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DEPARTMENT OF MATERIALS ENGINEERING.
FORGING AND BLACKSMITHING.
MSE 257.
GROUP 8.
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I
ABSTRACT.

Objectives.
Blacksmithing is essential in our daily life as it helps to create metal base objects used in our daily life**. Blacksmith**, craftsman who fabricates objects out of iron by hot and cold forging on an anvil.
This paper focuses on the scientific explanation of how some specific heat treatment and hammering techniques play a significant role in altering both microscopic and physical structures of metals giving it new desired properties.

Materials (tools) and methods.
Some of the materials (tools) needed in forging and blacksmithing include:
Anvils, forge and bellows, fuel, tongs and hammers, chisels and punches, vises, quenching buckets, metal cutting tools and grinders etc.
Some of the methods are annealing, quenching and tempering for heat treatment and drawing, upsetting, bending and punching for hammering.

Conclusion.

Blacksmithing and forging are the process of applying heat to a workpiece, usually metal so they can be hammered into desired shape. By applying the right heat treatment and hammering method, one can alter both the structural and physical properties of metals making it softer, weaker and more ductile.

Keywords: annealing, quenching and tempering, drawing, upsetting, bending and punching for hammering, etc.

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CHAPTER ONE

INTRODUCTION.

Before modern metalworking techniques were invented, blacksmiths used heat to make metal workable. Once the metal was formed into the desired shape, the heated metal quickly was cooled. Quick cooling made the metal harder and less brittle. Modern metalworking has become much more sophisticated and precise, allowing for different techniques to be used for different purposes.

Forging and hammering are the two foundational and essential processes to start blacksmithing. When you forge metal, you heat it in the forge to hammer and bend it into your desired shape. Heat treatment is the process of heating and cooling metals to change their microstructure and to bring out the physical and mechanical characteristics that make metals more desirable. The temperatures metals are heated too, and the rate of cooling after heat treatment, can significantly change metal's properties.

Fig 1: image of blacksmith at work.

ACKGROUND INFORMATION.

Blacksmith, craftsman who fabricates objects out of iron by hot and cold forging on an anvil. Blacksmiths who specialized in the forging of shoes for horses were called farriers. The term blacksmith derives from iron, formerly called "black metal," and farrier from the Latin *ferrum,* "iron." The application of heat impacts the crystal structure of the iron making it easy to manipulate. It also changes both the physical and structural properties of the metal impacting how the result might be.

MATERALS (TOOLS) NEEDED.

Some of the materials (tools) needed in forging or blacksmithing are:

1. **Anvil**

The anvil is a tool typically made of steel and usually has a large flat working surface. It can be cast steel, cast iron, or even forged steel. They come in many shapes and sizes. Some have horns on one side, both sides, or not included at all. Some anvils have a round hole called a pritchel hole, and a square hole called a hardy hole. Each has their purpose. The anvil is used as a working surface to help shape the material while it is being hammered upon for forging, shaping, and bending metal.

2. **Forge and bellow.**

A blacksmithing forge is a type of hearth that a blacksmith uses to heat and shape metals into objects, tools, and more. It is typically a basin that consists of a heat source and an oxygen input to bring metals up to a temperature where they can be easily worked and shaped. bellow are used to deliver a constant supply of oxygen to the fire. This helps with the combustion process and allows for higher temperature fires. Hot enough to heat iron to the point that it can be molded and manipulated to create all sorts of objects.

3. **Fuel.**

Depending on the forge you choose, you will either be using a gas such as propane or a solid fuel such as coal. A gas forge typically uses propane and other forges uses wood or coal as their fuels.

4. **Tongs and hammers.**

Tongs - Long handled pliers to hold the hot metal while working and for placing it in and retrieving it from the fire. Hammers are used to shape the workpiece into desired shape.

5. **Chisels and punches.**

Chisels are always nice to have on hand for cutting and adding decorative patterns into your work.
Punches can be used in place of drilling holes. They can be more efficient than drilling since there is typically much less waste than drilling because the hot metal is moved to the sides rather than cut away.

