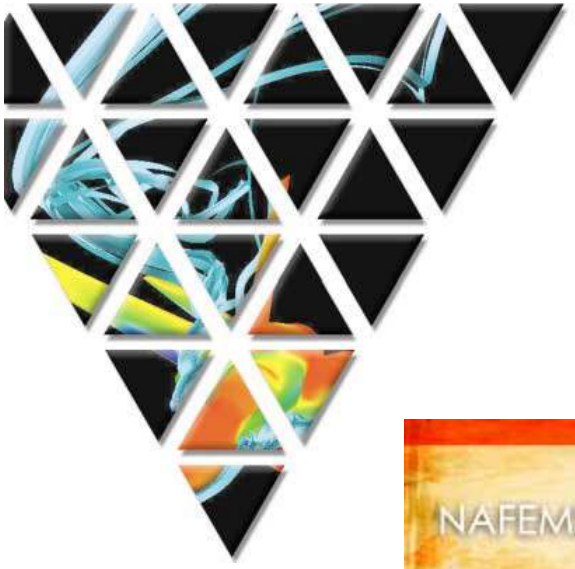

NAFEMS

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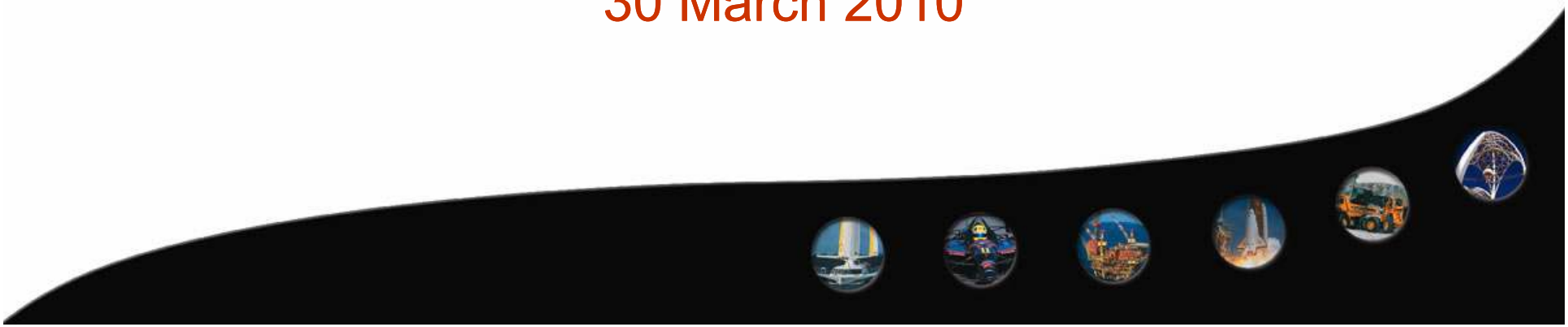
Accepted Practices in Practical Finite Element Analysis of Structures

Hosted by NAFEMS India

30 March 2010



Accepted Finite Element practices

Title : Accepted practices in practical finite element analysis of structures

Presenter name: S S Subramanya Sastry,

Designation : Lead Consultant,

Infotech Enterprises Limited,

Bangalore

Date : 30.3.2010

Accepted Finite Element practices

References:

1. Ten common mistakes in finite element analysis, Chalice Engineering simulation limited,
2. A few best practices for FEA users, Paul Dvorak, 2003, www.machine_design.com
3. Management of Finite Element Analysis - Guidelines to Best Practice, Beattie G A, 1995 Feb, NAFEMS
4. M. Young, 'The Technical writer's handbook', Mill Valley, CA University Science, 1989.

Accepted Finite Element practices
Topics

1. Checklist before starting the analysis
2. Important features to be captured and ignored for satisfactory prediction of the behaviour of the structure
3. Importance of checklists in a production finite element analysis
4. Importance of Excel templates
5. Points to be practiced during reporting stage
6. Points well known but ignored

Checklist before starting the analysis

Accepted Finite Element practices

- Make sure of the requirements before starting the analysis.

