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OPTIMIZATION SYSTEM APPLIED TO REDUCE OR ELIMINATE THE EFFECTS OF SPRINGBACK GENERATED BY SHEETS METAL DEEP DRAWING

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Abstract: *The most frequent defects generated by cold plastic forming in parts made from metal sheets are caused by the following instability phenomena: springback and wrinkling. The present paper analyses the application of different methods and techniques in order to increase the accuracy of drawn parts made from metal sheets by reducing or eliminating the springback effects and it also proposes a system of drawing process design that will permit to reduce the springback effects just from the designing stage.*

Key words: *Metal sheets drawing, springback, tool and process accuracy.*

1. INTRODUCTION

An important factor, that has a great influence on the accuracy of final part obtained by cold forming of metal sheets, is the quality of the forming tools. The main defects of the drawn parts that occur as results of the above mentioned characteristics are presented in Table 1.

Another important factor that also has a great influence on the final part accuracy in the case of metal sheets cold forming is the optimal settings of the following process parameters: forming force, forming speed and blankholder force. Remarks:

1. Taking into consideration that the accuracy of shape and dimensions of the formed parts made from metal sheets is affected by the springback that occur in the cold forming processes and are mainly influenced by the blankholder force value, the main working parameter that must be optimized is the blankholder force. Generally, the increase of the blankholder force can determine the decrease of the instability phenomena intensity but a high value of the blankholder force can cause the metal sheet fracture.

2. The methods and techniques applied till present to eliminate or reduce the springback effects were as follows: tools correction based on data obtained from their using in production; after such correction it is needed the experimental testing of their accuracy; the use of tools and devices having a special construction in order to reduce or eliminate the springback or wrinkling effects; the optimization of the forming process by using mathematical models that establish a relation between the parameters of the instability phenomena and the factors of influence regarding their intensity [1, 2, 3].

Table 1

Defects of parts generated by deep drawing of metal sheets

Defect type	Causes and factors of influence
Incorrect part geometry	caused by incorrect geometry of part or springback phenomenon;
Variation of the wall thickness	caused by the incorrect movement of the punch during the stroke;
Scratches on the part surface	caused by the high roughness of the die surface or of the blankholder;
Wrinkling	caused by the absence of the blankholder, to the use of an insufficient blankholder force or to forming of part having big radius between flange and wall.

The deficiency of the applied models and methods is given by the fact that their application can be only made for certain materials, for particular cases of components made from thin metal sheets (integrated lead frames, parts having simple shapes) and lead to the increase of the tools complexity and costs and to the increase of the manufacturing times etc [3].

The present paper analyses the application of different methods and techniques in order to increase the accuracy of drawn parts made from metal sheets by reducing or eliminating the springback effects and proposes a system of deep drawing process design that permit to reduce the springback effects just from the designing stage.

2. TECHNIQUES APPLIED TO OPTIMIZE THE FORMING PROCESS PARAMETERS

2.1. Conventional techniques

The achievement of optimum conditions to obtain a high working accuracy in the case of metal sheets cold forming can be made by considering the following steps: to establish an optimal geometry of forming tool; to establish optimal parameters for the cold forming process. From the analysis of investigations concerning cold forming of metal sheets, instability phenomena and applied methods to increase the parts accuracy, it is possible to establish the following general conclusions: the instability phenomenon which considerably affect the formed part accuracy (the shape and dimension of parts) is springback; the deviations from theoretical profile of parts that are caused by springback are quantified by the following modifications of the part shape and dimensions: modification of wall shape or wall curvature radius, modification of the angle between part wall and part bottom, modification of angle between part wall and part flange; the most important process parameter that affects the intensity of springback regarding the shape and dimensions of the formed part is the blankholder force. The utilization of classical methods in order to reduce or eliminate the effects of the springback is expensive and requires many experimental tests [3]. As a consequence, new methods were developed to avoid and reduce the springback effects in optimum technical and economical conditions.

2.2. Nonconventional techniques

An optimal solution - that allows the optimization of tools and process parameters just from the designing stage – can be obtained by using the finite elements method combined with some statistical and mathematical models that permit the description of the influence of different process parameters on geometrical and shape parameters of the worked part.

The Taguchi technique is developed in the following main steps: problem formulation, the success of each experiment being dependent on a correct understanding of the nature of problem; identification of the output parameters of performance that are most relevant for the problem; identification of control factors, noise factors and signal factors (control factors are those that can be controlled in the conditions of normal production; noise factors are those that are either too difficult or too expensive to control in the conditions of normal production; signal factors are those that affect the mean performance of the process); selection of the factor levels, possible interactions and interaction effects; design of an appropriate orthogonal array; preparation of the experiments / simulations; running of the experiment with appropriate data collection; statistical analysis and interpretation of experimental results; undertaking a confirmatory run of the experiment [4].

