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Model Reduction Techniques with RBE2 and RBE3 Connection for Structural Results of Handling/Lifting Fixtures for Satellite Payloads

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Abstract: A fixture is design to hold, support and locate every component with accuracy. Fixture design is very important step for the setup-planning phase. The present work aims to get proper result with accurate connection of the fixture. In this work, two techniques are built for fixture analysis, give the comparison of structural results of full model, and reduce model with connection of RBE 2 and RBE 3. Design and analysis of fixture is done by using known softwares, inventor and hyperworks.

Keywords: fixture design, structural analysis, RBE2 and RBE3 connection.

I. INTRODUCTION

A handling/lifting fixture is a device, which is used for handling and/or lifting a payload during its various phases of assembly, handling and transportation.

The satellite payloads are delicate and need to handle with extreme precautions. The handling/lifting fixture must be able to catch to the above requirement as well as the strength requirement so that the fixture must perform satisfactorily without failed for its designed life span.

Finite element analysis techniques are used for assessing the structural integrity of various structures. This paper presents identification of critical components of the fixture and comparison of 2 finite element modelling methodologies to analyze the stresses on the critical component.

II. LITERATURE REVIEW

Jing Guo, Xinsheng Wang, [1] in this paper validated structure design through the modal and static analysis.

Prof. Mr. Uday C. Agashe, Mr. Adwait Ranpise, Mr. Mayur Mahajan, Mr. Anil Shrirame,[2] in this paper, have described the various aspects of fixture design.

Kiran Valandi, M.Vijaykumar, Kishore Kumar S,[3] in this paper, have described the systematic Methodology approach and analysis method for fixture. Ugur Hayirli, Altan Kayran,[4] in this paper have discussed the MPCs (multipoint point constraints) using RBE2 & RBE3 elements for finite element model reduction.

III. METHODOLOGY

A handling fixture of 1-tonne capacity is selected for analysis and evaluation, shown in fig. 1. Two methodologies are used for analyzing the critical component (lifting plate with ribs).

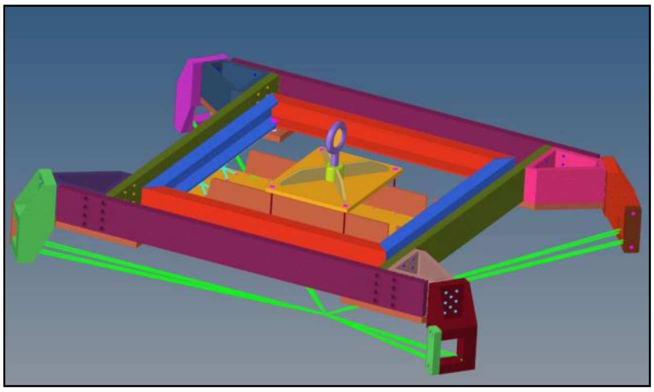

Fig. 1. Handling fixture

First methodology uses full finite element model with point mass lumped at C.G. location of the payload, while second methodology consists only the lifting hook with plate connected to an equivalent mass at equivalent C.G. location of first model. Both of these two methodologies the lamped mass is connected by using RBE2 and RBE3 type multipoint constraints (MPCs), making total 4 cases for comparison. Only linear static analysis is considered for evaluation and comparison.

A. CAD model:

The basic and initial step for the designer is to study of the fixture component. The component design is carefully checked to extract the maximum possible information. For design the component important information available is the critical dimensions of component, and its locating position and clamps areas. Geometric modeling of fixture is done using available all the critical dimensions. Here for design the fixture inventor is used.

