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# A REVIEW ON SHEET METAL RUBBER-PAD FORMING

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## ABSTRACT

*In this study is presented a systematic analysis of already published works on the field on sheet metal rubber-pad forming. This analysis consists on a comparative approach about different methods used in metal forming processes. During last year's different technologies were developed and studied. New approaches and research directions were identified. Using new materials for punches and dies the metal forming processes become more and more competitive from cost point of view and also they are in trend with aerospace and automotive industries which use the knowledge to improve their products and their cost reduction/saving strategies. This overview of the actual status of the researches developed in sheet metal rubber-pad forming provide a basis for future work and futures development projects.*

**KEYWORDS:** rubber-pad, sheet metal forming, forming process, techniques.

## 1. INTRODUCTION

In the economical actual environment, automotive, aerospace and defence industries established their objectives in order to improve the quality of their products and the fiability, in the same time the cost management strategies and projects are considered. In order to achieve these targets all industries aim to modernise their technologies by defining and implementing different investment programs and also by implementing the research results.

In these industries one of the most important process is the sheet metal forming which have influence on different aspects of production such as the process cycle time and the quality of the final products. Upgrading these technologies will lead to optimize the cycle time and production costs and also to decrease their effect on the environment by minimise their carbon emissions.

For the new forming tool different materials are used instead of the classic materials. One of these is the rubber who replace the active elements of the dies.

In recent years, numerous studies on the issue of sheet metal rubber-pad forming have been developed. The forming process using rubber-pad is largely used in automotive and aerospace industries to manufacture small depth cups. Also the process is used in prototype phase or to manufacture small batches [1].

Rubber pad forming [2] highly improves the formability of the blank because the flexible contact between the rigid die and the rubber pad.

The implementation of this process have the advantage that using rubber-pad and high hydrostatic pressure the forming process is more stable due to the fact that this pressure is applied in a uniform way on the blank surface, this lead to small local thining areas due to over-stress of the material and also to a more favourable stress for the forming process [3].

The parameters that can influence the forming process can be: material parameters; geometric parameters; process parameters (rubber hardness, rubber type and elasticity).

This study presents a systematic analysis of the current status of already published research on the subject.

The paper is organized as follows: section II provides a literature review related to the rubber-pad forming and there are presented the advantages and disadvantages for this process. In section III are presented the forming methods with rubber-pad forming by specific processes. In sections IV is developed a critical review of sheet metal rubber-pad forming parameters, as reflected in the published research up to date. Finally, section V presents the study's conclusion and future research directions.

## 2. RUBBER-PAD FORMING PROCESS

Rubber-pad forming dates from the second half of the nineteenth century. In 1872, Adolph Delkescamp employed rubber pad for cutting and shearing thin sheets. Fred C. Cannon used rubber over metal dies to eliminate scratching of the work piece surface during forming in 1888. In 1912, Leonard Beauroth used a rubber bulging technique to form metal barrels. Friedrich Hamptemeyer used rubber-pads for formed the dental plates in 1922 [4].

Rubber-pad forming process is a versatile sheetmetal fabrication process used in commercial automotive and aerospace application, where the sheet metal is pressed between a rubber punch and a die. In the industry the sheet metal forming is the most important technology. The sheet metal and rubber are deformed under the pressure into the rigid die, forming the part. To eliminate scratching of the sheet surface are used the rubber-pads on metal die during forming process. She has a general purpose shape, like a membrane, or can be machined in the shape of die or punch.

The rubber-pad forming is similar with a deep drawing method, and is ideally suited for the production of small and medium-sized series. In deep drawing you get benefits in terms of function integration, weight reduction, cleanability and such but the tools are expensive which is a disadvantage

In the forming process with rubber, the equipment is composed from two dies. An elastic upper die, usually made of rubber, wich is connected to a hydraulic press and a rigid lower die, a form block, which gives tthe form of the sheet metal [5].

