Algorithm for Springback Prediction of the Automotive Body Cars Based on the Knowledge and Decision-Making Process

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ABSTRACT

This paper presents an algorithm for springback prediction of the two assembled parts by superposing the values of the springback measured for each part. It is appreciated that the springback affects the final assembly only with the difference between the values of the springback measured for each part. This algorithm was applied for a U-bending part carried out within a springback estimation test REV3D of the five grades of materials used in the automotive body car production. The proposed algorithm could be used for decision making process in the manufacturing of the automotive bodies car and could lead to saving material time of calculation that has a direct consequence reducing the price of the parts.

Keywords: *springback, metal sheets, algorithm, knowledge based, decision-making*

1. Introduction

The increasing number of automobiles has led to various societal and environmental concerns, such as fuel efficiency, emission, and global warming. The automobile industry is under considerable pressure to reduce the fuel consumption and the emissions of their vehicles.

In general, the car body and its interior accounts for approximately 40 percent of the vehicle weight. Thus, weight reduction of car bodies offers a promising way of improving the fuel economy of automobiles.

The springback is the factor key in appreciating the quality of the parts made from thin sheets obtained by cold plastic deformation processes. Nowadays in automobile constructing industry this defect is 50% controlled which makes its prediction to be an important aim of the automotive constructors. More than that the appearance of some new materials meant for autobodies with mechanical characteristics modified in order to obtain a light weight of the body causes the necessity to modify the constitutive behaviour models during deformation.

To be effective in decreasing the costs of the car bodies, the number of the rebuts should be diminshed. Existing of some tools for prediction of some defects will lead to an efficient production avoiding stops of the manufacturing processes. Elastic behaviour of the materials destined to car bodies produce so-called springback. This is the effect of the reaction of the material undergo to a mechanical stress and the amount of this reaction is count as a defect of shape and dimensions. Many authors found different solutions to decrease the springback effect, to diminish the simulation time of the parts deformation before starting the real production. There are substantial progresses in this direction, but the capacity of the tools developed are limited and the prediction is not fully precise. Moreover, new grades of steels, new advanced light materials replace the classical steels and new problems in estimation of the defects occur. In this context, the paper proposes an algorithm destined to be applied in prediction of the springback a resultant effect of joining two parts. Springback measured to one manufactured part 1 has no identity because its effect can be see when the part 1 is assembled with part 2. If the resultant springback is without acceptance range, this will determine the manufacturer to re-consider the part.

An algorithm for springback prediction of the automotive body cars based on the knowledge and decision-making process is carried out in this paper.

2. Dimensional management in autobodies manufacturing

The use of robots and automated assembling in auto bodies fabrication, the use of a great variety of materials and also the design of some complex forms generated by the higher and higher demands of the market solicit new solutions to the problems arisen by the dimensional precision of the assembling. The dimensional control in cold plastic deformation of thin sheets begins with the control of form precision and of the dimensions of the parts made through different processes in the reference points (corresponding points of assembled parts).

One of the effects of assembling some parts imprecisely processed by cold plastic deformation technologies is the appearance of some gaps that determines an unpleasant aspect of the body profile, untightened fixed joining, and from a technological point of view determines wastes in robotised assembling lines. In figure 1 are presented three cases of assembling from the structure of an auto body where are underlined in different sections the positioning errors of two surfaces: rear fender- front panel, respectively front panel – front door.

