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Quality Research of Metal Parts Produced by Cold Sheet Forming

Ieva MARKŪNIENĖ, Joris VĖŽYS**, Giedrius JANUŠAS*****
**Kaunas University of Technology, Studentų 56, 51424 Kaunas, Lithuania, E-mail: markuniene.ieva@gmail.com*
***Kaunas University of Technology, Studentų 56, 51424 Kaunas, Lithuania, E-mail: joris.vezys@ktu.lt*
****Kaunas University of Technology, Studentų 56, 51424 Kaunas, Lithuania, E-mail: giedrius.janusas@ktu.lt*
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1. Introduction

Sheet metal forming is one of the most popular technologies for obtaining finished products in the automotive industry. These methods are mainly focused on the improvement of the formability of materials, production of complex-shaped parts with good surface quality, speeding up of the production cycle, reduction in the number of operations, and the environmental performance of manufacturing [1].

Cold deformation of metals changes their physical, chemical, and mechanical properties. As the deformation increase, the hardness, strength, brittleness increase, but the plasticity and electrical conductivity decrease, the corrosion resistance. Hardening of many non-ferrous metal alloys is the only reinforcement method. Cold deformation results in precise dimensions and a high-quality surface [2].

Sheet-metal forming processes are used in mass production. Parts made from sheet metal have many attractive qualities [3]: good accuracy of dimensions, adequate strength, lightweight, and a broad range of possible dimensions Plastic deformation of metal causes not only the change of shape and sizes of billet during the process of cold plastic working but also the change of physical-mechanical as well as chemical properties of the metal [4].

In the review, talk about metal damage and deformation, surface damage, talking about metal chemistry structure recommendations, and other recommendations in the production way. This experiment aim is a qualitative evaluation of metal in search of the causes of metal damage. This work tasks: to review the quality of the surface of the manufactured parts, to measure it with a contour graph, as well measure limit parameters of the part and compare it with the drawing, and also to analyze the composition and impact on existing damage and to provide conclusions and recommendations. This experimental in this research is a novelty to look at metal damage reasons.

2. The main techniques of sheet metal forming

The sheet micro-forming process is recognized as one of the most efficient processes for producing micro parts from sheet metal. In this process are used rubber pad micro-forming, the rubber pad is compressed and formed to push the blank into the die cavity. In this method, only a single rigid tool is needed, and it avoids the punch cavity misalignment problem [5].

Warm forming is usually carried out at the melting temperature of the metal. It is important to distinguish warm forming from hot forming. In hot forming, the temperatures exceed the melting temperature of the material and this allows simultaneous recrystallization, which controls the refinement of grain size. In this way, warm forming improves the formability of material by lowering the yield stress [5].

The hot stamping process involves heating a steel blank in a furnace above the austenitization temperature material is transferred to a press tool where it is formed and subsequently quenched [6].

In incremental sheet, forming a sheet metal blank is simply clamped with the help of a blank holder and a tool with a hemispherical end incrementally forms the sheet into the desired shape. One surface of the drawing piece revealed small linear grooves because of the interaction of the tool tip with the workpiece [1]. The process uses a small generic tool under numerical control to create a local indentation in a clamped sheet and, by dragging; the point of contact around the sheet according to a programmed tool path, a wide variety of shapes may be formed without the need for product-specific tooling [7].

Flexible-die forming on sheet metal employs a pressure–transfer medium as a female die. The pressure–transfer medium can be polyurethane, oil, viscous medium, rubber, or compressed air. Flexible forming processes, like stamping, deep drawing, or bending, are widely used in the aircraft industry to deform difficult-to-form materials by a conventional deep drawing process.

A multipoint forming die uses reconfigurable matrices of pins, which can move normally to the die base to create the die surface. A reconfigurable tool consists of a large number of adjustable pins, the form of the ends of which define the specified shape of the part. The multipoint forming process is very flexible, permitting rapid changes in tool configuration to be accommodated without affecting tooling costs [8].

Electromagnetic forming is a kind of powerful and high-speed forming technique where the strain rate of the sheet metal is of the order of approximately. During electromagnetic sheet forming, a large electric current pulse passes through a conductive coil by discharging a capacitor bank [9].