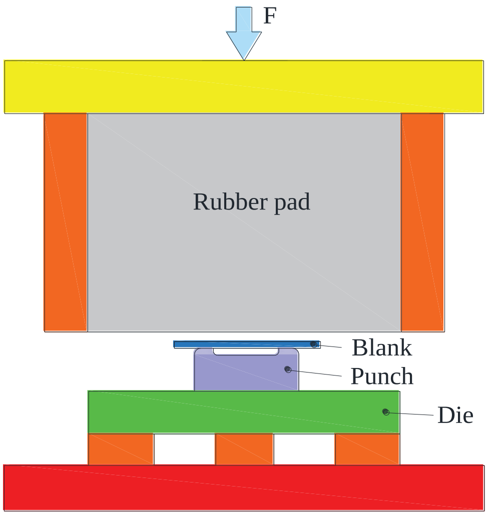



**Fig. 1.** *Schematic representation of rubber-pad forming process [5]*

The upper die can be used with different lower dies, thus the process is relatively cheap and flexible. Dies do not wear as fast as in conventional processes such as deep drawing. However, rubber die exert less pressure in the same circumstances as rigid dies.

The advantages of rubber pad forming process are: *i)* the rubber does not damage or scratch the sheet metal; *ii)* is not necessarily the accurate and the time consuming; *iii)* in one process cycle can be formed any of shape; *iv)* over the surface of blank to apply uniform pressure; *v)* the tools can be made of low cost and easy to use materials; *vi)* to manufacture of sheet metal that require only one punch.

However, the rubber pad formed process has certain disadvantages such as: *i)* the press must provide a high pressing force; *ii)* in the absence of sufficient forming pressure, the parts may require further processing; *iii)* require long time and large force; *iv)* this process can not be used at high temperatures due to the limited temperature range in which the rubber can be used [6].

## 3. CLASIFICATION OF RUBBER-PAD FORMING PROCESS

There are many processes such as Guerin process, Maslennikov's process, Marform process, Demarest process, Verson-Wheelon process, Verson Hydroform process and SAAB process which using rubber pad forming. These processes are being discussed in brief in following section.

*The Guerin process* was named after Henry Guerin, a head of the department of Douglas Aircraft California, the USA. The late 1930s he discovered the technique of using rubber as the half die instead of metallic part. This process is commonly used to form short runs of light metal parts. Using this process, complicated components such as aircraft panels and automobile panels are produced [7].

The Guerin process is considered to be one of the oldest and most simplest rubber pad forming process [7]. Using this process can be shallow drawn aluminum alloys, austenitic stainless steels and titanium alloys [7].

In this process, the pressure produced is ordinarily between 6.9 and 48 Mpa and the minimum pad thickness is 30 percent bigger than the height of the blank, and generally varies from 150 to 300 mm. The rubber pad is made of soft elastomer (50-75 Shore hardness) [8]. In figure 2 is shown the schematic diagram of this process.

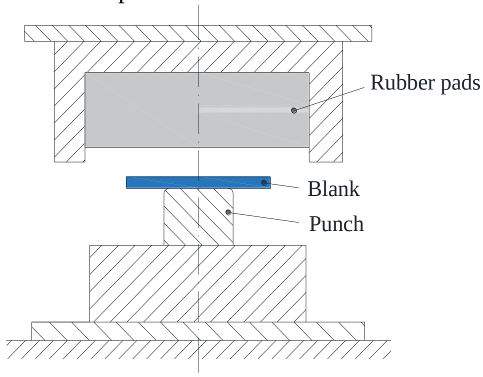



**Fig. 2.** *Guerin process [8]*

Another application of the Guerin process is shown in figure 3, here is used of rubber pad as low-cost die for press brake forming. At the bottom of the die are insulated the pads in order to form sheet metals of various thicknesses to V-section and U-section.

The defections of the pad due to the punch penetration exerts forming pressure around the punch. This rubber pad will assume the shape of the punch at the bottom of the stroke and the pad resumes its initial shape when the pressure is released.

