Prediction of Plastic Deformation in the Stringer According to the Press Head

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Abstract: - Due to the rapid growth of the aircraft market, the complete aircraft industry has been expanding its global outsourcing. It is to respond to these changes in aircraft production paradigm through the development of the forming systems. Aircraft structures are mostly produced, based on cutting or plastic working to minimize change of properties due to thermal strain. Forming press is used for bending stringers, which are main wing structures of aircrafts, and, precise control of press head displacement is essential to ensure high quality of stringers. Therefore, this study attempted to predict plastic deformation of the stringer according to the press head by using the finite element method, and to use the result for the forming press control.

Key-Words: - Stringer, Plastic deformation, Forming press, Press head

1 Introduction

Recently, the use of aluminum is increasing in various industrial sectors as a method of weight lightening. In the aircraft industry, aluminum is used for making the main structures of aircrafts in order to minimize the total weight[1, 2].

Stringer in aircraft's wing is made of the aluminum alloy and it is a part of the aircraft structure to keep the shape[3]. Arrangement of the stringers is parallel to the wing direction and on the floor beam that connects the main truss. Fig. 1 shows the arrangement of the stringers and Fig. 2 shows the shape of the stringer.

Forming press is an apparatus that is used for manufacturing stringers of the aircraft main wings and bends stringers based on force generated at the press head.

Precise manufacturing of stringers requires forming values according to displacement of the press head. In this study, based on plastic analysis of stringers, the forming angle according to the displacement of the press head was predicted, for the purpose of using the result for forming press control.

2 3D model and material properties

2.1 3D model of the forming press

For the plastic analysis of stringers, only the structures essential for stringer forming within the forming press system are indicated. Fig. 3 shows the result of the 3D modeling.

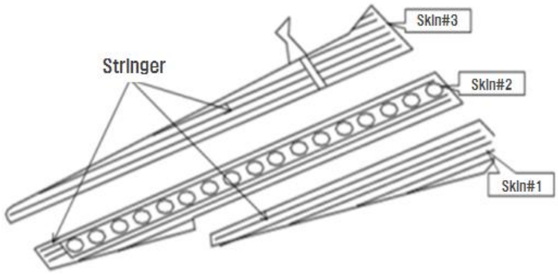


Fig. 1 Arrangement of the stringers

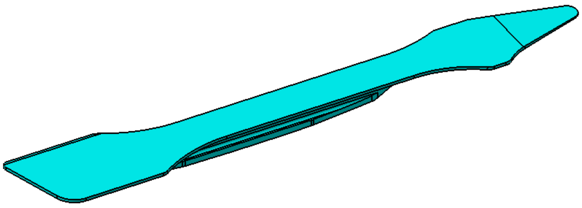


Fig. 2 Shape of the stringer

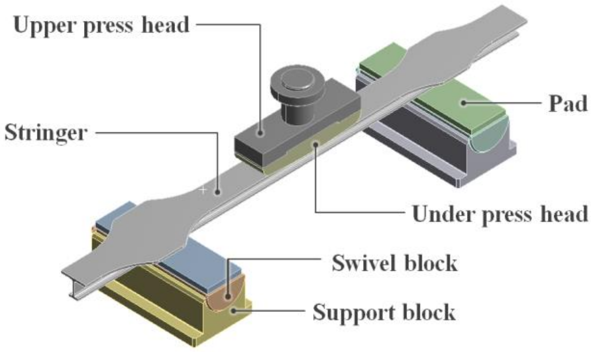


Fig. 3 3D model of the forming system

Table 1 Properties of the materials

Material	Density (kg/m^3)	Young's modulus (GPa)	Poisson's ratio	Yield strength (MPa)
SM45C	7,850	200	0.30	306
bakelite	1,420	7.5	0.38	23
MC-nylon	2,770	2.75	0.40	72
AA2026	1,330	71	0.33	370

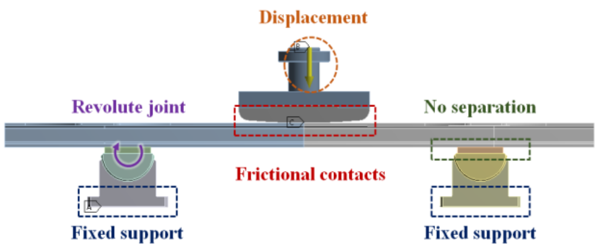


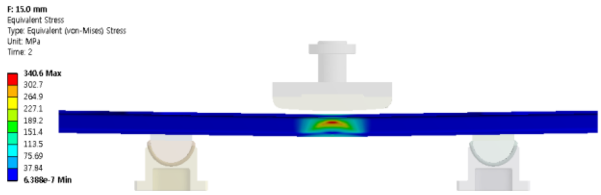
Fig. 4 Boundary conditions of the plastic analysis

The press head gives pressure on stringer, while the swivel block rotates according to the shape of the stringer in order to facilitate the bending process.

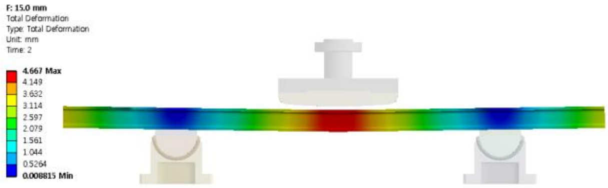
2.2 Material properties

The press head and the pad are made by using the bakelite and the MC-nylon, which are nonmetals, in order to prevent damage of the stringer, and the swivel block and the support block by using SM45C, which is widely used as the structural steel.

In this plastic analysis, nonlinearity is added to the AA2026 aluminum alloy and the plastic deformation occurs when the stress applied on the stringer is higher than the yield stress[4].



(a) Equivalent stress



(b) Total deformation

Fig. 5 Result of the residual stress

Table 2 Results of the plastic analysis

Displacement (mm)	Stress(MPa)		Angle (deg)
	Max	Residual	
5.0	287.7	3.91E-2	0
7.5	381.8	14.71	0
10.0	385.6	140.5	0.26
12.5	398.7	270.4	0.89
15.0	136.7	340.6	1.61
17.5	443.2	349.6	2.43
20.0	437.7	359.9	3.2
22.5	443.6	353.4	4.2
25.0	443.2	360.5	5.03

Other than the stringer, the rest of the components are assumed as a perfect plastic body. Table 1 shows the specific materials and their properties of each structure.

3 Structural analysis

No separation condition is applied to the space between stringer and pad in order to enable slip, and 0.1 of the coefficient of friction, which is commonly applied to cold working, is applied to the space between stringer and press head[5]. The press head displacement is set from 5.0 mm to 25.0 mm with 2.5 mm interval. Fig. 4 shows the detailed boundary conditions for the stringer plastic analysis.

4 Analysis results

In the stringer plastic analysis, the plastic deformation occurs at 10.0 mm or higher displacement of the press head. Until 15.0 mm of the press head displacement, the displacement and, thereby, the maximum stress and residual stress on the stringer increase. After the 15.0 mm point, however, they remain consistent.

Fig. 5 shows the residual stress on the stringer at 15.0 mm displacement. Table 2 shows the prediction of residual and maximum stresses and forming angle of the stringer according to displacement.

5 Conclusion

In this study, the forming angles of stringers are predicted according to press head displacement of the forming press, and maximum and residual stresses on the stringers verify. The findings in this study can help control forming press.

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