ISOGEOMETRIC ANALYSIS OF LOCAL DEFORMATION AND FRACTURE FOR AUTOMOTIVE FRAMES

Kenji Takada
Honda R&D Co., Ltd. Automobile R&D Center, Japan

KEYWORDS –
Isogeometric Analysis, NURBS, high-strength steels, fracture

ABSTRACT –
In order to reduce automobile body weight and improve the crashworthiness of passenger cars, the use of high-strength steels is greatly increasing in years past. However, the high-strength steels generally become less ductile. As the results, the fracture of steel material and spot weld failure may occur due to local deformation at corner of automobile frames. Therefore, the accuracy improvement of local deformation to predict the fracture is highly demanded by automotive industries. However, current shell and solid elements of conventional FEM generally use bilinear shape functions. It was found that bilinear shape function was difficult to predict a complicated local deformation with high accuracy. To resolve this problem, Isogeometric analysis was considered as a better alternative. Isogeometric directly deals with 3D CAD constructed by NURBS and calculates the NURBS model using high order shape function elements. First, NURBS generator tool was developed which can convert CAD data to analysis-suitable geometries. Using this tool, local deformations of typical crash verification models were investigated, which were S-frame model, 3-point bending model, L-T model of spot weld and hat-section model. These simulation results based on the Isogeometric analysis correlated well with the experimental tests regarding the local deformation. Next, V-notch plate models and 3-point bending models with V and U-notch were calculated to investigate the fracture and crack propagation. it was also found that 16 nodes shell and 64 nodes solid elements with C^2 continuity were highly effective for fracture and stress concentration problems.

TECHNICAL PAPER -

1. NURBS GENERATOR TOOL

In order to solve the local deformation and fracture of automobile frames with high order shape functions, Isogeometric analysis(IGA) was employed, which was proposed by Hughes (1). Isogeometric is a technology to analyse 3D CAD data composed of NURBS directly. Therefore, accuracy improvement can be expected compared to conventional FEM. Next, NURBS generator tool to transfer the data between CAD and Isogeometric analysis was developed. As the design CAD models (B-rep) of automobile body are complex, they are not practical for the direct use in CAE analysis. the developed tool is employed to simplify the CAD data while maintain the original tolerance to optimize the control points. Finally, this tool generates two kinds of Isogeometric models which were named as IGA type2 and type3 as shown in Figure 1.

Figure 1 – Isogeometric models made by NURBS generator tool and generated elements with high order shape function

2. LOCAL DEFORMATION

The local deformations of typical crash verification models were investigated, which were S-frame model with hat-section and 3-point bending model constructed by high-strength steels. In case of conventional FEM, local deformation of S-frame and 3-point bending model showed the triangle shapes at corner region of hat-section, while local deformation of Isogeometric results showed the hyperbola or elliptical shapes. It was found that Isogeometric results correlated well with the experimental results regarding the local deformation as shown in Figure 2. By contrast, fracture location of conventional FEM was not at corner region of hat-section.

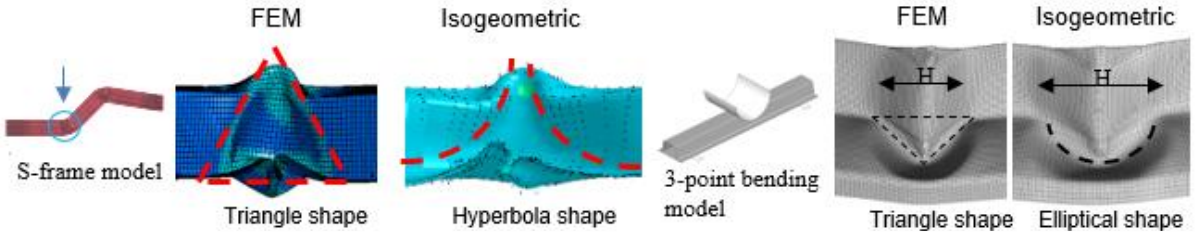
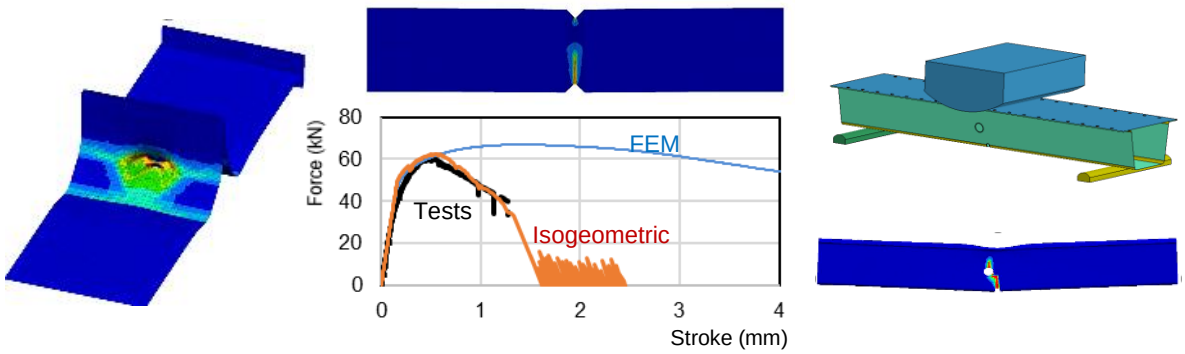


Figure 2 – Local deformation of S-frame and 3-point bending model

3. FRACTURE AND CRACK PROPAGATION

Using the Isogeometric analysis and Cockcroft-Latham fracture criteria (2)(3), LT spot weld model, V-notch plate models and 3-point bending models with U-notch were calculated to investigate the fracture and crack propagation. At same time, conventional FEM simulations were performed to compare with Isogeometric results. From these simulation results, Isogeometric analysis showed that fracture location, direction of crack propagation and stress concentration were accurately reproduced as shown in Figure 3. And it was also found that 16 nodes shell and 64 nodes solid elements with C^2 continuity were highly effective for fracture and stress concentration problems.



(a) LT model of spot weld (b) V-notch plate model (c) 3-point bending with U-notch

Figure 3 – Fracture and crack propagation of Isogeometric models

REFERENCES

(1) J.A. Cottrell, T.J.R. Hughes and Y. Bazilevs, Isogeometric Analysis: towards integration of CAD and FEA, Wiley, (2009)

(2) Cockcroft, M.G. and Latham, D.J., Ductility and the workability of metals. Journal of the Institute of Metals, 96 (1968).

(3) Takada K, Ma N, and Sato K, Fracture Prediction for Automotive Bodies using a Ductile Fracture Criterion and a Strain-Dependent Anisotropy Model, SAE Technical Paper, 2015-01-0152, 2015