Comparison of various methods of sheet metal forming engineering essay

The report presented contains a comparison of various methods of sheet metal forming, that were used in the past, and that are currently being used in the automotive industry. The comparisons made show that over the year's sheet metal forming has changed a great deal, particularly in the automotive field. As the industry increases, with demand for more stream lined bodywork getting far more complex and challenging to produce, new methods are needed to meet client demands.

Sheet metal has had a prominent role in the development of the automotive industry. The year of 1923 was approximately the year when wooden body panels were replaced by steel metal. Steel metal body panels were first introduced by a United States automotive brand called Dodge, and this was when sheet metal forming made significant developments in the automotive industry.

Introduction

The work presented in this report resulted from the need to understand the various method used in sheet metal forming. Furthermore how sheet metal forming has changed over the years, and the benefits gained or in some instances lost due to these changes. The information collated in this report can further be used to differentiate what methods would be more suitable for specific jobs over others. In addition, research of the historical methods would be useful when looking at the future trends that can be expected and the advances in metal forming in the automotive industry.

Aims and objectives

Collate a list of various methods of sheet metal forming used in the automotive industry for both past and present.

Present the types of materials suitable for different forms of sheet metal forming.

Describe the advantages and disadvantages of these methods in terms of material wastage, accuracy, time, cost and finishing.

Make comparisons of past and present methods and introduce future methods which may be used.

Modern Sheet Metal forming In the Automotive Industry

Due to increased competition between car automotive manufacturers, many companies and their production manager are looking for more efficient and most importantly economically beneficial sheet metal forming methods, to produce various parts for their products. Nowadays even the smallest parts are manufactured by the companies themselves to take advantage of savings from manufacturing cost and the resulting increase in profits.

At present automotive plants form about 40 to 50 major body panels per model of car within their own manufacturing plant. Some of the major body panels produced in-house from sheet metal include; External panels such as fenders, bonnets, side panels and roof, Fig. 1. (SHARMA, Indra R., 2007)

Figure (http://www. drishtikona. com/books/automobile-manufacturing/ch5. pdf)

Materials used to produce these various parts vary with the type of methods used to form the sheet metal. However, they require specific properties to meet present automotive challenges, for instance reduced CO2 emissions, which can be achieved by using lighter metals resulting in increased fuel economy. Other properties used to compare various metals include there toughness and the ability to resist corrosion which impacts the long term reliability of the car. The preferred metal within the automotive industry is High Strength low alloy steels due to their low weight and high strength, below is a table which shows various steels and there yield strengths along with their application on the car, Table. 1.

Steels for Different Automotive Panels

Table (http://www. drishtikona. com/books/automobile-manufacturing/ch5. pdf)

Classification of sheet metal forming

Metal forming can be classified in terms of the type of applied stress, Fig. 2.

– forming under compressive conditions,

– forming under combined tensile and compressive conditions,

– forming under tensile conditions,

– forming by bending,

– forming under shear conditions.

Figure (1998. Metal Forming Handbook. 1 Edition. Springer. p. 7)

Closed Die Forming

Closed die forming consist of two or more dies or tools which are manufactured with a predetermined shape. The materials are heated up and pressed or hammered between the manufactured dies, Fig. 3. Due to its closer tolerances the accuracy of work produced is very high. In addition to this fewer errors in manufacturing also result in less material wastage as well as lower cost to produce the work pieces.

On the other hand the process is not every economical if it is only used in the short term as the initial cost of producing the dies are high. Furthermore the costs of special building provisions, due to the vibrations caused when manufacturing are also high.

The types of material used in open die forming usually consist of varying steel such as carbon steel, steel alloy and aluminium alloy. This process is commonly used in the automotive industry in producing alloy wheels. (SPRINGER, 1998)

Figure (1998. Metal Forming Handbook. 1 Edition. Springer. p. 8)

Deep drawing

Deep drawing is a method of forming were the metal sheet otherwise known as a blank is placed over the die and a punch is pressed on the blank making it form around the die without reducing the thickness of the sheet metal, Fig. 4. This method is especially beneficial when producing high volumes as the

cost per unit decreases considerably once the dies have been created, the process can continue with little downtime or maintenance. In addition to this large quantity can be produced in short periods of time in comparison to the amount of labour needed to produce work pieces manually.

