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Methodology development for the sustainability process assessment of sheet metal forming of complex-shaped products

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Abstract. A methodology was developed for automated assessment of the reliability of the process of sheet metal forming process to reduce the defects in complex components manufacture. The article identifies the range of allowable values of the stamp parameters to obtain defect-free punching of spars trucks.

1. Introduction

Stamping is one of the most popular and effective methods of production. Stamping methods in most cases achieve the necessary quality parts (precision linear dimensions and relative position of surfaces, surface roughness), high performance and low cost. [1]

However, during products stamping, especially of complex forms, defects often occur such as dents; folds, tear sheet or cracks. It is important to note that the occurrence of defects is of a periodic nature, it is caused, first, by the difference in the quality of the source material, depending on its supply and, secondly, the operation of the tool in the limiting values of geometrical parameters of its deforming parts. Today, it is important to have a way to eliminate such defects, because the production of high quality parts is one of the main tasks of the leading companies in the world.

2. Basic part

After analyzing the causes of defects, factors of formability have been identified [2, 3]. These factors are indicators of the reliability of the sheet metal forming process, its content and structure, they were classified and presented in the profile view in [4]. The profile presents four groups of the reliability factors: material properties, stamping technology, geometric parameters of the tool and equipment parameters, which allow to combine different sizes of techno-economic parameters of the product in one dimensionless figure – integral coefficient of reliability and objectively evaluate and compare the technological processes. [5]

In [4] an algorithm to evaluate the reliability of the technological process of sheet metal forming also presents.

Reliability is understood as a property of the object to save time and within the established values of all parameters characterizing the ability to perform a required function under given conditions and conditions of use. Reliability is a complex property. [6]

As an example, spars trucks bends forming in the locations of the rear wheels was considered. This site is defective, because cracks and folds in the so-called elongation zone and the zone of coagulation take place. These zones are shown in figure 1.

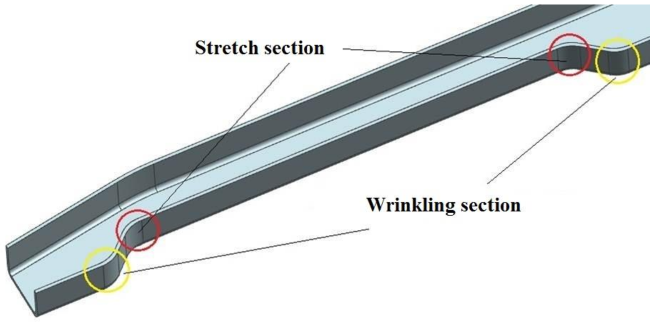

Figure 1. Defective zones in the elongation zone

Reliability factors "Material Properties" and "Hardware Settings" in this case are considered in the form of certain "constants", since they are the source data to the technological process and, accordingly, determine cause of defects. Therefore, for instance, these parameters are only possible to issue recommendations: apply additional material processing, conduct unscheduled repairs, equipment upgrades, measures to increase tool life, etc. [7 - 9]

Reliability factors "Punching Technology" and "Geometrical parameters of the tool" are controlled, because the required coefficient of friction can be achieved by applying a lubricant, and the necessary clearance between the workpiece and the tool can be achieved by changing the shape and dimensions of transition edges of working parts of the stamp. The list of these parameters is shown in table 1.

Thus, the profile of the reliability indices for the considered case will look as shown in figure 2.

Formability factors are the following: irrational geometry of the stamp deforming elements, damaged edges of the initial workpiece, temperature and the coefficient of friction between the surface of the workpiece and the working parts of the tool.

The source material is subjected to incoming control, and the temperature is maintained according to the manufacturing process. Therefore, to obtain defect-free stamping, it is necessary to consider the influence of geometrical parameters of the working parts of the stamp (in this case, it is the radius of the transition edge of the matrix) and to investigate the influence of contact friction in sheet metal forming process.

For simplicity of calculations, a part of the deformable region was taken (figure 3).

According to the simulation, graphic charts of values thinning under varying parameters stamp were built: $L_R = f(R) -$ distribution curve values thinning φ depending on the radius of rounding of the matrix R edges; $L_{[\varphi]} = 35\% -$ curve of valid values thinning φ for steel ([φ]=35%); $L_1 = 16$, $L_1 = 48-$ curves, expressing the condition of boundedness of the corner radii of the matrix edges ($16 \le R \le 48$mm). [10]

According to the graph, a range of allowable values of the parameters of the stamp was identified to obtain defect-free stamping (in figure 4 it is a shaded area), i.e. the radius of the rounded edges of the matrix must be in the range of 27.5°≤R≤48°.