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Payload weight → 1 tonne

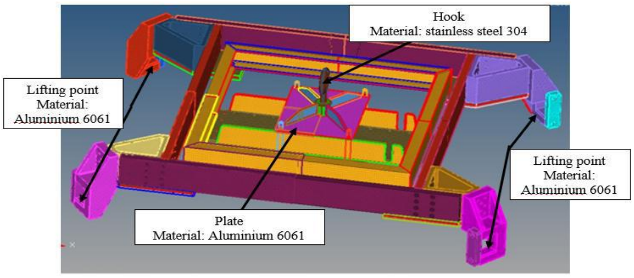

Fig. 2. CAD model of fixture

B. Material Properties

Fixture is used for different types of application so the material used in the manufacturing of fixture is depending on the application. Complete material selection and accurate combination of alloys changing percentages are required for finished fixture. In this model aluminum 6061 and stainless steel 304 is used.

Following table shows the material property used in this analysis.

Table 1. material properties for aluminium 6061[1]

Physical properties	Attribute value
Young modulus E/GPa	70
Poisson's ratio	0.3
density /(kg•m-3)	2780
yield strength /MPa	240
ultimate tensile strength /MPa	320

Table 2. material properties for stainless steel 304[1]

Physical properties	Attribute value
Young modulus E/GPa	210
Poisson's ratio	0.3
density /(kg•m-3)	7900
yield strength /MPa	215
ultimate tensile strength /MPa	505

C. Modelling Methodology

The finite element modelling of fixture is done using hypermesh.

(1) 1-D mesh = Line mesh (Beam element)

All bolts are modelled with 1D rigid element.

However, the long bolts with length to diameter ratio more than 5, are modelled using 1D beam element with bolt material and nominal diameter.

(2) 2-D mesh = shell mesh (Quad element)

2D mesh is used for components, which have plate thickness much less as compare to other two dimensions.

(3) 3-D mesh = solid mesh (Tetra, Hexa element)

3D mesh is use for irregular shape geometries are modelled with tetra10 element (CTETRA element). And for regular shaped geometries are modelled with hexa element (CHEXA element). The entire finite element model is composed of 940539 nodes and 588225 elements, and reduce model is composed of 23085 nodes and 15938 elements.

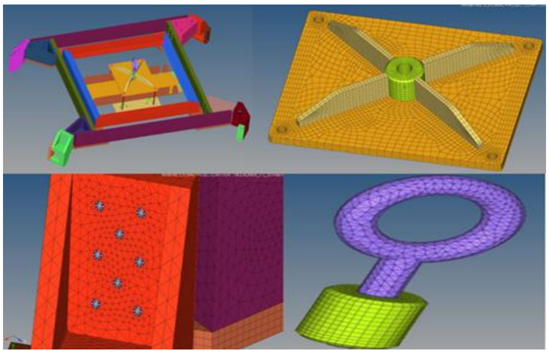

Fig. 3. Full model meshing

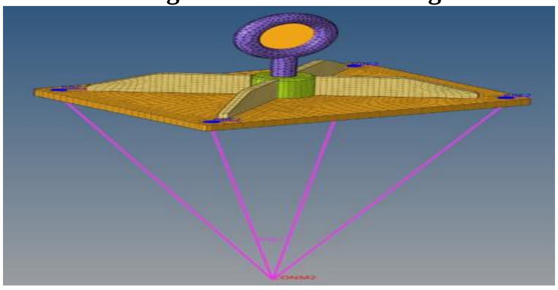

Fig. 4. Reduce model meshing

- The payload is modelled as point mass lamped at its C.G location with respect to the fixture
- The mass is connected to the fixture using two types of rigid connections, namely RBE 2 & RBE 3.

D. New location of Mass for Reduce Model Calculation

In the second methodology, all the geometry's except hook and plate are removed. Their mass is accounted in the point mass lamped at equivalent C.G location.