1. List the inputs provided
2. List the outputs requested
3. Connect all the inputs provided with the analysis requirements
4. Send the queries for additional inputs to client in the form of power point presentation with relevant figures

Accepted Finite Element practices

- Read and understand all the ‘Purchaser Technical Specifications’ applicable to the structure.
  - Raise the concern to the client if any point is not clearly understood,
  - Avoid guessing based on previous experience with similar structure / situation because requirement for each aircraft / client is different.

Accepted Finite Element practices

- Use only
  - approved software,
  - release,
  - version

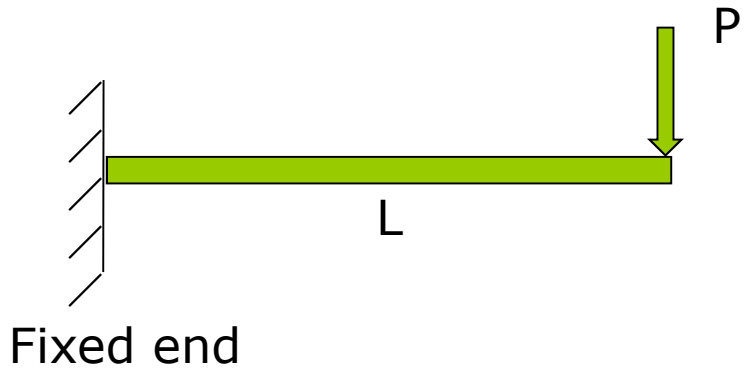
to be consistent with customer's expectations.

Accepted Finite Element practices

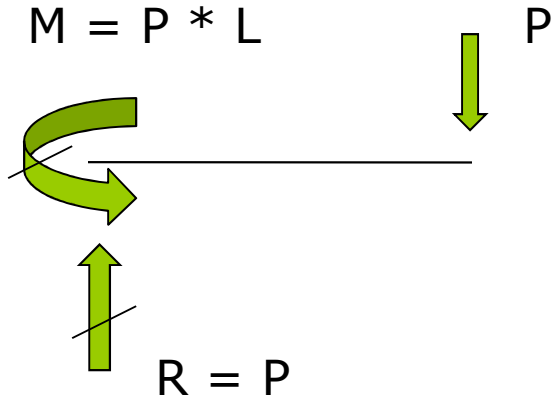
- Understanding of the various standard codes of compliance at least in course of time if not immediately. Eg.,
  - Read and understand all the applicable airworthiness standards/documents like CS (Certification Specifications) / JAR / FAR
- Use standard reference books such as Bruhn/Niu/Peterson immediately accessible for all simple analytical calculations for checking FEA results.

Accepted Finite Element practices

- Write Free Body diagrams for all hand calculations as and where applicable



Problem at hand



FBD

Note: ` ⁄ ` indicates reaction

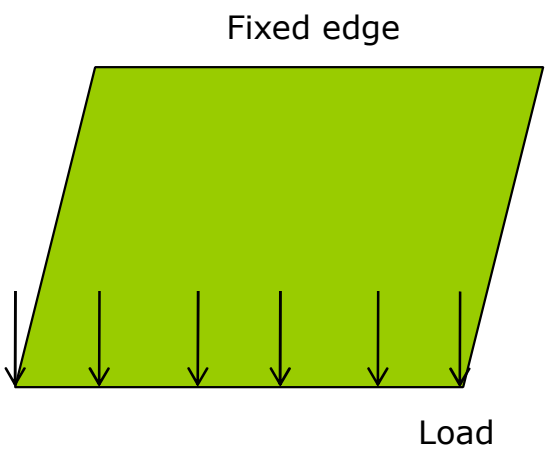
Accepted Finite Element practices

- Make an approximate model of the structure in which hand calculations can be used to generate deflections and stresses for a quick comparison with the FEA results.

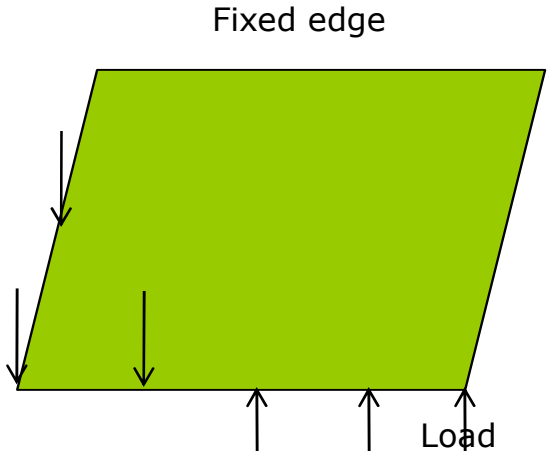
- Read, understand and apply all the fitting, wear and tear factors to be considered in the analysis.

