Volume 9, Issue 5, pp. 64-68, 2025.
International Journal of Scientific Engineering and Science
ISSN (Online): 2456-7361

Application of Robust Design Methodology in AutoForm R11 for Optimizing Sheet Metal Stamping Dies in Automotive Hood Manufacturing

Le Nhu Trang[1*], Duy-Vu Nguyen[2], Van-Tuan Bui[2], Xuan-Truong Le[2]
[1]Faculty of Mechanical Engineering, University of Economics - Technology for Industries (UNETI)
[2]School of Mechanical and Automotive Engineering, Hanoi University of Industry, Hanoi, Vietnam
lntrang@uneti.edu.vn

Abstract— *The stamping process for automotive body components often faces challenges such as wrinkling, thinning, and tearing, which adversely affect product quality and increase production costs. This study presents the application of the Robust Design methodology integrated with AutoForm R11 simulation software to optimize the design of sheet metal stamping dies, focusing on automotive hood manufacturing. By analyzing key process variables, including blank holder force, blank geometry, material yield strength, tensile strength, friction coefficient, and anisotropy coefficient, the robustness of the forming process was evaluated and enhanced. The Latin Hypercube Sampling method was employed to generate 80 simulation scenarios, allowing comprehensive sensitivity analysis. The results demonstrated that the proposed approach significantly improves dimensional accuracy, reduces material waste, and enhances process stability. The forming limit diagram and wrinkle analysis further confirmed the reliability of the optimized die design, offering valuable insights for robust, cost-efficient manufacturing in the automotive sector.*

Keywords— *Robust Design, Die Design Optimization, Material Flow Analysis.*

I. INTRODUCTION

In the manufacturing industry in general and the automotive industry in particular, the stamping process plays a pivotal role in producing vehicle body components with high dimensional accuracy, surface quality, and structural integrity. As automotive standards evolve to meet stringent safety, aesthetic, and environmental requirements, the demand for precision in sheet metal forming has significantly increased. However, the stamping process often faces a series of technical challenges including elastic deformation, surface wrinkling, tearing, uneven material thinning, and dimensional deviations. These defects not only affect the quality of the final product but also lead to elevated scrap rates, increased rework, and reduced overall production efficiency.

To overcome such challenges, the adoption of advanced computer-aided simulation and optimization techniques has become indispensable. These modern approaches enable the prediction and control of forming defects during the early design phase, facilitating die optimization, enhancing product quality, and minimizing process variation. Among these, Robust Design (RD) methodology has gained significant attention due to its ability to systematically address variations and improve process stability. In the context of sheet metal forming, robustness is a critical attribute as it ensures the consistency of part quality under real-world conditions where noise factors such as material variability, lubrication changes, and machine settings are unavoidable. Traditionally, stamping robustness has been considered primarily during the production phase, monitored by quality assurance departments. However, with the advent of powerful simulation platforms, companies can now proactively address robustness during the early stages of product and tooling design. One of the most prominent and widely adopted simulation tools in this field is AutoForm software. It offers comprehensive capabilities for simulating the entire sheet metal forming process, performing material flow analysis, evaluating deformation behavior, and optimizing die designs. Recent studies have demonstrated the effectiveness of AutoForm in improving the quality and consistency of stamped parts [1]. For instance, AutoForm Korea introduced a Robust Digital Process for achieving a "Quality Loop Zero," showcasing how digital tools can eliminate iterative physical trials and shorten development cycles [2]. Their use of the AutoForm DieDesigner® Plus module resulted in a considerable reduction in simulation time and a marked improvement in workflow accuracy [3]. Furthermore, the application of AutoForm Assembly has proven to be effective in evaluating complex structures such as side sill assemblies made of ultra-high-strength steels [4]. Companies like Gestamp have leveraged AutoForm's advanced engineering capabilities to reduce rework, detect forming issues early, and enhance product quality [5]. In one notable case, springback compensation—typically a complex task—was simplified to adjusting wall angles, highlighting the practical success of AutoForm-based simulations [6].