Old C.G. of full model:

X_{cg} = 1.679575E-04 mm

Y_{cg} = - 5.00000E+02 mm

Z_{cg} = 7.812539E-07 mm

We have,

M_1 = 0.00307183 tonne

M_2 = 1.0713 tonne

X_1 = -9.56695E-01 mm

Y_1 = -1.12728E+02 mm

Z_1 = -7.28003E-03 mm

New location of mass for reduce model is,

$$X_{cg} = \frac{M_1 * X_1 + M_2 * X_2}{M_1 + M_2} \rightarrow X_2 = 0.00291165 \text{ mm}$$

$$Y_{cg} = \frac{M_1 * Y_1 + M_2 * Y_2}{M_1 + M_2} \rightarrow Y_2 = -501.11045809 \text{ mm}$$

$$Z_{cg} = \frac{M_1 * Z_1 + M_2 * Z_2}{M_1 + M_2} \rightarrow Z_2 = 0.00002165815 \text{ mm}$$

X_2, Y_2, Z_2 are new location of mass for reduce model.

E. Analysis

Linear static analysis is perform using optistruct in hyperworks. The boundary condition is applied at the hook center, which is the lifting point of the fixture. The gravity loading of 2g (g = Gravity load) is

apply at whole model, considering twice the loading encountered by the fixture.

- **Boundary condition**

For boundary condition single point constraint (SPC) is created. All degree of freedom at this point are constraint.

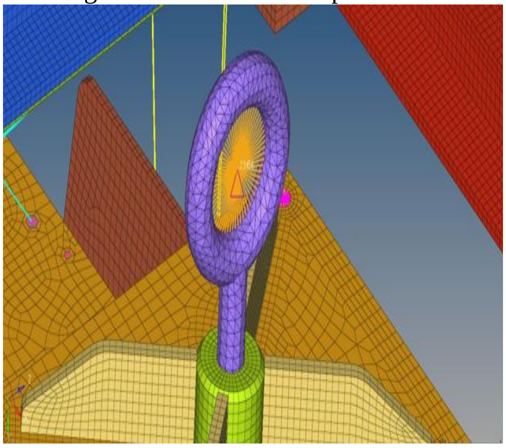

Fig. 5. Create SPC on node

- **Loading condition**

Inertial load 2g (g = Gravity load) is applied on model and create a 1 tonne mass element on C.G of fixture.

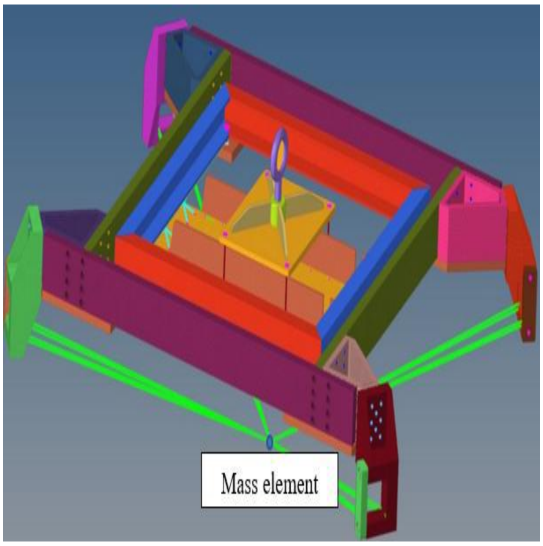

Fig. 6. Loading on fixture

F. Post Processing

The results are processed in hyperview of hyperworks software. The displacement and von mises stress are extracted for comparison purpose. Advanced averaging is considering for stress averaging at nodes.

IV. RESULTS AND DISCUSSION

This result is very important because It's given answer about our design is appropriate or not. Here take comparisons between full model of fixture and after the reduce the component of fixture with RBE2 and RBE3 connection.

- **Static analysis**

In hypermesh static analysis is give answer about the displacement and von mises stresses come on fixture.

Methodology-1

➢ Case 1: Full model result with RBE 3 connection

1. Displacement

Maximum displacement come on full model is 0.00865 mm.