This method also benefits from a wide range of metals that can be subjected to the forming process such as aluminium, brass and copper. This process is commonly used to produce fuel tanks in the automotive industry. (SPRINGER, 1998)

Figure (1998. Metal Forming Handbook. 1 Edition. Springer. p. 12)

Stretch forming

Stretch forming is a method of forming typically used in forming sheet metal, were the work piece is held in mechanical vices at either ends. The sheet metal is then stretched and simultaneously bent over a die of a specific shape, Fig. 5. (SPRINGER, 1998)

Some of the advantages of this method include the fact that approximately 70% less force is needed then that required in conventional press forming which results in lower running costs. Furthermore, material costs are reduced as much as 15% in comparison to other forming methods due to the material stretching and increasing surface area. (WALSH, Kenneth A., 2009)

However, this method of forming also has some drawbacks such as, it cannot form sharp contours and is restricted to forming near flat contours. In addition to this the process is also relatively slow as the metal has to be stretched gradually or fracturing could occur. The other downside to this

method of forming is that further equipment may be required to test tensile strengths to control the strain required on individual pieces to producing work pieces with uniform results. (SEMIATIN, S. L., 2009)

This type of forming is widely used in many industries particularly in the automotive industry in producing and shaping car body panels. The main reason behind this choice of forming to produce body panels is that during stretching deformation is uniform over the whole area whereas in other conventional types of forming stretching only occurs in the corners and very little in the centre areas. (SHARMA, Indra R., 2007) Materials used in stretch forming are high strength low alloy steels and aluminium alloys due to their ductile nature.

Figure (1998. Metal Forming Handbook. 1 Edition. Springer. p. 15)

Embossing

Sheet metal embossing is metal forming processes were sheet metal is pressed between two dies of which one is raised and the other sunken, Fig. 6. In most embossing operations one dies is stationary whilst the other is raised and pressed onto the sheet metal. (SPRINGER, 1998) The benefits of embossing include the ability to produce work piece with uniform results. Furthermore, the sheet metal also maintains its thickness before and after the process. Other benefits include the ability to form ductile metals.

The drawback of this process are the initial cost in producing the die, as two dies need to be created rather than just the one in other types forming.

The types of materials used in this process are usually ductile in nature. Some of the materials include brass copper and galvanised steel. (BRALLA, James, 1998)

Figure (1998. Metal Forming Handbook. 1 Edition. Springer. p. 16)

Hydroforming

Hydroforming is one of the modern methods of sheet metal forming used in the automotive industry. Hydroforming consists of fluid at high pressure which is used to press and form sheet metal against a die, Fig. 7. Hydroforming is widely used in the automotive industry due to its ability to form highly complex shapes, at a rate of approximately 60 to 180 parts per hour depending on the complexity of the shape. (SINGH, Harjinder, 2003)

Advantages include the fact that, hydroforming has significantly less material wastage then other methods of sheet metal forming, reduction of about 10%. In addition to this, the sheet metal is subject to uniform strain over the entire sheet as the fluid contacts only one side of it. Other benefits also included improved surface finish and lower cost to produce the dies. (SINGH, Harjinder, 2003)

Though hydroforming has many advantages over conventional sheet metal forming it also has a few drawbacks. The initial cost to set up hydroforming is very high and is not an economically good option in the short term. Furthermore, maintenance and upgrade costs are also significantly higher than other methods of forming. (Hydroforming In The Auto Industry, 2009)

Hydroforming is used by many car manufacturers to produce car body panels, such as GM, Ford, Chevrolet and Volkswagen. (Hydroforming In The Auto Industry, 2009)

Figure (http://en. wikipedia. org/wiki/Hydroforming)

