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Design and Optimization process of press tools using Forming analysis for Frame Bonnet Front Automobile Panel

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Abstract: *This paper highlights the springback compensation of frame bonnet front automobile part by using simulation tools. Frame Bonnet Front has more spring back than typical steel, affecting the end part's dimensional correctness. While stamping a sheet metal component, spring back compensation is a significant difficulty. Spring back is the geometric change that occurs when a part is freed from the tool press. Springback is caused by the elastic release from the bending stress given to the sheet metal during forming. By using over bending technique, the material is bent beyond its intended angle, allowing the springback to return it to the intended angle. The over bending compensation value can be carried out with the help of simulation. The compensation values from simulation applied to practical bending process. The final results of the part on the inspection fixture were within the allowed tolerance. Toolmaker can save a lot of time and money by using simulation for springback in their engineering and testing.*

Key Word*: Frame bonnet front, Over bending, Springback, simulation, Rectification springback*

I. Introduction

Automobile manufacturers currently strive to create lighter vehicles without compromising safety standards. High strength steels are employed instead of traditional steel to achieve this. However, using these innovative materials offers issues of springback that affects the geometrical shape of part. Auto form software addresses the challenges of springback. With this software, springback can be minimized since it allows you to calculate the effects after each bending or cutting operation. The Frame bonnet front panel is used as a part of automobile bonnet, its cold rolled sheet 2.3 thick DP590 High strength low alloy material. Have a springback characteristic Caused by elastic recovery of the plastically deformed sheet after bending operation. This springback carried out during simulation and use this springback compensated simulation tools to generate bend tool. The compensated surfaces helps to machine bend punch and bend die. The output of bend is spring backed shape within required tolerances. The compensation approach is used to increase the precision of the stamping process for vehiclecomponents, as well as the finished part's quality.

II. Literature Review

The Springback, Bending simulation and springback compensation of sheet metal have been studied widely by several researchers,

By Esther Mar (1) Springback in sheet metal forming, Methods of addressing springback include process design and part design. In terms of the process, over bending, retarding metal flow due by use of draw beads and higher binder pressure, using lower press speeds, restriking, applying tension during bending, using tighter die clearances, are all techniques that are used. In terms of part design, by utilizing tooling configurations that force higher strain over a small area springback can be minimized

Sung-Bo Sim, Sung-Taeg Lee (2) had concluded that the FEM simulation increased draw ability of production part for this progressive die development of five step drawing. The results of fine quality of production part were accomplished without fail by tryout and its revision after die components making and assembling. The auto-feeding treatment with a relevant attachment was comparative effect for this production part material strip progression.

Waluyo Adi Siswanto(3) In this research, two different methods, displacement adjustment (DA) and spring forward (SF), are joined in alternate manner to compensate the die tools to minimize springback error called hybrid method (HM).

Stefanos C. Spathopoulos (4) in this study, an innovative neural network system which predicts springback in sheet metal forming processes is proposed. For the ANN training purposes a number of examples were created, through a carefully prepared simulation of an S-Rail configuration. After validating the FE model for a test case used in similar industrial studies, a number of springback predictions were implemented by means of the Bayesian regularized back propagation neural network.

Rakesh lilhare (5) in this study, Sequence of operation is planned initially and then press tool is designed and analyzed. The purpose of carrying out analysis is to prevent the costly tryouts and thus optimize the quality and rate of production.

III. Geometric Parameters and Description

The Frame bonnet front panel is a 2.3mm thick sheet metal part made of material D513 with overall dimensions of 530mm length, 60mm width and 65mm height. The fig 1 shows CAD model of the panel.

