Aluminium in Arrows

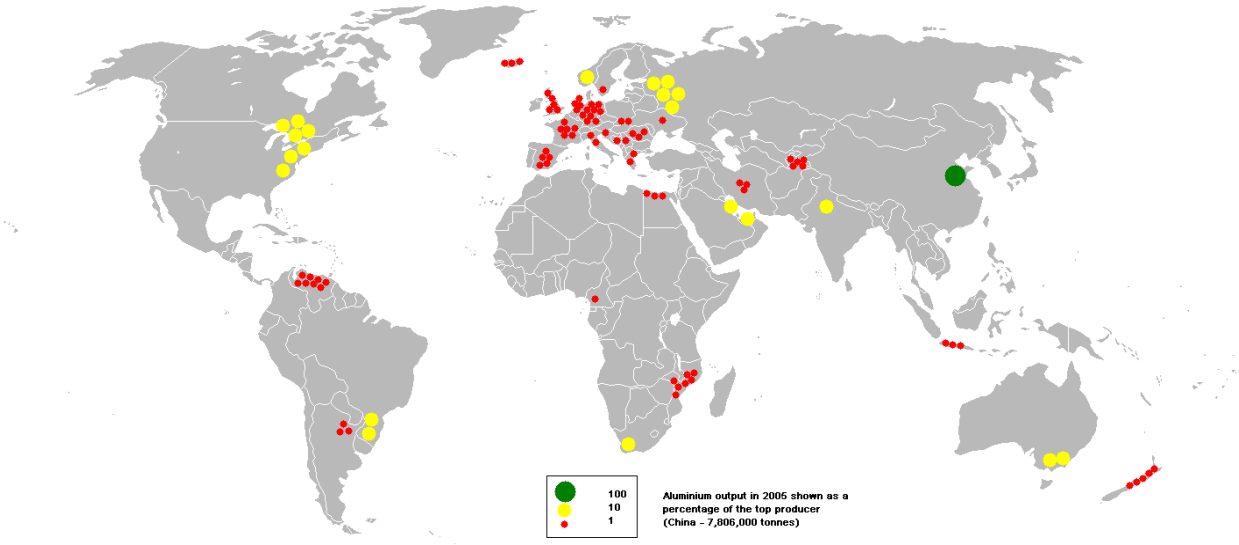
History of Aluminium

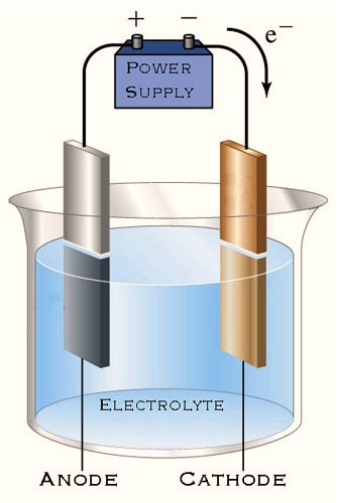
In the early 19th century, many scientists knew aluminium existed but was really hard to find. But in 1825 a Danish Chemist called Hans Christain Oersted found and prepared impure aluminium using a chemical process; causing more opportunities to research aluminium. Therefore aluminium was researched more after this discovery and between 1827 and 1845, Friedrich Wohler, from Germany, used a different chemical process to extract impure aluminium which helped to specific the gravity of aluminium and lead to specific the lightness of aluminium. This was important to make a better understanding of the metal aluminium, information about the properties of aluminium and what they could be used for, which could be useful for the future generation.

In 1854, Henri Sainte-Clair Deville, in France, has managed to obtained pure aluminium using a very expensive and large scale experimental plant. The pure aluminium extract was displayed in the Paris Exposition in 1855. The extraction of pure aluminium shows that it was possible to extract pure aluminium from ore and slowly aluminium was used but only for luxury and expensive like cutlery for rich people; this is because aluminium in the 19th and the early 20th century was very expensive; even more expensive than silver, gold or platinum due to the fact that a lot of energy is needed to extract aluminium which leads to the fact that aluminium wasn't commercially used yet. It was only in the past 100 years we started to extract aluminium using a different cheaper method which contributed a lot to the economy as they are still slightly expensive but the properties of aluminium are very useful for many items so they help people in different ways from household objects to vehicles.

Manufacture and extraction

In the 21st century, ten million tons of aluminium is extracted each year; with China as the most major producers. Large amount of energy is needed to extract and smelt aluminium, making aluminium very expensive and contribute a lot to the economy; this is because Aluminium is extracted from ore, like bauxite, by electrolysis.





Electrolysis is a chemical process which reduces the impure aluminium, usually aluminium oxide, to pure aluminium; the pure aluminium then can be alloyed with other metals to suit many different purposes. Electrolysis uses a lot of electrical energy making it very expensive, it works by passing electricity through the ore using two electrodes, anode and cathode. Positively charged ions are attracted to cathode where they form aluminium while other non-metallic elements are attracted to anode. Other cheaper methods of extracting aluminium are recycling; much less energy is needed and a lot of energy is saved. To put into content, recycling one aluminium can save enough energy to power up a television for one hour.

