Manufacturing processes for bicycle frame and golf club

Business, Manufacturing

Almost every item we use in our everyday life has been manufactured in some way using a series of different techniques. The task set out in this assignment is to look at two everyday objects and discuss the ways in which they have been manufactured and what materials have been used and why these specific manufacturing techniques and materials have been used. We also have to look at other possible techniques and materials that could have been utilized instead and what effect this would have had on the final product.

The two objects that I have decided to investigate are the bicycle frame and the golf club. I have chosen to investigate these two items due to their similarity in materials and manufacturing processes but also their diversity as I will demonstrate in the rest of the report. First I will look at the bicycle frame then the golf club and then finishing with a short conclusion and comparison of the two different objects.

2. BICYLE FRAME

The concept of the bicycle was first conceived in the late 18th century in France where an inventor created a wooden hobby horse known as a Celerifere, which had two wheels connected with a beam [1]. From this idea there have been numerous alterations and improvements to every aspect of the design that have led to the invention of the modern bicycle. These include the materials used (wood - alloys - composites), the structural design and the techniques used to manufacture the frame. The design of the modern frame can be seen in figure 1, with the names of the tubes labelled on the picture.

Figure 1 - Diagram of modern bicycle frame with all parts named [2]

2. 1 Materials

Modern bicycle frames can be made from a variety of different materials depending on its application. Standard bicycle frames are usually made from some form of metal alloy such as steel, titanium or aluminium. Steel and titanium alloy frames are generally more popular due to their increased strength over aluminium giving them a longer life. Aluminium alloy is an ideal material in applications where weight must be cut down and the loads placed on the frame are not excessive. The particular compositions of metals within the alloy are constantly being altered to improve weight, rigidity and strength. The strength of the material is particularly important in applications such as mountain biking and downhill racing where the frame comes under considerable loads. The structure of the frame also plays a large part in the loads it can take due to the front and rear triangles that distribute the load throughout the entire frame.

In the last two decades the use of composite materials has become more popular, especially in racing bikes due to their increased strength and low weight. These frames are most commonly made with some form of structural fibre such as carbon or glass. Due to the increased strength along the axis of the fibre, single piece frames can be produced giving increased strength in the areas that require it.

2. 2 Manufacturing Process

Looking primarily at metal alloy frames, there are two main types of tube that can be produced. These are seamless tubes, which are drawn through several stages from a block of metal and the others are known as seamed tubes, which are made from sheet metal rolled into tubes and welded along the length of the tube. Seamless tubes are generally seen as the better alternative due to the fact that they do not have a seam running along their length, which could be a possiblestressconcentration area.

The process for making seamless tubes is as follows: First the metal alloy to be used is annealed to soften it and then hollowed. Once it has been hollowed it is heated once again and then pickled in acid to remove any oxidation layers and then lubricated to prevent any oxidation after the pickling stage. Secondly the hollow is cut to the right dimensions and mitered, a process of shaping the ends of the hollows to fit the contours of the tube to which it is to be attached to. This process is done simply by sawing off the necessary shape of the fit and then filing it down to a smooth finish. Next the tubes go through a cold drawing process to get them to the right gauge by creating a thinner and longer tube.

The tube can also be 'butted', a process that increases the thickness of the tube at the ends due to the increased stresses located at these points and making the tube thinner near the centre as the stresses are smaller at this location. This process decreases the weight and increases the strength of the frame. The final stage in making the tubes is shaping and tapering them depending on which area of the bike they are to be used in.

Once the tubes have all been made, they are joined together to form the frame using either some form of welding if the tubes are made from metal or joined using an adhesive if they are made from composite. The most coming joining method for metal frames is, by far, brazing welding. This process involves placing the tubes together and heating the joints up to create a white flux, cleaning and melting the joint. Next the brazing filler metal is added, usually brass, which melts below the temperature of the joints and flows around them creating an even seal (figure 2).

This process is usually done by a machine but some specialist bike makers will still do this manually. This method of welding is preferred to others, such as MIG and TIG welding, as it can be completed at much lower temperatures and so not adversely affect the properties of the material as it may change its structure at high temperatures (i. e. steel). In some frame constructions welding is not required at all and rather a lug (figure 3) is used to fix the two frames together. This allows for easy bike maintenance and tube replacement with little effect on the rest of the frame, unlike its welded counterpart.

For composite frames, rather than welding the frame together, which would be ineffective, the joints are glued together using a strong adhesive. The adhesives used are capable of sustaining the same force as effectively, if not better, than welded joints.

Figure 2 - Example of braze Figure 3 - Aluminium lug connecting top tube and

welding on an L-section [3] seat tube [4]

While the joints are still hot enough, the frame is placed into a jig to ensure that all tubes are aligned properly and if not they are oriented to the right position before the metal cools. The frame is then pickled to remove any excess flux and brazing filler and then grinded for a smooth finish Small alignment changes can still be made once the frame has cooled.

Finally the frames are taking to be painted to help protect them from oxidation. First the lubricant used to protect them after pickling is cleaned off and then an undercoat is painted onto the frames. After which, a coloured enamel is painted on either by hand or by passing the frame through an electrostatic painting room where the positively charged paint is attracted to the rotating negatively charged frame. Once the frame is finished it is ready for the rest of the bikes components to be added.

3. GOLF CLUB

The origins of golf are unclear as many countries had some form of game involving hitting on object with a stick dating as far back as the Roman Empire. Golf as we know it today was popularised in Scotland in the 15th Century where players would use completely wooden clubs to hit a stuffed leather ball. It wasn't until the introduction of the modern hard rubber golf ball in 1848 [5] that the materials used in the club design were altered. First iron was introduced as a material for club heads, used to strike the ball.