Despite these advancements, manufacturing environments remain subject to various sources of variability—often referred to as "noise"—that are inherent and unavoidable [7]. To address this, Robust Design methods provide a structured approach for improving product reliability by minimizing sensitivity to these noise factors. Although there remains some skepticism and lack of clarity in the industry regarding the practical implementation and impact of RD methods [8], they continue to offer a widely recognized framework for parametric design exploration through both simulation and experimentation. The integration of these methods into the early design phase aligns with the principles of quality-by-design and contributes to a more resilient manufacturing process [9].

International Journal of Scientific Engineering and Science
Volume 9, Issue 5, pp. 64-68, 2025. ISSN (Online): 2456-7361

Robustness continues to be a central concern in sheet metal forming. With the growing accessibility of powerful simulation software, industries are now better positioned than ever to incorporate robustness not only during production but also throughout the design and engineering phases of stamping dies and processes.

II. RESEARCH METHODOLOGY

A. *Research Model*

This study is centered on the optimization of sheet metal stamping dies specifically for automotive hood components by applying the Robust Design methodology. The hood is a critical structural element in vehicle design, contributing not only to the aesthetic appearance but also to overall rigidity, crash performance, and thermal protection. As such, it requires exceptional dimensional accuracy, mechanical strength, and forming precision during manufacturing.

Nevertheless, the stamping process of such large and geometrically complex parts is often subject to significant challenges. Typical issues include elastic recovery (springback), localized thinning, surface wrinkling, and even fracture under suboptimal process conditions. These defects can negatively impact product quality, increase material waste, and reduce manufacturing efficiency.

To systematically address these issues, this study employs AutoForm R11—a specialized CAE software for sheet metal forming simulation—to model the hood stamping process virtually. The software enables accurate prediction of deformation behavior and defect formation under various processing conditions.

Key process parameters, including stamping force, stamping direction, initial blank shape, and friction coefficient, are selected based on their influence on formability and part quality. These parameters are varied systematically within defined ranges to assess their impact on critical output responses such as thickness distribution, strain localization, and springback behavior.

Through the application of the Robust Design methodology, the research aims to identify the most stable and optimal parameter configuration that minimizes sensitivity to variation (noise factors), thereby enhancing process robustness. The ultimate goal is to reduce forming defects, improve thickness uniformity, and increase dimensional consistency of the stamped hood panel—thereby ensuring high product quality and process reliability suitable for mass production in the automotive industry.

B. *Scope of the Study*

The study focuses on the stamping process of automobile hoods made of high-strength alloy steel. The stamping process includes many steps, from preliminary forming to final stamping. The study only considers the factors affecting the stamping quality through simulation, without performing actual tests.

C. *Research Limitations*

Does not consider the effects of material aging after stamping. The effect of environmental conditions such as temperature and humidity is not considered. Only focusing on stamping parameter optimization, not studying changes in the geometric design of the hood.

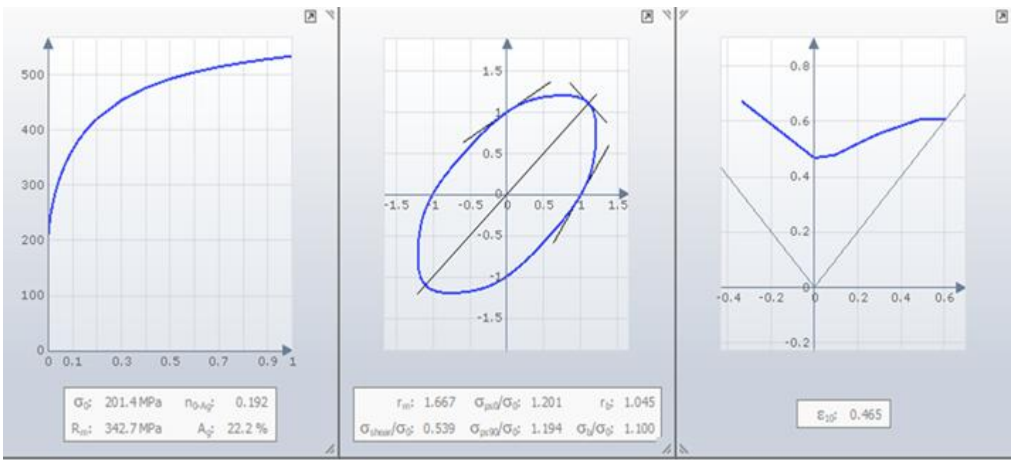
D. *Optimization Process*

1) Build a simulation model: Use AutoForm to create a simulation model of the hood stamping process.
2) Determine the input variables: Stamping force, stamping direction, blank shape, friction coefficient.
3) Run the simulation and evaluate the results: Check the indicators such as elastic deformation, residual stress, and thinness of the stamping plate.
4) Apply the Robust Design method: Analyze the sensitivity of the variables and optimize the parameters to achieve the highest performance.

