POSSIBILITIES OF USING HYDROFORMING IN AUTOMOBILE MANUFACTURE

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Abstract

The paper deals with the possibilities of using hydromechanical drawing in car production. The article describes the basic methods used in hydromechanical drawing, the advantages and disadvantages of hydromechanical drawing, and the application possibilities of hydromechanical drawing. Hydromechanical drawing in the manufacture of car body parts is described in more detail, there are also practical examples of the use of this technology and the reasons for such use.

Key words: hydromechanical drawing, tube hydroforming, hydroforming, car production

INTRODUCTION

The hydromechanical drawing technology (hydroforming) is one of the progressive technologies of mechanical engineering. The hydromechanical drawing process works on the basis of the action of liquid pressure on the sheet metal blank, where the pressure of the liquid gradually forms the material into the desired shape [1]. Fig. 1 shows a scheme of a hydromechanical drawing.

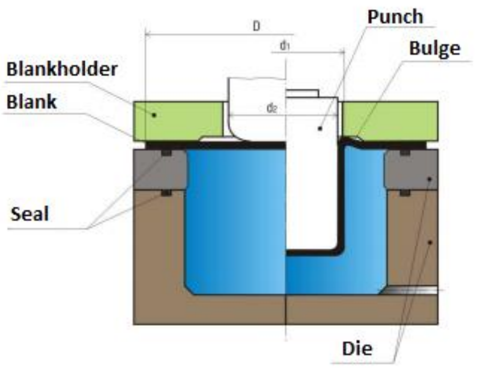

Fig. 1 Hydromechanical drawing [2]

The process of hydromechanical drawing is based on the principle of hydroforming, which was patented by Fred Leuthesser and John Fox in the 1950s in the state of Ohio. They used this technology to make faucets, the advantage of this technology was the strengthening of the steel as well as the lower surface roughness, which reduced the cost of finishing [3].

Toyota began experimenting with hydromechanical drawing in automotive manufacturing in the 1980s. The main reason for starting the research was the significant advantages of hydromechanical drawing compared to conventional drawing, these advantages are:

- wide use of hydromechanical drawing in low-series production of difficult-to-form materials such as magnesium and aluminum alloys, high-strength steels,
- pressure control prevents changes in the thickness of the formed blank,
- the use of only one rigid part of the tool reduces the friction between the blank and the tool, which results in better surface quality, a lower number of failures,
- lower costs for the production of the forming tool, due to the use of only one solid part of the tool.

The use of hydroforming is limited mainly by the following two reasons:

- relatively long process time,
- lack of experience, information in the field of hydromechanical drawing in comparison with conventional drawing.

Despite these shortcomings, hydromechanical drawing has received attention in automotive manufacturing, namely for the following applications:

- forming of difficult-to-form alloys of aluminum and magnesium, high-strength steels,
- low series, and prototype production [4].

Toyota used the research gained in the production of the front fender and hood for the Toyota Sera in 1994. A new Toyota Flexible Press System was designed for production, which reduced the number of operations from five to three operations, resulting in reduced production time and cost savings. The number of operations has been reduced using advanced technologies (hydromechanical drawing, CNC-controlled laser, and multi-press technology). This system can be seen in Fig. 2 [4].

At present, hydromechanical drawing in the automotive industry is used for the production of chassis parts, exhaust pipes, support frames, body parts made of steel, aluminum, and magnesium alloys, in the production of

A and B pillars made of high-strength steels. Hydromechanical drawing is also used in the production of bicycle frames, musical instruments, faucets, parts of gas pipelines, etc. [5]