6. **Wire brushes and files.**

Wire brushes are used for removing scales from the work piece after it has come out of the forge and to help clean it up when it is near completion.
Files can be used to help shape the metal and to help clean it up. It's also used to remove sharp edges that are left after cutting.

7. Vise

Vises are tools that come in a variety of shapes and sizes. Most of the vises you see on the market today are bench vises. Blacksmiths have a special kind of vise they use called a post vise or leg vise. This vice has a leg that extends all the way down to the ground which helps transfer the forces to the ground. These vices are also designed to take more beating at the jaws than the typical bench vice.

8. Quenching Bucket

A bucket full of water is needed to quickly cool down the end of the working piece. This bucket can also be used to hold oil that can be used in a slow cooling method.

9. **Metal cutting tools and grinders.**

Metal cutting tools are needed to cut workpieces. Examples are hack saws etc. Grinders are used in cleaning the ends of cut pieces.

An anvil.

A forge with bellow.

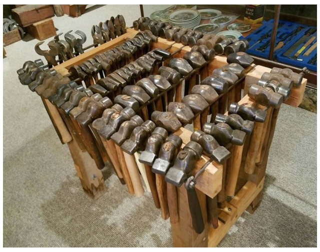
Set of chisels and punchers.

A standing vise.

A quenching bucket.

A cutting tool.

Wire brushes.



A bunch of hammers.

An electric forge.

CHAPTER TWO.

PROCESSES INVOLVED IN BLACKSMITHING AND FORGING.

FORGING AND HAMMERING.

These are two foundational and essential processes to start blacksmithing. When you forge metal, you heat it in the forge to hammer and bend it into your desired shape.
heat treatment is the process of heating and cooling metals to change their microstructure and to bring out the physical and mechanical characteristics that make metals more desirable. The temperatures metals are heated too, and the rate of cooling after heat treatment, can significantly change metal's properties.

The most common reasons that metals undergo heat treatment are to improve their strength, hardness, toughness, ductility, and corrosion resistance.

HAMMERING METHODS.

Drawing.

Drawing is an essential technique in blacksmithing and is used to make your metal longer and thinner. You will want to use your tongs to hold down your piece on the anvil and hammer both sides to extend the length.

Upsetting.

Upsetting is the opposite of drawing, and is used to make your metal thicker, shorter, and narrower. This requires a little more technical skill than many forging techniques. The process can be difficult to control and is used in more advanced stages of blacksmithing. You can heat the specific part of the metal in the forge that you intend to shape, rather than heating the entire piece in the forge.

Bending.

To make a bend or curve in the metal, heat it and hold it over the anvil horn and strike it with a hammer to make your desired curve. You can strategically heat sections of your metal in the forge before bending it, rather than heating your entire piece. You can also unbend metals by reheating the metal and reversing your steps.

Punching.

Punching utilizes a punching tool to make holes in hot metal. Begin by heating the metal, identify where you want to punch a hole and hammer your punching tool softly on the intended spot until you feel resistance from the anvil. Be careful not to hit too hard, so you do not damage the surface of your anvil.


Hammering a forged metal


Bending a forged workpiece.


Drawing a forged metal.


Punching a forged metal.

Upsetting forged metal.


Blacksmithing forging metal.

Effects of heating and hammering on metals.

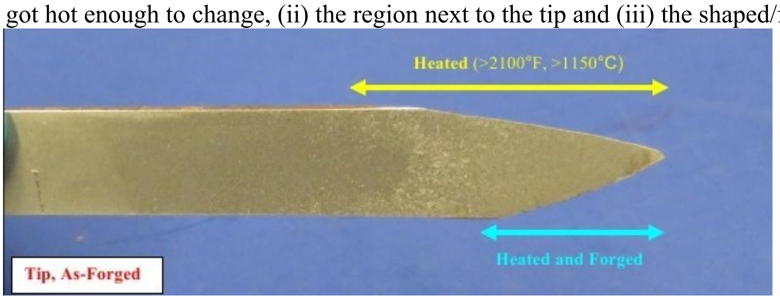
Subjecting metal to extreme heat causes it to expand in addition to impacting its structure, electrical resistance, and magnetism. Thermal expansion is pretty self-explanatory. Metals expand when subjected to specific temperatures, which vary depending on the metal. The actual structure of metal also changes with heat. Referred to as allotropic phase transformation, heat typically makes metals softer, weaker, and more ductile. Ductility is the ability to stretch metal into a wire or something similar.