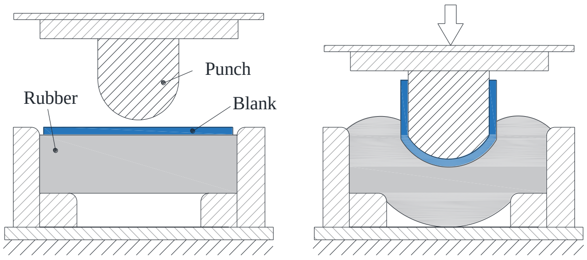



**Fig. 3.** *U-bending of sheet metals using rubber pad forming process [8]*

*The Maslennikov's process* is similar with a deep drawing technique that uses an ring rubber pad to draw very deep cups [9].

In figure 4 is presented the schematic of this process.

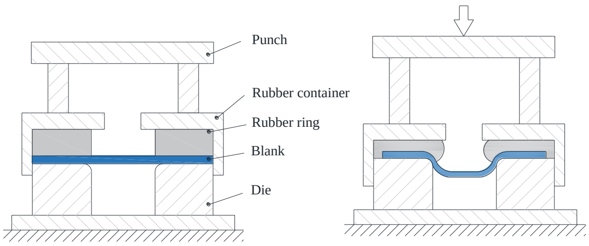



**Fig. 4.** *Schematic of Maslennikov's process [9]*

In paper [10], has been carried out an analytical analysis and FE simulations of Maslennikov's process to investigate the process variables and deformation mechanism. The authors are used a new friction model which allows the determination of coefficient of friction between the rubber/metal as a function of local contact conditions such as roughness, rubber characteristics, and contact pressure. The results obtained from analytical analysis are compared with the results obtained by FE simulations are carried out.

*The Marform process* (figure 5) was developed by Glen L. Martin Company in the USA, is a refinement of the Guerin process which features the addition of a blankholder and a die cushion to make the process suitable for deeper draws and to alleviate the wrinkling problems common to the Guerin process [11]. In this process, the rubber pressure used ranges from 34 to 69 Mpa, and the rubber pad used is similar to the one used in the Guerin process [11].

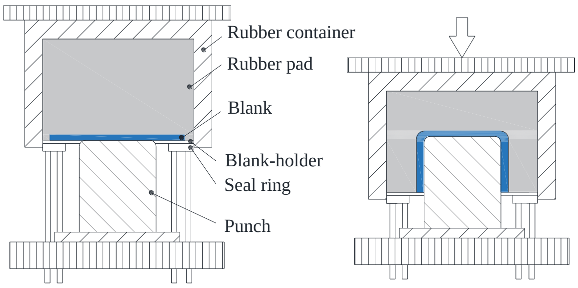



**Fig. 5.** *The Marform process [11]*

In this process, compared to the Guerin process, the tool includes a rigid blankholder supported by a hydraulic actuator equipped with a valve controlling pressure.

In paper [12], has been carried out an analytical analysis by finite element (FE) simulations to investigate the effect of the key process parameters on deep drawing of sheet metals using the Marform technique. The authors are presented also a new friction model for rubber/metal contact similar with [10]

*The Demarest process* was developed particularly to form axisymmetric shapes from cylindrical or conical semi-finshed products. Cylindrical and conical parts can also be formed by a modified rubber bulging punch [4].

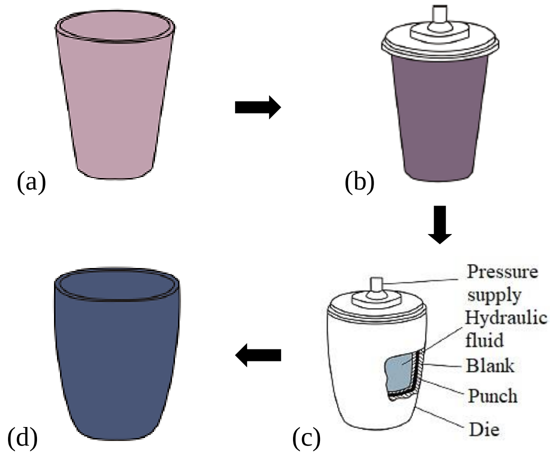



**Fig. 6.** *The Demarest process, (a) blank; (b) rubber punch; (c) punch and die assembly; (d) completed workpiece [4]*

*The Verson-Wheelon process* was developed initially by the Douglas Aircraft Company in the US, uses a comparatively lighter press with an inflatable rubber bag. Special presses for this process are developed and marketed by Verson Allsreel Press Company in the USA.

