes lots of dislocations in the crystalline structure of the metal as the atoms are forced to move under the extreme force. These dislocations cause internal forces in the material and will reach a point where the saturation of dislocations impedes further plastic deformation of the material. This process causes the material to develop increased strength and hardness. This process is also known as work hardening or strain hardening.



The process of cold working is used to improve the properties of sheet steel in the production of car body panels and in the drawing of copper wires.

Often work hardening is viewed as a negative effect of a machining or shaping process and can cause unwanted internal stresses in a completed component. These internal stresses can be relieved by a heat treatment called normalising which allows the atomic structure of the material to realign.

Revision questions

1. What is an alloy?

2. Explain how alloying can increase the strength of a pure metal.

3. What element is mixed with steel to create stainless steel?

4. Why is brass preferable to copper for use in the pins of a domestic 3 pin plug?

5. List some mechanical and physical properties that can be changed by alloying.

6. What effect does cold working have on the strength and ductility of a material?

7. Outline a method that could be used to increase the hardness of mild steel.

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8. Investigate the following alloys and create a table to show their composition, properties and applications.

   Stainless Steel, Low Carbon Steel, Medium Carbon Steel, High Carbon Steel, Brass, Bronze, Aluminium Alloy.

Additional resources

http://www.azom.com/article.aspx?ArticleID=310

https://www.youtube.com/watch?v=9LHDSB1n11k

https://www.youtube.com/watch?v=keGhF6o33P8

https://www.youtube.com/watch?v=UiYogITTl9w