Dovre Sertifisering AS

Notified body nr: 2654

**Note: PED 2014-68-EU 2017-003 R2**

# Guidance on the information to be included in a FEA report.

# Dovre Sertifisering AS

# Technical Note

**Guidance on the information to be included in a FEA report.**

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## Introduction

The focus of this note is on what is required when you are using a FEA to assist in the justification of the design of pressure equipment.

It is preferred that a design is justified using Design by Rule. This means that, if you are working with the design of pressure equipment (piping or pressure vessels) according to PED (2014/68/EU), the preferred way of design verification is the use of the requirements as laid down in the relevant standards (ex. EN13445-3 or EN13480-3).

There are situations where these standards are not applicable or do not cover your specific model, geometry or loads. In this case it may be necessary to perform other calculation methods. This can be manual calculations or a Design by analysis route (ex. EN13445-3 Annex B or Annex C).

In this case we focus on the Finite Element Analysis (FEA).

## What is Finite element analysis (FEA)

The finite element method (FEM) or finite element analysis (FEA) is a numerical method to predict the behaviour of a construction and for solving problems of engineering and mathematical physics.

Typical problem areas of interest include structural analysis, heat transfer, fluid flow, mass transport, and electromagnetic potential. The finite element method formulation of the problem results in a system of algebraic equations.

The method yields approximate values of the unknowns at discrete number of points over the domain *(Logan, 2011)*.

To solve the problem, it subdivides a large problem into smaller, simpler parts that are called finite elements. The simple equations that model these finite elements are then assembled into a larger system of equations that models the entire problem.

**Requirements FEA submission**

If the standard rules are not sufficient to cover the design a FEA could be applicable.

**The following items should be a part of the FEA report.**

1. **The scope of the FEA.**
   - Reason and explanation why the FEA is used.
   - Technical description of the structure
   - Description of the loads
   - Standard used for the FEA (ex. EN13345-3 annex B or C)

2. **The software used for the FEA.**
   - Originators / operators name
   - System modules
   - Software name and Version number of the software used
   - Operating system (Name and version)

3. **Executive summary.**
   - Describing how the FEA was used to support the design
     - Linear Static Stress Analysis:
       - Factor of Safety Calculation
       - Deflections and Strains
       - Contact Stress Computation
     - Thermal Analysis:
       - Thermal Stress Analysis of parts and assemblies
       - Thermo-mechanical Analysis
     - Non-Linear Analysis:
       - Material Non-linear Analysis
       - Geometric Non-linear Analysis
       - Impact Analysis
       - Elasto-plastic Deformation Analysis
     - Fatigue Analysis:
       - Durability Analysis
       - Failure Prediction Analysis
       - High Cycle Fatigue Calculations
     - Pressure Vessels Stress Analysis:
       - Stress Analysis per EN/ASME/AD 2000/ CODAP Codes
       - Nozzle stress analysis
       - Stress Intensity Calculations
       - Shell & Full Scale 3D Stress Analysis of Pressure Vessels among others
   - FEA model used
   - The results of the FEA
   - Conclusions of the FEA for the model

- Conclusions to the essential safety requirements of the directive (2014/68/EU)

## 4. Type of analysis (linear, plastic).

- Model description and generation
- Refer to the drawings used (correct number and revision)
- If simplifications or changes of the model are needed to perform a FEA, these must be explained and justified
- Explain meshing (mesh type and size) and refinement
  - Explain h
  - Explain p
  - Shape
  - Order ($1^{st}$, $2^{nd}$ )
  - All local refinements must be shown explained and justified

## 5. Chosen mesh size and local refinement.

- Element type and number of elements
- Forces on the model
- Contact elements (how 2 areas/ faces are connected, ex. Flange faces that are connected)
- Describe and show supports
- Describe and show forces
- Describe and show restraints
- Describe the method to prevent rigid body movement
  - Models can translate or rotate freely if they are not correctly re-strained.
  - An object has 3 translational and 3 rotational rigid body modes.
  - You can prevent rigid body movement by:
    - Restraints to the displacement
    - Study settings (soft spring)
    - Contacts
    - Connections
- Describe and explain boundary conditions to compensate for missing model parts. This is typically when you are performing an analysis based on sym-metry

## 6. Material properties.

- A complete description should be provided
- All of the material properties used must be presented in the report (do not re-fer to separate documentation)
- Use tables and graphical data (data provided as agreed with the NoBo)
- Be aware of material properties as function of the temperature
- Youngs modulus and Poisson's ratio
- Refer to PMI, EAM or harmonized standards for the material properties

## 7. Results of the FEA.

- Include a validation of convergence (it is allowed to refer to earlier models if applicable)
  Ex: Do the values "converge" toward a finite value as the mesh is re-fined and run repeatedly.
- Displacements of the model
- Deformed and un-deformed shapes (superimposed, shows the 2 models as layered)
- Mesh plots
- Stress plots
- Reaction forces on the model (compare with the forces applied)
- Check incorrect boundary conditions (temperatures, pressures, forces etc)
- If EN13445-3 is used reference should be made to the used annexes.
  - If annex B is used, reference to §B.5 Methodology should be made.
  - If Annex C is used, reference should be made to table C-3 (EN13445-3).

## 8. Analysis of the results.

- Accuracy of the model should reflect that the results are also applicable for the physical equipment being built
- Allowable stresses
- Element stress, nodal stress and compare the results
- Results are explained
- If results are excluded this should be explained/ justified
- If possible the results of the FEA must be be compared with the results of stress calculations of the pressure vessel or part of the pressure vessel with analytical method (DBF)
- Of all used results / plots it should be explained why the results are included and its purpose.
- Explain stress concentrations

## 9. Conclusion based on the results.

- Relate the results to the applicable standard
- Uncertainties of the results
- Conclusions to PED (2014/68/EU), the ESR must always be satisfied before the design can be approved.

*Remember:*

*An FEA program allows an engineer to make mistakes at a rapid rate of speed (R. miller).*

*FEA is a versatile tool, but not the best analytical tool for every problem. (Cook)*