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Springback Control in Sheet Metal Forming: A Virtual Manufacturing Approach

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ABSTRACT – This study explores springback control in sheet metal forming using finite element analysis (FEA) with virtual manufacturing tools to improve accuracy, reduce trial-and-error adjustments, and enhance efficiency in the automotive stamping process. Springback, the elastic deformation occurring after stress release in metal stamping, poses significant challenges, affecting dimensional precision and assembly quality of formed components. This research simulates springback behavior using Simufact.forming software, substituting SPH590 with SPH440 steel due to their comparable properties. The methodology involves a three-phase approach: defining simulation parameters, conducting simulations on a rear arm component, and comparing results with industry-standard CAD models. Key boundary conditions—blank holder force, temperature, and friction—were carefully set to reflect real manufacturing environments accurately. Results showed springback-induced deviations of up to 6.66% between simulated and CAD models, attributed to effective stress concentrations in complex geometries, emphasizing the importance of precise boundary conditions and parameter adjustments. Findings demonstrate FEA's potential for effectively predicting and minimizing springback, reducing physical trials, and lowering associated costs. Future work will focus on adaptive simulations that more accurately reflect industrial conditions, further advancing simulation precision and broadening applications in metal forming.

KEYWORDS : Springback, Virtual Manufacturing, Finite Element Analysis, Metal Forming, Stamping Process

1.0 INTRODUCTION

Metal forming such as stamping process is widely used in many industries due to its massive manufacturing capability in term of quality and quantity. In the automotive industry, many parts have been manufactured by using stamping process. All of the stamped parts are then assembled into a final product in a systematic way [1]. In order to reduce the weight of the car or to reduce the fuel consumption, the mould has been modified many times to reduce the time attempt to produce a part, so they can produce many mould design in a short time for improvement [2]. It is impossible to produce every dimension to an exact because of variation, but product dimension or geometry accuracy is very important quality factors in manufacturing automotive part.

Stamping is a process in which metal is pressed between two dies to form the workpiece into the desired product. The operations form the workpiece by plastic deformation, but some of the deformations occur to the workpiece will still be elastic in nature. After the stamping process, certain portions of the workpiece tend to elastically deform to relieve the residual stress during the removal of the dies. This relieving of residual stress is called Springback [3]. Springback deformation is one of the critical problems in stamping process that caused it returned to the original shape of the workpiece due to the elastic recovery of internal stresses during unloading. This can cause the final product low in stamping quality [4]. Figure 1 below presents Springback occurs after metal forming process.

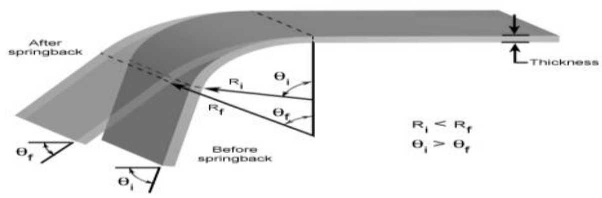

Figure 1. Springback occurs after metal forming process.

During the stamping process, many factors could affect springback in the process such as material variations in mechanical properties, tooling geometry, forming speed, the design of the mould, bend radius and bend design, part shape design, die design and die settings[5]. Besides springback may produce surface distortion and unexpected shape tolerances that may cause not only deviations from the design target shape but also will affect the assembly problems. Hence, springback prediction is one of the important issues in metal forming industry [6]. The accuracy of the methods such as analytical calculation and finite element analysis in predicting the springback value is also very important.