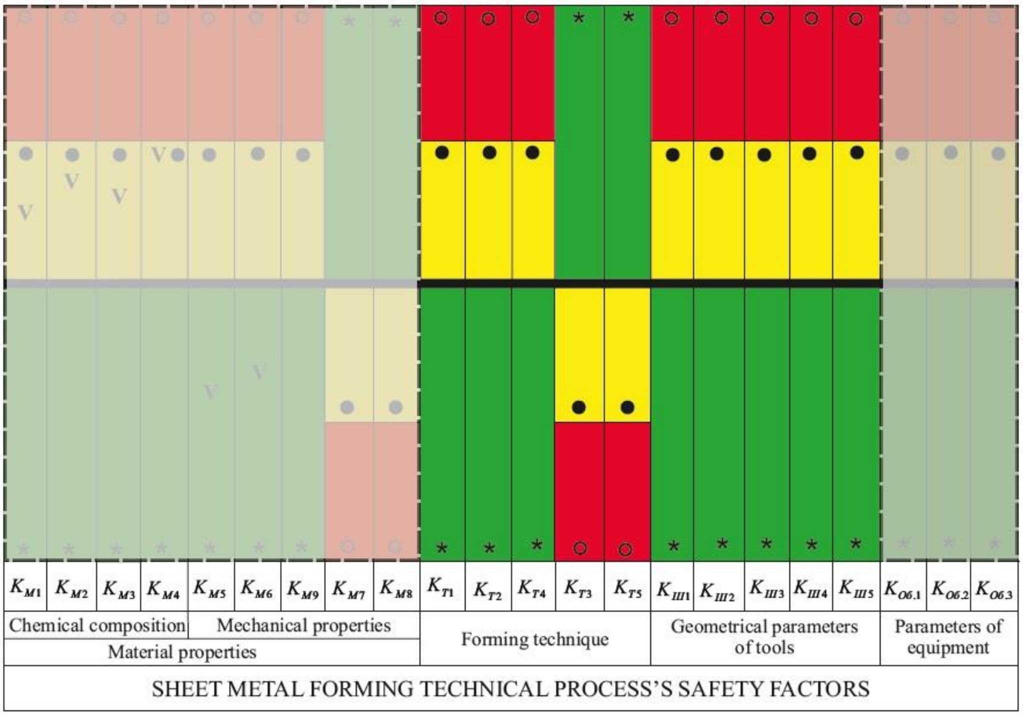

Figure 2. Reliability profile of the sheet metal forming technological process

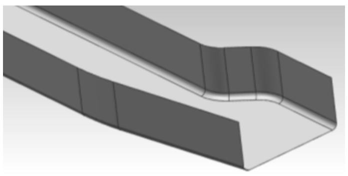

Figure 3 – Plot of the spar for calculations in LS-DYNA

The effect of the coefficient of friction between the surface of the workpiece and the working parts of the tool was further investigated. The simulation was conducted in three phases (three groups): with a constant coefficient of friction (Group №1); with a variable coefficient of friction in the system Procurement-Matrix and a constant coefficient in the system Plug-Procurement (Group No. 2); with a variable coefficient of friction in the system Plug-Procurement and the constant coefficient in the system of Procurement-Matrix (Group No. 3).

The curves are presented in figure 4.

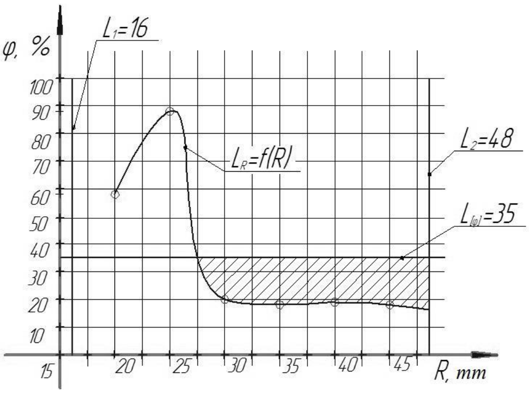

Figure 4 – Graphs of thinning values dependency from the matrix edge fillet radius

Table 1. Safety factors in group "Stamping technology" and "Geometric parameters of the tool".

Safety factors	Name title of safety factors
K_{T1}	the coefficient of friction between the surface of the workpiece and the working parts of the tool
K_{T2}	the coefficient of permissible deviations in thickness of the original sheet
K_{T3}	the coefficient of thermal regime
K_{T4}	the coefficient of permissible deviations of the size of the original sheet
K_{T5}	the limiting drawing ratio
$K_{Ш1}$	the coefficient reflecting the hardness of the material of the wetted parts of the tool
$K_{Ш2}$	the coefficient reflecting the value of the roughness of the surfaces of the working parts of the tool
$K_{Ш3}$	coefficient taking into account the wear of the working parts of the tool
$K_{Ш4}$	coefficient taking into account the misalignment of the upper and lower parts of the stamp
$K_{Ш5}$	coefficient taking into account the uneven gap between the working parts of the stamp

Due to the obtained data graphs of the metal thinning, depending on the friction coefficient, were constructed (figure 5). According to the obtained data, the conclusion can be made concerning the dependence of the measure of friction, i.e., the greater the friction, the greater the thinning.

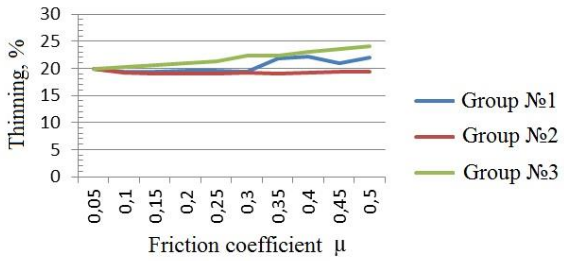

Figure 5. Graph of dependence between thinning and friction coefficient

If we consider modeling group separately, we can see that Group No. 2 practically does not change its characteristics, regardless of the friction coefficient. It can lead to the conclusion, that the influence of the friction coefficient on its reliability in this process is insignificant. Group No. 3 is characterized by a gradual increase in thinning depending on the increase of the friction coefficient. Group No. 1 is characterized by a sharp increase in thinning when exceeding the coefficient of friction value of 0.35. Thus, the practicability is in side members stamping when the coefficient of friction is less than 0,35.

3. Conclusions

Thus, it is possible to obtain defect-free stamping by changing the geometric parameters of the working parts of the stamp or by controlling the value of the friction coefficient. The work is aimed at solving urgent practical tasks – implementation of defect-free punching of complex shape sheet parts with a minimum expenditure of manpower and material resources for production preparation.

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