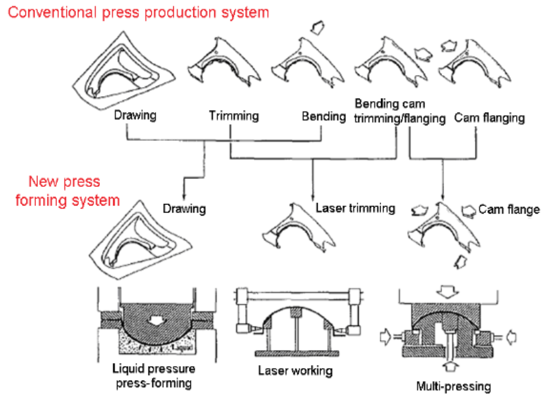

Fig. 1 Toyota Flexible Press System [4]

Reducing part weight, shortening production times, reducing tool production costs, reducing part production costs, better formability of high-strength steels, aluminum, and magnesium alloys, higher dimensional accuracy, and increased strength of hydromechanically drawn parts are among the main advantages of this advanced technology. Hydromechanical drawing research is currently being carried out mainly at universities in the USA and Germany [5].

In this paper production technology of hydromechanical drawing and its application in the automotive industry is presented. Mainly its use for the production of car body parts made of tubes and sheet metal is described.

HYDROMECHANICAL DRAWING WITH PUNCH

In the hydromechanical drawing with the punch, the die is replaced by a pressure chamber (pressure pot). The blank is pulled deep by the punch; the backpressure of the liquid ensures the deformation of the blank on the surface of the punch (Fig. 3).

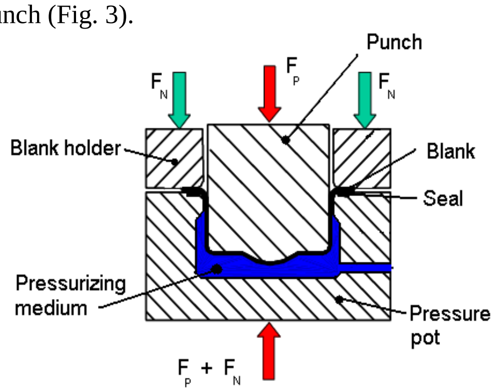

Fig. 3 Hydromechanical drawing with punch [4]

The fluid in the pressure chamber can be pressurized "actively", i. external source, or "passively". Passive pressurization of the liquid takes place when the blank is pulled by the punch, the pressure of the liquid is controlled by a throttle valve, this valve allows releasing a part of the liquid, thus reducing the pressure in the pressure chamber [4].

This method is mainly used for the production of sheet-metal car body parts namely fenders, hoods, and B-pillars.

HYDROMECHANICAL DRAWING WITH DIE

In hydromechanical drawing with a die, the blank is deformed by the pressure of the fluid against the die, in this case, the fluid replaces the punch. The scheme of this process is pictured in Fig. 4. During shaping, the holder ensures that the cut flange remains in place and also helps to seal the tool [4].

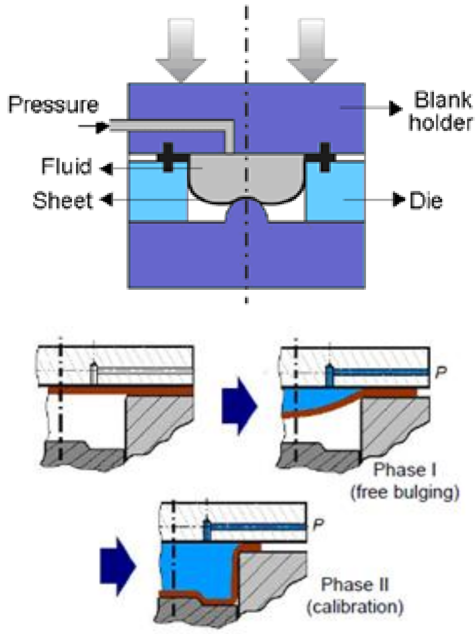

Fig. 4 Hydromechanical drawing with die [4]

This method of hydroforming has many applications. For example production of airplane sheet-metal parts, car body parts, car suspension parts. It can be also used in the production of sheet metal parts used in the construction of modern public buildings.