In automotive industrial, springback deformation is one of the critical problems in stamping and forging process that caused it returned to the original shape of the workpiece due to the elastic recovery of internal stresses during unloading [7]. This problem can affect the shape and size of the final product to be inaccurate with the shape and size of the die working surface. This can cause the final product low in stamping quality, surface quality, and assembly performance due to the springback [8]. Springback is very sensitive to various material and process parameter [6]. The major factors that affect the spring back are:

- Mechanical parameters of metal
- Anisotropy
- Grain arrangement
- Die shape design
- Magnitude of blank holder force
- Process condition
- Work hardening phenomenon

To verify the springback of a workpiece, most of the industry use trial and error method which can highly cost for repairing tool and also waste a lot of time. Hence, it will delay the manufacturing of the product. The finite element analysis (FEA), Design of Experiment (DoE) simulation of metal forming process is well-known and well-established tool for design engineers in most industry in order to compensate the springback behaviour in metal forming. It is not only for the final forming process but also can help to reduce the number of expensive experimental tests in forming process set-ups [9]. Nowadays, most of the industrial goals for the forming simulation can be summarized into three main points:

- Time reduction
- Cost reduction
- Increase of product quality

It has been proven to be effective in prediction of formability and springback behaviour [10].

2.0 METHODOLOGY

The research methodology consists of three distinct phases:

2.1 Phase 1: Study of Simulation, Design and Parameter

Based on the literature review, all of the information about Springback issue has been collected to prepare data collection and methods as well as of analysis procedures. Besides, CATIA V5R21 and VISI 2018 R1 software will be used to design the mould of the rear arm and Simufact.forming 12 is used to optimize the establish parameter that will influence springback.

2.2 Phase 2: Gather all of the Information and Dimension

A study will be conducted and the rear arm information and dimension will be collected from OSI Company. The parameters of the product will be the same as in the simulation and the actual one. The result of the production will be recorded for analysis and comparison between the design drawing and simulation.

2.3 Phase 3: Result Comparison

After all of the simulation has been done, the result will be compared to the design drawing and it will be analyzed for the optimal parameters in order to reduce springback. Based on the results obtained, the discussion and conclusion can be made and will be written in a paper. Figure 2 below presents the flowchart of the project's methodology consists of three distinct phases.