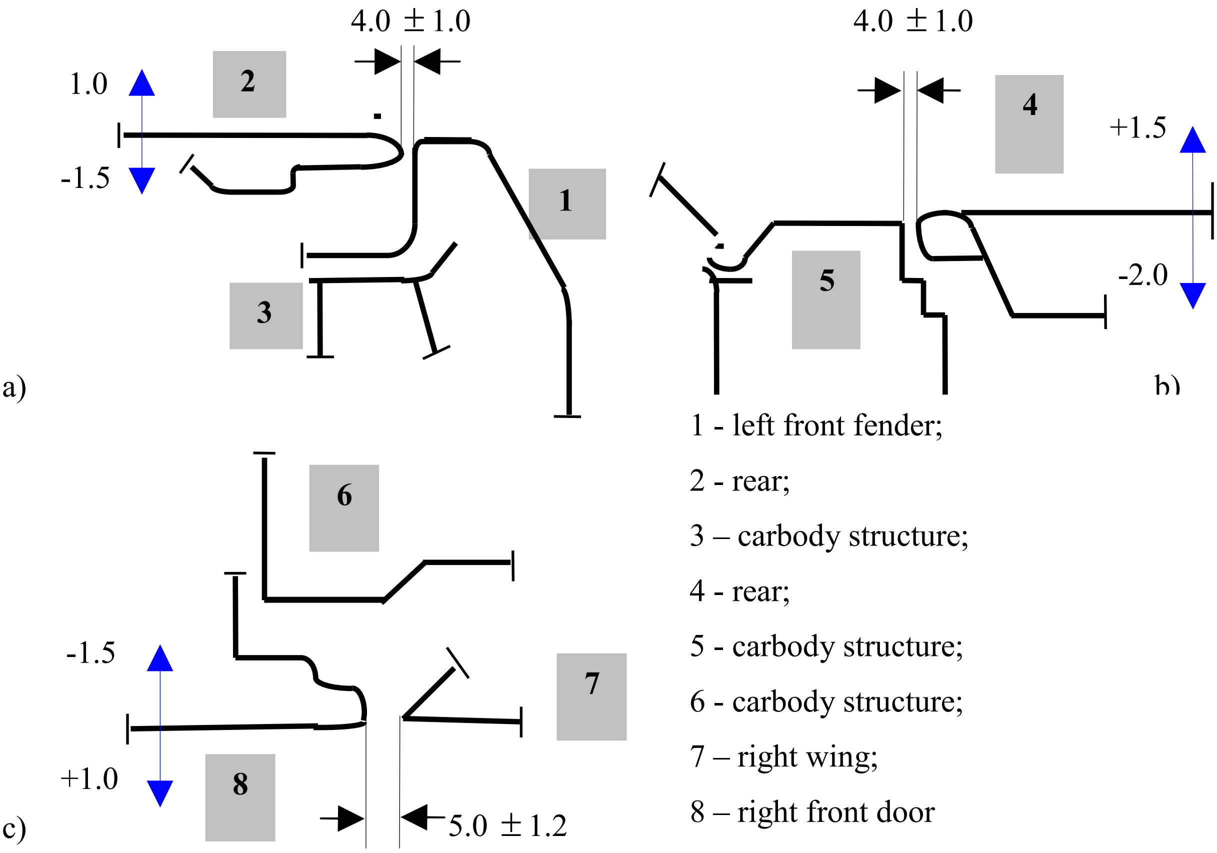

Figure 1. Examples (a, b and c) of assembling different automotive body car parts (1-8) where the tolerance of some dimensions imposes a certain value of the springback

At the first side the quality of an automobile is appreciated through its exterior aspect. In technological language it means that the auto body must show continuous, even perfect form lines with no gaps or incompatibility between the assembled parts. Since the specific demands of the precision depend on the execution class of each part, on the dimensional category, on the used equipment it is hard to be established general rules for their appreciation.

In this respect, in table 1 is presented an example of size of precision imposed to a robotised assembling line in order to assure deviations of 1-1 and 1,2-1,2 to dimensions 4, respectively 5 of figure 1, the size of springback of parts 2, 4 and 8 may be tolerated in ranges +1-1,5 respectively +1,5-2.

The dimensional precision of a deformed part is also determined by the precision of the equipment used to realise the deformation. Hence in figure 2 there are presented the main factors that determine the cost of a necessary die in an automobile body fabrication process.