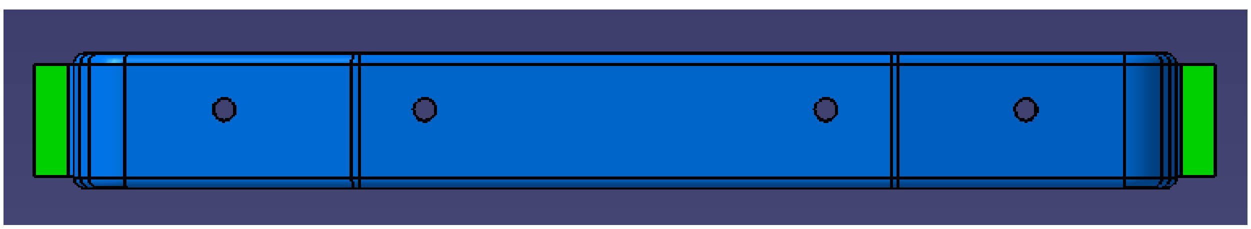

Figure1: Part Geometry

The fig.1 Shows part geometry, green color highlighted is a matching area of subsequent part in welding assembly. Flange of part matches and this zone should need to maintain surface tolerances +-0.5mm. After drawing operation, it's having a tendency to open flange out of tolerance, to overcome this problem generally a restrike tool is used for achieving matching flanges within tolerances. The flanges should be flat. If not, this can create poor or difficult resistance spot weld conditions.

Material properties,

Table no 1: Shows material properties of frame bonnet front.

Material	n value	R value	Poisson's ratio	Young's Mod.	Yield Strength	UTS	K Value
D513	0.2	1.29	03	210(GPA)	023(GPA)	0.34(GPA)	058(GPA)

n and r-values in Forming.

n – Value the work hardening exponent determines the rate at which a material hardens and describes the ability of the material to stretch

r – Value the coefficient of anisotropy or r-bar is used to measure the differences in material properties through the thickness of the sheet versus in the plane of the sheet and describes the draw ability of a material

The main material properties affecting forming are the n and r-value that are used in FTI software. The **n-value** is called the work hardening exponent and is obtained from a uniaxial tensile test on a material sample. Higher n-value means better stretching; the **r-value** is determined by the rolling direction of sheet metal. Higher r-value means better deep drawing. This panel requires three press tools such as Form Tool, in such operation flat part of sheet metal formed in required shape.

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I. **Form Tool** - Parts hold their permanent shape after plastic deformation in a Stamping Die. A flat blank is formed into the desired geometry with a punch and die. When blanks are deformed into parts, the metal has been plastically deformed, and exhibits strain.

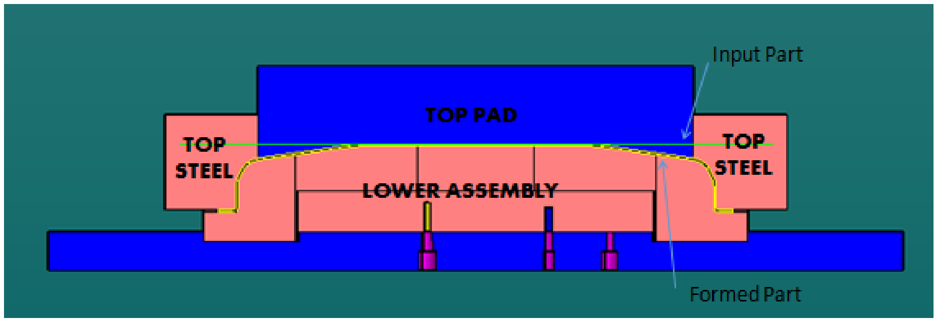

Fig.2 Form operation.

II. **Restrike Tool** – In Restrike tool matching area of part hitted and control the spring back. The flangesshould be flat. If not, this can create poor or difficult resistance spot weld conditions.

