

Parametric study on numerical simulation of the electromagnetic forming of DP780 steel workpiece with aluminium driver sheet

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Abstract. The purpose of this study is to investigate the influences of numerical parameters on the electromagnetic forming (EMF) simulation. The 3-dimensional coupled electromagnetic-mechanical simulations were conducted to predict the deformation behavior of the advanced high strength steel (AHSS) sheet receiving support in EMF with aluminum driver sheet. Dual phase (DP) 780 steel workpiece was formed into a hemi elliptical protrusion shape with aluminum alloy AA1050 driver sheet using a flat spiral coil actuator and open cavity die. The deformed shape of the DP780 workpiece and the computation time with respect to element size, N cycle number and time step of electromagnetic (EM) solver were analysed.

1. Introduction

There have been the demands to apply EMF process to the AHSS sheet for shaping a reinforcement rib or sharp edge on preformed automotive parts [1]. However, realizing it is not easy because low conductivity of high strength steel sheet disturbs to induce the eddy current during EMF process. One of ways to overcome this technical hurdle is using high conductivity materials as the driver sheet [2]. Because EMF process with the drive sheet is a complex problem coupled the mechanical, thermal phenomenon as well as the electromagnetism, the numerical simulation is essential tool for understanding the invisible multi-physics natures and designing the optimal processes. In EMF simulation, more iterative coupling and numerical discretization accompany inevitable increasing the numerical errors and the calculation time. Therefore the numerical parameters should be properly selected for guaranteeing reasonable prediction accuracy and computation cost. The purpose of this study is to investigate the influences of numerical parameters on the EMF simulation results for the AHSS sheet with driver sheet.

2. Numerical modeling

The workpiece and driver sheet utilized in this study are a DP780 steel sheet with a thickness of 1.4mm and an aluminum alloy AA1050 sheet with a thickness of 1.0mm, respectively. The blank size



of both is 200mm x 200mm. Table 1 summarizes the mechanical and electromagnetic properties of workpiece and driver sheet.

Table 1. The mechanical and electromagnetic properties of DP780 workpiece and AA1050 driver sheet.

	Mechanical					Electromagnetic	
	Young's modulus (GPa)	Yield stress (MPa)	Tensile stress (MPa)	Uniform elongation (%)	Total elongation (%)	Electric conductivity (MS/m)	Magnetic permeability ($\mu\text{H/m}$)
DP780	210	546.9	832.4	14.51	23.89	3.50	875.0
AA1050	68.9	89.3	107.7	2.15	6.01	35.6	1.26

The EMF of DP780 workpiece with AA1050 driver sheet was performed using the flat spiral coil actuator with an open cavity die to form an aimed hemi elliptical protrusion shape analogous to the reinforcement rib as shown in Figure 1. The flat spiral coil with a cross sectional area of 30mm x 3mm was wound with 15 turns. The gap distance between the windings is 2.5mm. The open cavity having approximately 40mm x 100mm was machined at a mean radius of the flat spiral coil to avoid the dead zone. A charge voltage was chosen to be 7.3kV. Refer to the reference [3] for more details.