After carrying out the dies for deformation, more than 20 % of the expenses are meant for experimental tests and 30 % out of them are due to later modifications in deformation equipments during the testing phase in order to satisfy the dimensional precision .

Table No.1

Robot type \ Precision	Precision imposed [mm / mm]	Precision carried out [mm / mm]
Multi - task robot	+1,5 / -2,0; -1,5 / +2,0	+0,7/ -1,0; +0,7/ -1,0
Welding robot MIG	+0,8 /-1,2; +0,8 /-1,2	+0,3 /-0,5; +0,3/ -0,5
Assembling robot	+0,5 /-1,0; +0,5 /-1,0	< +2,0; < -2,0

3. Estimation of the springback impact on the body car cost

In order to decrease the cost of fabrication for a die, a strict control of the defects that appear in plastic deformation is imposed and this can be done by introducing some feedback phases during the design process of deformation equipments, thus decreasing the size of correcting and repairs costs or even avoiding the appearance of defects in certain situations.

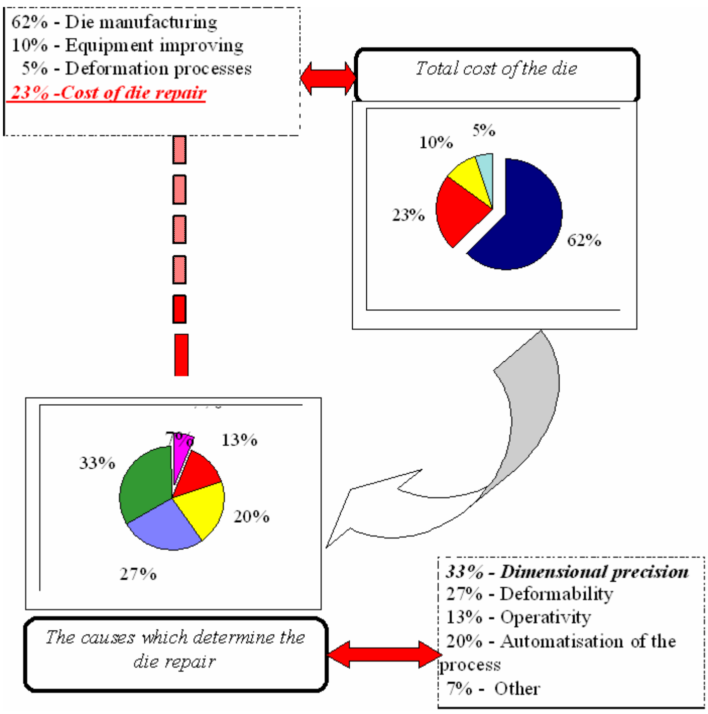

Figure 2. – The costs for carrying out a die and the weight of the factors that influence their size

4. The algorithm presentation

In order to exemplify the idea of springback prediction algorithm there taken into account the part of auto body where wrinkling and springback appear, the left front fender.

This part with great dimensions and complex shape made up of deep surfaces having great radius joining is characteristic for the category of the parts whose springback is a difficulty factor in their technological carrying out and even more, this part is assembled with another four parts as presented in figure 2.14.

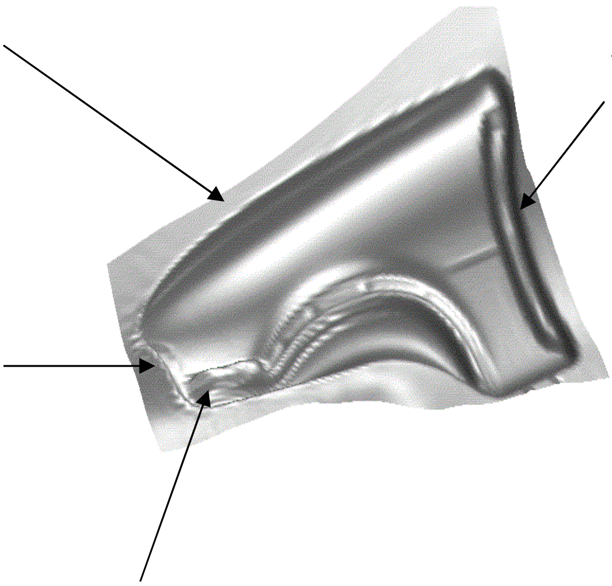

Figure 3 - Front left fender

A useful and economic instrument in obtaining information on the size of springback is numerical modelling. Through this process the final shape of the deformed part is obtained and the defects can be estimated. From this moment on it is difficult to interfere with the designing process to correct the tools.

