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Steet metal forming analysis with multipoint reconfigurable die using data mining technique

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ABSTRACT

A very important parameter to evaluate the quality of the deep-drawed complex parts is the springback. Using reconfigurable multipoint dies this parameter can be controlled by pins positions during the process. It result the necessity to have information in order to act very quickly in this direction. This paper goal is to dermine the rules type pins position-material response (sringback) in order to assure dimensional precision of the deep-drawed complex parts. The method to obtain this rules consist in: i). FE simulation of different schemas of the dies and different materials; ii). extraction of the input-output parameters in order to create the data base; iii). determination of the rules using the data mining technique.
Key words: *finite element simulations, data mining, multipoint die forming, reconfigurable*

1. Introduction

Reconfigurable multipoint forming is a flexible manufacturing technology which assures the production of a high sheet metals parts variety, used mainly in aeronautical and automotive industry, with low costs in comparison with the using of the monolithic dies. The main characteristic of the deformation method is given by the active surface discrete design of the forming elements, which is composed from a number of pins, vertically aligned, according with the geometry of the part. Thus, Hardt, Boyce and Walczky [2], [3], [4] and [5] developed numerical control algorithms for vertical displacement of the pins in order to generate the working surface of active elements. From the present state of researches it results the necessity to develop one rapid technique to assure the real time control of the pins positions based on the material response reaction during the forming process. The purposed method consists in the application of the FEM correlated with Data Mining Technique. A very important parameter to evaluate the quality of the deep-drawed complex parts is the springback. For this reason the springback is considered cost-function in this study. A correct position of the pins is based on the respect of this function considering the tolerance restrictions of the piece after springback. Numerical simulation, by this duration, cannot assure the real-time control of the pins position. The extraction of the rules regarding this one correction assure the small time necessary to adjust pins positions during the process in order to assure the quality of the pieces.

2. Data Mining General Prezentation

Data mining is an analytic process designed to explore large amount of data in search of consistent patterns and/or systematic relationships between variables, and then to validate the findings by applying the detected patterns to new subsets of data. The ultimate goal of data mining is prediction. The process of data mining consists in three stages: (1) the initial exploration, (2) model building o pattern identification with validation/verification, and (3) deployment (i.e., the application of the model to new data in order to generate prediction).

Stage 1: Exploration. This stage usually starts with data preparation which involves cleaning data, data transformation, selecting subset of records and – in case of data sets with large number of variables – perform some preliminary feature selection operations to bring the number of variables to a manageable range. Then, depending on the nature of the analytic problem, this first stage of the process of data mining may involve anywhere between a simple choice of straightforward predictors for a regression model, to elaborate exploratory analyses using a wide variety of graphical and statistical methods in order to identify the most relevant variables and determine the complexity and/or the general nature of models than can be taken into account in the next stage.

Stage 2. Model building and validation. This stage involves considering various models and choosing the best one based on their predictive performance. This may sound like a simple operation, but in fact, it sometimes involves a very elaborate process. There are a variety of techniques developed to achieve that goal-many of which are based on so-called "competitive evaluation of models", that is, applying different models to the same data set and then comparing their performance to choose the best.

Stage 3. Deployment. That final stage involves using the model selected as best in the previous stage and applying it to new data in order to generate predictions or estimate of the expected outcome.

3. Data Base Preparation

Data preparation and cleaning is an often neglected but extremely important step in the data mining process.
In our case the data base is obtained by FE simulation of deep-drawing process for one complex part considering 4 schemas of the dies:

- multipoint dies with face to face pins positions;
- multipoint dies with deescalated pins positions;
- multipoint dies with complete surface materialized by pins;
- mono-block dies without pins.

After analysation of the data base, in the first approximation, we select the parameters:

- input parameters:

* schema of the dies;
* maximal force:
* parameters of the i-node considered on the mesh:
* x,y,z node coordinations before forming stage;
* x,y,z node coordinations after forming stage;
* σ1, σ2, σ3 component of Cauchy stress tensor;
* Equivalent Von Misses stress before spring back;

- output parameters are the following node parameters:

* x,y,z node coordinations after springback;
* thickness variation after forming stage;
* σ1, σ2, σ3 component of Cauchy stress tensor after springback;
* equivalent Von Misses stress after spring back.

Considered point obtained by FE simulation before and after springback are reported to the coordination system witch the origin are different in comparison with the curvature centre. Geometrical calculs necessary to complet **decision** column must be performed in coordination systhem with origin in curvature part center. In this situation it is necessary to transform the considered node coordinations folowing the steps:

a). collect all parametrers for each 3rd node of the mesh;
b). center angle calculation for each i-node considered;
c). calculation of the and center angle coresponging to maximal/minimal values of admissible tolerance;
d). and coordinations calculation with respect of the imposed tolerance;
e). determination of the **decision** value considerig the coordinations after springback and interval.

a). Collect of the parameters values
After FE simulation we obtain a very large data bases for each schema of the dies
considering each 3rd node of the mesh, before and after springback. This data bases are: CapPini.xls, DecalatPini.xls, ContinuuPini.xls, Continuu.xls before springback and respectively: SpringCapPini.xls, SpringDecalatPini.xls, SpringContinuuPini.xls, SpringContinuu.xls after springback.

