Critical crack size computation for an axle

Presented by Sharon Mellings

CM BEASY
Overview

- Axle, Wheel and Gear Assembly
  - Geometry defined in paper by
    “An investigation on the influence of rotary bending and press fitting on stress intensity factors and fatigue crack growth in railway axles”
    M.Madia, S. Beretta, U. Zerbst
    Engineering Fracture Mechanics, 75 (2008), 1906-1920
Overview

- Model creation:
  - Using model created in ABAQUS 6.10
- Defect Scanner:
  - Identify critical crack sizes and locations.
- SIF Computation
  - Crack added to assembly using a crack library
  - SIF values over load cycle investigated
- Automatic Crack Growth
  - Full growth using load cycle
In this presentation the same assembly will be defined in ABAQUS.

- This will be used to create a BEASY model which is then solved using interference contact

- The model is created using solid FE elements in ABAQUS (or a shell representation could have been used)

- The FE model is then used to create a boundary element mesh.
Model assembly defined in ABAQUS
Contact Analysis

- The different parts of the model will be connected using interface conditions.
- Both conforming and non-conforming contact are available
  - Here conforming contact will be utilised
  - The press-fit or interference fit is simulated using a negative initial gap
    - Note: Use of non-zero friction coefficient and the define negative initial gap removes the need to stop the gear and wheel from spinning
- The basic contact areas are defined in the ABAQUS cae and the details defined in the BEASY-ABAQUS interface tool.
Area of contact between axle and wheel
Area of contact between axle and gear
Meshed part in ABAQUS (using solid elements)
The BEASY model is then created from this assembly using a BEASY-ABAQUS interface tool.

- This “skins” the ABAQUS model and the external element faces are used to create BEASY elements.
- The displacement/force loading is created using the loading define in the ABAQUS model.
- Contact interfaces are defined using the ABAQUS contact groups defined.
Contact Groups

Define contact in the model

This window is used to define contact groups in the model, press cancel if you do not need to define contact.

Contact boundary conditions are defined using groups of BEASY elements.

Select the type of contact in this analysis
- Non-Conforming (Node to Surface)
- Conforming (Node to Node)

Group Name: Contact Axle to Gear

Modify the area of application for the contact Slave Zone: 3

One or more group has been defined: Add group of elements

Define the directions for the conforming contact
- N Direction: Gap distance: 0.14
- T1 Direction
- T2 Direction

Static Friction: 0.6
Dynamic Friction: 0.8

Edit global contact options: Global contact options

Help
Ok
Cancel
Solved BEASY Model

- The BEASY model is then solved during which the contact solution will be run.
- The initial model has a single load case with the applied load, associated restraint and press-fit.
Exaggerated deformation of the axle
The BEASY Defect Scanner is a tool that computes critical crack sizes in an assembly.

Each point is investigated:

- The maximum principal stress is computed
- A crack is defined oriented by the maximum principal stress direction
- The critical crack size is computed using reference solutions (appropriate to crack location and size)
A critical crack is defined as one reaching either a threshold or critical SIF value

- With threshold SIF we are looking at the smallest crack that will grow at each point
- With critical SIF we are looking for the smallest crack that will fail at each point.

- The *smallest* critical crack sizes is reported
  - Cracks are assumed to be circular
- A map of critical crack sizes (in ABAQUS result format) is produced.
Result output

- The result of using the defect scanner is a map of smallest critical crack sizes.
- Plotting small numbers in contour plots
  - therefore a “Banded” output has been created.
  - The smallest critical crack sizes are placed in a high band and the larges in a low band
  - These can be customized as required.
Critical crack size (bands) for assembly
Plot of maximum principal stress values
Contact properties

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Static Friction: 0.6
Dynamic Friction: 0.6

Edit global contact options
How does the interference distance affect the critical

- Using a selected threshold SIF the computed critical crack sizes in the axle were computed using different interference distances.

<table>
<thead>
<tr>
<th>Interference Distance</th>
<th>Critical Crack Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.12mm</td>
<td>0.0085mm</td>
</tr>
<tr>
<td>0.14mm</td>
<td>0.0054mm</td>
</tr>
<tr>
<td>0.16mm</td>
<td>0.0044mm</td>
</tr>
</tbody>
</table>
Varying initial interference distances

Gap = 0.12mm

Gap = 0.14mm

Gap = 0.16mm

Red is smallest critical crack sizes < 0.005mm
Detailed analysis of the critical crack

Initiating & growing a crack at the identified critical position
A crack will now be added at one of the critical crack locations.
- This is chosen from a library of pre-defined crack shapes

The loading will be changed, initially to be a series of 8 loads and associated restraints at different positions around the axle and wheel.
- In this analysis the load cases are solved independently
- Analysis could be performed using a load sequence to give transition from on load to the next
Adding the crack to the assembly model
Axle, wheel assembly
In BEASY boundary elements is used to model the crack in the structure.

This allows for just the crack faces to be defined:

- It is not necessary to remesh the entire domain
- Complex meshing and element grading around the crack is avoided.

A wizard tool automatically meshes the part at each stage of the analysis.
Mesh after crack is added

The mesh is just modified around the crack itself.
The mesh locally is matched to the crack mesh
Initial SIF values along the crack front
Variation of SIF during the load cycle
The crack is now going to be grown.

In this analysis the two extreme load cases are being used for the load cycling:
- Here the load cycle is relatively simple.
- For a small crack, the same load case gives the maximum & minimum values for the entire front.
- All load cases CAN be used to define the load cycle if required.
Growth of the crack
Crack growth pattern
Summary

- This presentation has shown:
  - Creation of a BEM model using the ABAQUS cae
  - Computation of critical crack size in a conforming contact model
  - SIF analysis of a small crack at the critical crack location
  - Growth of a small crack under a cyclic loading.