To:

XYZ Company

Date: One Day

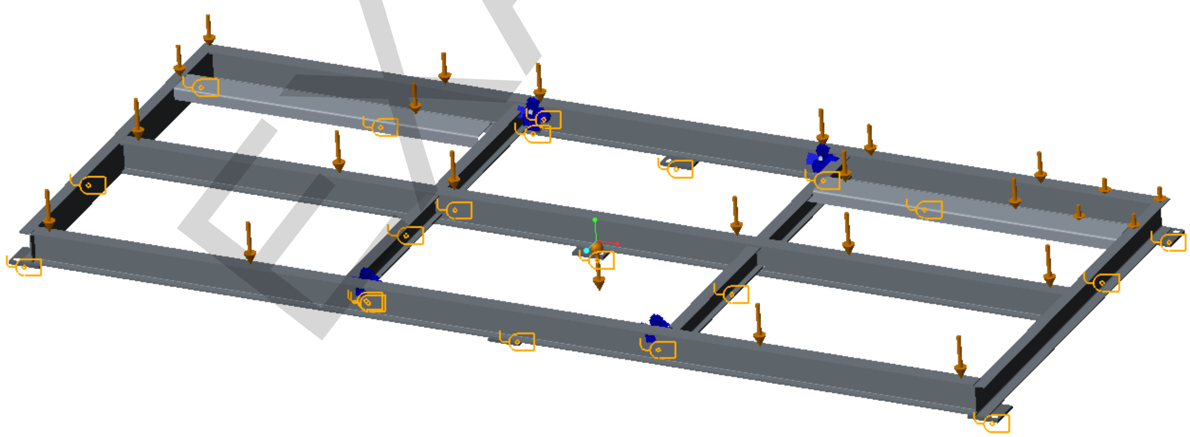
Title:

Structural Analysis of a Pallet Frame Superstructure

Abstract:

This report details the results of a finite element analysis (FEA) that was performed on a pallet frame superstructure using Creo Simulate, to determine its reaction to the intended loading. The pallet frame is to be fabricated from A36 low carbon steel commonly available worldwide. During fabrication, transport, and installation the frame will be lifted using four lifting lugs welded to the superstructure and provided for that purpose. When suspended from these four points the frame will support the weight of several large components, the hardware associated with them, and all interconnections between them. The total mass of the pallet when fully assembled is estimated to be 4200 kg (9200 lbs.) which includes the frame itself (845 kg).

The results show that, as designed, the structural integrity of the pallet frame is maintained with a safety factor greater than 4 during lifting and handling operations when the applied load is maximum.



1. Scope

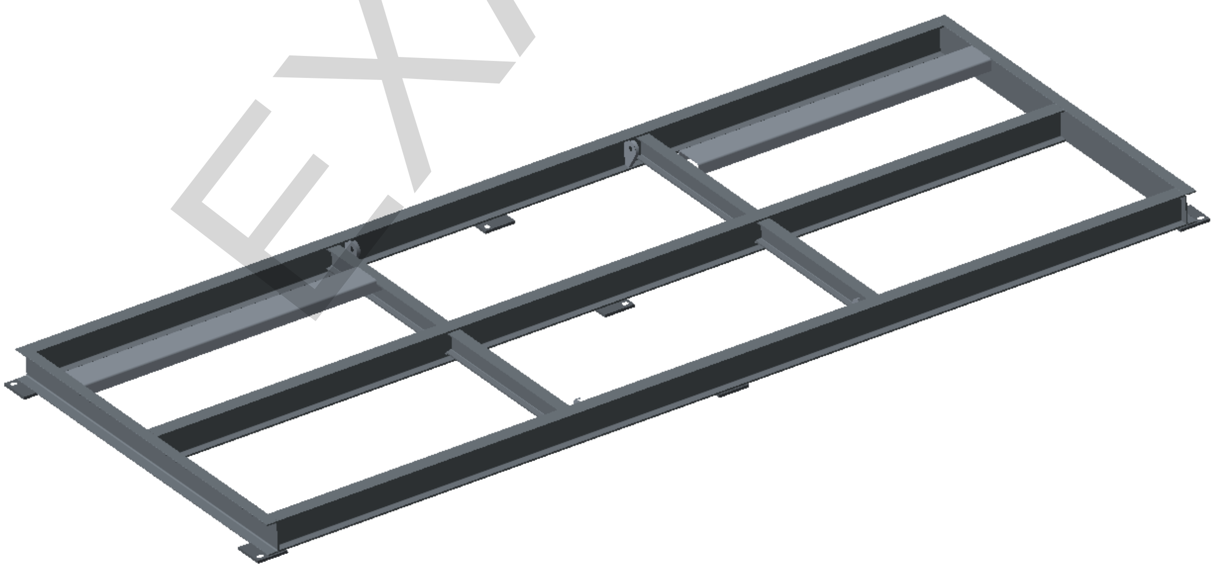
- Determine the maximum stress induced in the pallet frame under its intended loading.
- Determine the adequacy of the lifting features (lugs) to support the assembled pallet.
- Determine the reasonableness of the results by comparing those generated by Creo Simulate to calculations performed using textbook equations for stress and strain.