Furthermore, the ITAS3D program does not estimate correctly the shape and the size of the springback during the tools unloading.

A new idea is taken into account in this paper. The idea of analysing the part in the assembling that part will belong to, and to -numerical modelling using ITAS3D, the version including a new constitutive model of the material behaviour; propose materials combinations that might decrease the size of springback.

In order to achieve that it is proposed an algorithm that integrates several cumulated actions in order to predict the springback and to find out solutions for diminishing the springback effect. This algorithm can be applied to complex parts after its validation using probe parts and after its modules are elaborated based on real studies.

The actions involved by this algorithm are: -the creation of the data base for simulation with ITAS3D; -generation of the data files and tools files;

-the springback analysing in a special joining system of the parts and the prediction of the total springback size of the assembling that the parts will belong to.

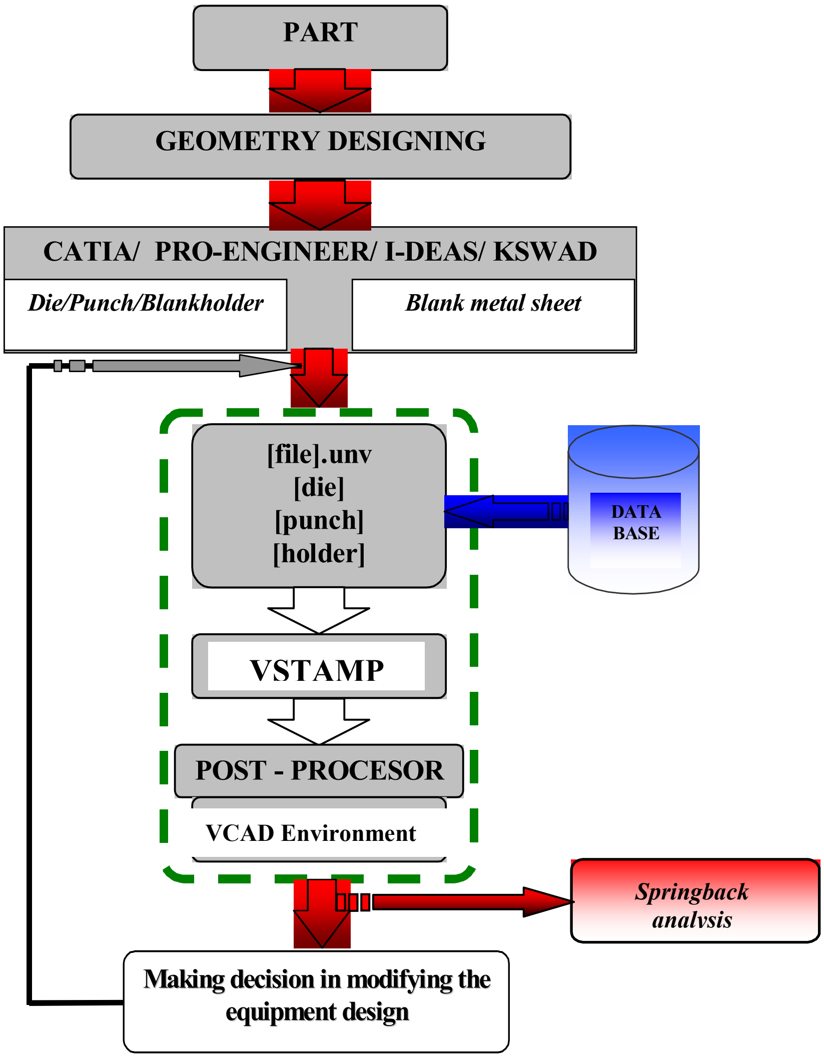

Figure 4 - Algorithm of springback prediction

The application of this algorithm was done in the case of prediction of the springback of a probe obtained within REV3D test in University Dunarea de Jos of Galati. The results obtained for five materials are presented in table 1, where HS370 and HS590 are high strength steels with 370 MPa yield stress, repectively 590 MPa, SPCE is a grade of carbon steel for advanced use of autobodies, IF is a interstitial free asteel and Al5182 is an aluminium-magnesium alloy of series 5000. All these materials are of the new generation of the materials used in the manufacturing of the autobody parts and in the same time exhibit springback effect at a high level due to the structural modifications in ordet to have a impact resistance improved. The part are obtained within U-bending test with a blankholder force of 150 daN and 10 mm filling radius. Bending and stamping are largely used metal forming process used in manufacturing of the bodycars.

For each part has determined springback but its absolute value is not important because if the part 1 is assembled with part 2, like in figure 5, the two spinbacks will be compensated until the resultant value.

5. Decision making process in springback estimation