FLEXFORMING

Flexforming (Flexform) (Fig. 5) is a method of forming sheet metal blanks, where the punch is replaced by a rubber membrane that is subjected to fluid pressure. The blank is located on a rigid part of the forming tool; this part defines the future shape of the part. The fluid pressure compresses the membrane into the forming cell. The rubber diaphragm "wraps and presses" the blank onto the solid part of the tool, thus achieving the desired part shape [4].

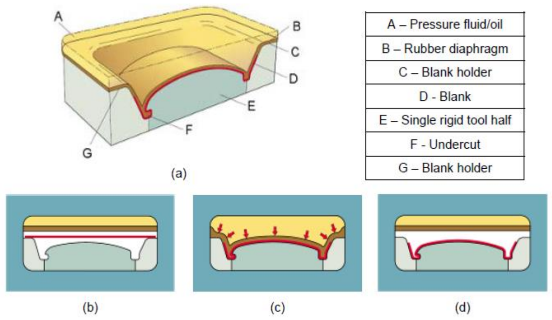

Fig. 5 Flexforming technology [4]

The Flexform fluid cell method was developed by ASEA (ABB, Sweden). Thanks to the flexibility of the rubber membrane, parts with sharp edges and blanks with different initial thicknesses can be formed. The Hydroform method, developed by Cincinnati Machine tools, and the Wheelon method, developed by Verson in Chicago, is fundamentally similar to the Flexforming method [4, 5].

TUBE HYDROFORMING

The shaping of the tubes is performed utilizing a liquid by hydromechanical drawing, where the liquid acts directly on the metal tube (Fig. 6). The piston, which engages in the tube, acts on the liquid and expands the tube. An evenly distributed pressure acts on the tube, thus ensuring an even thickness of the tube walls. Even complex stampings can be produced by hydromechanical tube drawing [4].

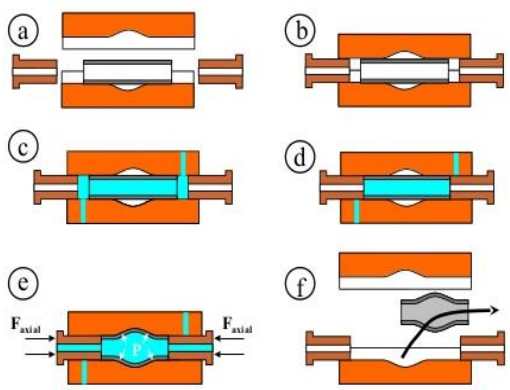

Fig. 5 Tube hydroforming [4]

Formable semi-finished products (brass, copper, aluminum, low-carbon steel, and alloyed steel) are used as a material in the production of parts by tube hydroforming. The recommended elongation of the starting material should be at least 15%. Mainly seamless pipes are used, but welded can also be used if the weld is placed in a less deformed part of the stamping [6].

This technology has been applied for the production of musical instruments, faucets, car-body stampings, suspension parts, frame parts, etc.

USE OF HYDROMECHANICAL DRAWING IN THE MANUFACTURING OF CAR BODYWORK

Hydromechanical drawing of sheet metal blanks is slower than conventional drawing because it takes some time to achieve sufficient fluid pressure, also filling and emptying the chamber takes time. For this reason, hydromechanical drawing of blanks is more suitable for small-lot production (5 to 40 thousand vehicles per year) [4]. Such vehicles included the Pontiac Solstice, in which the hydromechanical drawing was used to make body parts (Fig. 7).