- Feel the structure without going into the numbers to understand the behaviour under a given loading condition.

Accepted Finite Element practices



Bending without twisting



Bending with twisting

Note: Distinguish between Isotropic and Orthotropic material behaviour

Important features to be captured and ignored

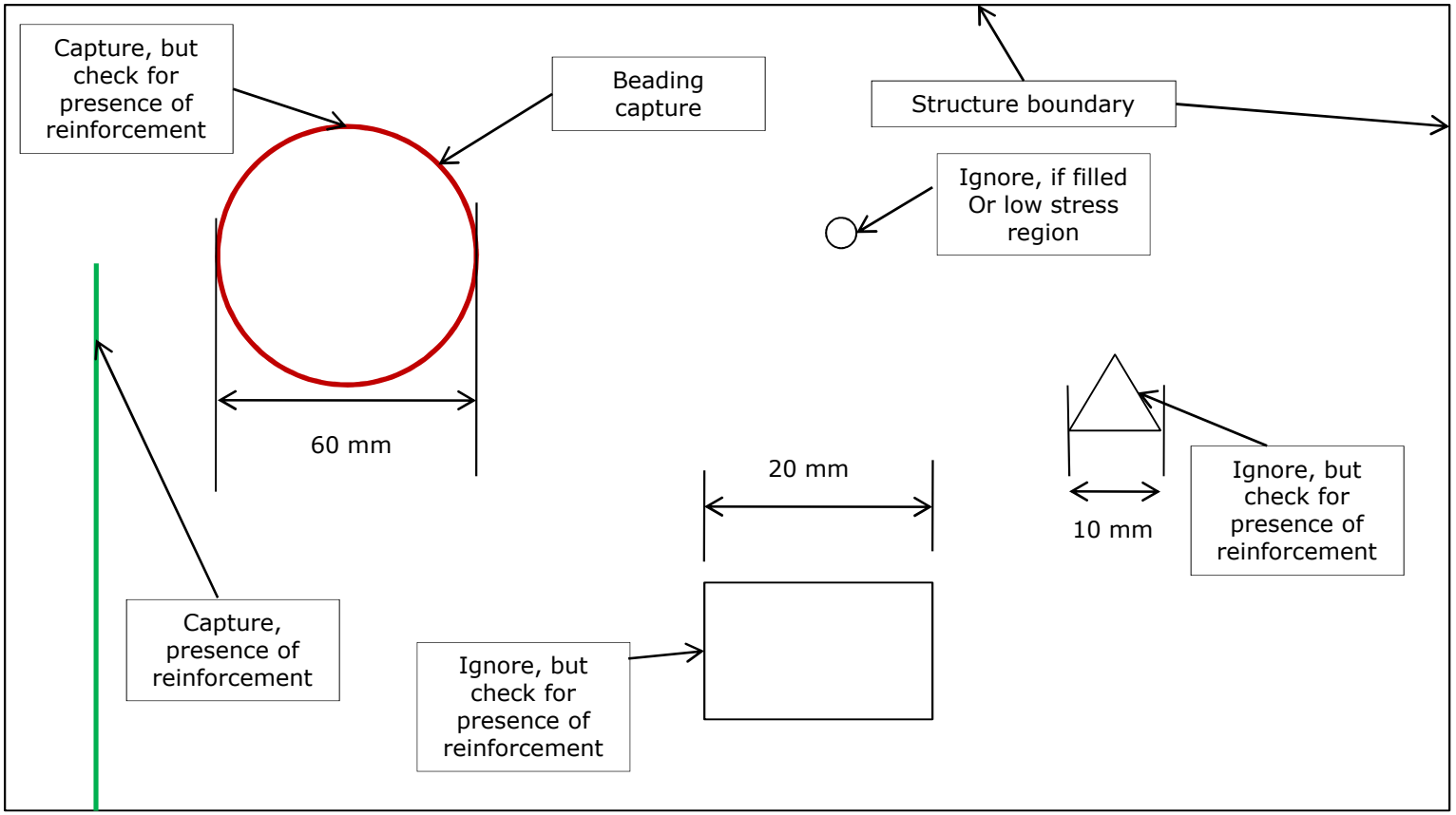
Accepted Finite Element practices (Features to be considered)