Further context of Aluminium

Economy

Aluminium allows countries to trade aluminium to other countries so they can make money from trading aluminium therefore boosts countries' economy. Also the extraction of ore which contains the aluminium oxide like bauxite create jobs for people and increase their spending power; also allowing the economy to increase. Businesses also use aluminium to create sports equipment and sell them like arrows which also increase the economy.

Social

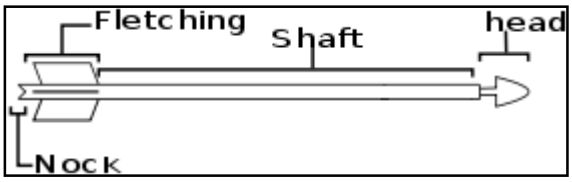
The usage of aluminium in sports like archery makes the sports more accessible due to the greater performance of equipment; this will increase the quality of people's lives as they have more hobbies to take up and it also increase the performance of advanced archers which allows records to be broken.

Environmental

The extraction of aluminium required space which will lead to destruction of habitats and ecosystem, harming wildlife and putting animals at risk of extinction. Also more transport is needed to transport aluminium which will harm the environment as vehicles will create fumes and CO_2 so it will contribute to Global Warming. Another feature of aluminium, which also contributes to Global Warming, is the amount of energy used in electrolysis to extract aluminium; it uses a lot on energy to extract pure aluminium from bauxite using electrolysis so energy sources are used up more and contribute to Global Warming as the main methods of creating energy is fossil fuel which emits greenhouse gases therefore making a factor of Global Warming.

Background on arrows

Archery was a mode of hunting; a weapon to kill and now a sport to compete in. The equipment is very much the same throughout the times; it consists of a bow and an arrow. However the material which made this equipment has changed a lot due to new material being found and the advance of technology, allowing newer and better properties for the equipment which leads to better performance on the archer.



The diagram on the left shows an arrow with its different parts labelled. Each part of the arrow has its own purpose. The head allows the arrow to cut through the air and stab into the target, the fletching helps give the arrow flight by guiding it through the air and the nock allows the arrow to be connected with the string of the bow.

The shaft is the most important feature of the arrow because it connects all the parts of the arrow together and is the main factor of the flight of the arrow as its shape is designed to fly through the air. In the medieval times the shaft was made out of wood due to its cheapness, suitable strength and lightness. As time passed and until recently, aluminium was introduced to arrows because of its many unique properties which helped arrows to fly better and benefited archers.

Properties of aluminium

Aluminium has very useful properties which has made arrows perform better. It is usually alloyed with other materials to increase its value of properties.

Light and strong

It has a very good density to strength ratio; meaning it is very light and very strong. Pure aluminium has only has strength of 7-11 MPa but alloyed aluminium has strengths up to 600 MPa. Aluminium is light because its density is low, a density of 2.7 g cm^{-3}. There are only 3 lighter metals: lithium, beryllium and magnesium. The lightness of the metal allows the arrow to fly further as the weight doesn't have such a big affect on the fly arrow, allowing the archery to shot further targets.

Quite stiff and tough

It is also quite tough and stiff, on average compared with the range of metals; with stiffness of 70 GPa (Young's Modulus). The stiffness of aluminium is very important as bent arrows affect the flight of the arrow as the shaft cuts through the air, stiffer arrows means that arrows won't get bent and remain straight which means it will fly much straighter increasing the archer's performance. It is much tougher and stiffer than magnesium, which is one of the metals which are lighter than aluminium, with toughness of about 10kJ/m^2 which proves that aluminium has a good density to strength ratio compared with other metals. The toughness of aluminium is important because the arrow has to withstand the impact of hitting the target, prevent propagating cracks and shattering.

Resistance to corrosion

Aluminium is resistant to corrosion; making a good material for arrows as sometimes archers shoot under rain which might corrode noncorrosive resistance objects like wood.

Shiny

Aluminum is one of the shiniest metals; this is somewhat of a useful property of arrows as shiny arrows look good on archers and the arrows are easier to clean as they are more slippery due to its shininess.

Malleable and ductile

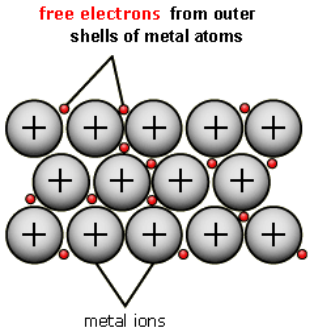
It is malleable and ductile which means it can be rolled out into wires, making arrow manufacture easy which means it is cheap.