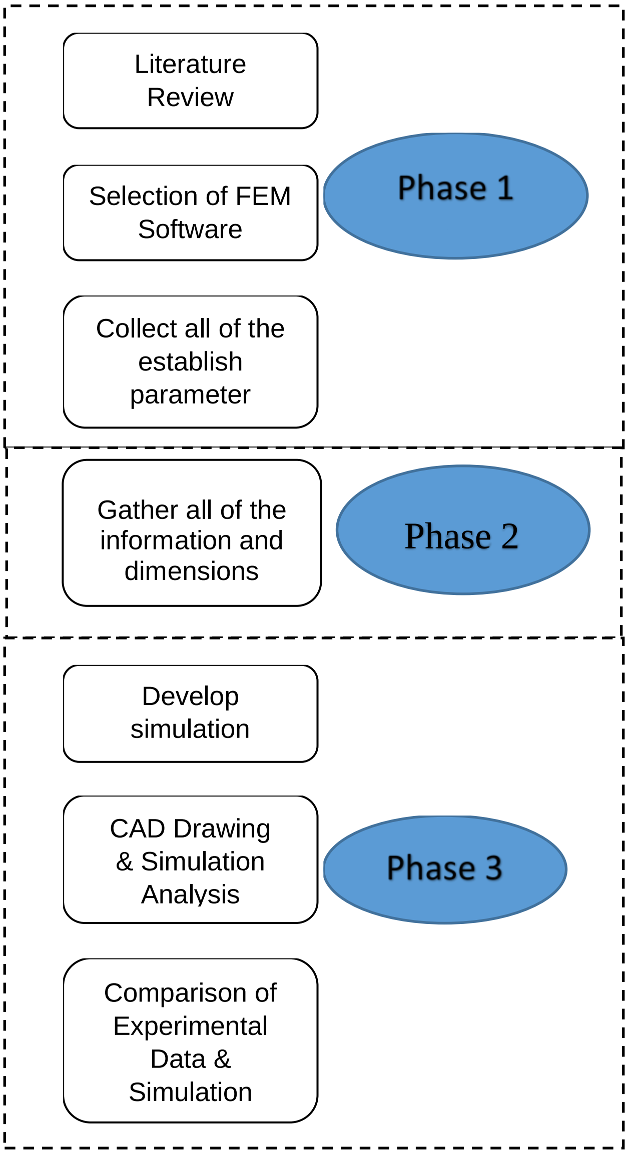

Figure 2. The flowchart of the project

2.4 Selection of Material

General steel (SPH590) is used in the stamping process for the right-hand rear arm part. But for the simulation, Simufact.forming software does not provide the material (SPH590) in the library. In that case, another new material has been selected to replace material (SPH590). Therefore, general steel (SPH440) is used in the Simufact.forming for the simulation due to its properties and chemical composition does not have much different compared to the material (SPH590). Table 1 below presents the Chemical Composition of SPH440 and table 2 shows the chemical composition of SPH590.

Table 1. The Chemical Composition of SPH440.

Carbon (C)	Manganese (M)	Phosphorus (P)	Sulphur (S)
0.15%	1.1%	0.02%	0.027%

Table 2. The chemical composition of SPH590.

Carbon (C)	Manganese (M)	Phosphorus (P)	Sulphur (S)
0.05%	1.35%	0.007%	0.003%

Material (SPH440) has been selected based on a research made by Mohd Shahir, 2014. He found that both of the material (SPH590 & SPH440) have almost the same value of springback when a test is conducted on them. Both of the materials show the similar reaction under tensile test. Although there was a slightly different in chemical composition between of the materials, there was no other material in Simufact.forming library can replace material (SPH590) like material (SPH440) does.

CATIA V5R21 and VISI 2018 R1 software were selected for the design drawing due to its capability to draw the part design with efficiency and accuracy. The design drawing for this product has been provided by Oriental Summit Industries using CATIA V5R21. By using the reverse engineering method, both of the die (upper and lower) and the sheet metal (workpiece) has been designed using CATIA V5R21 and VISI 2018 R1. Figure 3 and 4 below presents the CAD drawing of the upper die of the product and the assemble of both dies.

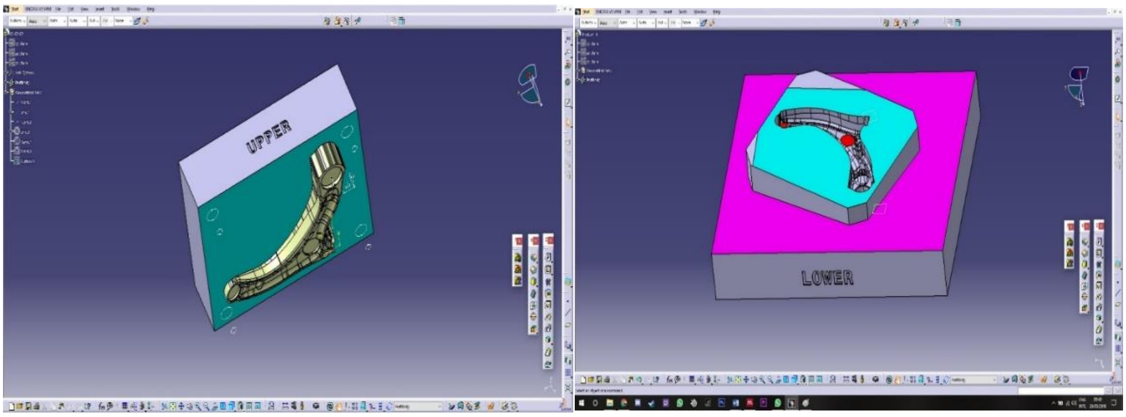

Figure 3 The upper die of the product.