- All cutouts greater than 40 mm should be considered in the design/analysis.
- All beadings/lips to the cutouts should be appropriately modeled in metallic structures.
- All cutouts in composite structures will have additional reinforcements. As far as possible this must be symmetric layup.
- Proper dropping sequences of layups for smooth transition of load to the adjacent structure
- All local stiffeners.

Accepted Finite Element practices (Features that can be ignored)

- All cutouts less than 40 mm size.
- All tappings where additional reinforcements are provided.
- All tappings which are filled and closed with proper reinforcement after the installation of internal gadgets.
- All cutouts in low stress area.
- All features that provide additional strength to the structure without inducing a redistribution of stress significantly.

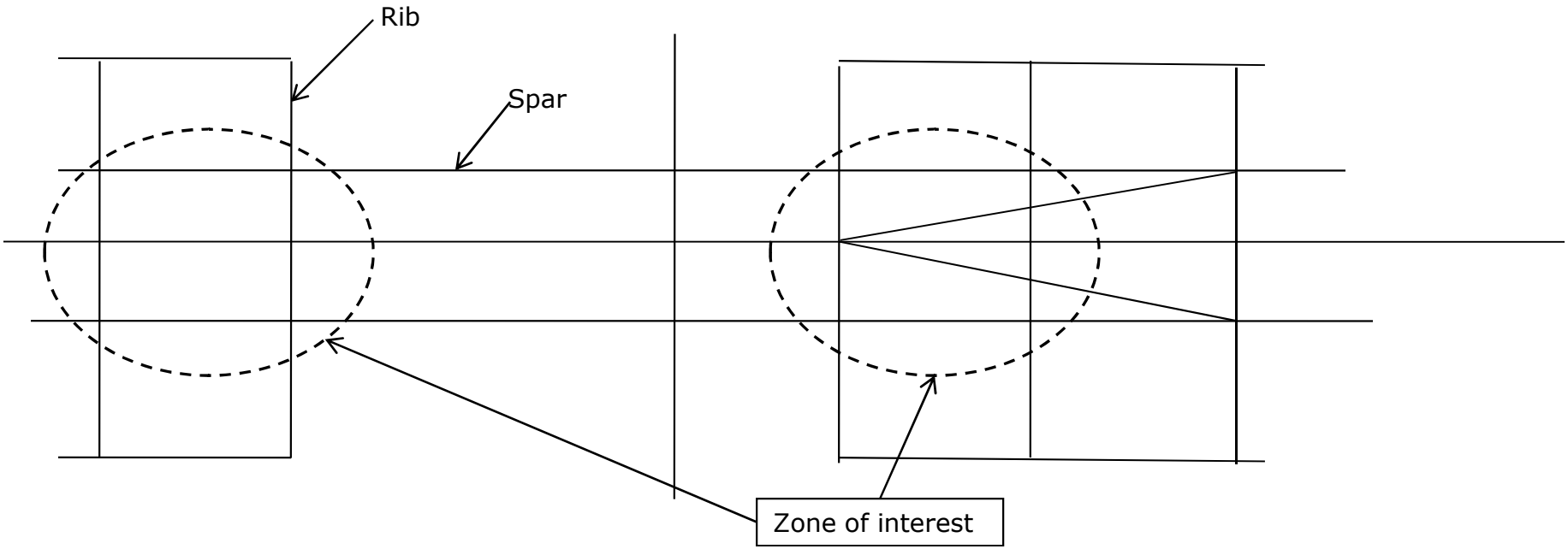
Accepted Finite Element practices



Pictorial representation of features (important / unimportant)

Accepted Finite Element practices

- No triangular elements in zones of load transfer, zones where there is a sudden change of cross section, junctions like spar-rib, skin-rib etc



Importance of checklists in production finite element analysis

Accepted Finite Element practices
Check lists

- Prepare checklist (separate for model and analysis) and get it audited with the client before implementation.
- All points in the checklist must be adhered to strictly. Don’t over rule the checklist.
- Note all the deviations with explanation in the remarks column.
- Specify all the numerical quantities likes strength, stiffness of elements used in the analysis for clarity in the checklists.