When a capacitor bank discharges electrical energy, the energy is delivered to the fluid by two electrodes attached to the wall of the chamber, and this discharge creates high-pressure shockwaves. A very thin wire connects the tips of the two electrodes [10].

Apart from promising results regarding the feasible part geometries, this process allows a quite efficient production due, to its potential to reduce equipment expenses. It can be seen that when using electrohydraulic forming, an increase of discharge energy leads to smaller radii than achievable by quasi-static hydroforming [11].

Spinning is the shaping of a rotating disc or draws piece by applying local pressure using a spinning tool. A forming tool, in the form of a mandrel or a roll, can roll [13] or slide over the surface of the sheet. A characteristic feature of the spinning process is that the thickness of the sheet metal, from which the element is formed, changes within only a very small range.

In shear spinning forming, a sheet blank is formed by a roller into an axisymmetric part with a desired shape and thickness distribution [1].

To break through the limitation of traditional axisymmetric spinning, a discretization method is made to form an oblique cone by the die less shear spinning technique. Due to the characteristics of asymmetric spinning, the roller feed should harmonize with the spindle rotation, and the roller path is derived through a discretization method [12].

3. Cold stamping and metal deformation

Sheet-metal parts are usually made by forming the material in a cold condition, although many sheet-metal parts are formed in a hot condition because the material when heated has a lower resistance to deformation. Strips or blanks are very often used as initial materials and are formed on presses using appropriate tools. The shape of a part generally corresponds to the shape of the tool. Sheet-metal forming processes are used for both serial and mass production. Their characteristics are high productivity, highly efficient use of materials, easy servicing of machines, the ability to employ workers with relatively less basic skills, and other advantageous economic aspects. Parts made from sheet metal have many attractive qualities good accuracy of dimensions, adequate strength, lightweight, and a broad range of possible dimensions.

The cold stamping process is completed by using mold and stamping equipment. Compared with other processing methods, it has the following characteristics [13]:

1. The workpieces with complex shapes such as the shell parts can be obtained by the cold stamping method, which is hardly formed by other machine processing methods;

2. The dimensional accuracy of cold stamping is determined by the molds. Therefore, it has the advantages of dimensional stability and good interchangeability;

3. Because of its simple operation and low labor intensity, it is easy to realize mechanization, automation, and high productivity;

4. Because of its high material utilization ratio and its workpieces with lightweight, good rigidity, high strength, and low energy consumption, the cost of workpieces is rather low;

5. The structure of the mold used in the stamping process is relatively complex and the mold has a long production cycle and high cost. Therefore the stamping process is mainly used for mass production, and its application for single-piece and small-batch production is subject to restrictions.

The shaping process is a stamping process in which plastic deformation produces under the condition of no material cracking, and then the stamping parts with a certain shape, size, and precision are obtained.

Cold deformation of metals changes their physical, chemical, and mechanical properties. As the deformation increases, the hardness, strength, brittleness increase, corrosion resistance. Hardening of many non-ferrous metal alloys is the only reinforcement method, but it is undesirable for further deformation and cutting by cutting. Cold to restore the plasticity of the deformed metal applies recrystallization annealing, small grains without internal stresses and excess dislocations). Cold deformation results in precise dimensions and a high-quality surface.

The metals have a crystalline structure. As usual, metals consist of a great number of crystals of different shapes and sizes, which are called grains. Grains are combined between themselves as a single whole by the forces of inter-atomic bonds. Metals have the arrangement ordered and form a lattice (Fig. 1).

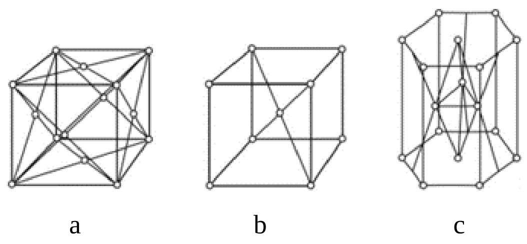

Fig. 1 Types of metals' lattices: a) face-centered cubic lattice; b) body-centered cubic lattice; c) c hexagonal cubic lattice [13]

The definite orientation of the crystallographic axes causes anisotropy of the physical properties of crystals. However, in the case of the disordered arrangement of grains in the metal volume, the physical properties at different directions are averaged and the body becomes as it was isotropic. Under the action of tangential stresses, the shear deformation in the cells of the lattice is taking place. In case if the value of atom displacement of one layer relative to the other one exceeds half of the inter-atomic distance, the transition of atoms to the new position of stable equilibrium is taking place, that is the transition of atoms becomes irreversible, the metal deformation will be residual – plastic. This mechanism of plastic deformation is called slipping. As usual, the slipping is going on simultaneously in many parallel planes, in which the connection the number of these planes is increasing as soon as the deforming force is increasing.