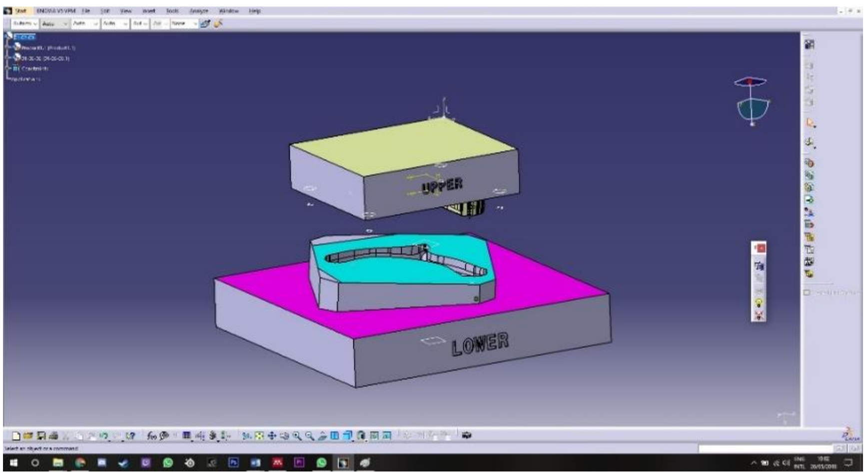

Figure 4. The assemble of both dies.

3.0 RESULT

For stamping simulation, Simufact.forming software is used to conduct the analysis. Simufact.forming is one of the powerful software that can give the most accurate measurement in the metal forming process. All of the parameters needed to perform the stamping simulation was obtained at the same industry. Figure 5 below presents the CAD drawing of the right-hand rear arm (upper) alongside the actual rear arm (below) and Figure 6 below presents the assemble of the dies and workpiece in Simufact.forming meanwhile table 3 presents the all of the parameter used for simulation process.

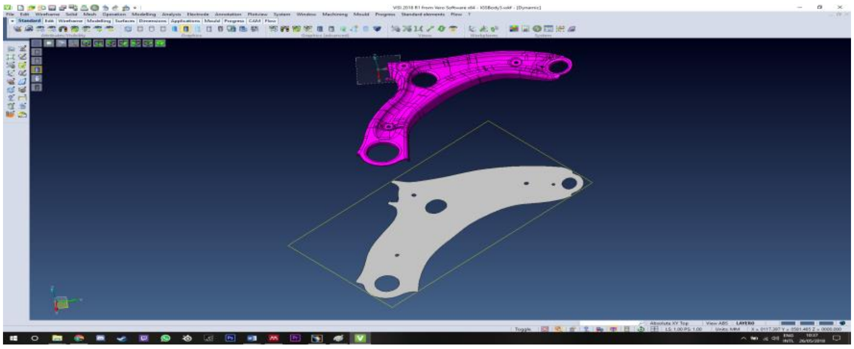

Figure 5. The right hand rear arm part.

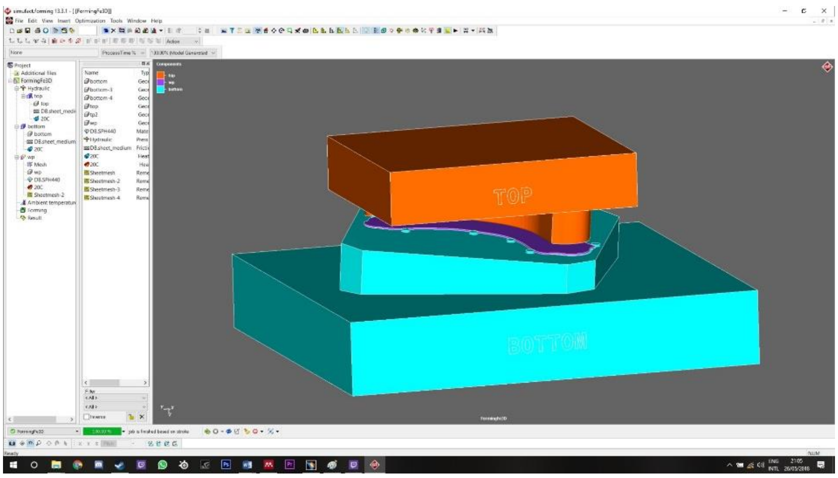

Figure 6. The assemble of the dies and workpiece in Simufact.forming

Table 3. All of the parameter used for simulation process

Parameter	Type/Value
Forming process	Sheet forming
Process type	Cold stamping
Ambient Temperature	20°C
Material	SPH440
Press	Hydraulic press
Die Friction	Medium
Temperature	Die - 20°C / Workpiece - 20°C
Mesh	5mm Hexahedral
Stroke	50mm

