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Control of dimensional accuracy in deep drawing process with more phases

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Abstract:

Results of accuracy tests presented in this paper were obtained during the control of dimension of the cover of the second stage pressure regulator on breathing mask that is made of stainless austenitic chromium-nickel steel WNr. 1.4301 0,6 mm thick, with deep drawing process.The analysis of the mechanical properties and thickness of material assume the appearance of dimensional inaccuracies due to elastic spring recovery. The process of deep drawing which forms a roundel to the demanded geometry is realized in several operations which result in a cumulatively greater elastic spring recovery. The greater the extent of such discrepancies resolved by redesigning of product and introducing two additional phases aimed to draw reinforcements. Test results confirm that deviations appear even after the redesign and as a consequence of the tool wear on functional area. Based on the identified discrepancies in the products and subsequent control of the tool, it was concluded that it is necessary to correct it with grinding.

Key words

Austenitic steel, spring recovery, deep drawing, tool deflection

1. INTRODUCTION

The cover of the regulator of second stage is made from a roundel with diameter Ø115 mm, and 0.6 mm thick stainless austenitic chromium-nickel steel WNr.1.4301 with deep drawing technology on the cam presses. Because of the complex geometry of our product, several operations (phases) are needed to obtain a defined shape. Tool geometry (on die and punch) is used to define the final product geometry. During the in-process control, discrepancies between geometry of tools and products in the individual phases were noticed, which have occurred due to elastic recovery. In order to avoid the elastic recovery, two additional operations are introduced to draw reinforcements but before the operations that are essential for the final dimension of product. These operations leads to the slight redesign of product geometry, and a result is that recovery and inaccuracy are reduced. Nevertheless, and even these corrections where made, dimensions of the final product are still dispersed and dimensional control leads to discrepancies. Reason for residual deviation is searching in tool consistency. Deviations occur due to wear of tools, and appear on a different test pieces than the required final shape.

2. THE PROPERTIES OF MATERIAL

Austenitic stainless steels have a large range of use and represent the most important group of stainless steel. The material that is used for production of the cover of regulator of second stage is a stainless austenitic chromium-nickel steel WNr.1.4301 and a main features are referred to high resistance to corrosion. Corrosion resistance is important because the second stage regulator is placed on the breathing mask where it creates a humid atmosphere during exhalation. These steels have good ability to transform deep-drawing and can not be subjected to temperature strengthening.

Tab.1, Chemical composition, %

Material WNr	C	Cr	Ni	Mo	Mn	P	S	Si	N
1.4301	≤0.07	17+19.5	8.0+10.5	-	≤2	≤0.045	≤0.03	≤1	≤0.1

Tab.2 , Mechanical properties

Material WNr	Tensile strength R_m (N/mm^2)	yield R_{po2} (N/mm^2)	elongation %	hardness HB
1.4301	500÷700	195	35÷45	55÷85

These properties are average values at 20 ° C.

3. PREVENTING THE ACCUMULATION OF ELASTIC RECOVERY

In order to reduce the influence of elastic recovery to the lowest possible level, two additional operations are introduced. Dimensions essential for the proper functionality of the cover are outer (*D*, mm) and inner (*d*, mm) diameters, and the height (H, h) of the same. Important is to draw reinforcements before the drawing critical diameter. The first reinforcement is carried out as a ring at the site of extraction of the internal diameter *d* = ø26 mm, as shown in the drawing, Figure 1. Another reinforcement is given in the form of a wreath forming the outer ring with the formation of the final outer diameter of the cover *D* = Ø 76 mm, which is shown in the drawing Figures 2.