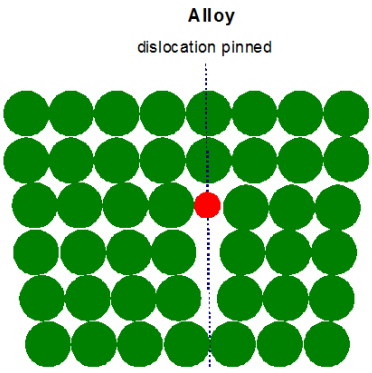
Relatively Cheap

Aluminium is relatively cheap compared to other metals, about 1,300 GBP m^{-3}. For archery sake one aluminium arrow cost £3 each.

Structure

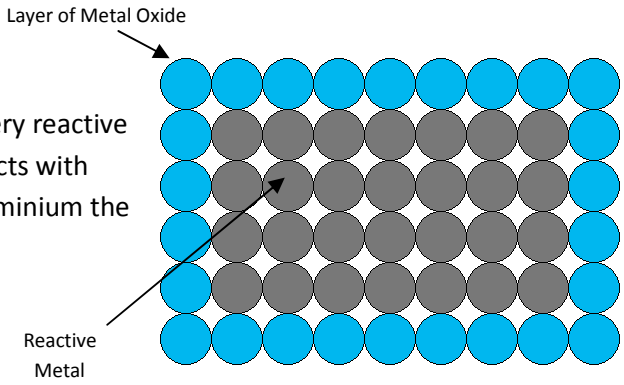
As with most metals; aluminium has a metallic bond. The ions are in a 'sea of free electrons,' this makes aluminium very conductive; both terminal, because the free electrons carry heat energy, and electrical, because the free electronics carry electrical charge.





Aluminium alloys has dislocation inside the atomic structure; this makes it tough because it is ductile; the dislocation and reduce the stress of cracks by moving itself around.

The diagram on the right shows the atomic structure of a very reactive metal, aluminium is one. Reactive metal is so reactive it reacts with oxygen in the air, creating a layer of its oxide. This gives aluminium the property of being resistance to corrosion.



Comparison

Wood

In the medieval times, arrows were used to be made out of wood. The strength of wood on average is only about 10Mpa but alloyed aluminium has strengths up to 600MPa; this means wood would reach its yield stress more quickly and break easily. Wood has toughness of about 0.1kJ/m², aluminum has toughness of about 10kJ/m²; so wood compared with aluminum is more likely to shatter on impact of hitting the target therefore not reusable. Another advantage on aluminum over wood is that wood is more flexible, with Young Modulus of about 2 GPa on average while aluminum has Young Modulus of 70 GPa; this means wooden arrows are more unlikely to be straight and therefore won't fly straight. Wood isn't very resistant to corrosion so it is more likely to rot and get eaten by wood bugs therefore won't last long.

One advantage on wood over aluminium is that wood is much cheaper than aluminium, an aluminium arrow cost about £3 while a wooden arrow only cost £2 each on average. Also wood is much lighter than aluminium with density of 0.3 g cm^{-3} so it can fly much further without carrying much weight.

Carbon Fiber

Carbon fibre, which is a composite material, was recently introduced to archery due to its excellent properties it has which are suitable for arrows. Carbon Fiber is much lighter because it is less dense; density of 1.2 g cm^{-3}, aluminium has a density of 2.7 g cm^{-3} so compared with aluminum, carbon fiber is less dense therefore lighter therefore fly further without carrying much weight. Carbon fiber is much tougher and stronger (toughness of 12 and strength of 1,000 MPa) so carbon fiber arrows won't break easily and won't shatter easily. Carbon fiber has the same Young Modulus as aluminium so it is as flexible

One disadvantage on carbon fiber is that it is very expensive, £8 for one carbon fiber arrow making it the most expensive arrow out of the 3 main materials.

Conclusion

Aluminium, wood and carbon fibre (the main 3 material used to make arrows) all have different properties. Aluminium is a very suitable material for arrows for novice archers because it is cheap so beginners can afford them and the weight to strength ratio is good enough for archery. Carbon fibre is much lighter but it is much more expensive so competitive and experienced archers will use carbon fibre arrows more as it will increase the archer's performance. Wood can be used for have-a-go archery where accuracy of the arrow flight is not important and the price has to be low for children to play with in camps and trips.

Bibliography

- http://encarta.msn.com/encyclopedia_761575249/Aluminum.html#p1
  - History
  - Useful properties of aluminium and how they are used
  - 3 metals lighter than aluminium
- http://en.wikipedia.org/wiki/Aluminium
  - Value of the properties of aluminium
  - Extraction of aluminium from bauxite by electrolysis
  - Aluminium was much more expensive than platinum in the 20th century
- Advancing Physics AS Student Edition CD-ROM
  - The material matrix
  - Value of properties of other materials
- http://www.bowsports.com
  - The price of arrows
- http://en.wikipedia.org/wiki/Arrow
  - The structure of an arrow
- AQA GCSE Chemistry revision guide
  - Information on electrolysis