The optimization method of the forming process using LMecA - Taguchi method is applied in the following six steps: definition of geometric parameters that characterize the geometric deviations of the part; selection of process parameters that influence the part geometry and its field of variation; selection of the model of linear or quadratic polynomial dependence and construction of fractioned factorial plane of experiment; process simulation according to experimental plane and the measurement of geometric deviations of the resulted parts; calculation of coefficients of the polynomial models and verification of the models; optimization of the process parameters in order to obtain the desired geometric parameters of the draw part [5, 6]. The precision of optimization can be increased by enlarging the number of factors that can be considered and influence the process [2].

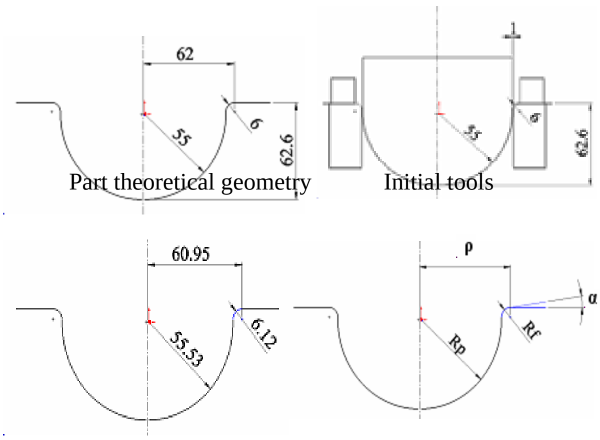
The utilization of the artificial neural network in order to find the optimum relation between the process parameters, tools geometry and springback parameters is performed the following steps: data collection that consists in generation of training data; choice of the ANN model, when the number of neurons within the hidden layer must be chosen so that the mean square error to the end of the training process to be minimal; the learning process of neural networks when the neural networks must first be trained in order to be generalized [7, 8].

The utilization of the Fuzzy Logic method involves the setting of input and output variables [9] that will be used to establish the influence of different factors on springback and on the geometrical parameters of tool. The optimisation module searches for a combination of factor levels so that the requirements equally imposed to the influence factors and tool geometrical parameters to be simultaneous satisfied. Its application will also allow the optimisation of tools geometry and the change of several technological parameters of drawing process.

By comparing the results obtained from the application of the above presented techniques of optimization in the case of a hemispherical part (Fig. 1) it was concluded that all methods could be successfully used to control the springback phenomenon. Insignificant differences could be observed, both as concern the optimum identified values of the process and part parameters resulted from their using (Table 2). By the accuracy point of view, the LMecA technique can be advantageous. It also permits to choose the optimum value of the output parameters from the entire field of variation of the input parameters. By this point of view the Taguchi and Neural Networks techniques permit to select the optimum values of the output parameters only for some values from the variation field of the input parameters.

The analysis of the above presented results that were obtained from the application of the non-conventional optimization techniques leads to the following conclusions:

- all methods could be successfully used to control the springback phenomenon; insignificant differences could be observed, both as concern the optimum identified values of the process and part parameters resulted from their using;



Real part Parameters to be optimized

Fig. 1. Hemispherical part.

Table 2

Process and part geometry parameters

Technique	**Resulted parameters**			
	BHF	$\mathbf{R_p}$	$\mathbf{R_f}$	**α**
	[kN]	[mm]	[mm]	[degrees]
Theoretical	35.00	55.00	6.00	0
Experiment	35.00	55.53	6.12	0.40
Taguchi	50.00	55.18	5.91	0.96
LMecA – quadratic	40.00	54.92	5.96	0.20
Neural Network	40.00	54.50	5.90	0.80
Fuzzy Logic	45.00	55.75	6.00	0.20

- by the accuracy point of view, the LMecA method can be advantageous; it also permits to choose the optimum value of the output parameters from the entire field of variation of the input parameters; by this point of view the Taguchi, Neural Network and Fuzzy Logic methods permit to select the optimum values of the output parameters only for some values from the variation field of the input parameters;
- a little bit advantage seems to present the Taguchi and Neural Network techniques because once the adequate model was identified the determination of optimum process parameters could be performed in a very short time and with a minimum effort of calculus;
- in order to obtain a refining of the optimized parameters and the maximization of precision, the LMecA technique can be used in a preliminary analysis of raw data and after that the resulted data can be used to develop the Neural Network and Taguchi techniques [3, 4].

3. THE SYSTEM OF OPTIMIZATION

A logical scheme of the optimization system that can be applied in the case of deep drawing of parts made of metal sheets is shown in Fig. 2. The logical scheme of the optimization system integration into the manufacturing technology of metal sheet parts is presented in Fig. 3.