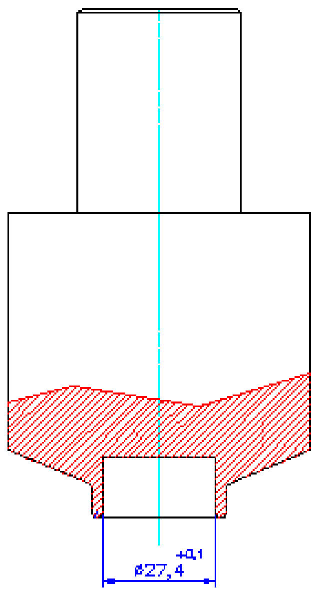

Fig.1 Tool shape used for strengthening the internal diameter

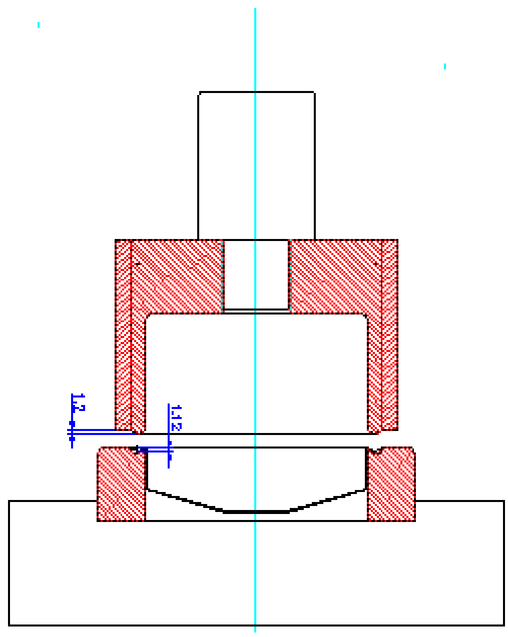

Fig 2 Tool shape used for bending the rim

Although with the introduction of two new operations, or reinforcements, the maximum effect of elastic recovery is reduced, the final re-established control of the dimensions are determined by the deviation.

4. TESTING THE ACCURACY OF DIMENSIONS

During the final tests of the accuracy of the pressure regulator cover of the second stage, deviation are detected. The measured values are given in Table 3, and a location of measurement of the pressure regulator cover of the second stage are marked in Figure 3.

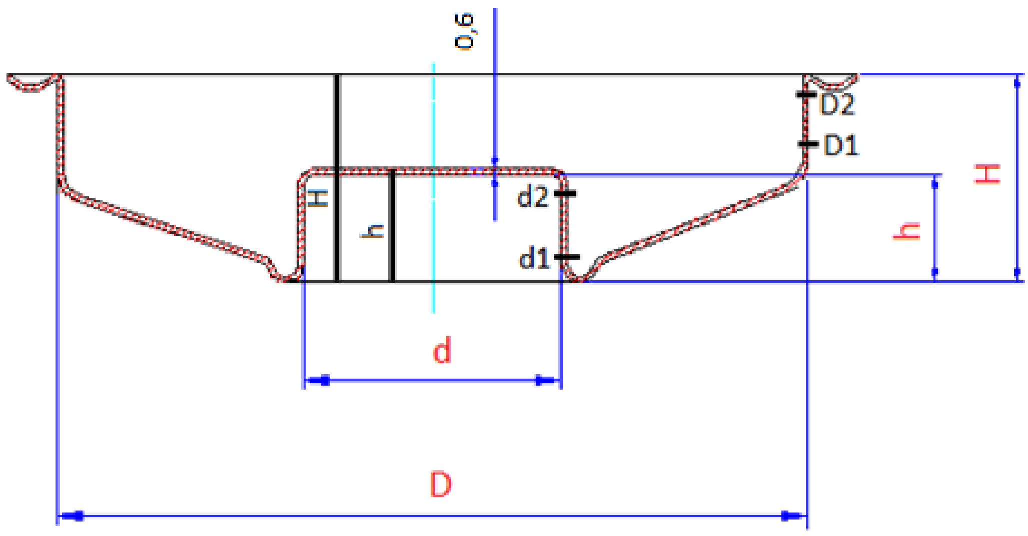

Fig.3 Test piece shape with marked measured values and location

The required dimensions for the observed locations are:

H = 21,5 mm ; h = 10 mm ; D = Ø 76 mm ; d = Ø 26 mm .