E. *The Role of AutoForm In Optimizing Plate Stamping Die Design*

Can the software help us accurately model the forming process of the parts in the stamping die, as well as the final elasticity? And thus, allow us to reduce the time to design the die?

The software helps us analyze the material on the product so that we can make material choices for the die (punch, mortar, etc.).



a. b. c.

Fig. 1. Given (a) Analysis of stress-strain characteristics of materials (b) uniaxial tensile analysis of the mater (c) Analysis of the forming curve of the material.

IJSES

International Journal of Scientific Engineering and Science

Volume 9, Issue 5, pp. 64-68, 2025. ISSN (Online): 2456-7361

F. Simulation And Optimization Process

1. Input data Material: JCS340H

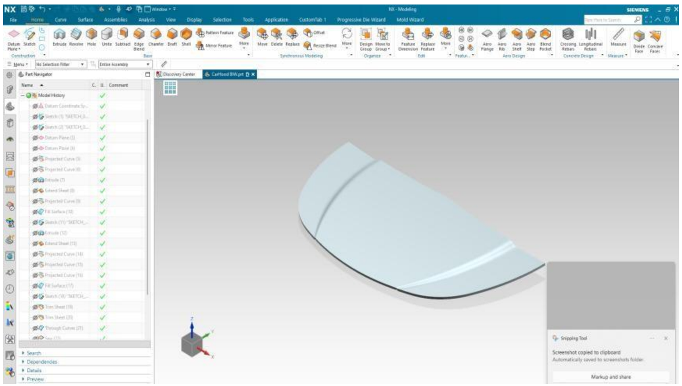


Fig. 2. Products designed on software siemens NX

Using NX CAD design software such as Fig. 2 will help us design easily and manage and avoid product defects when entering AutoForm to perform simulation steps.

Simulation of the stamping process and its influence by variables:

Assuming a normal distribution of the response, the process capability ratios Cp and Cpk are defined as [10]:

$$C_p = \frac{USL-LSL}{6\sigma} \quad (1)$$

$$C_{pk} = \min\left(\frac{USL-\mu}{3\sigma}, \frac{\mu-LSL}{3\sigma}\right) \quad (2)$$

Where μ and σ reflect the process mean and standard deviation, respectively. Note that C_p is insensitive with respect to the location of the mean, whereas C_{pk} is not.

Using AutoForm R11 software for simulation. In which the input parameters are set based on actual production conditions. The thickness of the workpiece (thickness) ranges from 1.4 mm to 2.6 mm, while the stamping force (Mat01_Sigma0) varies from 181.24 MPa to 221.52 MPa to evaluate the influence of the impact force on the stress distribution. In order to accurately reflect the mechanical properties of the material, the simulation model also considers the change of tensile strength (Mat01_Rm), with values ranging from 308.41 MPa to 376.94 MPa. The coefficient of friction (lube) is adjusted in the range of 0.18 to 0.22 to examine the influence of lubrication conditions on the forming process. In addition, the strain index r (R-value), an important parameter that determines the stress and strain distribution of the workpiece, was also changed from 1.334 to 2.001 to evaluate its impact on the quality of the product after stamping.

The simulation process is performed with 80 automatic running scenarios, in which the input parameters are changed in a controlled manner according to the Latin Hypercube Sampling (LHC) method to ensure the diversity and accuracy of the obtained results. With the Robust Engineering method, we get values such as: thickness parameters, stamping force, material yield stress, tensile stress, material deformation coefficient

TABLE 1 shows us the parameters according to each size.

