Maximizing the joint strength of a clinching process using AFDEX and HyperStudy

Whitepaper Author
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Executive Summary:

In order to determine optimum process parameters and conditions, the FE simulation models need to be integrated with optimization algorithms. This is very important for metal forming processes as they are dependent on a number of process parameters affecting the product quality and manufacturing efficiency. In this white paper, a suitable FE model of a joining process(clinching) is built using the metal forming simulator AFDEX and then the process is optimized using the multidisciplinary optimization software HyperStudy from Altair. Through the optimization approach, the process parameters are optimized, and the joint strength is increased by about 36%.

Introduction:

The usage of aluminium alloys is pivotal in reducing the weight of an automobile. Conventional joining methods of aluminium sheets such as the welding are not effective because of the formation of an oxide layer surface as well the high thermal conductivity of the material. An economically feasible alternative to welding is the clinching process. Figure 1 shows the schematic of the clinching process. The two sheets are joined by applying a force through the punch resulting in their plastic deformation.

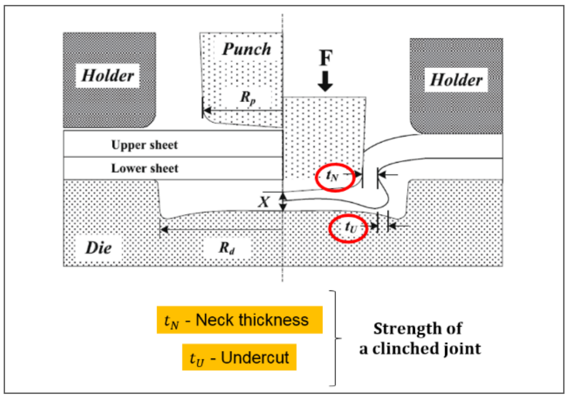


Figure 1: Schematic of the clinching process [1]

AFDEX, an intelligent metal forming simulator developed by MFRC, is used to simulate a 2-stage forging process. Based on the results of the initial design run, two die shape parameters in the process are optimized using Altair HyperStudy, the multi-disciplinary design exploration and optimization software.

Setup of the FE Model:

The actual clinching process consists of only one stage. For the sake of testing and improving the joint strength, a second stage is included in this study. The first stage is where the actual deformation happens to clinch the two sheets together. And the second stage consists of applying a tensile load that will pull the two clinched sheets apart. Higher this force, greater is the joint strength. The joint strength, which is the tensile load or the second stage forming load will be used as an objective function which ought to be maximized. Figure 2 has the simulation information and the deformed shape of the workpieces after joining.

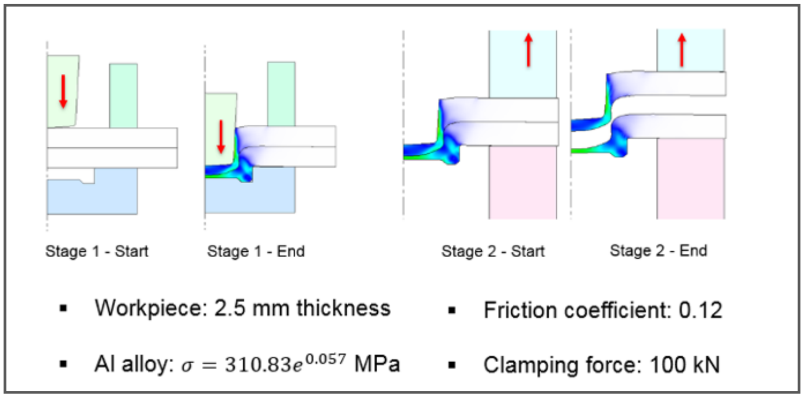
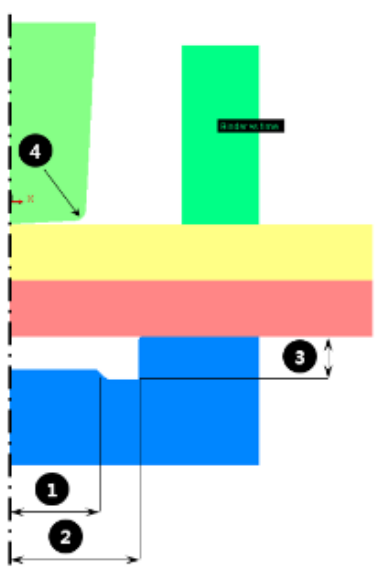


Figure 2: FE model of a clinching process in AFDEX and the simulation details

Setup of the optimization problem:

After carrying out an extensive literature survey, the design variables that significantly influence the joint strength of the clinching process are chosen as shown in Figure 3.