Wooden heads were still used for certain shot types. Wooden shafts were still used despite the head material until the early 20th century when the first steel shafts were introduced. In the following years specialised clubs were developed (i. e. sand wedge) and in 1970's the first composite shafts made from high strength materials were introduced but did not gain popularity straight away due to their apparent decrease in stiffness resulting in flexing. Developments into composite shafts have made them a popular alternative to steel shafts due to their light weight and strength.

Figure 4 - Variety of different club heads [7]

3. 1 Materials

The materials used to manufacture a golf club vary widely depending on the part that is being made such as the grip, shaft and head. The grips can be made of either a moulded synthetic rubber or bound leather, materials with a high coefficient of friction preventing slip. The shaft material can sometimes depend on the application of the club (driver, putter etc.) and are generally made from a stainless steel, titanium or aluminium for metal frames and a carbon/boron fibre reinforced epoxy.

The material used for the golf heads can depend a lot on the type of club that it is. For wood type clubs the most popular materials to use are similar to those used for the shafts; stainless steel, titanium and carbon fibre epoxy. Oversized wood heads are often filled with synthetic foam so that the weight is similar to a smaller headed club. It is still possible to purchase wooden heads for the club but these are generally more for aesthetic and traditional

purposes than for performance. Irons and wedges generally have heads made from stainless steel, titanium, tungsten, beryllium nickel/copper or a combination of these materials. Putters can be made from a lighter, weaker material such as aluminium due to the low impact forces that they sustain as they travel at slower velocities.

3. 2 Manufacturing Process

As mentioned previously there are three components to the golf club, the grip, shaft and head. Each can be made using a variety of techniques that depend on the material being used and the preference of the manufacturer. The synthetic rubber grips are made by placing the end of the shaft into a hollow die, the required shape of the grip, and injecting the rubber into the hollow. The mould is then left to harden and the shaft is removed from the mould.

Depending on the material the shafts can be created in numerous ways. If the shafts are made from steel or stainless steel then they will be made by a process known as tube drawing. There are several different methods for this process such as rod drawing, fixed mandrel drawing and tube sinking. As these methods are closely related I will only look at the situation where the shafts are made via tube sinking. This process involves pulling the tube part way through a die that has a slightly smaller inner diameter than the tube, causing the tube to neck down in diameter.

This is down several times with smaller lengths of the tube. This process helps to reduce the weight of the shaft and increase its strength in the areas

of greatest stress (i. e. the shaft/head connection). If the tube is made from a carbon fibre composite a different process can be used. The most common is known as pultrusion where the carbon fibres are fed through a heated die with epoxy resin being fed through at the same time (figure 5). The resin hardens under the heat and forms the shaft. The composite shaft does not need to be necked during its manufacture.

The metal club heads are made by a process called investment casting. A die, often made of rubber or metal, is made in two separate halves and has a hollow in the shape of the part to be moulded to allow easy removal once the mould has hardened. Wax is injected into the mould and left to harden. The mould is removed and the process is repeated several times until a collection of moulds have been produced. These moulds are then placed on the stem of a 'tree' known as a sprue.

The sprue is then invested with liquid slurry and coated in a ceramic powder and left to dry. This process is repeated until the coat is roughly 5-10mm thick. The investment is then placed in a furnace at about 550 - 1100 oC to melt the wax, which is allowed to flow out of an opening in the bottom of the cast. The cast is then fired and preheated and then inverted to allow the molten metal to be poured into the opening of the cast. Once the metal has cooled and hardened the ceramic shell is broken apart and the heads are removed from the tree. The heads are then finished with a heat treatment to harden the surface of the material and then grinded and polished for a clean surface finish.

Another possible method of creating the heads is to heat up a stock piece of metal and forge it in a die to produce the part needed (figure 6). The advantage to this method is an increase in strength as the grains follow the flow of the component rather than being broken up due to casting and machining. The disadvantages of this method can be a poor surface finish and the component will usually have to go through several finishing stages to get the finished piece.

Figure 5 - Composite shaft being made Figure 6 - Club head made through the through the process of pultrusion [6] process of forging [6]

Once all the parts have been made the shaft needs to be connected to the head. This can be done by a variety of methods such as creating a thread on the end of the shaft and a thread socket in a short tubular protrusion on the head and screwing them together. Another method is to place the shaft into the head socket and drill a hole through both tubes and inserting a metal pin, set with an epoxy resin. If the shaft is made from a carbon fibre composite it is connected to the head using an adhesive, with the advancements in adhesive technologies it is now possible to use an adhesive to bond metal shafts to the heads. The final stage is to check the surface for any blemishes, removing them, and then giving the surface a final polish.

4. CONCLUSION

The two most similar components of the two items are the tubes of the bike frame and the shaft of the golf club. Both these components are made from the same general materials such as steel, titanium, aluminium and carbon

fibre composite but utilize different methods in their construction. While the bike frame tubes are made from hollowing out lengths of metal and then cold drawing them to achieve the right gauge, golf club shafts are made directly from another method of tube drawing known as tube sinking where the tube is drawing through a die with decreasing diameter, creating a necked tube. Although these methods could be interchanged with each other they usually stick with their own methods as they give the best properties to the components.

A similarity in connecting the parts together in both examples was found with the use of an adhesive to bond the carbon fibre tubes of the bike frame and even the metal shaft of the golf club with the head. Although this method could also be implemented with the metal bike frame the common method of joining is still blaze welding as its seen as the most economic method to use.