ST T	Thickness (mm)	Mat01_Sigm a0 (MPa)	Mat01_Rm (MPa)	Mat01_RVa lue
1	1.4	181.239	308.405	1.334
2	1.6	220.814	375.540	1.823
3	1.8	205.401	332.475	1.526
4	2.0	201.377	342.672	1.667
5	2.2	188.566	311.371	1.957
6	2.4	189.971	314.404	1.703
7	2.6	221.515	376.940	2.001

Fig. 3 shows us: a scatter plot is used to visualize the relationship between two variables, a dashed trend line shows the overall direction or tendency of the data, a highlighted stability zone refers to a region on the chart where the data is considered stable, safe, or within acceptable limits.

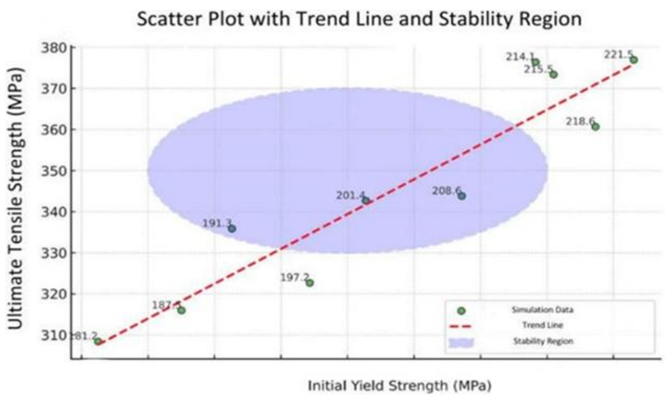


Fig. 3. Scatter plot with dashed trend line and highlighted stability zone

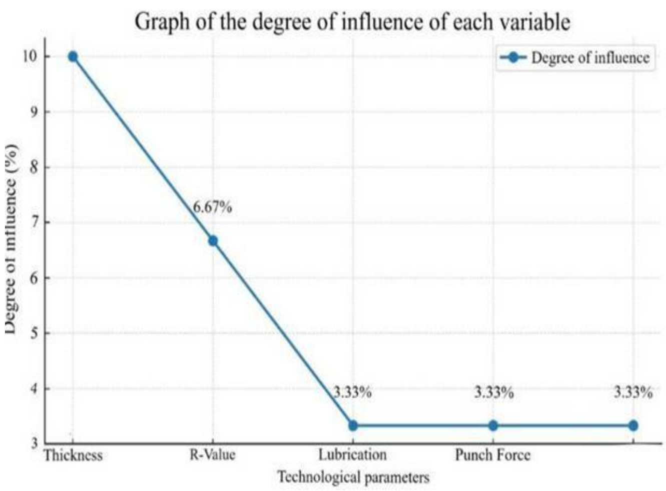


Fig. 4. Chart Of The Influence Level Of Each Variable.

Meaning Fig. 4 This type of chart shows how much each variable affects a certain outcome or result. It's commonly used in statistics, machine learning, or engineering studies to identify the most important factors influencing a system

Through the above statistical tables and charts, the design engineer can choose the appropriate application of the product to maximize efficiency in the production process. With AutoForm R11 software, we can simulate the stamping process, from which we can see the points on the part that can be torn,

International Journal of Scientific Engineering and Science
Volume 9, Issue 5, pp. 64-68, 2025. ISSN (Online): 2456-7361

wrinkled or lack of material, safe areas, dangerous areas that will certainly produce waste.

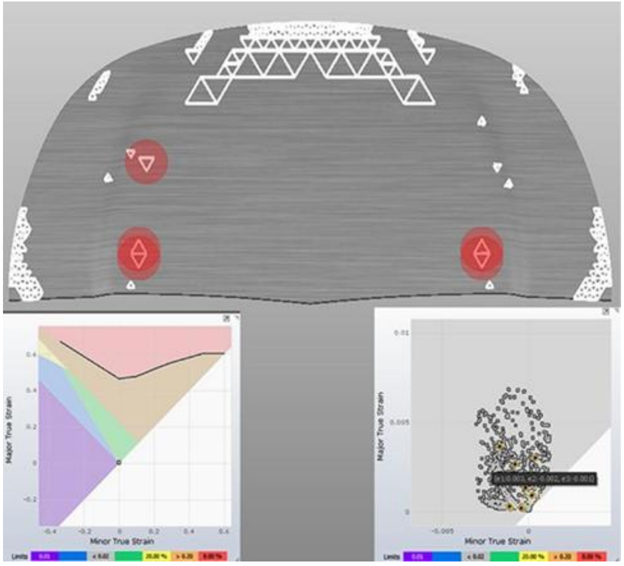


Fig. 5. Forming limit analysis chart of the part

This forming limit analysis diagram evaluates the material separation based on the tensile and compressive state of an element and it models the entire part. Each point is as above the part and all of them make up the result of the section:

- Purple: is the area where the material thickness is increased compared to the basic thickness.
- Blue: is the area where the material is compressed.
- Gray: is the area where there is insufficient tensile stress on the surface.
- Green: is the safe area where tearing does not occur,
- Yellow: is the area at the failure boundary.
- Red: is the torn area.

So which color area each point is located on will represent the status of that point on the part. This will help the engineer assess the condition of the part during the stamping process so that he can quickly make appropriate adjustments.

Evaluating the wrinkles of the part during the simulation process will help the designer control wrinkles to ensure a smooth product surface, without unwanted folds or deformations.

Fig.6 Steel billets help us know the original size so we can prepare accurately to avoid waste.

Improve the shape and size of the original blank: Minimizing excess material can contribute to controlling wrinkles. Adjust the shape of the blank stop face and the mold face: Helps optimize the material flow, reducing wrinkles. Reduce the scrap rate by controlling wrinkles right from the design stage.

Increase the stability of the production process, helping mass production with high precision, without having to make too many changes and edits during the production process. Wrinkles can create unwanted stresses, leading to rapid wear or failure of the mold. With AutoForm software, we can evaluate wrinkles with 2 methods: - Potential wrinkles: describes wrinkles due to thickness changes. Considered in the range of 0-0.03.

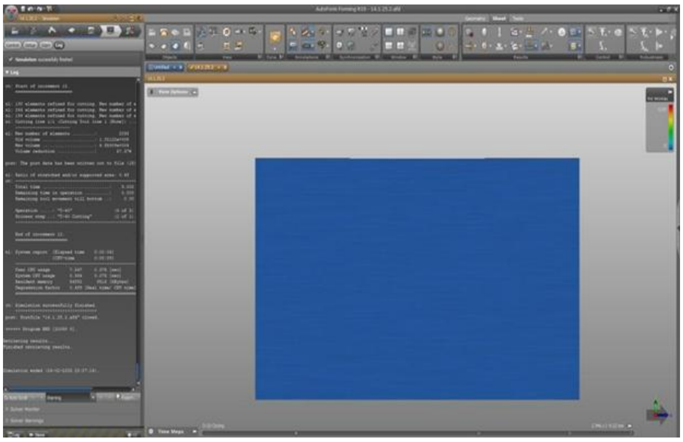


Fig. 6. Steel billet

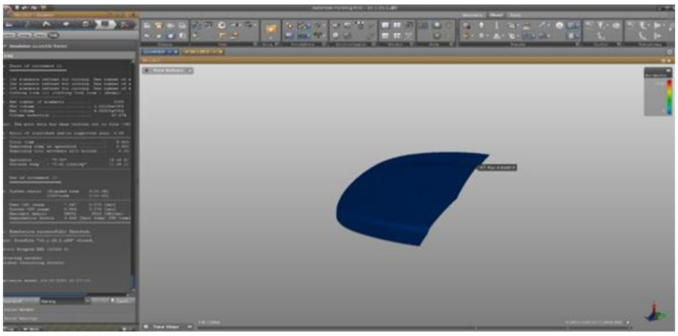


Fig. 7. Wrinkles due to geometrical deformation

As can be seen, wrinkles due to thickness variation are almost absent. Wrinkles: wrinkles due to geometric variation. Consider values from 0-0.15. We see fig.7 that wrinkles due to geometric transformation are also almost absent.