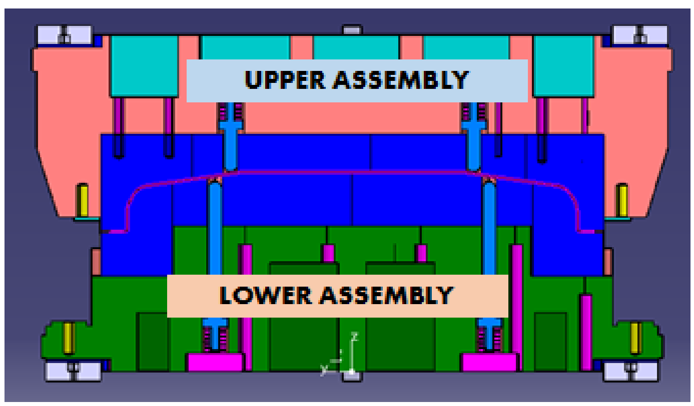

Fig.3 Restrike operation.

III. **Cam Pierce Tool** – In Cam Pierce operation, Piercing side the holes which is not possible vertically. This operation comes after Restrike. It may carry out in one tool or two or more tool depending on complexity of component.

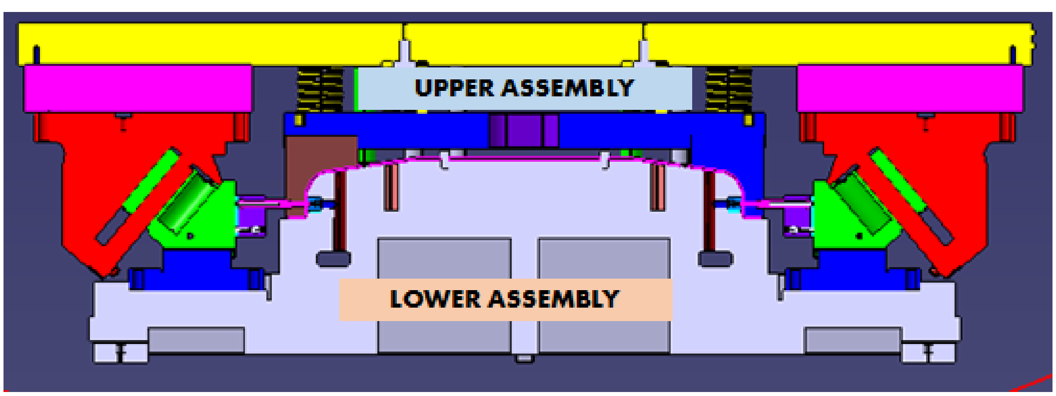

Fig.4 Cam Piercing Operation

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Mathematical Calculations:-

Force required to Forming - For Forming operations two forces need to calculate, ram force and blank holder force.

Forming force: Fd, max = k* (π*d)*t*UTS

For this panel (π*d) is Ring line periphery=1120mm, t-sheet thickness, UTS- Ultimate Tensile Strength, n-Drawing coefficient.

For material D513, UTS = 340 Mpa YS = Yield strength 230 Mpa, Drawing coefficient k= 0.7, t=1.2

Fd, max = 0.7* 1120*2.3*340/9810 = 62.5 T

The blank holding pressure required depends on the wrinkling tendency of the cup, which is very difficult to determine and hence it is obtained more by trial and error. The maximum limit is generally to be one third of the drawing force.

Force required to Piercing,

F (Pierce) = L*t*s, L- is total cutting length (; t- thickness of sheet, s- is shear strength which is generally used 80% of tensile strength.

Cutting Force = 21*2.3*272/9810=1.3 T Each Side.

Pad Stripping force is 10% of cutting force = 7.389 T

Spring Back- Spring back/Elastic recovery relates to the change in shape between the fully loaded and unloaded configurations the material encounters during a stamping operation.

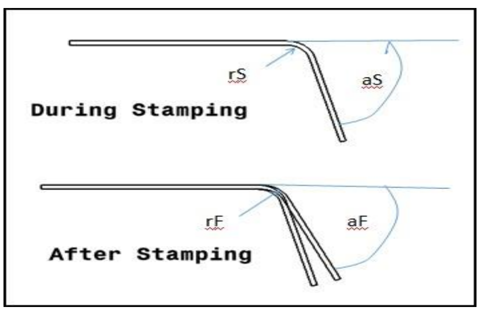

Fig.5 Spring back.