The concave-concave assemble; figure 5a, of the two parts that are put together having the cavity positioned on the same part of the imaginary axes, will have a resultant value of the springback, denoted $S_{\theta 1}$. In this case, the springback size is calculated by the following relation

$$S = S_1 - S_2 \qquad (1),$$

where S_1, respective S_2 are the valuea S considered for part 1 and for part 2, depending on the its material. This reference axes is drawn through the flange of the parts.

Table 1

REV3D Test	$F_{blankholder}$ 150 daN, R10mm	
Material	S_θ [mm]	Initial yield point N/mm^2
HS370	6.5	290
HS590	8.0	387
SPCE	5.5	147
IF	7.5	177
Al5182	6.0	112

The concave-convexe assemble, figure 5b, of the two parts that are put together having the cavity positioned on the same part of the imaginary axes, will have a resultant value of the springback, denoted $S_{\theta 1}$. In this case, the springback size is calculated by the following relation

$$S = S_1 + S_2 , \tag{2}$$

where S_1, respective S_2 are the value S considered for part 1 and for part 2, depending on the its material. This reference axes is drawn through the flange of the parts.

If, for example, there are two parts made of HS370 and HS590 MPa, of the same shape, but will be assembled like in figure 5, the compensation algorithm and sometime is less time and material consuming then the procedure of finding solutions to prevent the springback or to decrease by modifying the die shape or the control parameters of the process.

6. Conclusions

In the automotive body parts designing process, the tolerances of the sub-ansambles of automotive body cars can be defined and these are the starting point in determining the maximum allowed springback of each part, as in figure 1. Decision making-process consists in acting knowing the target, based on the previous experience. In this way, the dimensional springback for each part will be better controled and the numerical modeling will act as a tool for calculation of the stress and strain states, critical area of the part instead of being a tool for springbvack optimisation. The saved time in the case of appplying the algorithm could be significantly diminish, of course depending on the situation. Still there are complex parts that request sophisticated algorithms of virtual manufacturing before starting the production. The algorithm proposed in this paper was tested using the parts carried out within REV3D U –bending test, and the results shown that the algorithm is robust and efficient.