3.1 Comparison of Data

Some of the dimensions of the rear arm obtained from the stamping simulation were slightly different from the original drawing. The data obtained from the simulation was then compared to the design drawing obtained from the industry. Two points were plot at both of the rear arm at the same position and all of the measurement is recorded. This simulation helps to verify whether the stamping process performed by the industry was done according to the specification. Figure 7 below presents the measurement 1 of rear arm from drawing and simulation, Figure 8 presents the measurement 2 of rear arm from drawing and simulation and Figure 9 shows the measurement 3 of rear arm from drawing and simulation

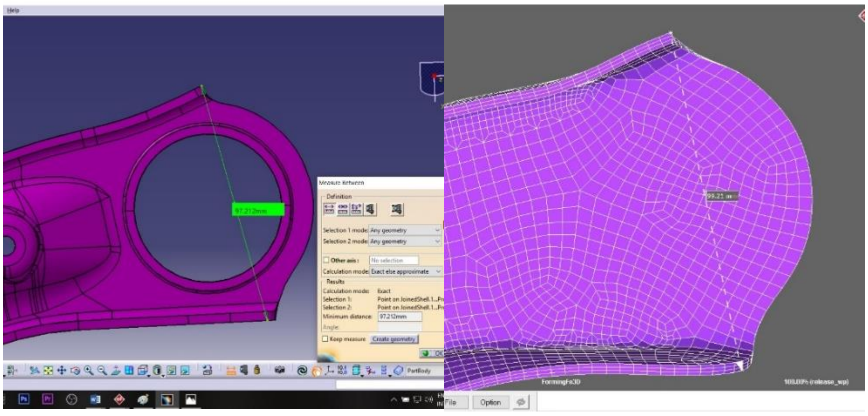

Figure 7. The measurement 1 of rear arm from drawing and simulation.

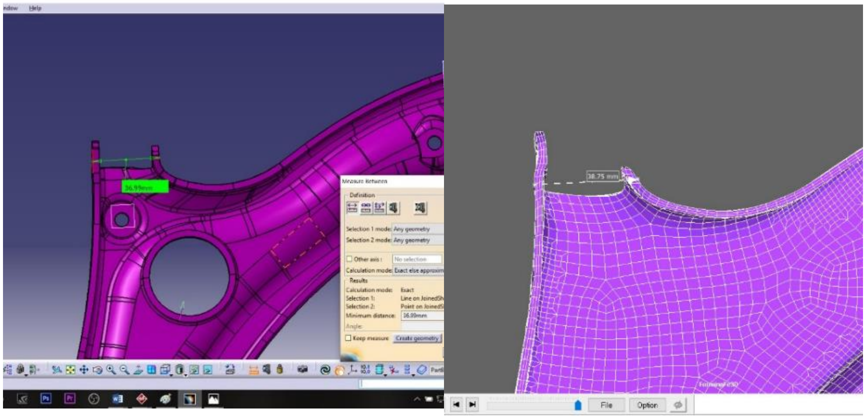

Figure 8. The measurement 2 of rear arm from drawing and simulation.

