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Analysis of Forging Processes for Machine Building Industry Modeling

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Abstract: This paper presents the efforts of forging process. As new uses for various metals multiplied, and the superior quantities imported to metals by forging came to be more positively recognized, the forging industry accelerated its efforts to produce more and better products at diminishing cost. During the production of a crankshaft weighing 17 kilograms from a bar of rolled steel, up to 31.5 kilograms are irretrievably lost as chips in machining. When the same weight of crankshaft is manufactured by the forging process, only 13.7 kilograms of steel are lost in chips. i.e. the loss is 56.6 percent less. When the temperatures increase, it is found that forging load decreases. Forging load is directly proportional to the percentage of reduction. Low carbon steels are easy to forge and super alloys are difficult to forge .In this paper, three different types of materials namely, 1020 carton steel (crankshaft), A-286 alloy (turbine disc) and 6061 alloy (aircraft housing) are analyzed to determine the relationship between the forging temperature, forging loads and percentages of reduction. There were made at the laboratory, Department of Metallurgical Engineering and Materials Science, Yangon Technological University.
Keywords: Hammer Forging, 1020 Carbon Steel, A-286 Alloy, 6061 Alloy.

1. INTRODUCTION

Forging processes are extremely important in the machine building industry. No machine, whether simple or complicated can be built without the use of forging. There are seven forging methods. These are hand forging, hammer forging, smith forging, drop forging, press forging, upset forging and roll forging. Among them, hammer forging method is the most suitable for any materials and it is the easiest to do. It is particularly wide spread in the tractor, automobile, agricultural machinery, ship building, locomotive building and other industries.

For instance, in the railway car building industry up to 70 percent of all the parts which go to make a car are forging. Selection of a basic process of forging is determined by two chief requirements-first, production of an object of a specified shape, and second, improvement of the physical properties of the metal. [1]

Important advantages of the forging are as follows,

1. When designing the required part, the engineer has considerable freedom because of a wider range of materials at his disposal to meet specific demands in service.
2. Since forged parts have ample strength to resist external forces, the use of parts of lighter sectional thickness is permitted, thus considerable reducing the dead weight of these parts.
3. Forging a part to the required shape also produces in the part the desired combination of physical properties in the correct proportion, thus insuring maximum strength and toughness, properties so vital in service.
4. Thoughtful and careful design of proper tools results in accurate shaping of parts with the least amount of allowance for finishing, thereby reducing substantially the cost of final machining. [1]

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2. MAJOR REQUIREMENTS IN FORGING

It is understood without specific mention that are excess metal or flash of forgings shall be removed by trimming and that forgings shall be free from injurious defects. Standard specification for forgings are quantity, size, coining or sizing, surface conditions, special requirements, dies, and tolerances. [2]

Combining Forging Operations

In some cases, forgings are completed using more than one type of forging operation. [2]

Forging Defects

Faults in the original metal, incorrect die design, improper heating, or improper forging operation are some of the reasons for forging defects. Samples of incoming metal should be given a careful metallurgical inspection before the lot is accepted.[2]

Forging Design

When the production-design engineer specifies a forging or metalworking process, he is usually trying to design a product with more attractive mechanical characteristics, such as greater strength, or else to economize on the weight of the finished part, thus saving on material cost.[2]

Inspection and Acceptance of Forgings

All finished forgings are inspected for quality. The aim of quality inspection is to ascertain whether the strength of the forging meets the conditions for which it is designed.[3]

Hammer Forging

Heavy machine parts cannot be forged by hand, since the comparatively light blows of a hand or sledge hammer are unable to produce a great degree of deformation in the metal being forged.

Moreover, hand forging is a lengthy process and requires repeated heating of the metal. For this reason, hammer forging, sometimes also called power, machine forging, is used for the manufacture of heavy forging.

3. MATERIALS PROPERTIES UNDERFORGING CONDITIONS

Practically all metals of industrial importance can be forged successfully, but there is some difference between metals in the ease with which this can be done.

1. steel
2. Alloy steels
3. heat resisting steels and stainless steels
4. Iron
5. copper, brasses and bronzes
6. Nickel and nickel-copper alloys
7. light alloys
8. titanium alloys [4]

Steels

Low carbon steels are the easiest of their class of forge. They also have better transverse properties than the harder alloys. Fine grained ingots produce getter transverse properties than coarse grained; thus, high quality forgings are made generally from killed, ladle-deoxidized steel showing a minimum of segregation.C1020, C1030, C1035 are for small forgings and C1040 are used for medium forgings. Temperature range is from 1500 to 2500°F. [4]

Alloys

Forging temperatures for aluminum and its alloys ranges are from 650°F to 900°F.