Acknowledgements

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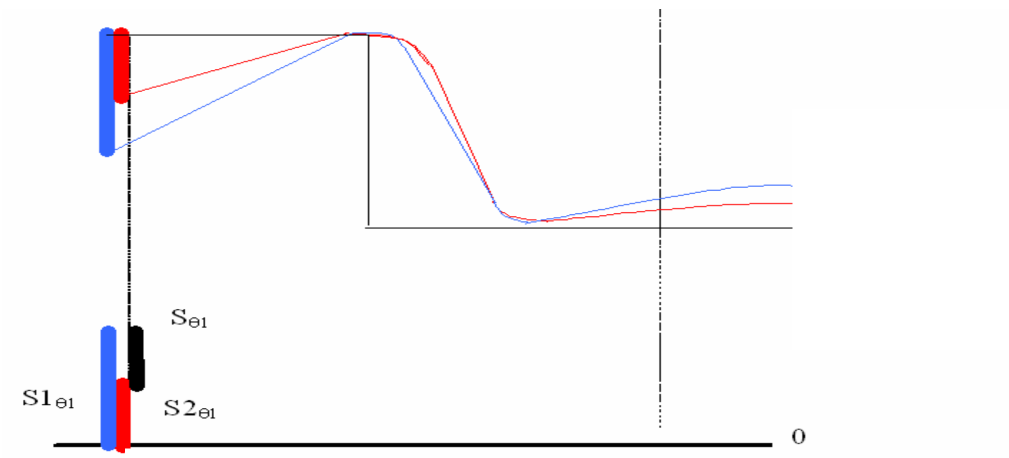
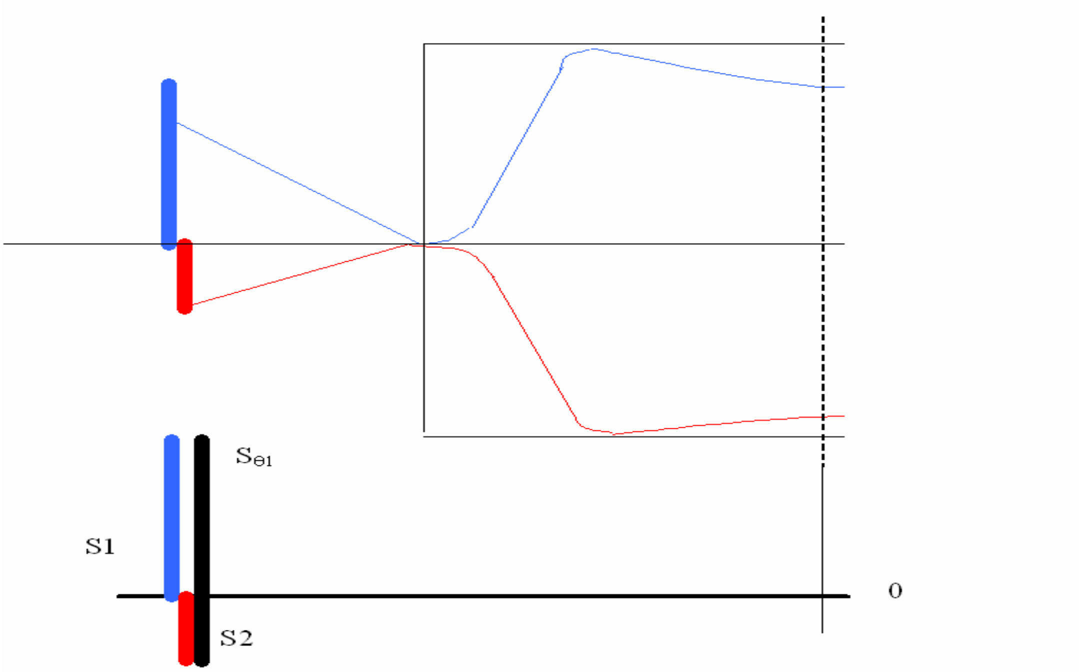
Legend of figure 5

Part 1 Shape
Part 2 Shape
Springback size of part 1, S_1

Springback size of part 2, S_2
Resulted springback size $S_{\theta 1}$



a)



b)

Figure 5. Compensation of the springback by assemble of two parts with different materials a) concave-concave and b) concave-convex

References

[1] **Xintao, Cui, Shuxin Wang and S. Jack Hu,** *A method for optimal design of automotive body assembly using multi-material construction*, Materials & Design, Volume 29, Issue 2, 2008, Pages 381-387

[2] **Stenti, A., D. Moens, P. Sas and W. Desmet,** *Low-frequency dynamic analysis of automotive door weather-strip seals*, Mechanical Systems and Signal Processing

[3] **M.-G. Lee, Daeyong Kim, Chongmin Kim, M.L. Wenner, R.H. Wagoner and Kwansoo Chung,** *A practical two-surface plasticity model and its application to spring-back prediction,* International Journal of Plasticity, Volume 23, Issue 7, July 2007, Pages 1189-1212.