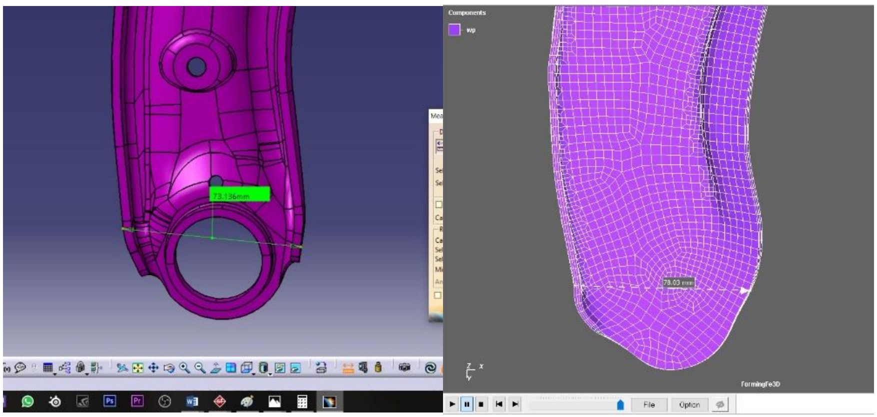

Figure 9. The measurement 3 of rear arm from drawing and simulation

Table 4. The comparison of measurement between CAD and simulation

Measurement	CAD Measurement (mm)	Simulation Measurement (mm)	Percentage Difference (%)
1	97.21	99.21	2.05
2	36.99	38.75	4.76
3	73.16	78.03	6.66

The percentage differences in the measurements as present in the Table 4 above shows the value of springback occurs during the metal forming process. Since the actual material is not provided in Simufact.forming library, another material has been replaced for the simulation process. Hence, the differences between the chemical compositions of both materials could contribute to these errors. Ambient temperature is also one of the main factors affecting the metal forming process. The temperature inside the industry might change or fluctuate depending on the weather. This could influence the material characteristic during the stamping process. The dies design also need to be considered. Although the reverse engineering method has been applied in designing the dies, the rear arm dimension still has slightly different after metal forming simulation. After the stamping simulation process, an analysis is made for this material (SPH440). The material is subjected to a high value of effective stress at a specific area across measurement 3 and 2. Springback value will increase as the value of effective stress increase. The highest effective stress acting on the material is 680.42 MPa. The factors that contribute to these high value of effective stress includes the complex geometry and curve as shown in Figure 10 The effective strain distribution at measurement 1,2,3.

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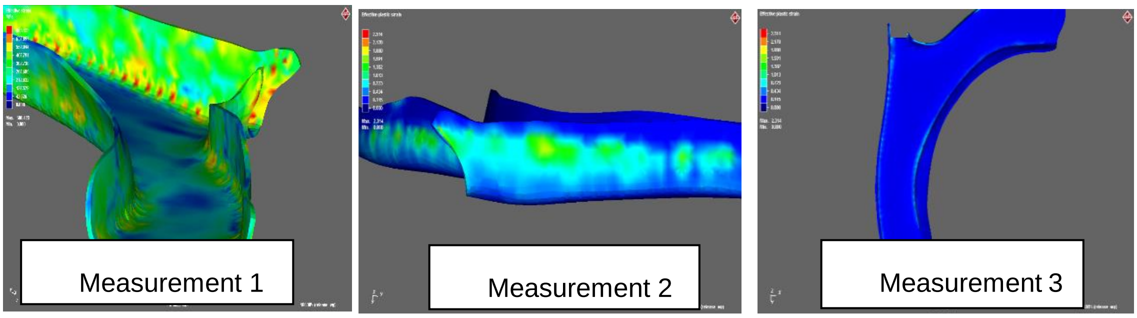

Figure 10. The effective strain distribution measurement 1,2,3.

4.0 CONCLUSION

The FEA simulation with Simufact.forming successfully captured springback behavior, providing a realistic depiction of dimensional deviations that align closely with real-world observations.The springback magnitude in the rear arm simulation was influenced by effective stress levels and boundary conditions.Material substitution impacted springback values but remained within an acceptable range, highlighting that SPH440 can effectively approximate SPH590 under similar conditions. By using Simufact.forming software, the simulation conducted only involves a simple single process which increases the probability of errors to occur. This study demonstrates that virtual manufacturing via FEA can be a reliable alternative to physical trials, potentially reducing cost and time associated with tool adjustments.The results emphasize the importance of precise boundary conditions and parameter tuning to improve the fidelity of springback predictions.Time and cost for the company to manufacture the rear arm can be reduced. Future studies could incorporate more adaptive FEA settings that account for temperature fluctuations to better simulate factory environments. Additional work should also explore multi-material simulations and adaptive meshing techniques to further reduce computational costs while enhancing accuracy in complex geometries.

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