Tab.3 The measured values during the final control

Observed value	*Measures nr.*	*piece 1*	*piece 2*	*piece 3*	*piece 4*	*piece 5*	*piece 6*	*piece 7*	*piece 8*	*piece 9*	*piece 10*
D1	1.	75,86	75,75	75,81	75,85	75,78	75,77	75,7	75,82	75,74	75,7
	2.	75,85	75,73	75,79	75,9	75,77	75,81	75,81	75,82	75,75	75,78
D2	1.	75,05	75,05	75,15	75,25	75,1	75,2	75,25	75,2	75	75,2
	2.	75,05	75,15	75,15	75,15	75,05	75,05	75,25	75,1	75,15	75,2
d1	1.	25,9	25,84	25,88	25,9	25,81	25,82	25,83	25,9	25,93	25,8
	2.	25,83	25,95	25,88	25,81	25,82	25,8	25,77	25,8	25,89	25,82
d2	1.	25,44	25,3	25,54	25,47	25,34	25,44	25,37	25,36	25,46	25,55
	2.	25,43	25,29	25,55	25,52	25,4	25,4	25,43	25,51	25,49	25,33
H	1.	8,85	8,77	8,85	8,93	8,99	8,62	8,69	8,82	8,83	8,92
	2.	8,87	8,52	8,9	8,89	9,05	8,58	8,69	8,89	8,84	8,91
H	1.	18,6	18,41	18,43	18,42	18,41	18,39	18,32	18,42	18,51	18,4
	2.	18,66	18,5	18,62	18,88	18,58	18,66	18,56	18,62	18,66	18,63

4.1 Analysis of the measured dimensions

The analyses of measured data led to the minimum, maximum and mean values for each point at which to measure. The data are presented in Table 4

Tab 4 Minimum, maximum and mean values of measured data

	max	**min**	**avarage**
***H*, mm**	18,65	18,44	18,53
***h*,mm**	9,02	8,645	8,834
D_1, mm	75,88	75,74	75,79
D_2, mm	75,25	75,05	75,14
ΔD, mm	0,805	0,505	0,652
d_1, mm	25,91	25,8	25,85
d_2, mm	25,55	25,4	25,45
Δd, mm	0,46	0,335	0,4

Analyzing and comparing the dimensions of diameter and height led to the following data: the increase of diameter *D* of the cover of the regulator comes to lids to increasing the height *H*, so there is a slight taper inwards. Similarly, a slight taper appears at the smaller diameter, but the outside, ie by increasing the diameter *d* the height *h* is decreased. This is evident from Figures 4 and 5

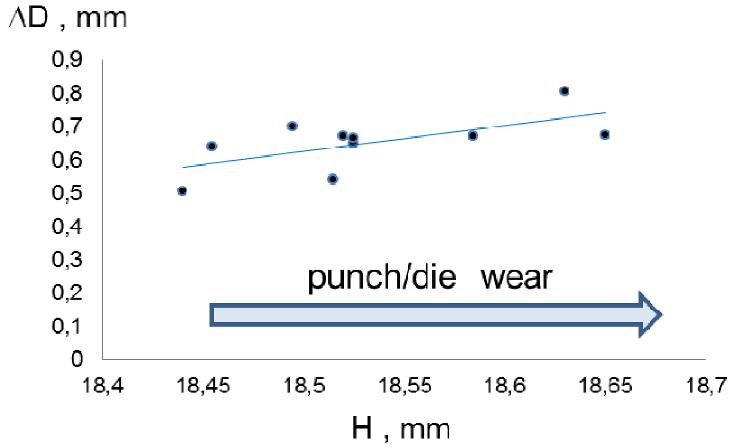

Fig.4 Effect of tool wear on the change of height H and the increase of diameter D

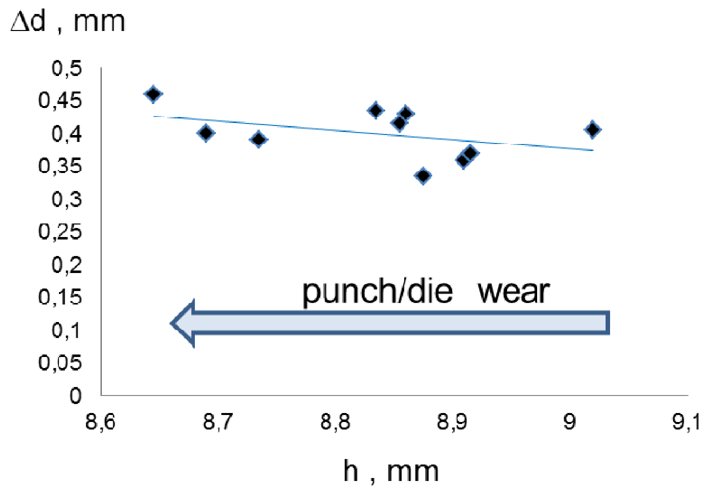

Fig.5 Effect of tool wear on the change of height h and the increase of diameter d

The appearance of the cover takes the form shown in Figure 6.

