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ISOGEOMETRIC ANALYSIS OF STRESS INTENSITY FACTORS FOR CURVED CRACK PROBLEMS

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ABSTRACT

An isogeometric analysis method is developed for the stress intensity factors in curved crack problems. In the isogeometric approach, NURBS (Non-Uniform Rational B-Spline) basis functions in CAD system is directly utilized in the response analysis, which enables the seamless incorporation of the higher continuity and the exact geometry such as curvature and normal vector into the computational framework. In mixed-mode curved crack problems, the precise evaluation of crack-face integral is essential to compute the precise stress intensity factors, especially for the path-independency of interaction integral. The CAD-based exact representation of tangential and normal vectors facilitates to exactly define a local coordinate system at the crack-tip, and accurately evaluate the crack-face integral. Compared with the standard finite element approach, a higher continuity of stress and strain fields are expected in the interaction integral domain.

Keywords: isogeometric analysis, NURBS, stress intensity factor, curved crack, crack-face integral, interaction integral.

INTRODUCTION

Many researches based on linear elastic fracture mechanics have been performed to predict the behavior of the crack. Recently, the controlling method for crack initiation, propagation, and termination is applied to microscopic pattern generation (Nam, 2012). However, for the precise control of the crack formation, it is necessary to predict the initiation and stability of the crack growth using precise stress intensity factors (SIF). Recently, taking advantage of the NURBS (Non-Uniform Rational B-Spline) basis functions, an isogeometric analysis (IGA) method that has many advantages over the standard FEA (Hughes, 2005) was developed in various engineering applications such as structural vibrations, fluid-structure interactions, and turbulent flow simulations. The geometric approximation which is inherent in the finite element mesh could lead to accuracy problems in response. The piecewise linear approximations of geometry turned out to be the root cause. The major feature of the isogeometric method is to employ the same NURBS basis functions as used in the CAD systems, which is a significant advantage of exact representation of geometry. In this paper, the curved geometry of the cracks is exactly represented by taking advantage of the isogeometric approach.

RESULTS AND CONCLUSIONS

Consider a circular crack in a plate under a remote tension $\sigma^\infty = 1$, Figure 1. The SIF analysis is performed for various angles $\beta$ with a fixed crack-tip position. The plate has a width (2W) of 20 and a length (2L) of 20. Table 1 compare the performance of the IGA (1308 DOFs) and
the conventional FEA (1360 DOFs) in the SIF analysis for the circular crack problem. Almost the same numbers of DOFs are used for both the IGA and the FEA. As angle $\beta$ is increased, the linear FEA (b) shows significant errors in Table 1. In the case when the local coordinates at the crack tip are corrected (linear FEA*(b)), the results improved and became even better than the quadratic FEA(b). This study shows that the importance of the developed IGA method and its superior points especially for the curved crack problems.

![Model description of circular arc crack problem](image)

(a) Problem description  (b) M-integral domain ($\beta = 60^\circ$)

Fig. 1 - Model description of circular arc crack problem

<table>
<thead>
<tr>
<th>$\beta$</th>
<th>Analytic Solution(a)</th>
<th>Linear FEA(b)</th>
<th>Linear FEA*(b)</th>
<th>Quadratic FEA(b)</th>
<th>Quadratic IGA(b)</th>
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<tbody>
<tr>
<td>10°</td>
<td>0.8628</td>
<td>0.8365(96.96%)</td>
<td>0.8307(96.28%)</td>
<td>0.8397(97.32%)</td>
<td>0.8582(99.46%)</td>
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<td>20°</td>
<td>0.7950</td>
<td>0.7925(99.69%)</td>
<td>0.7698(96.83%)</td>
<td>0.7766(97.70%)</td>
<td>0.7915(99.56%)</td>
</tr>
<tr>
<td>30°</td>
<td>0.6894</td>
<td>0.7221(104.75%)</td>
<td>0.6733(97.67%)</td>
<td>0.6776(98.29%)</td>
<td>0.6871(99.67%)</td>
</tr>
<tr>
<td>40°</td>
<td>0.5558</td>
<td>0.6295(113.25%)</td>
<td>0.5484(98.66%)</td>
<td>0.5510(99.13%)</td>
<td>0.5543(99.72%)</td>
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<tr>
<td>50°</td>
<td>0.4054</td>
<td>0.5200(128.25%)</td>
<td>0.4040(99.64%)</td>
<td>0.4070(100.38%)</td>
<td>0.4038(99.59%)</td>
</tr>
<tr>
<td>60°</td>
<td>0.2494</td>
<td>0.3999(160.31%)</td>
<td>0.2504(100.38%)</td>
<td>0.2565(102.83%)</td>
<td>0.2469(98.97%)</td>
</tr>
</tbody>
</table>

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**REFERENCES**