b). In order to calculate the center angle for each i-node considered it is necessary to transform values in values considering the new origin. We determine firstone value reprezented by distance between the curvature center and the origin of coordinations system in FE simulations (fig.1). This value can be calculated considering value for one node from the frontiere of the mesh before the forming stage – B1 in figure 1 – and the length of O1B2 segmentcalculated for the same node by foloweed geometrical considerations:

$$z_{const} = O_1B_2 + 41.420158$$

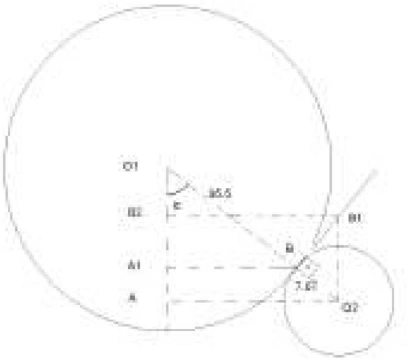


Figure 1

$$\Delta O_1AO_2 : \Delta O_1A_1B \Rightarrow \frac{95.5+7.07}{95.5} = \frac{60}{A_1B}$$

$$A_1B = \frac{95.5\cdot 60}{95.5+7.07} = 55.864287$$

$$\Delta O_1AO_2 : O_1A = \sqrt{102.57^2-60^2} = 83.19$$

$$\left.\begin{array}{l} \Delta O_2BB_1 : O_2B_1 = \dfrac{O_2B}{\cos\alpha} \\ \sin\alpha = \dfrac{60}{102.57} \Rightarrow \alpha = 35.8 \end{array}\right\} \Rightarrow O_2B_1 = \frac{7.07}{\cos 35.8} = 8.71695$$

$$O_1B_2 = O_1A - O_2B_1 = 83.19 - 8.71695 = 74.47305$$

$$z_{const} = 74.47305 + 41.420158 = 115.893208$$

$$\boxed{z_{const} = 115{,}893208\ \text{mm}}$$

In this state we can re-calculate values for each node considered with the folowing ecuation:

$$z_i = z_{const} - z_{i_{sim}}$$

c). Calcul of the center angles α_{i-} and α_{i+}

For each i-node considered we have the situation presented in figure 2. In this case:

$$\cos\alpha_i = \frac{z_i}{95.5}$$

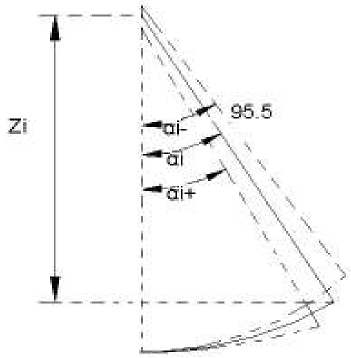


Figure 2

Considering STAS 11111 the imposed tolerance to the radius R95 of the piece are . The length of the piece in the section presented in figure 3 is the same in the considered and extremaly cases (R+= 96,5 mm, R-= 94,5 mm). For each i-node considered it result:

$$const = \frac{\pi\alpha_i\cdot 95.5}{180} = \frac{\pi\alpha_{i_+}\cdot 96.5}{180} = \frac{\pi\alpha_{i_-}\cdot 94.5}{180}$$

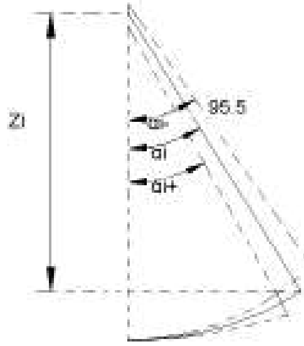


Figure 3

From this ecuation it result:

$$R_+ = 96.5 \Rightarrow \alpha_{i_+} = \frac{95.5}{96.5}\cdot\alpha_i$$

$$R_- = 94.5 \Rightarrow \alpha_{i_-} = \frac{95.5}{94.5}\cdot\alpha_i$$

Uset to calculate the center angles α_{i-} and α_{i+}.

d). Calcul of the and coordinations

This values can be obtained folowing ecuations:

$$z_{i_+} = 96.5\cdot\cos\alpha_{i_+}$$

$$z_{i_-} = 94.5\cdot\cos\alpha_{i_-}$$

Using the ecuations obtained for determination of center angles and we obtain:

$$z_{i_-} = 94.5\cdot\cos\left(\frac{95.5}{94.5}\cdot\arccos\frac{\left(\text{constanta}(z) - z_{i_{sim}}\right)}{95.5}\right)$$

$$z_{i_+} = 96.5\cdot\cos\left(\frac{95.5}{96.5}\cdot\arccos\frac{\left(\text{constanta}(z) - z_{i_{sim}}\right)}{95.5}\right)$$

e).Determination of the decision value

In order to complet the decision column in data base it is necessary to compare z_i value with z_{i+} and z_{i-} values.