The blanks are placed over simple male dies, similar to those used in the Guerin process. This process is designed to formed small parts but sometimes also to formed large parts, using a rubber-pad as a die, which is used in the aircraft industry. In this process is used a 60-70 mm thick rubber pad.

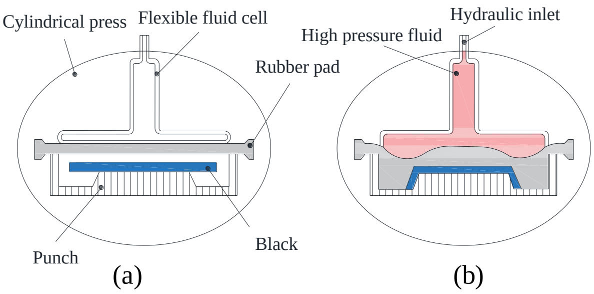
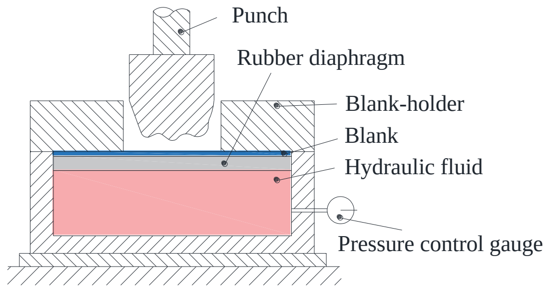



**Fig. 7.** *The Verson-Wheelon process, released position, (b) forming position [11]*

*The Verson Hydroform process* is different to the other rubber pad forming processes because she has is the fact that the die cavity is not filled with rubber but with hydraulic fluid. This cavity is termed the pressure dome. In this process it is used a 60-70 mm thick rubber diaphragm, this is put between the fluid and the sheet metal. For this process is used a special press, called a Hydroform press. In figure 8 shows the schematic details of this process.



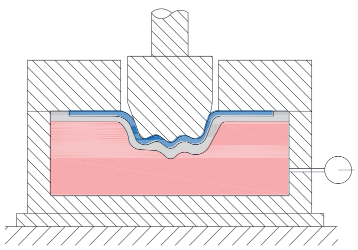



**Fig. 8.** *The Verson Hydroform process [11]*

In paper [13], is presented a numerical simulation of the Verson rubber pad forming using a 2D axisymmetric approach in LS-DYNA software package. For simulation the author used a Inconel 625 and DX56D galvanized sheet metal blanks with the support of four rubber pads.

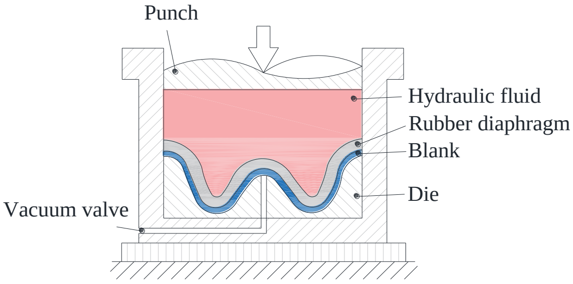



**Fig. 9.** *The SAAB process [11]*

*The SAAB process* was developed in 1950 by the Swedish aerospace company. This process is illustrated in figure 9, which uses a flexible diaphragm punch which assumes the shape of the die.

## 4. PARAMETERS ANALYSIS OF THE RUBBER-PAD FORMING PROCESS

During the last years, a large number of researchers analyzed the problems related to formed process using the rubber pad.

In the paper [14], the authors analyzed and simulated by finite element analysis the rubber-pad forming process in a stamping of aluminum sheet metal with soft punch. They investigated the effect of some important process parameters like hardness of rubber, type of rubber on the variation of the thickness, the springback and damage of aluminum sheet metal [14]. During flexible forming operation an elasto-plastic constitutive model with J2 yield criterion and mixed non-linear isotropic/kinematic hardening coupled with Lemaitre's ductile damage for the aluminum blank has been adopted [14]. In the finite element simulation is used a Mooney-Rivlin theory for to model the hyper-elastic behavior of rubber .