Heat also can impact the electrical resistance of metal. The hotter the metal gets, the more the electrons scatter, causing the metal to be more resistant to an electrical current. Metals heated to certain temperatures also can lose their magnetism. By raising temperatures to between 626 degrees Fahrenheit and 2,012 degrees Fahrenheit, depending on the metal, magnetism will disappear. The temperature at which this happens in a specific metal is known as its Curie temperature.

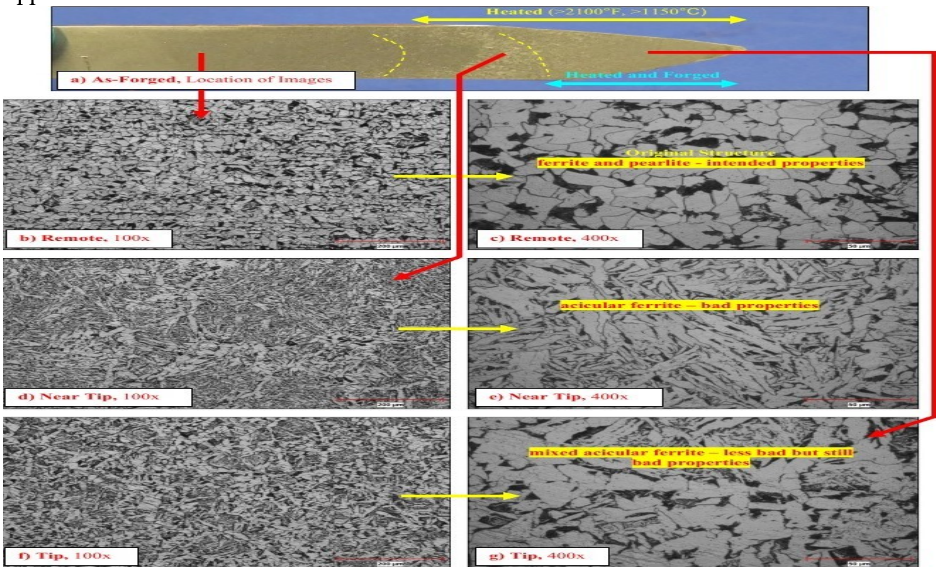
The summary of forging low carbon steel (<0.2wt% carbon) is simple. Heat to above 2100°F (1150°C). At this temperature, the steel has very low strength and is soft, allowing it to be shaped. Hammer, beat and pound to form. As it cools, even while still red hot, it gets noticeably harder to form. Reheat as many times as needed between the hammering.

When done shaping, most low carbon steel parts are then air cooled back to room temperature. At this point, for engineered components, the as-forged parts are typically not deemed fit for service. Not to scare people by being too technical, but needed to briefly explain why steel properties are based upon two things: (1) composition (what it's made of) and (2) microstructure (arrangement of atoms/phases within the steel). The composition of the steel part should be relatively uniform throughout yet forging produces a diversity of structures including some less than ideal.

For example, to shape a square low carbon steel bar into a tip, only the tip is heated and pounded to shape. Three different microstructure zones are formed by this – (i) the bar length that never got hot enough to change, (ii) the region next to the tip and (iii) the shaped/forged tip.



The region next to the bar tip, that was repeatedly subjected to >2100°F (?1150°C) but not the hammering, had formed large austenite grains that, upon cooling, created an acicular structure. At 2100°F (1150°C), the structure grows larger and larger until the eventually air cools when, at that point, it changes to a course, needle-like ferrite structure. This structure provides poor toughness (usually <10ft-lbs, <13J), leaving it prone to impact failures and not safe for many applications.