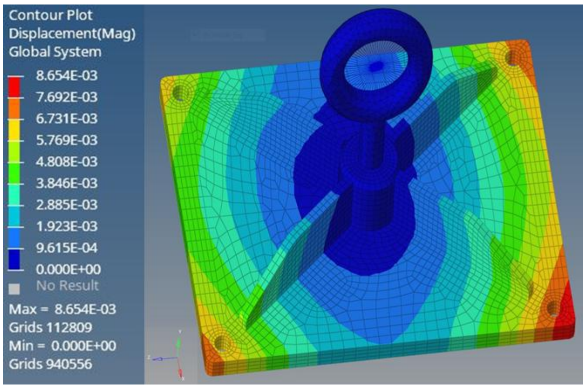

Fig. 7. Displacement of full model with RBE3 connection

2. Stresses

Maximum stress is come on full model is 1.345 MPa.

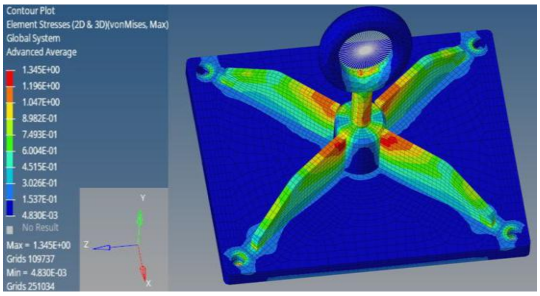

Fig. 8. Stresses on hook and rib with RBE3 connection

➢ Case 2: Full model result with RBE 2 connection

1. Displacement

Maximum displacement come on full model is 0.3839 mm.

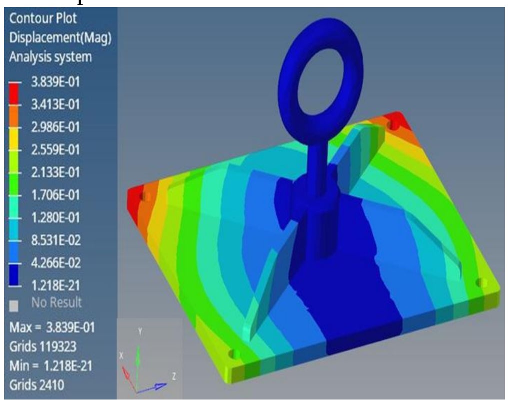

Fig. 9. Displacement of full model with RBE2 connection

2. Stresses

Maximum stress is come on full model is 55.53 MPa.

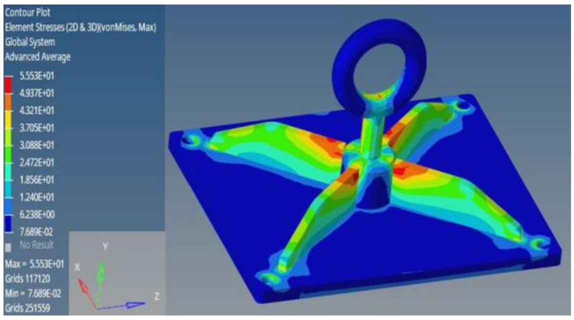

Fig. 10. Stresses on hook and rib with RBE2 connection

Methodology-2

➢ Case 1: Reduce model result with RBE 3 connection

1. Displacement

Maximum displacement come on reduce model is 0.0003665 mm

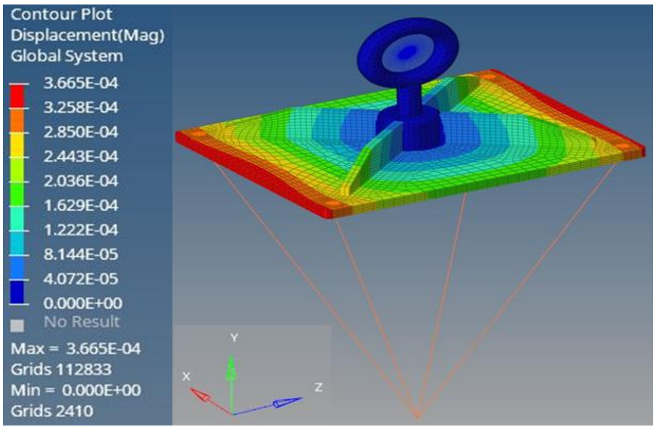

Fig. 11. Displacement of reduce model with RBE3 connection

2. Stresses

Maximum stress is come on reduce model is 0.1564 MPa.