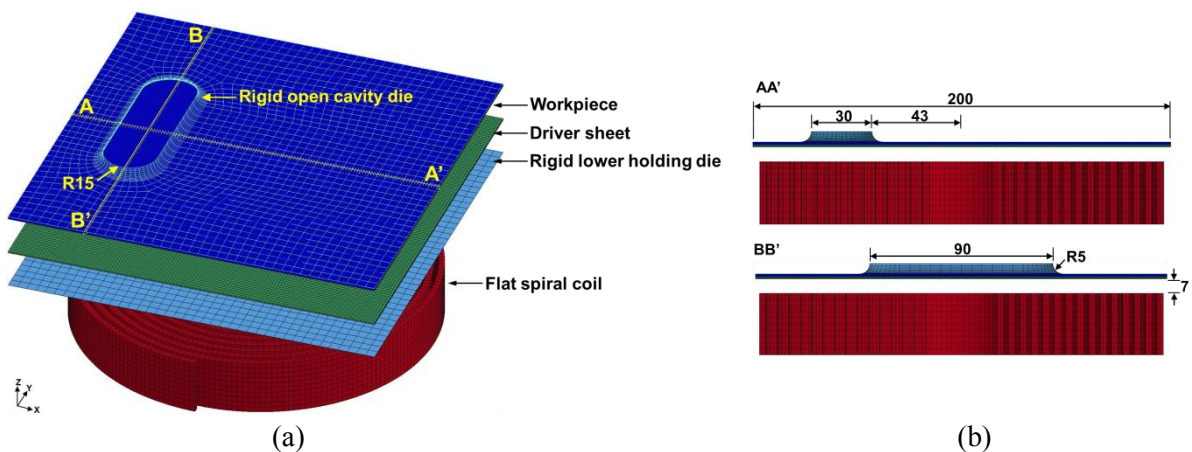


Figure 1. (a) Finite element meshes of the assembly model and (b) side view of the flat spiral coil and the open cavity die (unit: mm).

Figure 1(a) shows the mesh assembly for EMF simulations. The eight-node hexahedron solid elements for the workpiece, the driver sheet and the flat spiral coil, while the four-node quadrangular shell elements for the rigid open cavity die and the lower holding die were utilized. An isotropic elasto-plasticity model was adopted for workpiece and driver sheet by neglecting their anisotropy for the sake of simplicity. The commercial software LS-Dyna was used to fully couple with electromagnetic and mechanical systems in 3-dimensional spaces [4].

The influence of three numerical parameters on the numerical simulation was investigated: (1) the element size of the workpiece and driver sheet, (2) N cycle number for electromagnetism computation frequency between EM and structural solving matrices and (3) time step of electromagnetic solver. Each parameter for the base line condition is chosen to be element size of 1.5×1.5 (mm x mm), N cycle number of 20, and time step of 2 (μs), respectively. For parametric studies, the plane element sizes were varied as 1 x 1, 1.5 x 1.5, 2 x 2, 2.5 x 2.5 and 3 x 3 (mm x mm), N cycle numbers as 1, 5, 10, 15, 20, 25, 50, 75 and 100, time steps as 0.1, 0.5, 1, 1.5, 2, 2.5, 3, 3.5 and 4 (μs). The deformed

shape in the BB' cross section of the DP780 workpiece and computation time with respect to each parameter were predicted and compared.

3. Results

3.1. Influence of element size

The forming height increases and is gradually saturated as the element size decreases as shown in Figure 2(a). Figure 2(b) shows that the computation time rapidly increases as the element size approaches to 1.0mm.