In order to reduce the CPU time in the simulation of the rubber-pad forming process is used an axisymmetric finite element model (figure 10). The rubber is contained in a retainer which will be moved against a die with 5 mm depth by the punch in order to form the blank of diameter 40 mm and thickness of 1 mm.

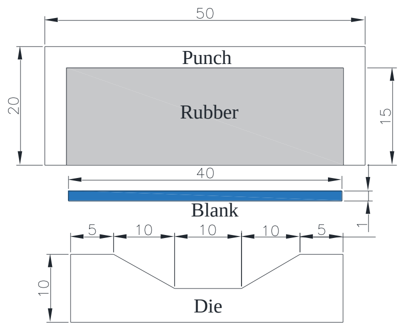



**Fig. 10.** *Schematic of rubber-pad forming [14]*

Chen et al. studied in [15] the wrinkling in shrink flanging obtained by rubber forming process with orthogonal experimental design and simulation. This paper is motivated by the need of using advanced sheet metal forming processes in aluminum aircraft sheet applications. The authors has analyzed four effect factors: die radius, the flange length, die fillet radius and forming pressure and used as three alloy materials: 2024-O, 7075-O, 2024-T3 [15].

A diagram of a shrink flange shows in figure 11.

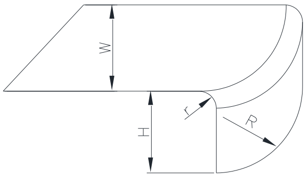



**Fig. 11.** *Scheme of shrink flanging [15]*

In figure 12 is shows the blank shape for shrink flanging.

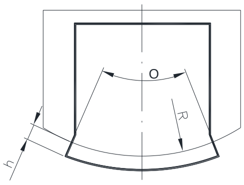



**Fig. 12.** *Blank shape [15]*

In [16] was carried out a finite element simulation of the rubber-diaphragm forming process for an aluminum alloy sheet aircraft component. Aluminum alloy (AA) 2024-O is widely used in various industrial applications and especially in the manufacturing of aircraft components. In your paper was studied AA 2024-O material with 1.27-mm (0.05-in.) thickness. The authors have studied the effects of the process and material parameters such as friction and the ductile fracture modeling. They have constructed an elastoplastic constitutive models of an aluminum alloy sheet with an anisotropic yield function and ductile fracture criteria and a hyperelasticity model of rubber materials that exhibit nonlinear stress–strain behavior under large deformation.

The process of rubber-diaphragm forming is described in figure 13.

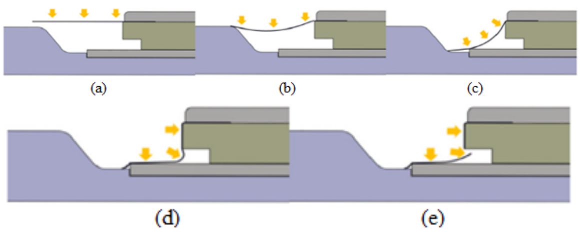



**Fig. 13.** *Process of rubber-diaphragm forming [16]*

In figure 14 shows the die for rubber-pad forming, the shape of the blank sheet, and the final product.

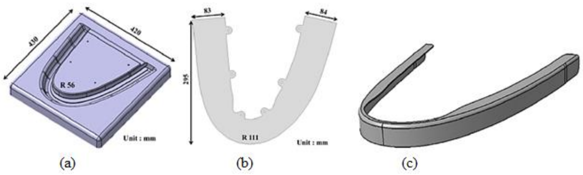



**Fig. 14.** *(a) Die for rubber-diaphragm forming; (b) the shape of the blank sheet; (c) final aircraft component [16]*

Sun et al. have investigate in [17] the wrinkling of the Ti-15-3 alloy sheet during the Fukui’s conical cup forming test. Utilizing the foundational problems with commonness in the simulation of conical cup, wrinkling behavior in the convex flange manufactured by rubber forming was predicted. The authors was employed the rubber forming, with a rubber pad contained a rigid chamber, to stamp the Ti-15-3 alloy sheet component. The component has a convex flange, and the geometric of the flange is with convex radius of 140 mm, bend angle of 90° and circumferential angle of 94°. The schematic diagram of the experimental set-up is shown in figure 15.