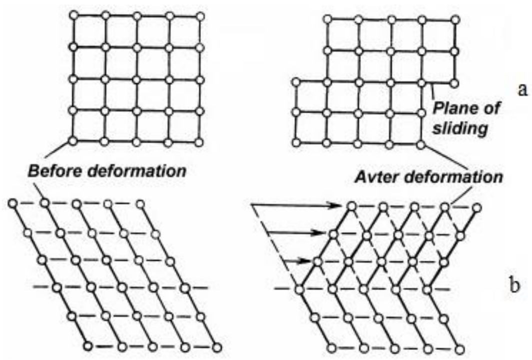

Fig. 2 Mechanisms of plastic deformation: a) slipping; b) twinning [13]

The sliding planes are those with the greatest density of atom distribution and the sliding is going on along the directions where the distance between atoms has the minimum value. The distortion of planes of sliding is taking place during the process of plastic deformation, which makes the deformation along with these directions more difficult, the new shears are originating in the new directions

(Fig. 2a). The second mechanism of plastic deformation is twinning, which presents the shear of the crystal part with the formation of mirroring of one part of the crystal regarding the other (Fig. 2b).

Plastic deformation of the metal causes not only the change of shape and size of the billet during the process of cold plastic working (stamping, drawing, thin sheet rolling), but also the change of physical-mechanical as well as chemical properties of the metal. The strength characteristics are increasing with increasing deformation degree and the plastic characteristics are decreasing [13].

4. Experimental setup

The following methods will be selected for the qualitative experiment: the parts were pressed with a Ravne cold stamping press, the stamp was inspected, the press was adjusted to the previous production. The second qualitative method chosen is the measurement of surface smoothness. The third method is to scan with a 3D coordinate scanner and compared it to the original drawing.

Used metal categories and standard: Quality: DC 01, Dimension in [mm]: 2,00 x 180,00, Standart EN 10131 / EN 10130. This metal is recommended use for cold sheet stamping.

The equipment used for the experiment and its specification is provided in Tables 1, 2 and 3. Table 1 is a cold stamping press Ravne VPS400 1992 specification. Table 2 is a Contourograph CV-2100 M4 specification. Table 3 is a 3D coordinate measuring machine specification.

Fig. 3 shows the original layout, which uses for the 3D measuring machine for comparison with the manufactured part.

Table 1

Specification code stamping press Ravne VPS400

Ravne VPS400 1992
Tonnage 400 to
Working area table: 2000 mm x 1400 mm
Sheet- Strip width -ca. 580 mm
Electric power: 81 kW

Table 2

Specification Mitutoyo Contourograph CV-2100 M4

Mitutoyo Contourograph CV-2100 M4
X- axis Inclination angle (MAX): +-45
Z-axis travel range 350 mm
Measurement range X-axisd 100mm, Z1-axis 50 mm
Drive method X-axis Motorizes drive (0-20mm/s)
Drive method Z1-axis Manual (quick up-down motion, fine feed)

Table 3

Specification Coordinate measuring machine 606T

3D coordinate measuring machine Mitutoyo SurfaceMeasure 606T
Laser irradiation method-Line Laser (single)
Laser Type-Red semiconductor
Wavelength-635 nm