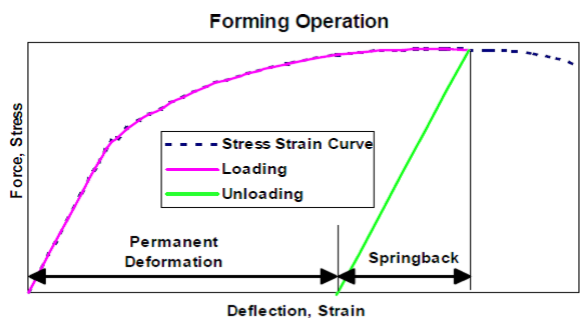

Fig.6 Stress strain behavior during forming operation.

The spring back factor denoted by Ks, the relation between initial and final angles Ks = aS/aF, a spring back factor Ks= 1 means there is no spring back. When a value is 0, then its total spring back. Using lower press speeds, restriking, applying tension during bending, using tighter die clearances, are all techniques that are used. In terms of part design, by utilizing tooling configurations that force higher strain over a small area spring back can be minimized.

IV. Finite Element Analysis

According to the practical condition, we set some process parameters in drawing simulation process as following

Table no. 02. Process Parameters

Analysis type	Friction coeff.	Blank thickness	Stamping velocity(mm/s)	Blank holder pressure (Ton)	Clearance 10% of sheet thickness (mm)
Forming	1.25	2.3	2000	17	2.32

Required simulation tools for analysis is generated in CATIA and forming simulation was run using auto form software. The part related surfaces are created with inner side (Matching side) as a master. A physical modeling is costly and time consuming, due to a sheet metal simulation done, which gives a virtual idea to define the operation process. Correct process parameters give an exact result of defects at simulation stage.

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Simulation Tools:-

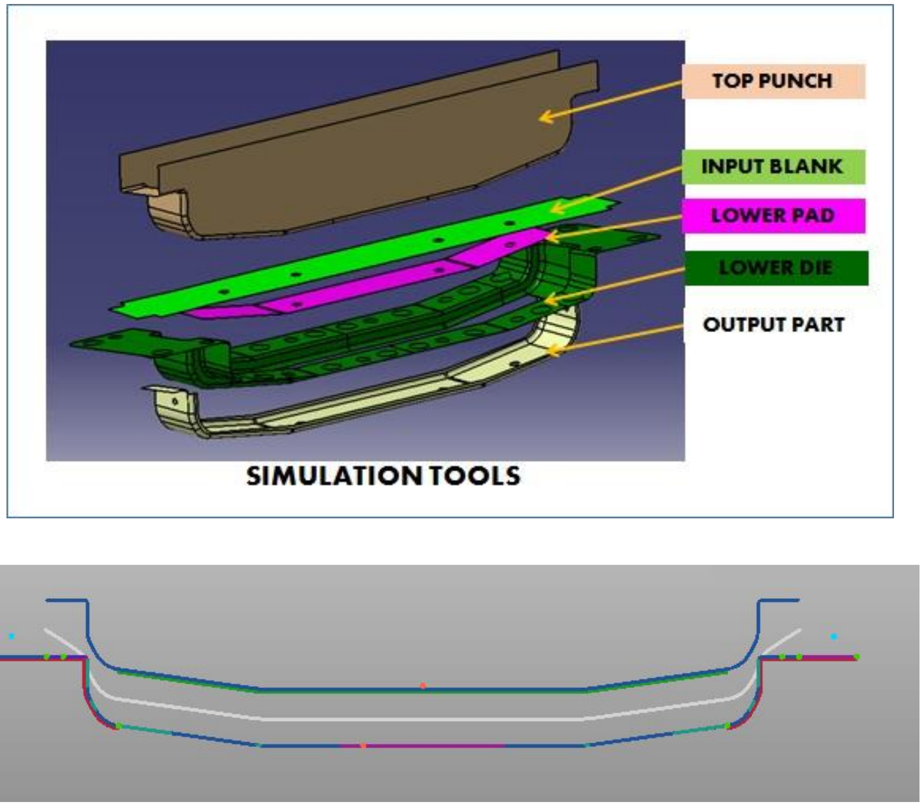

Fig.7 Tools used for forming simulation.