Super plastic forming

Along with hydroforming, super plastic forming is also one of the modern methods of sheet metal forming and is in continuous development at present by companies such as Ford. The development of super plastic forming method is the result of the need for reduced vehicle weight. Whilst other methods such as stretch forming require high strength low alloy steels, aluminium can be used in super plastic forming, which brings a weight saving of as high as 55%. (FORD RESEARCH AND ADVANCED ENGINEERING, 2010)

Aluminium is less formable with other methods at room temperature which can result in restrictions on the exterior design aspect of the car. Furthermore, splitting the parts into smaller work pieces increases cost for separate dies and increased assembly line points. Super plastic forming removes these restrictions of the design of the car and allows complex shapes to be formed from the aluminium sheet. The process is achieved by applying gas pressure to the sheet of aluminium which is placed on a die.

As well as having the advantage of reduced vehicular weight it also bring the advantage of only needing a single one-sided die reducing the cost of production. In addition to this, the force required to form the sheet metal is considerably reduced when the temperature of aluminium sheet is raised. On

the other hand, this method of forming also has its downfalls. Super plastic forming has a relatively slow cycle time which varies from two minutes to two hours, and so it is only viable for short term production. (DEGARMO, E. Paul, 2003)

Electromagnetic forming

Electromagnetic forming is also another method of forming being continuously developed to form aluminium by automotive manufacturers such as Ford, GM and Daimler Chrysler. This method of forming makes use of electromagnetic forces to form specific parts of aluminium sheets.

Electromagnetic force is induced by a pulse of current from a capacitor passing through a coil, which is located in close proximity to the specific point which is being formed. The process generates a strong magnetic field around the coil and induces eddy current in the sheet. “ Eddy currents are currents induced in conductors, opposing the change in flux that generated them”. (Eddy Current, 2011) The eddy current in the sheet creates its own magnetic field which is of the same polarity as the field around the coil. The two magnetic fields generate sufficient repulsive force on the sheet of metal causing it to permanently deform.

Electromagnetic forming has many benefits over conventional methods of forming. The main advantage being that as an EMF is used there is no contact between the work piece and the tool, which results in a final work piece with no tooling marks and a near perfect finish. In addition to this the rate of forming are also very high and is only limited by the time taken to

load and unload the work piece. (Innovative Forming and Fabrication Technologies, 2007)

The disadvantages of this process are that as the forming process is relatively fast the material does not stretch. Furthermore, the forming process is limited to only forming thin sheets of metal as the methods is restricted to a maximum force of about 350MPa. (Innovative Forming and Fabrication Technologies, 2007)

Figure (http://www. matsceng. ohio-state. edu/~daehn/mahadevanthesis/tabofcont/ch2/Image1. gif)

Classical Methods of Sheet Metal Forming

Sheet metal forming came about several centuries ago and was used to produce many household items such as utensils and ornaments. The methods used in sheet metal forming progressed in the late 19th century along with the technological advances, mainly due to mass production of parts of weapons. Furthermore, in the early 20th century sheet metal forming played a prominent role in many industries, more so in the automotive industry in the production of car body panels. Described below are a few methods used by the automotive industry in the early 20th century.

Beating

Beating was one of the methods used to form sheet metal to produce car body panels in the early 20th century. Metal smiths would use a hammer and leather bags filled with sand or lead shots and beat the metal until the

desired shape was formed. The hammer marks left on the sheet metal would then be filled before being painted over.