The tip looked a bit different as, each time it was impacted while red hot, small grains reformed which essentially reset the growing cycle (called "recrystallization"). Continuously hammering while hot keeps the grain size down. Still, cooling from such a hot temperature tends to form partial acicular structures which is still less than ideal.

The formation of these acicular structures is why most engineered components need an additional heat treatment after forging or hot forming is done. Forged low carbon steel parts (<0.2wt%, ASTM A105N, A350, A234, etc) are given a heat treatment at 1600-1700°F (870-925°C) to establish better properties. As illustrated below, the heat treatment forms a finer grained, more uniform structure thought the part. Giving it better properties than the as-forged condition and greater durability in service.

Image showing the structural makeup of different parts of workpiece.

HOW TO IMPROVE BLACKSMITHING AND FORGING.

Blacksmithing and forging can be improved by applying different heat treatment methods. These methods help to alter the structural and physical makeup of metals thereby changing the characteristics of it. Some of the Common techniques for heat treatment include the following:

Annealing is a form of heat treatment that brings a metal closer to its equilibrium state. It softens metal, making it more workable and providing greater ductility. In this process, the metal is heated above its upper critical temperature to change its microstructure. Afterward, the metal is slow cooled.

quenching is a heat treatment method that quickly returns metal to room temperature after it is heated above its upper critical temperature. The quenching process stops the cooling process from altering the metal's microstructure. Quenching, which can be done with water, oil, and other media, hardens steel at the same temperature that full annealing does.

Material is heated to the suitable temperature for hardening, then cooled rapidly by immersing the hot part in water, oil or another suitable liquid to transform the material to a fully hardened structure. Parts which are quenched usually must be aged, tempered or stress relieved to achieve the proper toughness, final hardness and dimensional stability.

Precipitation **hardening** is also known as age hardening. It creates uniformity in a metal's grain structure, making the material stronger. The process involves heating a solution treatment to high temperatures after a fast-cooling process. Precipitation hardening is usually executed in an inert atmosphere at temperatures ranging from 500 to 600 degrees Celsius. It can take anywhere from an hour to four hours to carry out the process. The length of time typically depends on the thickness of the metal and similar factors.

The use of this treatment will result in an improvement of the mechanical properties, as well as an increase in the level of hardness, producing a tougher, more durable item. Alloys are heated above the critical transformation temperature for the material, then cooled rapidly enough to cause the soft initial material to transform to a much harder, stronger structure. Alloys may be air cooled, or cooled by quenching in oil, water, or another liquid, depending upon the amount of alloying elements in the material. Hardened materials are usually tempered or stress relieved to improve their dimensional stability and toughness.

Commonly used in steelmaking today, **tempering** is a heat treatment used to improve hardness and toughness in steel as well as to reduce brittleness. The process creates a more ductile and stable structure. The aim of tempering is to achieve the best combination of mechanical properties in metals, and the combination of quenching and tempering is important to make tough parts. The tempering temperature and times are generally controlled to produce the final properties required of the steel. The result is a component with the appropriate combination of hardness, strength and toughness for the intended application. Tempering is also effective in relieving the stresses induced by quenching.

Stress relieving is a heat treatment process that decreases stress in metals after they have been quenched, cast, normalized, and so on. Stress is relieved by heating metal to a temperature lower than that required for transformation. After this process, the metal is then slowly cooled.

Normalizing is a form of heat treatment that eliminates impurities and improves strength and hardness by altering the grain size to be more uniform throughout the metal. This is achieved by cooling the metal by air after it has been heated to a precise temperature.

CHAPTER THREE.

CONCLUSION.

Blacksmithing and forging are the process of applying heat to a workpiece, usually metal so they can be hammered into desired shape. By applying the right heat treatment and hammering method, one can alter both the structural and physical properties of metals making it softer, weaker and more ductile.

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