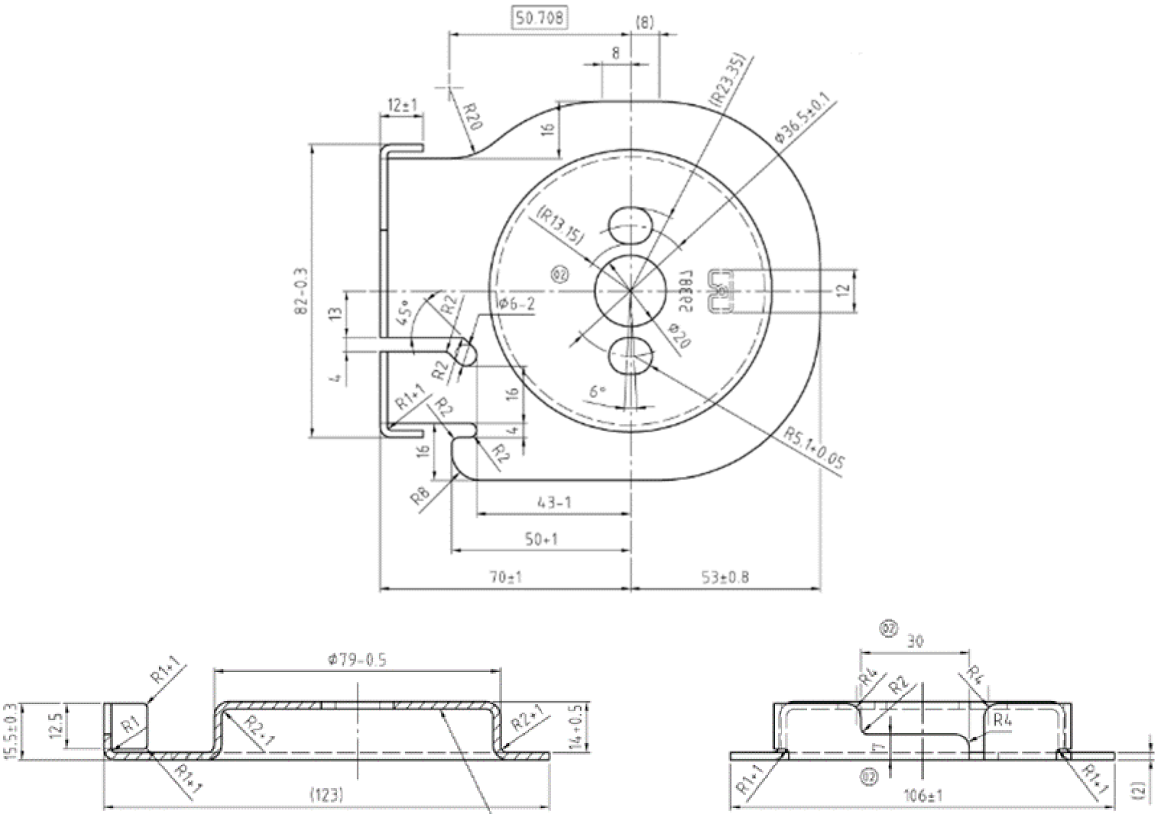

Fig. 3 Research object

Various elements are added to steel to impart properties of hardenability, strength, wear resistance, workability, and machinability. The metal standard and category specify how many and which elements must be present to the quality parameters of the production method.

In Table 4, these elements are presented with both their beneficial and detrimental effects. The sign "+" connotes positive effects, and "-" means negative effects. Double marks mean greater effects.

Table 4

Influence of alloying elements on the characteristic properties of steel

Properties of steels	Alloying elements in steels											
	C	S	P	Si	Mn	Ni	Cr	Mo	W	V	Ti	Co
Strength	++		+	+	+	+	+	+	+	+		+
Hardness	++			+	+	+	++	+	+	+		+
Tensile	-	-		++	--	+	+					-
Elasticity	++		+	++	+	+	+			++		
Impact strength	-	--		-	++	+		++		++	--	
Hardness and strength at elevated temp.												
Dynamics strength												
Corrosion resistance	-	--	++	+	+	++	+++	+		+	+	+
Formability	--	-	--	--	-	--	-		-	--		
Machinability	-	++	+	-	-	-	-		-	-	-	
Wear resistance	+				+		+	+		+		
Weldability	-	-	-	-	-							+
Toughness			-			+	+	+				

5. Results

In this research, using the cold metal stamping process, because this is the most effective process in massive production making. We take twenty serial production details, which we a little change: with a velocity (V) and tonnage (T). These details make one tact process. In Table 5 is the measurement amount. In results Table 6, we can say the recommendation – if the detail we make for one then more tact process, a detail was not damaged, but this extra process is a very grown price.