Effect of Temperature on Material

The forging processes work material cold or hot, depending upon the nature of the material and its size. The ability to work cold material depends upon its ductility and malleability. The ability to work hot material depends on its range of plasticity at higher temperatures. The greatest ductility is near the melting point. The forming properties of any metal or alloy depend on the temperature of the material. [5]

Hot Working

The product of such hot-working is operations are called wrought metals and are important engineering materials because they are worked under pressure to:

1. Obtain the desired size and shape form the original ingot, thereby saving time, material, and machining costs.
2. Improve the mechanical properties of the metal through refinement of the grain structure, development of directional "flow lines" and breakup and distribute unavoidable inclusions, particularly in steel.
3. Permit large changes in shape at low power inputs, per unit volume.

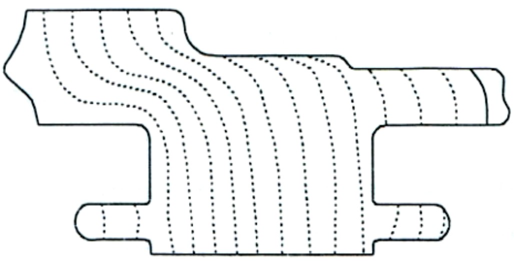

Figure 1. A cross section of a forging for a crank shaft.

Hot Working Processes

1. Rolling
2. Forging
3. Extruding
4. Upsetting

Forging

Forging is the forming of metal, mostly hot, in the early dawn of civilization, man discovered that a heated piece of metal was more easily hammered to desired shapes.

Steps in Forging a Crankshaft

The various steps in forging a single-throw crankshaft are:

1. Form flange and draw tong hold stock in turned in the dies between hammer strokes, to gather flange metal.
2. Flatten. Done between plain flat dies.
3. Bend. Done to make stock fit into die impressions.
4. Forge in crankshaft impression. Stock is forged until chilled flash prevents further metal flow.
5. Trim flash.
6. Reheat.
7. Forge again in crankshaft impression. Continue if necessary until shaft is reduced to drawing size.
8. Trim flash again.
9. Restrike in crankshaft impression for final straightening and sizing.
10. Saw off tong hold.
11. Heat treat.

4. RESULTS AND DISCUSSIONS

A case study is made at the laboratory of Department of Metallurgical Engineering and Materials Science, Yangon Technological University.

This paper studies hammer forging method.

The different results are used for different materials. In this paper, three different types of materials are analyzed to determine the relationship between the forging temperatures, loads and percentage of reduction [6]

Low carbon steel is easy to forge and super alloy is difficult to forge. If the temperatures increase, the forging loads decrease. The forging load is directly proportional to the percentage of reduction. The varying forging temperatures results the varying forging loads and pressures.

The different temperatures of three materials are described in Table 1.

Table 1. Calculated results for gears

No	Material	Maximum Temperature	Minimum Temperature
1	1020 carbon steel	2300°F	1300°F
2	A-286 alloy	2100°F	1600°F
3	6061 alloy	900°F	600°F

The collected datas for this paper are shown below. The experimental datas are done on the basic of hammer forging method.

Crankshaft will depend on its design, on the dimensions and on the grade of material. The selection of forging temperature for carbon steel is based on (1) the carbon content, (2) the alloy composition, (3) the temperature range for optimum plasticity, (4) the amount of reduction.

Table 2. Effect of temperature on load, pressure and percentage of reduction for Crankshaft Steel

No: of Step	Material Used	Forging Tempe-rature	For-ging load	Frog-ing pres-sure	% of red-uct-ion
1.	1020carbon steel (Crankshaft steel)	1800ºF	60 lb	21psi	60%
2.			50 lb	20psi	50%
3.			42 lb	19psi	40%
4.			40lb	18psi	30%
5.			39lb	17psi	20%
1.	1020carbon steel (Crankshaft steel)	2000ºF	35 lb	12psi	50%
2.			30lb	12psi	40%
3.			25lb	12psi	30%
4.			22lb	11psi	20%
5.			20lb	10psi	10%
1.	1020carbon steel (Crankshaft steel)	2200ºF	30lb	10psi	60%
2.			25lb	10psi	50%
3.			22lb	10psi	40%
4.			20lb	10psi	30%
5.			19lb	10psi	20%

According to the results, it is noticed that the varying temperatures result varying forging loads and pressures .At 1800 ºF, forging load is from 60lb to 39 lb and forging pressure is from 21 psi to 17 psi .The higher the temperatures , the lower forging loads, forging pressures and percentage of reduction.