Accepted Finite Element practices
Check lists

- Control the version of the checklist with the quality department from time to time.
- Specify consistent units to be used, in check list wherever applicable so that mistakes are avoided.
- Checklist should cover all the information required to do a successful FE analysis.
- It should have minimum 3 sections, modeling checks, pre-analysis checks and post analysis checks

Importance of Excel templates in organizing results

Accepted Finite Element practices
Organizing results

- Excel template is an elaborate and sure method of capturing all the required information.
- Arrange the information starting from the description of structure to the RF in various work sheets.
  - How it works
  - Description of structure / work flow diagrams
  - Loading
  - Induced stresses and allowable stresses

Accepted Finite Element practices
Organizing results

- Factor of safety
- Include all relevant figures. Create all tables connecting the relevant sections through equations.
- Build conservatism into the calculations.
  - Real status: Total stress = Stress due to mech. Load (Tensile) + Stress due to temperature effect (Tensile) - Stress due to bending (Compressive) = Lower stress hence better RF (Real status, not practiced)

Accepted Finite Element practices
Organizing results

- Conservative status: Total stress = Stress due to mech. Load (Tensile) + Stress due to temperature effect (Tensile) + Stress due to bending (Tensile) = Higher stress hence lower RF (Hypothetical status, but practiced)

- Cover all cases under a more general case rather than solving individual cases. Clear other less severe cases by comparison.

  - Eg. In D & DT, 10 scratches and 10 stresses are given.

Accepted Finite Element practices
Organizing results

- Scene 1: Calculate 10 different cycles to failure and choose the lowest number of cycles and declare the final result. (Real case, not recommended, because time consuming)
- Scene 2: Choose the highest stress and the largest damage. Calculate life and declare the final result (Hypothetical case, followed in practice)

- Avoid mixing of loads while checking for strength or buckling. Mixing of tension and compression loads while finding RF.

Points to be practiced during reporting stage

Accepted Finite Element practices
Reporting stage

- Check the header, footer and front sheet of the report for correctness of all entries.
- Connect the figures, tables and references using links if permitted.
- Adopt internationally accepted reporting practices to avoid confusion. Eg. Indicate references by [1].
- References should not be included within the table, instead, should be included at the bottom of the table with proper superscripts. Eg. xxx$^{(1)}$

Note: (1) : Reference 1

Accepted Finite Element practices
Reporting stage

- No figures and tables must be left free without referring to in the report.
- No figures should continue beyond a page length and should have a proper title.
- All tables continuing on more than 1 page should have the tag “……..(Continued)” and on last page should have the tag “……..(Concluded)”

Accepted Finite Element practices
Reporting stage

- Check all the calculations for correctness to the typed digits for consistency.
- Run spell check without forgetting before closing the report.