Due to the continuous beating required it would often take a day or so to reach the desired result depending on the complexity of the shape. In addition to this, as the hammering was done manually it would have been difficult to get a uniform finish across the whole surface. (Coachbuilders, 2004)

Drop hammering/Power Hammering

Drop hammering consisted of a solid base which contained a fixed die and a lift able arm which also had a fixed die with the opposite shape. Sheet metal was placed on the base and the arm was raised by rotating a circular drum at the top of the machine, Fig. 1. The hammer was then dropped onto the sheet metal causing deformation; this method was later operated by steam power and was renamed to power hammer. The use of steam allowed heavier hammers to be used in forming, reducing the number of blows required to produce desired shape. (WOODWORTH, Joseph Vincent, 2008)

Operating a drop hammer was dangerous as workers would be positioning the sheet metal and the drop hammer would be accidently tripped dropping the die towards the sheet metal. In addition to this, as the Power hammer machines were operated with steam it would create a humid environment for workers to work in. The advantage of this type of forming in those days was that it allowed forming of sheet metal to be formed at a faster rate. (SMITH & ASSOCIATES, 2009)

Figure (Left) Drop Hammer (http://chestofbooks. com/crafts/metal/Sheet-And-Plate-Metal-Work/images/Drop -Hammer. jpg)

Figure (Right) Steam Hammer (http://www. oldbookillustrations. com/gallery/science/drop-hammer. jpg)

English Wheel

English wheel also known as a wheeling machine was a tool used extensively to form wheel fenders in mid-19th century and continues to do some to some extent. A typical English wheel consists of a C shaped frame with two rollers, the upper and lower roller. The upper roller has a flat cross section whereas the lower roller otherwise known as an anvil wheel has a domed cross section, Fig. 11. Sheet metal is placed between the rollers and stretched resulting in a thin curved sheet. (English Wheel, 2010) (ANDERSON, David L)

Though the English wheel is still used today in producing custom cars, the majority of mainstream manufactures which use it today, such as Rolls Royce for coach manufacturing and Lamborghini for custom made cars have switched to powered wheeling machines. Powered wheeling machines allow larger and thicker sheets metals to be formed. (Coachbuilders, 2004)

The advantage that this method bought was that it allowed sheet metal to be formed, tested and reformed until the desired shape was achieved. In addition, the sheet metal was free from any hammer marks which may be caused if using methods such as beating.

This method also bought drawbacks, for instance as the sheet metal was formed by hand the size of metal had to be small enough to be held by the

craftsman. Furthermore, in terms of design the craftsman would have to ensure the metal was not over stretched making the sheet thin which could compromise the strength of the metal. (English Wheel, 2010)

Figure (http://www. custom-choppers-guide. com/images/engshlishbw1. jpg)

Conclusion

Development of Sheet metal Forming

Sheet metal has been used in many industries to form various objects and parts, since the early 19th century. However, methods used to form the sheet metal have predominantly been developed due to the need to overcome challenges faced by the automotive industry.

In the late 18th century the choice of material used to form car body panels was plywood. Due to the exposure to rain water and lack of waterproof adhesive, manufacturers switched to sheet metal. The most used method to form sheet metal was by beating. However, this left hammer marks which had to be manually smoothed out or filled. This lead to increased cost in production and was only affordable by people who were financially well of. (A Technological Breakthrough, 2009)

To overcome the challenge of decreasing cost and increasing production new methods were developed such as deep drawing which gave a better finishing then panel beating and drop hammering. In addition to this the production rate was increased as panel beating was done manually by hand, it would have taken significantly longer to form then methods such as hydroforming,

which can produce approximately 60 to 180 parts per hour depending on the complexity of the shape.

Another challenge faced by automotive industry was the complexity of the shapes to form. There was an ever increasing demand for more stream lined attractive shapes. These would have been harder to produce with methods of beating which was restricted to small scale body parts. Methods developed for example stretch forming allow metals to be formed with uniform results across the whole metal. Furthermore, methods such as Super Plastic Forming give formed metals a clean finish.

These developments in sheet metal forming increased production which in turn reduced cost. More cars are sold know then back in early 19th century one of the reasons being the developments of methods of these sheet metal forming.

Future Trends

The automotive industry continues to develop sheet metal forming techniques to improve many aspects of cars. Car manufacturers know face the challenges to produce cars with better efficiency and lower CO2 emissions, one way of this is reducing the vehicular weight. Research is being carried out to form metals such as aluminium with faster turnarounds and reduced costs.