[4] **G. Chen, Jiangqi Zhou, Wayne Cai, Xinmin Lai, Zhongqin Lin and Roland Menassa,** *A framework for an automotive body assembly process design system,* Computer-Aided Design, Volume 38, Issue 5, May 2006, Pages 531-539.

[5] **M. Banu, Makinouchi,** A., *Improving of springback prediction by finite element simulation*, Journal of Japanese Key Technology Center, Issue no. 12, 2000, 2-10-1 Toranomon, Minato-ku, Tokyo, 14-19.

[6] **N. Yamamura, A. Makinouchi, M. Banu, C. Teodosiu,** *Springback Simulation for Hat-Bending by Static Explicit FEM Code using a New Algorithm for Canceling the Non-Equilibrated Forces*, Journal of Materials Plasticity, Proceedings of the 2001 Japanese Spring Conference for the Technology of Plasticity, ISSN4-0919-1925, p. 102-1-4, 2001, Japan.

[7] **M. Banu**., *Teza de doctorat*, 2000, Galati

[8] **R. Lingbeek, J. Huétink, S. Ohnimus, M. Petzoldt and J. Weiher**, *The development of a finite elements based springback compensation tool for sheet metal products*, Journal of Materials Processing Technology Volume 169, Issue 1, 30 October 2005, Pages 115-125

Algorithmus für die Springback Vorhersage der Automobilkörperautos gestützt auf die Kenntnisse und Beschlussfassungsprozess

Zusammenfassung

Dieses Papier präsentiert einen Algorithmus für die springback Vorhersage des zwei gesammelten Teiles wo die Werte des springback superaufstellend, maßen für jeden Teil. Der springback betrifft den Endzusammenbau nur durch den Unterschied zwischen den Werten des springback gemessen für jeden Teil. Dieser Algorithmus wurde angewandt für eine U- Verbiegen des Teils ausgeführt innerhalb eines springback Bewertungstests REV3D fur fünf der Automobilkörperautoproduktion verwendete Materialien. Der vorgeschlagene Algorithmus konnte für den Entscheidungsbilden-Prozess verwendet werden in der Herstellung des Automobilkörperautos und konnte zum Sparen des Materials, Zeit der Berechnung führen, die eine direkte Folge haben, die den Preis der Teile reduziert.

Algoritm pentru determinarea revenirii elastice la piesele destinate caroseriilor auto prin utilizarea deciziei pe baza de cunoştințe

Rezumat

Lucrarea prezinta un algoritm pentru determinarea revenirii elastice la deformare tablelor destinate piselor de caroserie auto. Acest algoritm integreaza metode de calcul numeric prin metoda elementului finit, metode de experimentare pentru determinarea coeficientilor legilor constituive, si in final utilizeaza tehnica luarii deciziilor pe baza de cunostine. Astfel, se propune o noua abordare a revenirii elastice, ca fiind o rezultanta a imbinarii a doua piese, avand reveniri corespunzatoare formei si materialului din care sunt realizate. Revenirea elastica rezultanta va fi egala cu suma/diferenta revenirilor fiecarei pise, in conformitate cu tipul imbinarii – concav-concav, concav-convex. Acest alforitm poate duce la scaderea timpului de lansare in executie a unui set de pise, dar si la gestionarea mai buna a erorilor dimensionale ce se obtin in prelucrarea caroseriilor auto.