Points well known but ignored

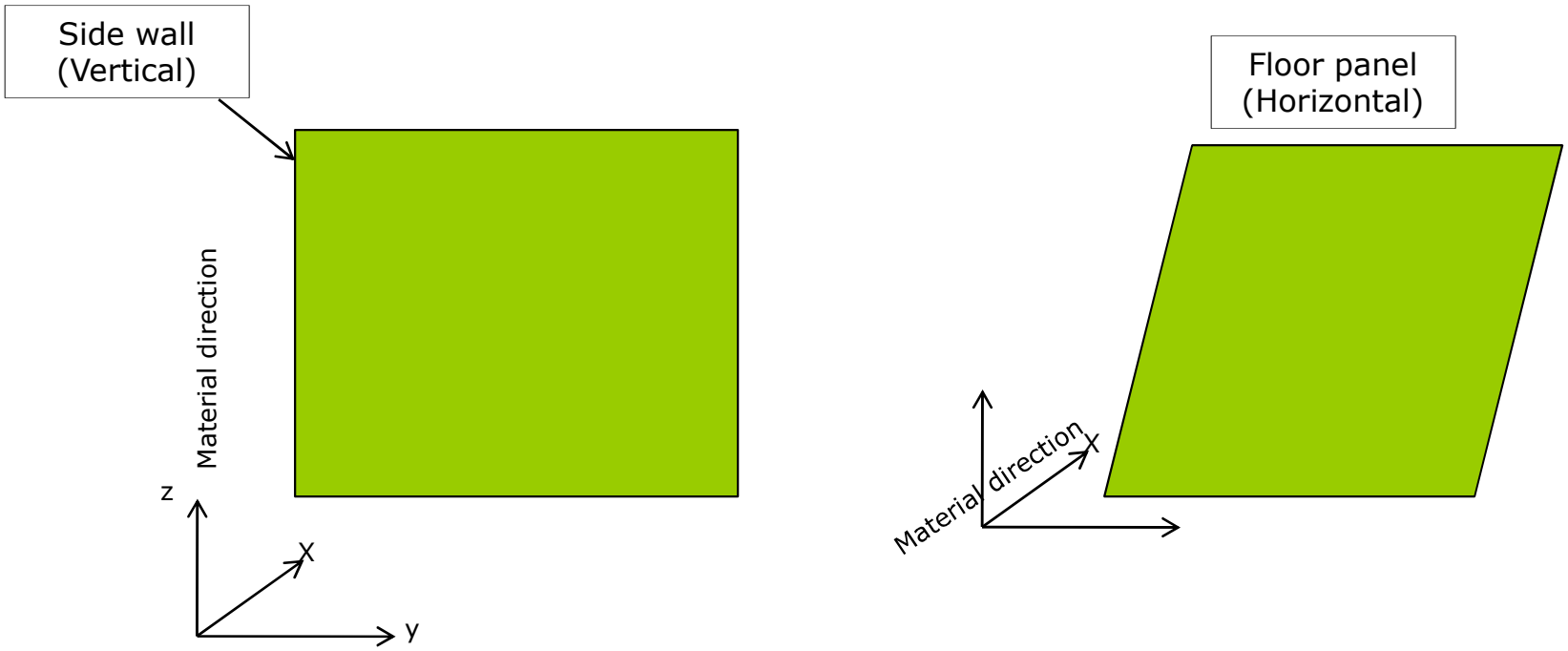
Accepted Finite Element practices (Modeling)

- Shell elements shall be modeled at the mid surface, line elements at the centre of the cross section and solid elements are modeled so as to capture the entire geometrical shape.
- Element direction should be consistent and necessary to simplify load application and output evaluation.
- Shall element normal should point in a direction corresponding to nearest positive global coordinate direction

Accepted Finite Element practices (Modeling)

- All other panels side walls, sloping outboard panels… etc. with material orientation defined in the global positive Z (up) direction
- For all horizontal panels (floor or ceilings) the material orientation is defined along the positive X (aft)
- Regions of stress interest should not have any triangular elements.
- Brick elements should be used for meshing solid parts.

Accepted Finite Element practices (Modeling)



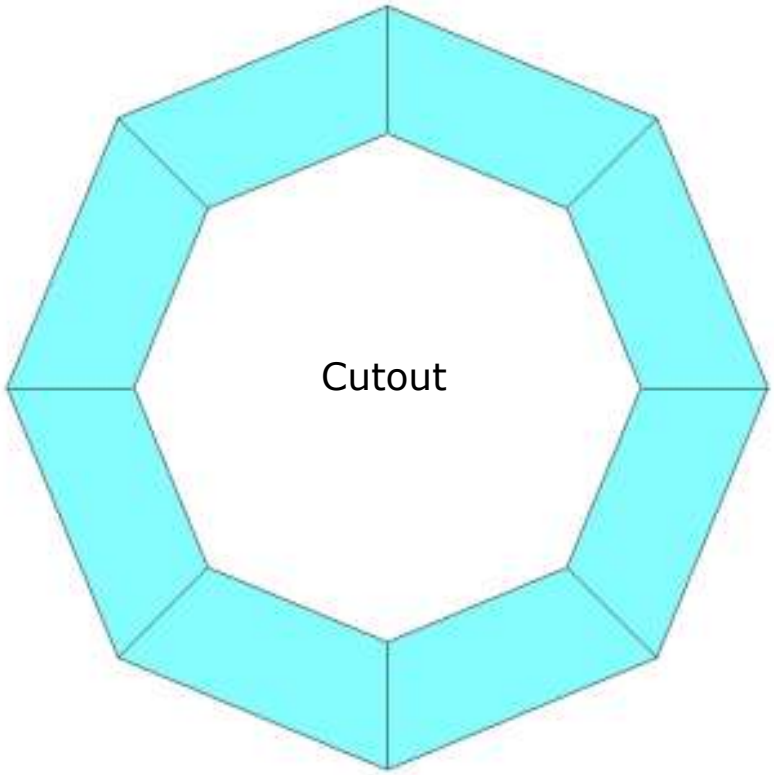
Accepted Finite Element practices (Modeling)