1. **Blank: -** The blank is flat sheet, input part for forming. Its mechanical properties, shape, and location in the tool defined at earlier stage. Blank shape and location impacts on the final production performance.
2. **Lower Pad: -** Lower pad to hold blank and facilitate controlled material flow into the die radius. In order to solve the problem of sheet metal wrinkling a blank holder is used by applying pressure to the surface of the blank.
3. **Punch: -** A punch is a tool that is used by pressing it against a material. Normally a punch is used in combination with a die, and transfers the shape to the material.
4. **Die Cavity: -** It is a tool pushes downward on the sheet metal (Blank), forcing it into a die cavity in the shape of the desired part.

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V. Experimentation and Validation

At first iteration, the results the results from auto form were not satisfying showing springback at flange matching surfaces, wrinkling and cracks at some area which is not acceptable as per functionality of part and automobile standard.

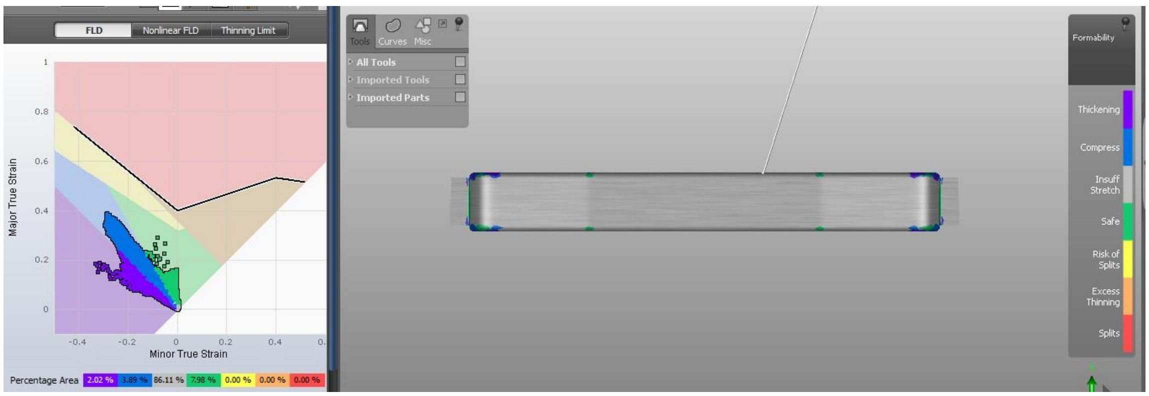

Fig.8 forming simulation result with FLD.