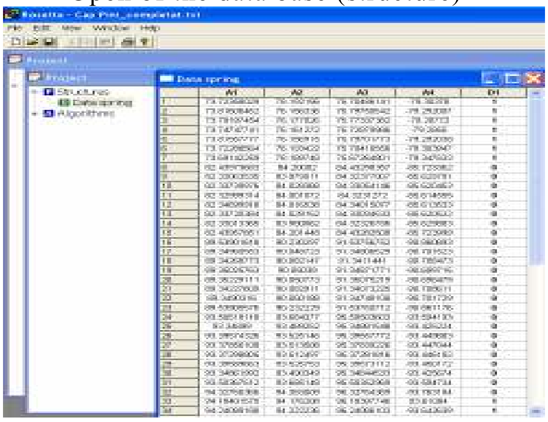
$IF\left(z_{i_{sim}}\right) \in \left[z_{i_+}, z_{i_-}\right] \Rightarrow$ THEN ***decision***=0

ELSE ***decision***=1

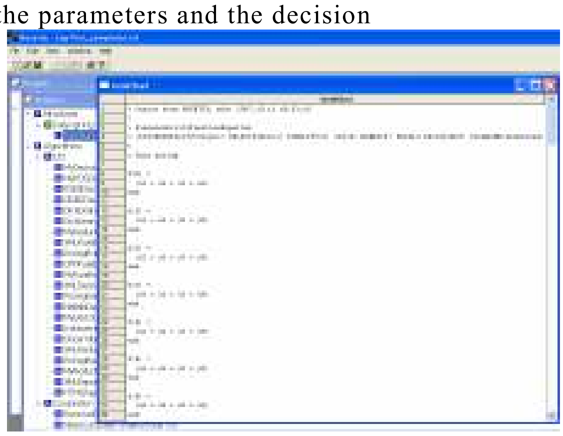
4. Model Building AND Validation

The software used in this researches is Rosetta. We perform the foloweeng steps:

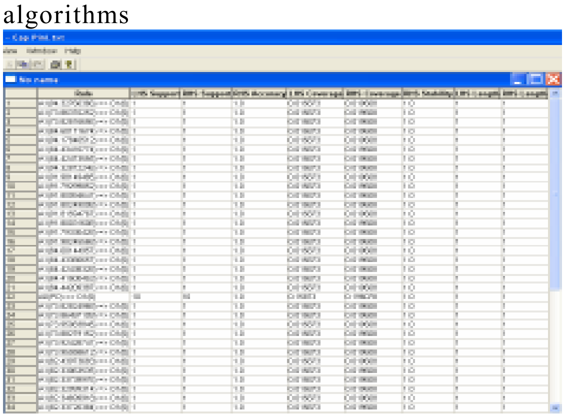
- Open of the data base (structure)



- Identification of the relationships between the parameters and the decision



- Generation of the rules using differents algorithms



5. Conclusions

Once the relationships between the variables established and validate, this method of sheet metal forming analysis we can establish the conditions to perform on-line control of the complex deep-drawing process in order to assure good quality of the manufactured parts.

6. Acknowledgements

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Refernces

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Analiza deformarii plastice a tablelor metalice cu matrite reconfigurabile multipunct utilizad tehnica data mining

Rezumat:

Revenirea elastica este un parametru foarte important in aprecierea calitatii pieselor complexe ambutisate. Utilizand matrite reconfigurabile multipunct acest parametru poate fi controlat in timpul procesului prin intermediul pozitiei pinilor. Rezulta, astfel, necesitatea existentei unor informatii care sa permita interventia rapida in acest sens. Scopul acestei lucrari este de a determina legile ce guverneaza pozitia pinilor in functie de reactia de raspuns a materialului (revenirea elastica, in special) astfel incat sa poata fi asigurata precizia dimensionala a pieselor complexe ambutisate. Metoda de obtinere a acestor legi consta in: i). simularea cu EF a diferitelor scheme constructive ale elementelor active deformatoare si pentru diferite materiale; ii). extragerea parametrilor de intrare si de iesire in vederea generarii bazei de date; iii). determinarea legilor necesare folosind tehnica data mining.

Analyse de la mise en forme des toles metaliques avec matrices reconfigurables discretes en utilisant la technique data mining

Resume:

Le retour élastique est un très important paramètre pour la qualité dimensionale des pièces complexes emboutis. Si nous utilisons les matrices réconfigurables discrètes, nous pouvons contrôler en temps réel le processus par l’intermède des positions des pins. Dans cette situation résulte la nécessite d’avoir les informations nécessaires pour agir rapidement dans cette direction. Le but de ce papier est d’établir les relations entre la position des pins et la réaction-responce du matériau (retour élastique, en principal) ainsi que la qualité dimensionale des pièces complexes emboutis soit assurée. La méthode proposée pour obtenir ces relations consiste en : i). simulation numérique EF des différentes schéma de la construction des matrices et pour différents matériaux; ii). dépouillement des paramètres au but d’obtenir les bases de données; iii). détermination des lois (relations) nécessaires par la technique data mining.