A-286 alloy is iron base alloy. Iron bases super alloys are widely used in the manufacture of turbine discs for turbo-jet engine application. The control of grain flow and grain size during forging depend on the sequence of forging operations as well as forging temperature and reduction. [6]

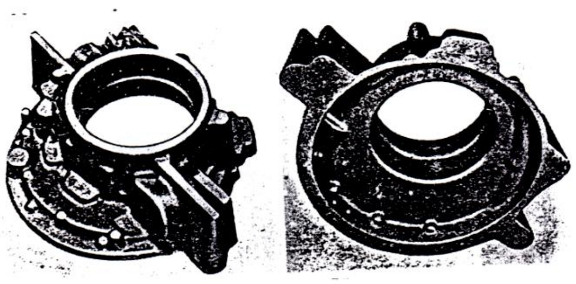

Figure 2. Two Views of Finished Aluminium Housing forging

Table 3. Effect of temperature on load, pressure and percentage of reduction for Turbine Disc Material

No: of Step	Material Used	Forging Tempe-rature	Forgi ng load	Frogi ng press ure	% of red-uctio n
1.	A-286 alloy Turbine Disc Material	1800ºF	130lb	49psi	50%
2.			110lb	48psi	40%
3.			100lb	47psi	30%
4.			90lb	47psi	20%
5.			80lb	44psi	10%
1.	A-286 alloy Turbine Disc Material	2000ºF	100lb	35psi	50%
2.			80lb	30psi	40%
3.			65lb	30psi	30%
4.			60lb	29psi	20%
5.			53lb	28psi	10%
1.	A-286 alloy Turbine Disc Material	2200ºF	80lb	30psi	50%
2.			65lb	25psi	40%
3.			58lb	24psi	30%
4.			50lb	23psi	20%
5.			40lb	20psi	10%

Production of an Aluminium-alloy Housing

A large number of aircraft parts are forgings made of strong and light aluminium alloys. The finished housing is approximately 14.25 inches in diameter and 5.5 inches in height. Aluminium alloys have excellent forge ability and have higher strength to weight ratio compared to steel forgings. Aluminium alloys are used where temperature environment does not exceed 200ºC. Besides the advantages high strength to weight ratio and lightness, aluminium alloys are quite ductile and forgeable to be readily formed to precise, intricate shapes.

The most significant reasons for these are, (1) alloys are ductile due to its basic F.C.C. structure, (2) they can be isothermally forged, (3) they do not develop scale during heating, (4) they require low forging pressures. A significant problem with heat treatable Aluminium alloy forgings is associated with the residual stresses imposed by quenching and sometimes by straightening just to adequately remove the residual stresses. [6]

Three different temperatures are described in table II. The study also shows percentage of reduction depends of forging temperature and forging load .At 2200ºFforging load is 80lb and forging pressure is 30psi give percentage of reduction of 50%. At 2000ºF forging load is 80lb and forging pressure is

30psi. The percentage of reduction is 40%. So, the study also shows the same load and pressure .The higher the temperature, the less the percentage of reduction.

Table 4. Effect of temperature on load, pressure and percentage of reduction for Aircraft Housing

No: of Step	Material Used	Forging Tempe-rature	Forging load	Forging pressure	% of red-uction
1.	6061 alloy (Aircraft housing)	900ºF	30lb	11psi	60%
2.			24lb	10psi	50%
3.			22lb	10psi	40%
4.			20lb	10psi	30%
5.			18lb	10psi	20%
1.	6061 alloy (Aircraft housing)	750ºF	58lb	20psi	60%
2.			45lb	19psi	50%
3.			39lb	18psi	40%
4.			35lb	17psi	30%
5.			30lb	16psi	20%
1.	6061 alloy (Aircraft housing)	600ºF	70lb	25psi	60%
2.			62lb	24.5psi	50%
3.			55lb	24psi	40%
4.			48lb	23psi	30%
5.			42lb	20psi	20%

Table 3 and 4 show the same percentage of reduction but higher temperatures give lower forging loads and pressures.

5. CONCLUSIONS

Low carbon steels are easy to forge and super alloys are difficult and have higher strength. After forging process, metals are stronger than other metals which are manufactured by other processes and also the forged metals have more shock and fatigue resistant and more durable than other un-forged products. Because of the forged metals have fine grain size and fibrous structure with highest strength, they may provide required properties with less weight. On the other hand, a forging process offers the cheapest mean for producing a component. The hammer forging method can be done at this Department. In this paper, three different types of materials are analyzed to determine the relationship between the forging temperature, forging loads and percentages of reduction. Forging process touch the industrial lives everyday. Industrial developments have direct effect on the standard of living today.

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