Table 5

Samples measurement for velocity and tonnage

No.	Velocity, V	Tonnage, T	Thickness, mm 0 and 90 point	Thickness, mm 180 and 270 point
1	>50	>88	2	1,75
2	>50	>88	1,9	1,85
3	>50	>88	1,85	1,85
4	30	84	1,8	1,9
5	40	75	1,8	1,95
6	40	76	1,85	1,9
7	40	76	1,9	1,85
8	40	79	1,9	1,8
9	40	76	2	1,8
10	40	75	2,05	1,8
11	40	79	**1,2**	**1,35**
12	20	75	**1,25**	**1,4**
13	19	80	1,55	1,6
14	18	88	1,7	1,7
15	25	80	1,9	1,75
16	25	81	1,85	1,65
17	45	76	1,8	1,55
18	32	83	1,55	**1,4**
19	30	84	1,5	**1,2**
20	30	78	1,5	**1,4**

In Table 5, the thickness column was measured point, in the same Countourograph way (Fig. 4). The minimum elongation for DC01 metal is 28 % [14].

Some parts are cut and measured thickness in four points in every detail. Table 5 bold results mark where thickness is low than 28 % (if the metal is 2 mm thickness, minimum elongation is 2 mm * 28 % = 0.56 mm)**.** This is metal structure damage reason.

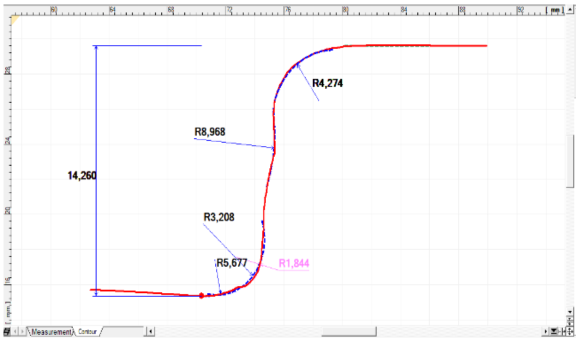

Fig. 4 Contourograph result example

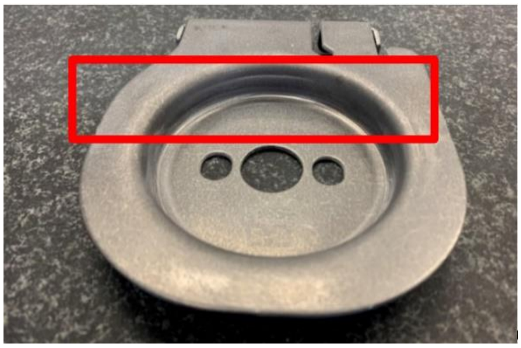

Fig. 5 Steel detail

Table 6

Comparison of sample measurement and drawing tolerance

No.	Dif.1		Dif.2		Dif.3		Dif.1	Dif.2	Dif.3
	Tall drawing	High	*R* drawing	*R* meas.	*R* drawing	*R* meas.	Cnt	Cnt	Cnt
1	14+0.5	14.26	R2+1	R4.27	R2+1	R3.20	+	1.27	0.20
2	14+0.5	14.28	R2+1	R4.29	R2+1	R2.61	+	1.29	+
3	14+0.5	14.28	R2+1	R3.91	R2+1	R2.74	+	0.91	+
4	14+0.5	14.13	R2+1	R4.23	R2+1	R2.97	+	1.23	+
5	14+0.5	14.01	R2+1	R4.22	R2+1	R3.06	+	1.22	0.06
6	14+0.5	13.99	R2+1	R4.42	R2+1	R2.82	0.01	**1.42**	+
7	14+0.5	14.03	R2+1	R4.20	R2+1	R2.99	+	1.20	+