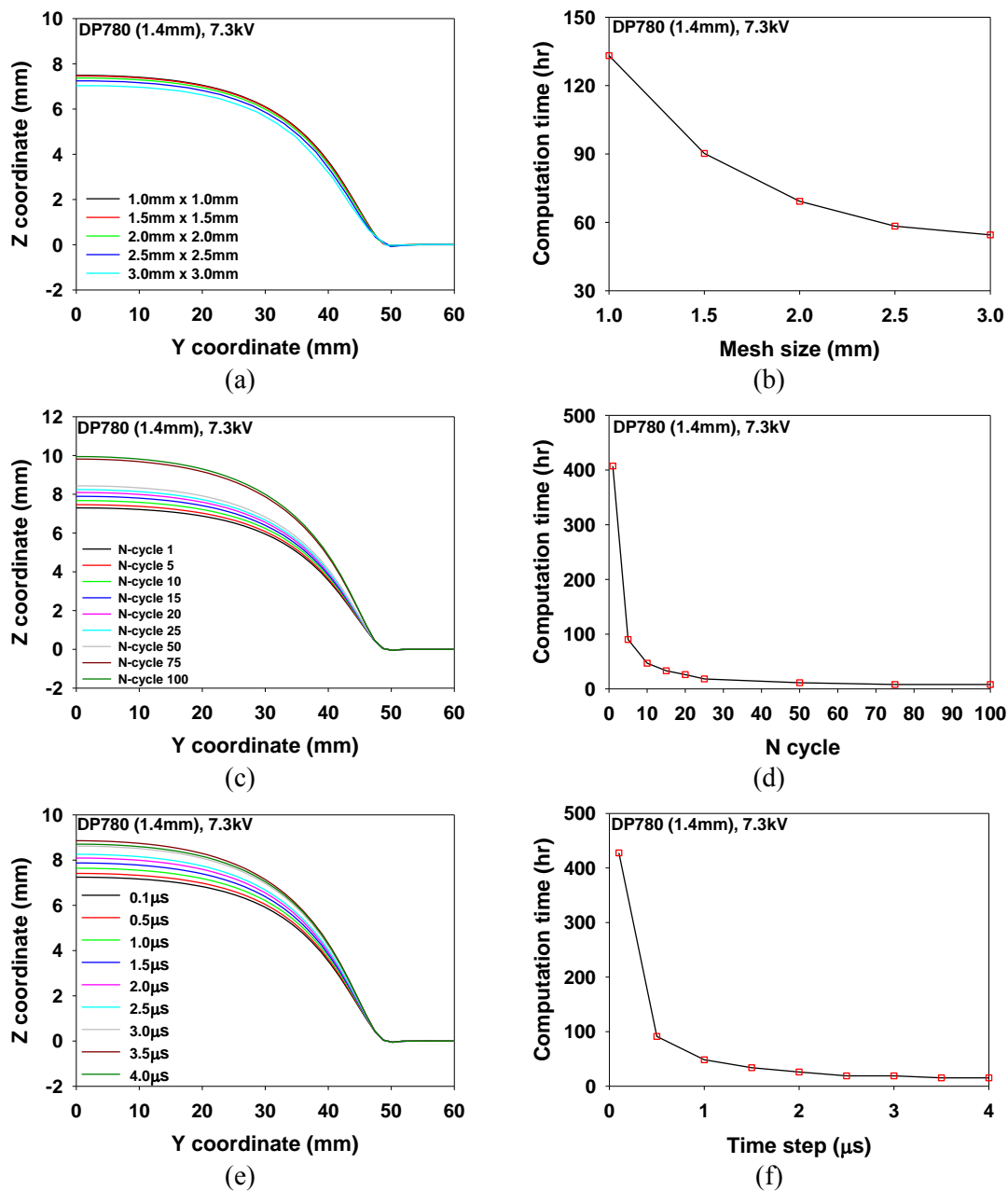


Figure 2. (a), (c) and (e) deformed shape and (b), (d) and (f) computation time with respect to mesh size ((a) and (b)), N cycle number ((c) and (d)) and time step ((e) and (f)).

3.2. Influence of N cycle number

The forming height proportionally increases until N cycle number increases up to 50 as shown in Figure 2(c). When N cycle number is more than 50, the unexpected increase of forming height is observed. Figure 2(d) shows the computation time decreases as the N cycle number increases and drastically increases when N cycle number is less than 10.

3.3. Influence of time step

The forming height increases as time step increases as shown in Figure 2(e). Figure 2(f) shows that the computation time increases as the time step decreases and drastically increases when time step is less than 1 μ s.

4. Summary

The present study aims to evaluate the influence of the numerical parameters on prediction accuracy and computation cost in the numerical simulation for the EMF of the DP780 workpiece with an AA1050 driver sheet to hemi spherical protrusion shape. The deformed shape of the DP780 workpiece and the computation time with respect to element size, N cycle number and time step of EM solver were predicted. The forming height increases as the element size decreases, N cycle number and time step increase. On the other hand, the computation time increases as all parameters decrease. Further study to select proper parameter set is needed to compromise between the prediction accuracy and computation cost.

References

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