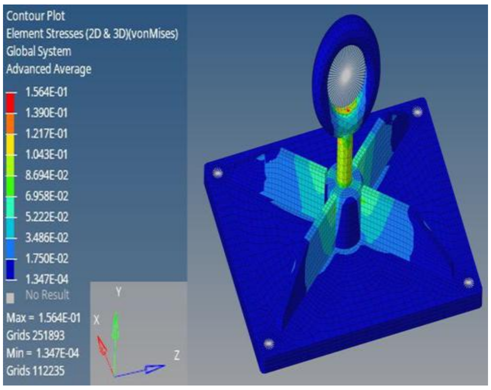

Fig. 12. Stresses on hook and rib with RBE3 connection

➢ Case 2: Reduce model result with RBE 2 connection

1. Displacement

Maximum displacement come on reduce model is 0.3263 mm.

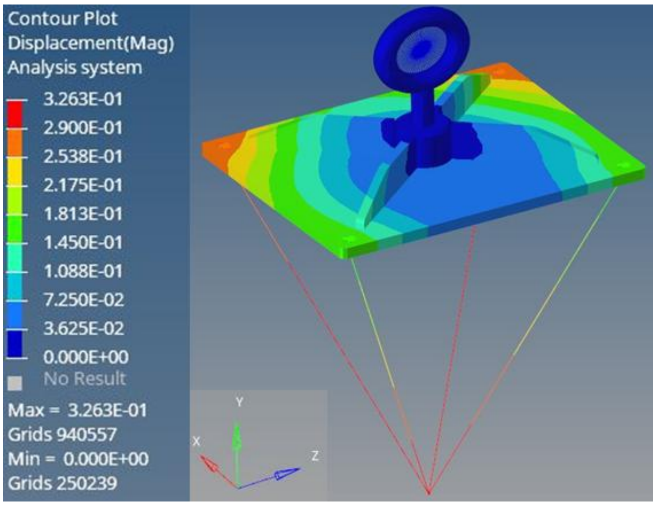

Fig. 13. Displacement of reduce model with RBE2 connection

2. Stresses

Maximum stress is come on reduce model is 86.27 MPa.

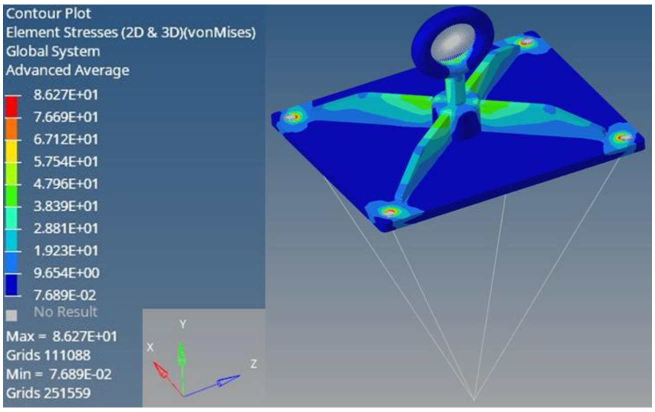

Fig. 14. Stresses on hook and rib with RBE2 connection

❖ Comparison of methodology 1 and methodology 2:

	Displacement	Von mises element stress
Full model with RBE3	0.00865 mm	1.345 MPa
Full model with RBE2	0.3839 mm	55.53 MPa
Reduce Model with RBE3	0.0003665 mm	0.1564 MPa
Reduce Model with RBE2	0.3263 mm	86.27 MPa

V. CONCLUSION

From the result of methodology 1 and methodology 2 the RBE2 connection is give the proper analysis result like displacement and von mises stresses on fixture is right according to material property. RBE 2 connection is better than the RBE 3 connection because its result is comparable according to the other analysis result. So, from the above evaluation of two methods RBE 2 connection is best instead of RBE 3 connection.

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