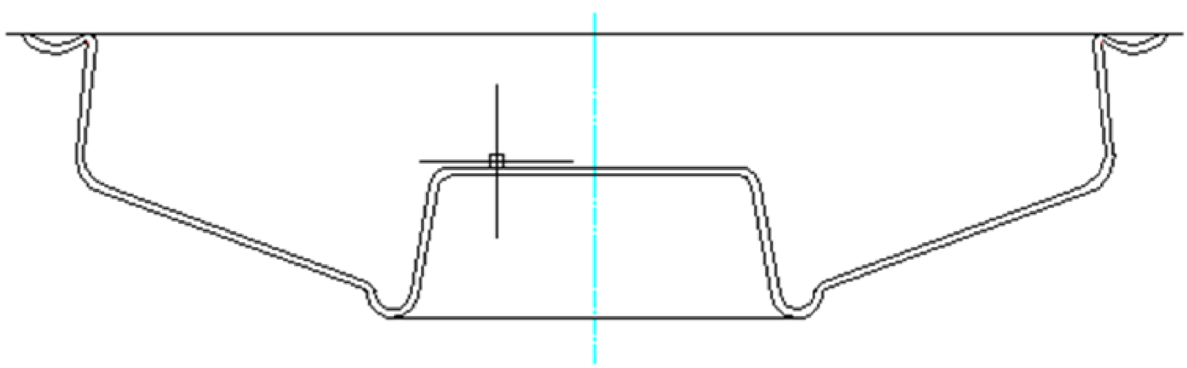

Fig.6 The actual form of the cover

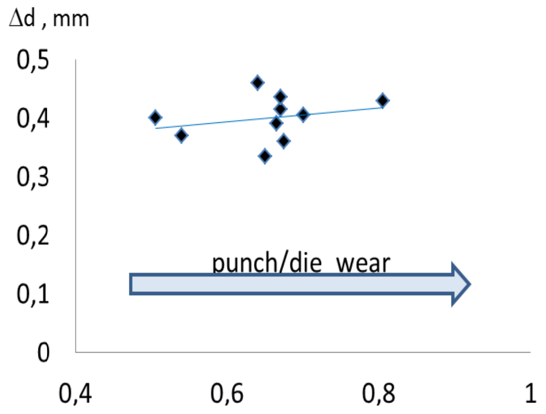

Fig.6a The impact of wear on the diameter D and d

4.2 Measuring the dimensions of tool

As the actual look of the cover shown on Figure 6 shows a conical surface on the observed value *d* and *D* (instead of the expected cylindrical surface), and whose discrepancies are greater than allowed it is accessto measure the dimensions of tools to determine the cause of appearing the cone diameter. During deep drawing comes to a gradual tool wear at the points where the tensions in contact with the object of deep drawing are maximum. The greatest tensions occur at points D_1 and D_2 of the large diameter and points d_1 and d_2 of the small diameter of the cover.

On Figure 7, the greatest zone of tool wear is marked (on punch and die area) that form the observed value *d* (small diameter of the cover), ie point d_1 and d_2. Figure 8 shows the enlarged conical appearance of the small inner diameter of the cover that due to tool wear and increased clearance between the punch and die irregularly deformed in a way that after the deep drawing can be determined by measuring cone shape instead of cylindrical.