- For complicated geometries TET10 shall be used to mesh solid geometry.
- It is permissible to use TET4 elements just to understand the behaviour of the structure.
- TET4 mesh should not be used for substantiation of the structure.

Accepted Finite Element practices (Modeling: Element size)

- Acceptable element size for panels is 10 to 25 mm.
- Acceptable mesh size for metallic brackets is 1 mm.
- Element size is dependent on thickness of the panel.
- For end cap panels mesh size less than 10 mm is required and the thickness may be greater than 10 mm
- Put at least 8 elements to capture a cutout

Accepted Finite Element practices (Modeling: Cut-out)



At least 8 element around the cutout, ignore one complete round of elements before reporting the stress, because it is possible that this cutout has reinforcement or replaceable bush etc. around the cutout.

Accepted Finite Element practices (Modeling: Parameters, Mass)

- Always run solver with minimum stiffness parameter option off and don't suppress normal rotation to detect possible singularities and properly interpret them.
- Density is specified in tons/cu.mm, NSM in tons/sq.mm, model units in mm, acceleration in mm/sec^2 Eg., 9g is specified as 9*9810 = 88290 mm/sec^2

Accepted Finite Element practices (Modeling: Parameters, Mass)

- Unless specified otherwise, all masses must be modeled using the material density of the element.
- Masses of all external items (like decoration rail, edge fillers) are to be applied as NSM

Accepted Finite Element practices (Modeling: Mass)

- Non Structural Mass can be specified as a factored structural mass.
- Mass of all attached items like monitor, coffee machine, microwave oven, speakers, woofers etc. are to be modeled as concentrated masses and attached to the panel using the interpolation element.

Accepted Finite Element practices (Modeling: Mass, Abuse load)

- Inertia loads are applied using the GRAV card. Six inertial load cases shall be considered for the analysis two in each X, Y and Z directions.
- Abuse loads shall be considered as per technical note document.

Accepted Finite Element practices (Modeling: Loads)

- Abuse loads are stationary loads and don't move along with the deformed structure (follower force effect should not be considered)
- Unless specified otherwise, the order of the load cases will be inertia load case, air load case and abuse load cases.

Accepted Finite Element practices (Modeling: Fitting/wear & tear factors)

- No fitting factor shall be applied where the strength is proven by limit and ultimate load tests in which the actual maximum stress conditions are simulated in the fitting (or in a similar fitting in terms of material and size) and surrounding structure.
- No fitting factor shall be applied to continuous or multiple load path joints. Such joints may be mechanically fastened, welded or bonded. Example, bond line between two composite panels

Accepted Finite Element practices (Modeling: Fitting/wear & tear factors)

- If a fitting factor is required then it is to be applied in the final stage of the analysis where the RF is calculated. i.e., RF = Allowable load or stress / (FF*Applied load or stress)
- Where more than one factor is applicable to a structure only the larger of those factors is to be used.

Accepted Finite Element practices (Modeling: Representation, gravity load check)

- The fasteners must be modeled using zero length elements unless stated otherwise.
- FE model should accurately define the physical system of the structure
- Do an unit gravity loading check for the structure to correctly understand the behaviour. Alternatively do a free-free analysis.
- Unit gravity loading check verifies that the model will provide accurate displacements and reaction forces under gravity loading.

Acknowledgement

- I sincerely thank and acknowledge the support and encouragement provided by Mr. M. Lakshmana Rao, AVP and Mr. K. Ashok Kumar, CTO and other senior management members of InfoTech Enterprises Limited for allowing me to conduct in the webinar.

Thank you