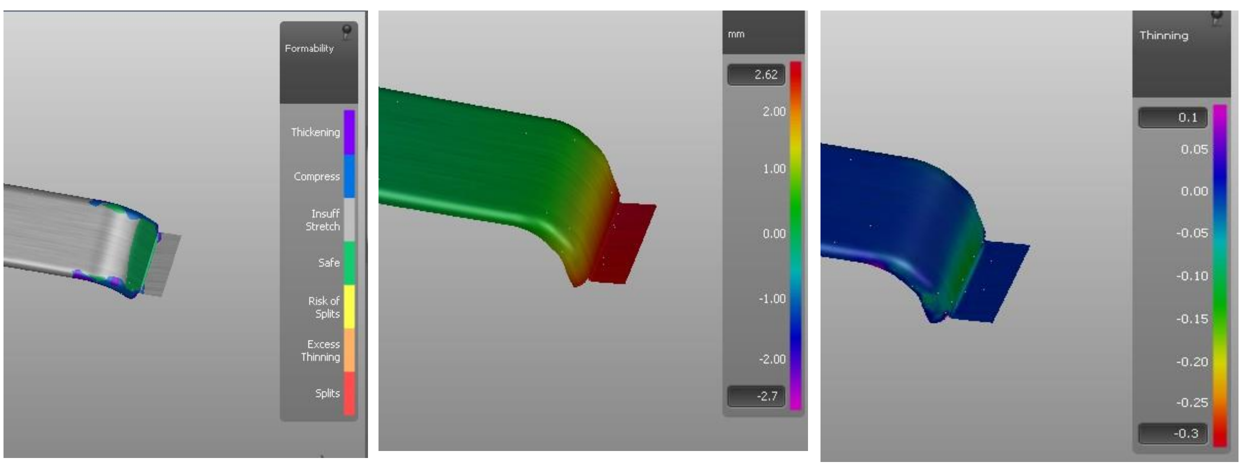

Fig.9a Formability. Fig.9b Spring back. Fig.9c Thinning.

Fig.9 shows the forming with FLD. A forming limit diagram, also known as a forming limit curve, is used in sheet metal forming for predicting forming behavior of sheet metal. A combination of major and minor strains will fall in one of three zones, safe, marginal, or failure. If a measured deformation gives a point representing a major and minor strain combination that lies below the marginal curve, it is in the safe zone. On the basis of the simulation results we tried various no of iteration by changing the simulation tools, geometry and parameters which are affected such as Blank holder pressure, Die cavity depth and radius, Friction between the blank, blank holder, punch and die cavity. Clearances between the blank, lower pad punch and die cavity. Blank shape and thickness. The simulation was run and taking a number of iterations. Fig.9a shows formability of part, in such case part cracks at radius area, thickening shows but it's outside of actual part area. At some places it shows splits. Fig.9b shows spring back, in particular z direction the flange of parts out in ranges from +2.62. Fig.9c shows thinning, which is under control less than 20% of part thickness.

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From IT_2 to IT_5, The simulation tool geometry changed, Radius on the die at addendum increased from 3 to 4. The material flow increased. For spring back point of view, matching flange surfaces, a countermeasure of spring back, is carried out and developed tools.

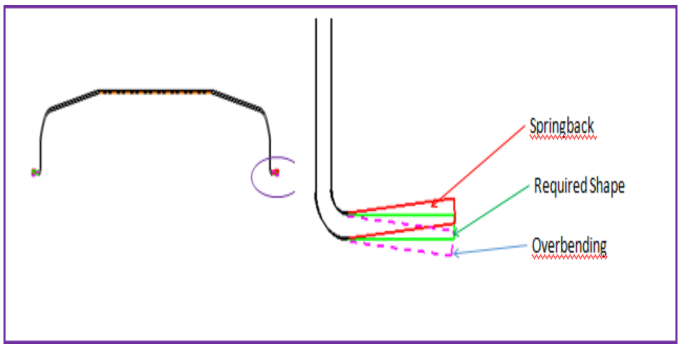


Fig.10a spring back compensation sections.

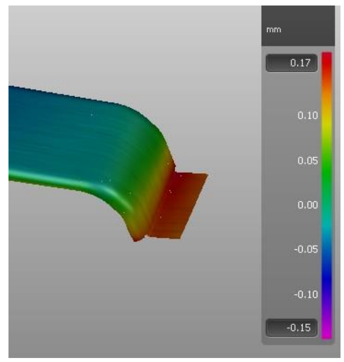


Fig.10b springback within tolerance.