No.	Dif.1		Dif.2		Dif.3		Dif.1	Dif.2	Dif.3
	Tall drawing	High	*R* drawing	*R* meas.	*R* drawing	*R* meas.	Cnt	Cnt	Cnt
8	14+0.5	14.12	R2+1	R4.18	R2+1	R3.43	+	1.18	0.43
9	14+0.5	14.08	R2+1	R4.45	R2+1	R3.65	+	**1.45**	0.65
10	14+0.5	14.10	R2+1	R4.24	R2+1	R2.84	+	1.24	+
11	14+0.5	14.13	R2+1	R4.01	R2+1	R3.51	+	1.01	0.51
12	14+0.5	14.28	R2+1	R4.52	R2+1	R2.98	+	**1.52**	+
13	14+0.5	14.17	R2+1	R4.48	R2+1	R2.87	+	**1.48**	+
14	14+0.5	14.07	R2+1	R4.41	R2+1	R3.65	+	**1.41**	**0.65**
15	14+0.5	14.16	R2+1	R4.31	R2+1	R3.73	+	**1.31**	**0.73**
16	14+0.5	14.06	R2+1	R4.37	R2+1	R3.80	+	**1.37**	**0.80**
17	14+0.5	14.09	R2+1	R4.46	R2+1	R2.98	+	**1.46**	+
18	14+0.5	14.04	R2+1	R4.58	R2+1	R3.89	+	**1.58**	**0.89**
19	14+0.5	14.05	R2+1	R4.42	R2+1	R3.82	+	**1.42**	**0.82**
20	14+0.5	14.23	R2+1	R4.35	R2+1	R4.19	+	**1.35**	**1.19**

In Table 6, we see the drawing (Fig. 3) and measurement tolerance comparison in all twenty details. "+" is a good tolerance – it's no deformation. In "Dif. 2" and "Dif. 3" we see is radius deformation and this result is the surface and geometric deformation reason. This biggest deformation in Dif 2 marks bold, when velocity is the slowest (Table 5), the tonnage doesn't have an impact on this radius deformation. Dif 3 in bold results amount is the biggest radius *R* deformation, when the velocity is medium and slowest (Table 5), the tonnage doesn't have an impact. In Fig. 6, we have results for the 3D coordinate measuring machine Mitutoyo SurfaceMeasure 606T. In scan processing, we take 157945 points for looking at difference tolerances. The green color is a good result because we don't have differences. The red color is the biggest result from the layout counter and blue is the lowest result from the layout counter. And we see, in detail which place have damage, we have results lowest from layout, we see blue color. If we make detail not one tact process, but more tact's making, detail the thickness would be evenly gradually. The crystalline structure of the metal broke due to excessive thinning.