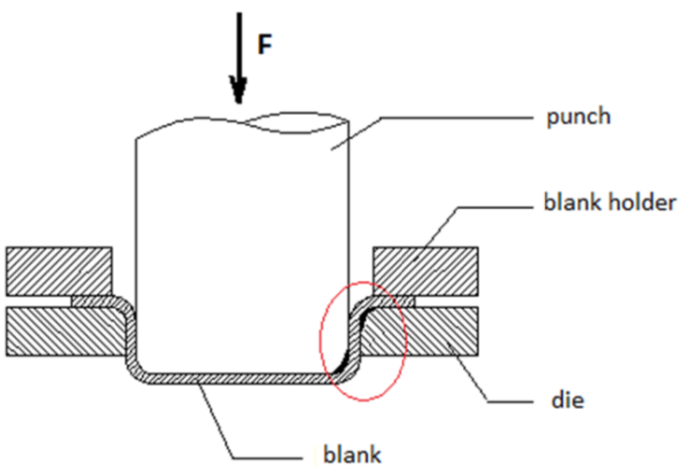

Fig.7 Sheme of the form of tool wear

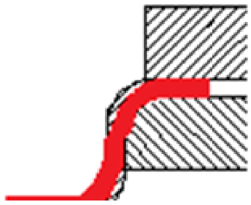

Fig.8 Sheme of the appearance of a cone

In opposite to the observed size of a small diameter (*d*), during deep drawing a wreath on a large diameter (*D*) leads to deformation tool as shown in Figures 9, 10 and 11 and as a consequence produces a cone on observed dimension *D*.

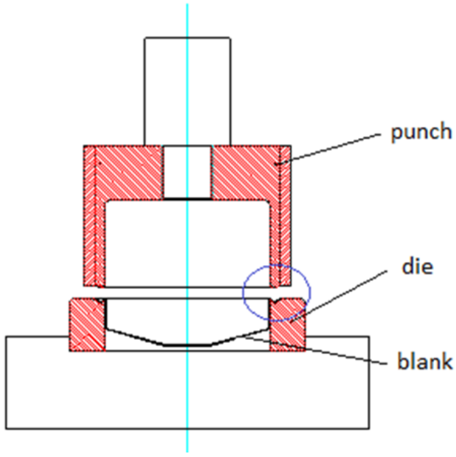

Fig.9 Sheme of tool for deep drawing of the wreath on the large diameter

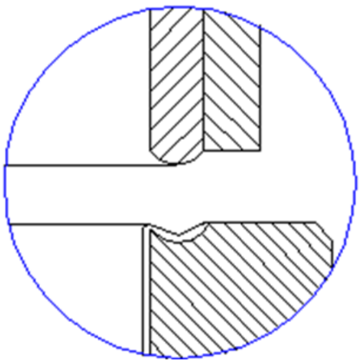

Fig.10 Enlarged view of the initial (not weared) layout tool

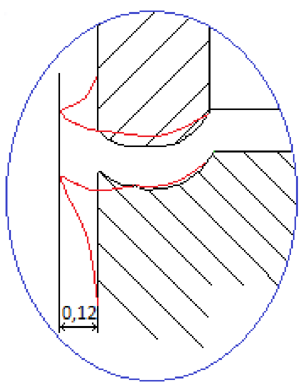

Fig.11 Magnified appearance of worn tools (marked in red) after 1000 pieces

With the increase of the tool wear, the inner diameter becomes smaller so there is an inverted cone shape appeared in relation to the small diameter and with increasing the diameter and the height *H* increases too, which is shown in Figures 4 and 5.

5. CONCLUSION

During the final dimensional control, it was found that the measured data differs from required. Also, the final shape of the lid is shaped differently than requested, ie the cone appears at the small (*d*) and large (*D*) diameter. To reduce the impact of elastic recovery two additional operations are introduced, which had the task to compensate for the cumulative effect of elastic recovery. Two additional operations creates a reinforcing ring workpiece, and the sequence is performed before the final draw (required) diameter. The occurrence of discrepancies on cylindrical surfaces has not completely eliminated with additional operations. It was found that the remaining discrepancies are result of tool wear at locations of contact that are exposed to very high loads. When the dimension *d* (small diameter) is observed, punch and die wear result in such a way that increases the diameter D_1 at the point of contact and reduces the diameter d_2 at the point of contact, and comes to the emergence of the cone and also reduce the height *h* of a small diameter of cop. In contrast to the small diameter (*d*) lid, with a large diameter (*D*) to wear the mark and the matrix occurs in a manner that leads to enlargement of the internal diameter of the tool at the point of contact D_2 or decrease the diameter of the finished cover. Suffers from the slight taper inwards and thus to increase the height *H* of a large diameter lid.

To avoid these discrepancies it is necessary to make the correction of tool after each 1000 pieces have been produced. Punch has to be corrected with grinding and deep-drawing of a large diameter can continue. Oppositely the new tool for deep drawing of a small diameter has to be introduced after the tool is worn.

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