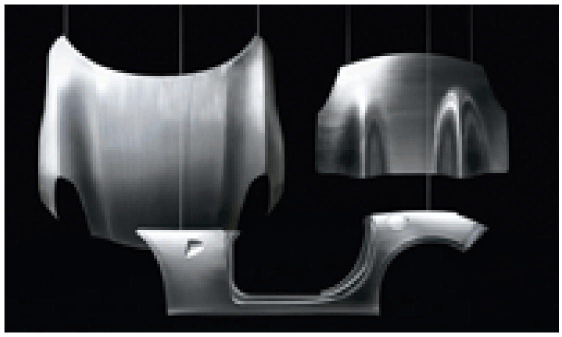

Fig. 7 Pontiac Solstice car body parts made by hydroforming

The use of hydromechanical drawing in the production of body parts has allowed designers to design such body parts that could not be produced by conventional forming technologies, or their production would be uneconomical. Another advantage of using hydromechanical drawing was the reduction in the number of operations for the production of car body parts. The side panel of the Pontiac Solstice is made by hydromechanical drawing in three operations, for comparison, in a conventional drawing, it would be five operations. Doors, hood, and trunk lid were also made using hydromechanical drawing [7].

USE OF TUBE HYDROFORMING IN THE MANUFACTURING OF CAR BODYWORK

Ford Motor Company was the first company to produce hydromechanical drawing for the production of steel A and B-pillar parts. They use this technology in the production of the Ford Mondeo.

A new technology was used in the production of the A-pillar and the side roof frame (Fig. 8) of the car. The change of the design of the A-pillar and using hydromechanical drawing of tubes instead of conventional pressing technology, it saved weight (2.1 kg), production and material costs, reduced material consumption and increased passive car safety in the event of an impact [8]. They also used this technology in the production of the B-pillar made of high-strength steel.

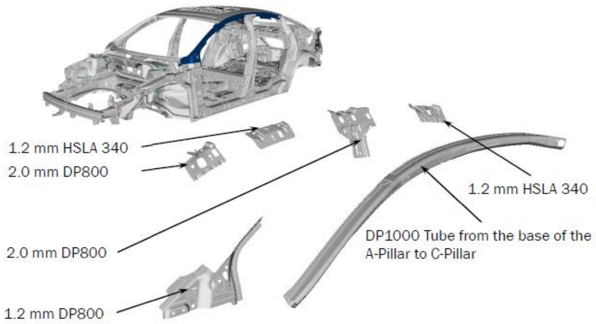

Fig. 2 A-pillar and side pillar of Ford Mondeo made by hydroforming [8]

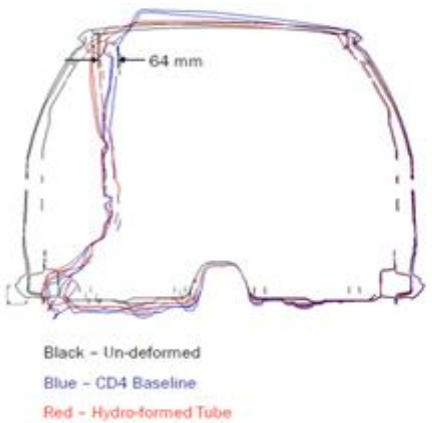

Fig. 9 Comparison of side impact results [8]

The technology of hydromechanical drawing of pipes (tube hydroforming) was used in the production of the B-pillar. This technology has allowed engineers to significantly reduce the weight of the pillar by 6 kg compared to the original solution, as well as reduce the cost of its production. The high strength of the B-pillar is ensured by the use of hydromechanically formed tubes made of dual-phase steel DP 1000, which allows better absorption of the side impact than the original blanks (Fig. 9), the strength in the upper B-pillar section increased several times. Another element that improves the strength of this pillar is the use of laser welds instead of MIG welding technology and spot welding [8].

CONCLUSIONS

The paper presents information in the field of hydromechanical drawing and its application in automotive production. The methods of this technology are presented here, as well as practical examples of the use of this method of production by several car manufacturers.

By using hydromechanical drawing, it is possible to reduce the number of operations for the production of parts, reduce costs, the weight of car parts, and increase the geometric accuracy of stampings. Limiting factors of hydromechanical drawing may include a longer working cycle, as well as a lack of experience, knowledge in the field of hydroforming compared to the conventional stamping.

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