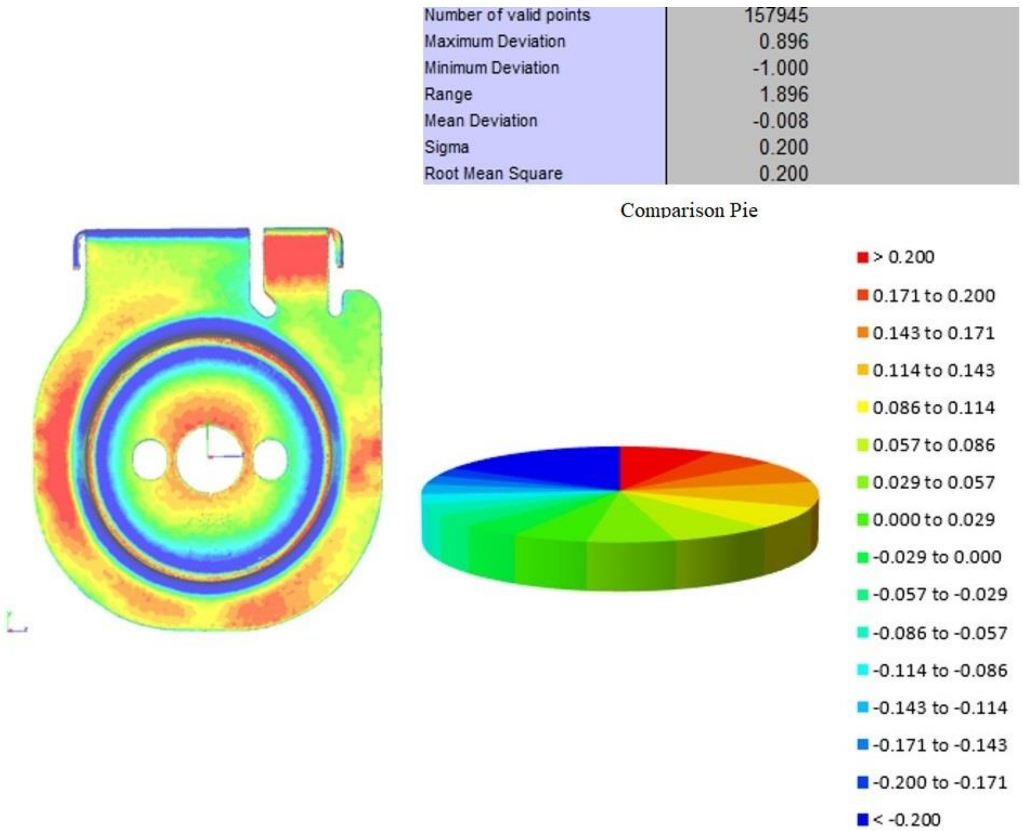

Fig.6 Steel detail

Our used steel structure can see in Table 7. Chemistry components are: carbon, Silicon, Manganese, Phosphorus, Sulfur, Aluminum, Chrome, Vanadium, Niobium, and Titanium components is the same as the Table 4 component. Some component has an impact on some mechanical properties in Table 4, we have an addiction for a steel property. Our samples have some structural damage (we can feel the touch surface), then we can say steel does not have enough elasticity, and in steel structure, then it can be recommended take more carbon C, Silicon Si, and Vanadium V. Silicon Si, is important for a machinability and tensile properties as well and this element is very important in steel structure. DC01 metal categories chemical Composition analyst standart: C (0,12%), Mn (0,60%), P (0,045%), S (0,045%) [14].

Table 7

Steel chemistry analyst and mechanical properties, our used metal

Properties	Element	%	Properties	
Chemical analyst	Carbon C	0,036	Table 4	
	Silicon Si	0,011	Table 4	
	Manganese Mn	0,288	Table 4	
	Phosphorus P	0,010	Table 4	
	Sulfur S	0,005	Table 4	
	Aluminum Al	0,039	Table 4	
	Chrome Cr	0,026	Table 4	
	Vanadium V	0,003	Table 4	
	Niobium Nb	0,001	Table 4	
	Titanium Ti	0,001	Table 4	
Mechanical	-	-	Stretch limit	205 N/mm2
Mechanical	-	-	Tensile strength	305 N/mm2
Mechanical	-	-	Strain	46,5 %

6. Conclusions

In the production line of Ravne VPS400 1992, we take twenty details for looking quality review, looking for surface damage reasons. A little changing tonnage and speed. The biggest deformation, when velocity is the slowest, tonnage doesn't have an impact in this radius deformation.

Firstly, was measured surface for all twenty detail with Contourograph CV-2100 M4. In one measurement point, we have ten points which are the biggest or slowest tolerance, these results can be the reason why detail is damaged. These details make one tact process. We can say recommendation – if detail will be making for one more tact process, a detail not was damage, but this extra process has very grown the price.

Second, we see metal steel chemistry alloy elements, and we can be looking which elements have some reason properties of steels.

Our samples, don't have enough elasticity, and in steel structure, it can recommend taking more carbon C, Silicon Si, and Vanadium V. Silicon Si, is important for machinability and tensile properties as well and this element is very important in steel structure.

Thirsty, we used 3D coordinate measuring machine Mitutoyo Surface Measure 606T, looking for tolerance's differences.

And we see in detail which places will have damage, we have the results lowest in the layout, we see the blue color. If we make detail not one tact process, but more tact's making, detail the thickness would be evenly gradually. The crystalline structure of the metal broke, due to excessive thinning. Was cut our few details and measuring the thickness in 4 points in every detail. 7 counter

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I. Markūnienė, J. Vėžys, G. Janušas

QUALITY RESEARCH OF METAL PARTS PRODUCED BY COLD SHEET FORMING

S u m m a r y

Sheet metal forming is one of the most popular technologies for obtaining finished products in the automotive industry. The main techniques of sheet metal forming: are sheet microforming, warm/hot forming, incremental sheet forming, flexible-die forming, Electromagnetic sheet forming, Electrohydraulic forming, Spinning and Shear Spinning, Shear Spinning and Flow Forming, and cold sheet forming. One most popular cold stamping process. In the production line of Ravne VPS400 1992, we take twenty details for looking quality review, looking for surface damage reasons-a little changing tonnage and speed. The biggest deformation, when velocity is the slowest the tonnage doesn't have an impact on this radius deformation.

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Keywords: forming, cold stamping, metal, surface, damage.

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