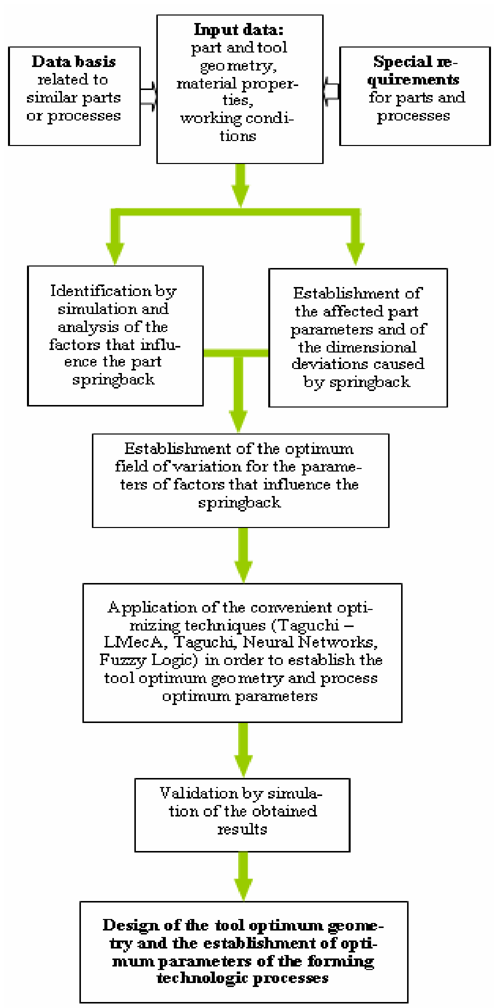


Fig. 2. Logical scheme of generalized system of optimization.

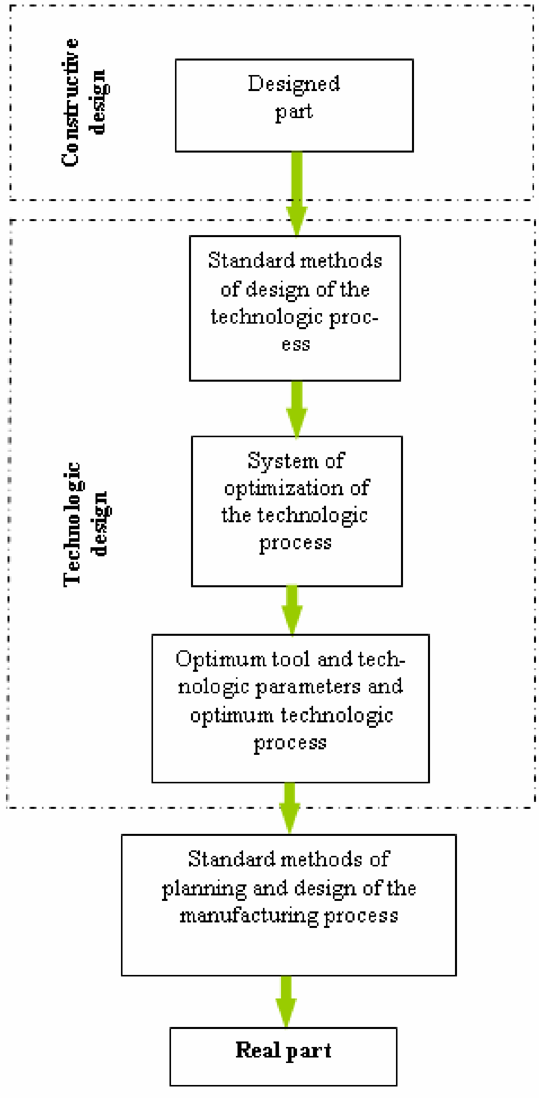


Fig. 3. Integration of the optimization system in the manufacturing process.

4. CONCLUSIONS

By eliminating the phases for the process and tool correction, the proposed system presents the following advantages: the considerable reduction of manufacturing times; the reduction of materials consumption; the increase of manufacturing accuracy and of quality of the drawn parts; the improvement of working conditions by eliminating some difficult operations (tools correction, additional handling of tools and parts etc.); the active and relatively easy control of the process etc.

The utilization of the non-conventional methods (such as: Taguchi – LMecA, Taguchi, Neural Networks, Fuzzy Logic optimization techniques; specialized software or simulation techniques for the control of working parameters and accuracy etc.) for the design of tools and drawing process can be more advantageous by comparing with the application of classical technical solutions or theoretical models enumerated in the paper introduction. So, it can be remarked that the non-conventional methods permit to obtain a reduction or elimination of springback effects just from the designing phase of the drawing process and can bring the following technical and economical benefits: the elimination of next corrections of the tools geometry or process parameters, the reduction of the number of needed experiments, the reduction of manufacturing time, the reduction of material consumption etc.

Based on the optimal parameters obtained by all techniques, it is possible the correction from the design stage of tools geometry and of technologic parameters of the forming process by minimizing the effects of the springback.

The application in industrial conditions of the optimization system and its integration with the deep drawing technology of parts made from metal sheets, in order to increase the parts manufacturing precision by eliminating or diminishing the springback effects on part shape and dimensions, can lead to the following technical – economical benefits: reduction of rejects; elimination of operations needed for defects remediation; reduction of the working times; reduction of power and materials consumption; increase of profit and profitableness rates by comparing with the classical technology.

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