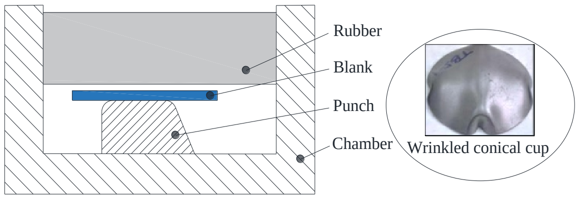



**Fig. 15.** *Schematic representation of experimental set-up [17]*

In [18] the authors explored the rubber forming process of an aluminum alloy aeronautic component using the numerical simulation and investigated the significant parameters associated with this process, have been taken into account several effects, depending on some parameters like part geometry, stamping strategy and rubber pad properties. Using commercial finite element software, the authors aims at simulating the rubber pad forming process, interesting considerations can be made on the influence of process variables on the product/process performance.

The rubber pad forming process requires: a rubber filled chamber, a blank and a punch (figure 16).

The advantages of the process are: *i)* the flexibility of operation, *ii)* embossing of simple or moderately complex parts, *iii)* the capability for drawing, *iv)* bending, *v)* low tooling costs, *vi)* the protection of sheet surface by rubber.

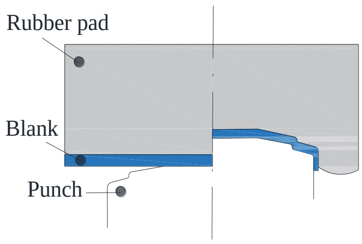



**Fig. 16.** *Rubber Pad Forming (RPF) process schematization: flexible rubber die (rubber pad) and rigid tool (punch) [18]*

Tandogan et Eyercioglu in [19] applied the finite element method to investigate the fracture, thinning and effective stress distribution conventional forming type is also analyzed to compare the formability of sheet. They have used two types of shape for straight rib and a part of components of aircraft wing, they selected the aluminum sheet Al 1100 with 0.5 mm thickness and polyurethane rubber with 60A and 80A shore hardness as workpiece materials and flexible material, respectively. In their paper, they used a female dies are rigid and male dies for produced flexible material and the rubber pad forming was carried out by means of Guerrin process.

In figure 17 is presented schematically the straight rib die set was used in experiments. To prevent the flexible material flow to outside during pressing the authors utilized the silicone rubber and styrene butadiene rubber a die holder.

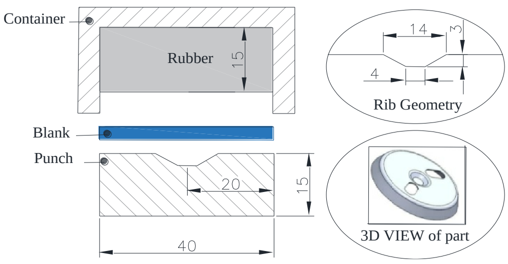



**Fig. 17.** *Schematic representation of straight rib die set [19]*

## 5. CONCLUSIONS

After analysing a large volume of papers published in field on sheet metal rubber-pad forming (not all included here, for reasons of space) one can draw the following conclusions:

The proposed approaches are extremely diverse and in the same time each has particular characteristics due to the kind of studied process and the scope of the used rubber pad forming.

Rubber-pad forming process is widely used in producing many parts for automotive and in special for aerospace applications.

Rubber-pad forming is suitable process financially and time consuming, because, it uses the half of die as a rigid.

Although the process is quite old, in the last two decades generated a lot of interest in the research community.

The rubber pad forming process has been shown to be capable of producing shallow formed parts with a reduced metal thinning from thin aluminum alloy blank.

Guerin process has remained the most understood technique.

Using this kind of forming process can be shallow drawn aluminum alloys, austenitic stainless steels and titanium alloys.

The process can be analyzed using finite element (FE) package, for an appropriate set-up of the process model.

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