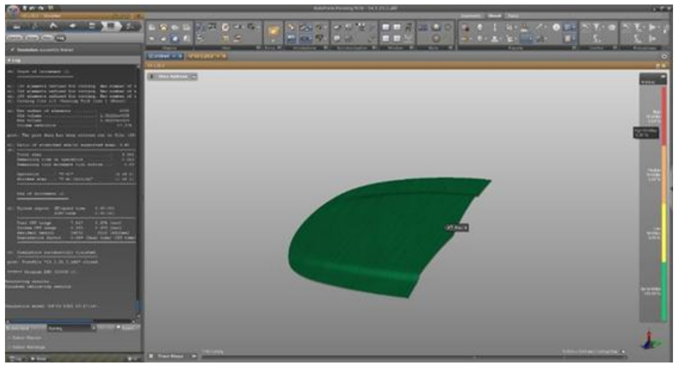


Fig. 8. Wrinkle assessment based on geometric variation.

Fig.8 Improve product quality: avoid aesthetic defects: Wrinkles will cause waves and creases that damage the surface of the part. Ensure accurate dimensions: Wrinkles can cause the product to deform from the desired shape.

III. Conclusion

This study successfully applied the Robust Design methodology in combination with finite element simulation using AutoForm software to optimize the forming process of automotive hood panels. By systematically investigating the influence of key process parameters—namely stamping force, stamping direction, initial blank shape, and friction coefficient—the study achieved notable improvements in dimensional accuracy, thickness uniformity, and overall product robustness.

The simulation results revealed that the application of the Robust Design approach significantly reduced geometric defects and improved the consistency of the formed parts under varying process conditions. Sensitivity analysis using the signal-to-noise (S/N) ratio further facilitated the identification of optimal parameter settings, thereby enhancing the stability and reliability of the stamping process. Furthermore, the simulation-driven optimization framework's reliability was supported by comparative analysis using Abaqus to validate the findings.

The study admits to some shortcomings despite the positive results. The effects of post-stamping material aging and external environmental factors—such as temperature and humidity—were not considered. Moreover, the findings are based solely on virtual simulation without experimental validation. Future research should aim to incorporate physical trials to calibrate and validate simulation models more precisely and to extend the applicability of the proposed methodology to other critical body-in-white components in the automotive sector.

In conclusion, this work has demonstrated that the integration of Robust Design principles with advanced simulation tools offers a promising pathway for optimizing sheet metal forming processes. The approach contributes meaningfully to improving product quality, minimizing production variability, and enhancing manufacturing efficiency in the automotive industry.

REFERENCES

[1] R. Daams, "formingworld," Phoenix 3D Metaal, 2025. Available: https://formingworld.com/phoenix-3d-metaal-netherlands/.
[2] B. Ahn, "Forming world," AutoForm, 7 1 2025. [Online]. Available: https://formingworld.com/gmtck-korea-stamping/.
[3] M. Kruithoff, "Formingworld," Auto form, 2024. [Online]. Available: https://formingworld.com/cameroon-tool-die-face-quality/.
[4] X. Jian, "Formingworld," LINGYUN, 2024. [Online]. Available: https://formingworld.com/side-rail-assembly-optimization/.
[5] F. Grandizoli, "formingworld," AutoForm, 2024. [Online]. Available: https://formingworld.com/gestamp-sustainable-manufacturing/.
[6] T. Cacis, "formingworld," 2024. [Online]. Available: https://formingworld.com/tom-cacic-gs-die-design/.
[7] I. SAYS, "autoform," 2004. [Online]. Available: https://www.autoform.com/fileadmin/public/Redaktion/all/newsroom/publications/2004/ISMR-SeptOct04.pdf.
[8] København, "ISoRD," 2014. [Online]. Available: https://backend.orbit.dtu.dk/ws/portalfiles/portal/102244050/123_133_ISoRD14_ Proceedings_2.pdf.
[9] F. C. S. H. B. S. Tobias Eifler, "cambridge.org," 2023. [Online]. Available: https://www.cambridge.org/core/journals/proceedings-of-the-design-society/article/perspectives-on-robust-design-an-overview-of-challenges-and- research-areas-across-industryfields/C4082F2CDF8E85764E12A367DEA1B97C.
[10] D. C. Montgomery. Introduction to Statistical Quality Control. John Wiley and Sons, Inc. New York, USA, 5th edition, 2005