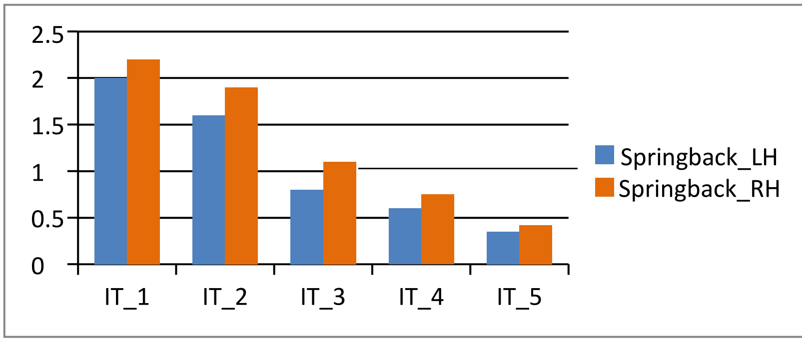
Spring back compensation: - Fig. 8 shows a cross section of the part, Red color highlighted is springing back having values 2mm lifted from original part and 2.2 mm lifted in other side. The part is symmetrical from the centre, but springbok is different on both sides. To overcome this springback, yellow color highlighted surface generated which is initially taken as 0.5mm over bent both side and taken trial. In this trial, the springback is 1.8mm in right side and 1.89 mm at left side.

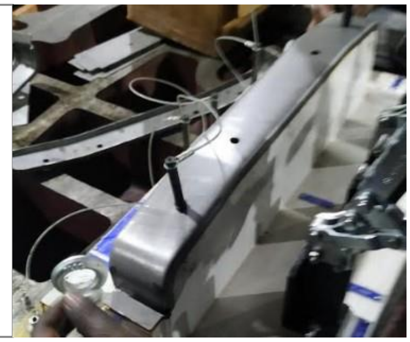
VI. Results and Discussion

The over bending values are changed and taken nine iterations till part comes within the tolerance range. Below table II shows iteration wise results. The results obtained from forming simulation helped to develop tools and taken no. Of iterations till part geometry matching faces come within tolerance. The final iteration forming simulation tools used in form die and spring back controls in initial stage in first press tool form operation only. Thus spring back issue resolved earlier operation; there is no requirement of additional restrike tool.

IT. No.	Modification in simulation tools	Wrinkles	splits	Thinning	Spring Back		Remark
					LH Side	RH Side	
					Flange height out in mm.	Flange height out in mm.	
1	Initially prepared surfaces used.	YES	YES	NO	2	2.2	Out of Tolerance range +- 0.5
2	Springback compensation done by pressing flange in reverse by 0.5 degree & 0.5mm.	YES	YES	NO	1.6	1.9	Out of Tolerance range +- 0.5
3	Pad force increased, Springback compensation done by pressing flange in reverse by 1.5 degree & 1mm.	YES	NO	NO	0.8	1.1	Out of Tolerance range +- 0.5
4	Die radius reduced, Springback compensation done by pressing flange in reverse by 1 degree & 0.8mm.	NO	NO	NO	0.6	0.75	Out of Tolerance range +- 0.5

5	Springback compensation done by pressing flange in reverse by 1.2 degree & 1mm.	NO	NO	NO	0.35	0.42	Within Tolerance range +- 0.5





VI. Conclusion

With reference of five experimental iterations, the spring back rectification done of frame bonnet front panel at matching flanges, and create a new path to rectify spring back. By considering iteration wise spring back error values, Modified input data for simulation known as simulation tools with a changed angle value in surfacing software CATIA. Used auto form to simulate the forming operation with the modified tools, and analyzed the defects of the frame bonnet front panel which stamped with new die and punch whose surfaces were compensated. This iterative trial and error method used to predict and measure the spring back of a final output part of form operation. It is valuable in optimization of press tool process, the spring back compensation and dimensional precision of a frame bonnet front panel achieved without the use of restrike tool, and panel produced in two operations only. We saved the cost tool, press stroke, labor, material handling and reduced process cycle time.

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