No	Parameter	Initial	Minimum	Maximum
1	Die base width	4.00	3.80	4.20
2	Die radius	5.84	5.54	6.14
3	Die depth	7.94	7.64	8.24
4	Punch radius	0.50	0.20	0.80

(All dimensions are in mm)

Figure 3: Design variables of clinching process

HyperStudy is solver neutral and allows the realization of parameterization in various ways including from an excel spreadsheet. It can integrate to any simulation software that has ASCII input files through template files [2]. Template files (with extension '.tpl') are parameterized versions of the simulation input files which usually depend on the solver which is used for carrying out the nominal run. The input files of AFDEX are SIF and SCF which correspond to Simulation Input File and Simulation Control File respectively. As the names suggest, SIF file contains information about workpiece and die geometry, the input process parameters like friction, die velocity etc., and SCF consists of the factors that control the simulation and it is subject to change during execution.

The above design variables are defined in HyperStudy using the SIF file of AFDEX. In the case of the second and third design variables (Die radius and Die depth), the variables are defined using expressions as these are not a single parameter. For example, the value of die depth is dependent on y-coordinate value of two points. So, in this case, it will be entered as an expression whose value will be equal to the difference of the y-coordinate values.

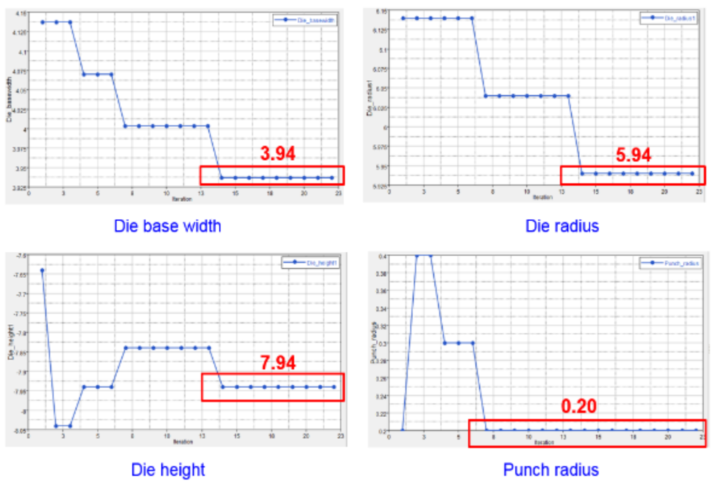


Figure 4: Optimization of the design variables in HyperStudy

The forming load of the second stage is chosen as the objective function which ought to be maximized. The global response surface method (GRSM) is chosen as the optimization method. This deterministic global search method generates a set of designs for every iteration and these are solved in parallel. The response surface is nothing but an algebraic or numeric expression describing the model's response as a function of the design variables. Several evaluations are carried out within the feasible design space and the optimized values of the design variables are presented in Figure 4.

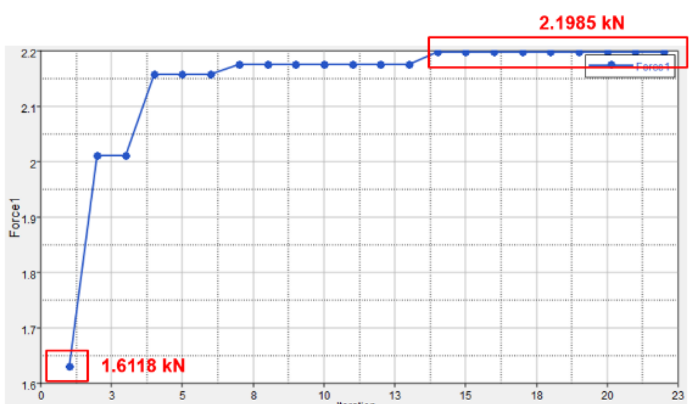


Figure 5: Joint strength after optimization

The optimized(maximized) joint strength values are also plotted in Figure 5 with respect to the number of iterations. The final optimized values of the design variables as well as the joining force is presented in Figure 6. It can be observed that the strength of the joint has been increased by a significant 36.4% through this optimization process.

No	Parameter	Initial	Minimum	Maximum	Optimized Value
1	Die base width	4.00	3.80	4.20	3.94
2	Die radius	5.84	5.54	6.14	5.94
3	Die depth	7.94	7.64	8.24	7.94
4	Punch radius	0.50	0.20	0.80	0.20
Initial joining force		**1.6118 kN**	**Optimized joining force**		**2.1985 kN**

Figure 6: Optimization results

Conclusion:

The joining strength of the clinching process of two aluminium alloy sheets of 2.5 mm thickness was increased up to 36.4% using FEM and deterministic optimization approach in this work. This framework of using a FEM simulation tool and an optimization algorithm is very general and versatile in nature. This increases the application spectrum of this technique to a wide range of metal forming processes and their optimization.

References:

[1] C. J. Lee, J. Y. Kim, S. K. Lee, D. C. Ko, B. M. Kim, 2009, Design of mechanical clinching tools for joining of aluminium alloy sheets, Materials and Design 31(2010), 1584-1861

[2] Varis J., Economics of clinched joint compared to riveted joint and example of applying calculations to a volume product, J Mater Process Technol, 2006; 172: 130-8

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