2. Assumptions

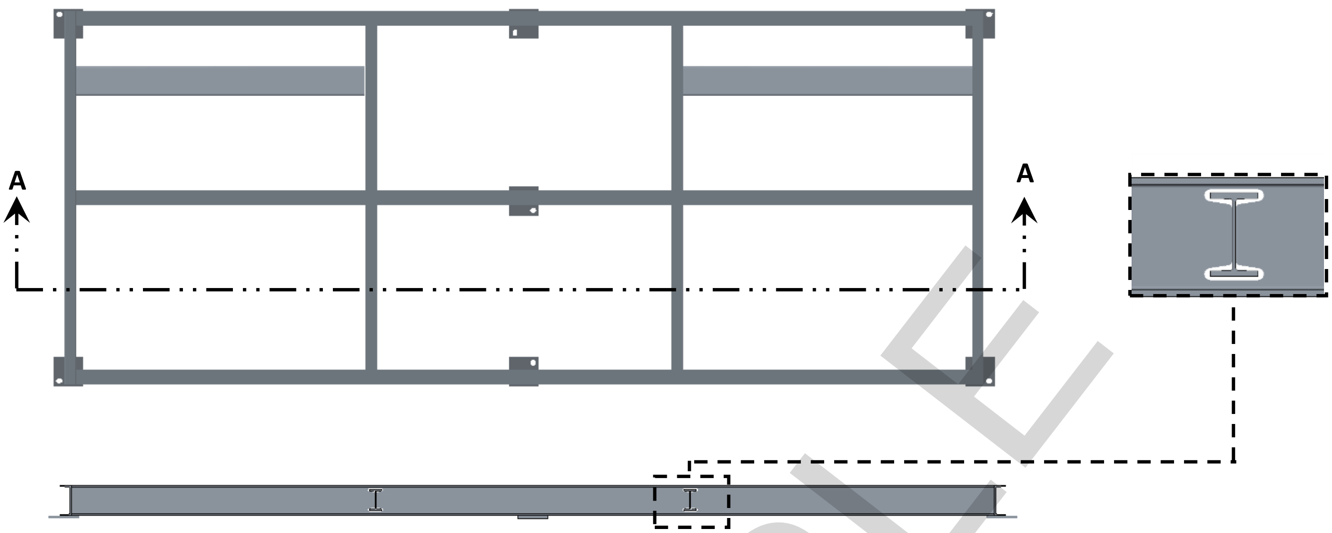
- The centers of gravity for each of the major components are symmetric with respect to their footprints.
- Component masses provided by the individual vendors are within 5% of actual.
- All fabrication welds are in accordance with AWS standard welding procedures, or equivalent.
- Material properties of A36 low carbon steel are isotropic.
- Ambient temperature conditions apply (21˚ C).

3. Frame Construction

- Length ~ 6.1 m
- Height (with feet) ~ 0.23 m
- Width ~ 2.56 m
- Material: A36 low carbon steel
    - Main rails: W8 x 15# I-beam
    - Cross members: W6 x 12# I-beam
    - End rails: C8 x 18.75# C-channel
- Mass of pallet frame superstructure = 845 kg
- Additional component & decking support to be added as required.



Pallet Frame Weldment – Superstructure



Section A-A

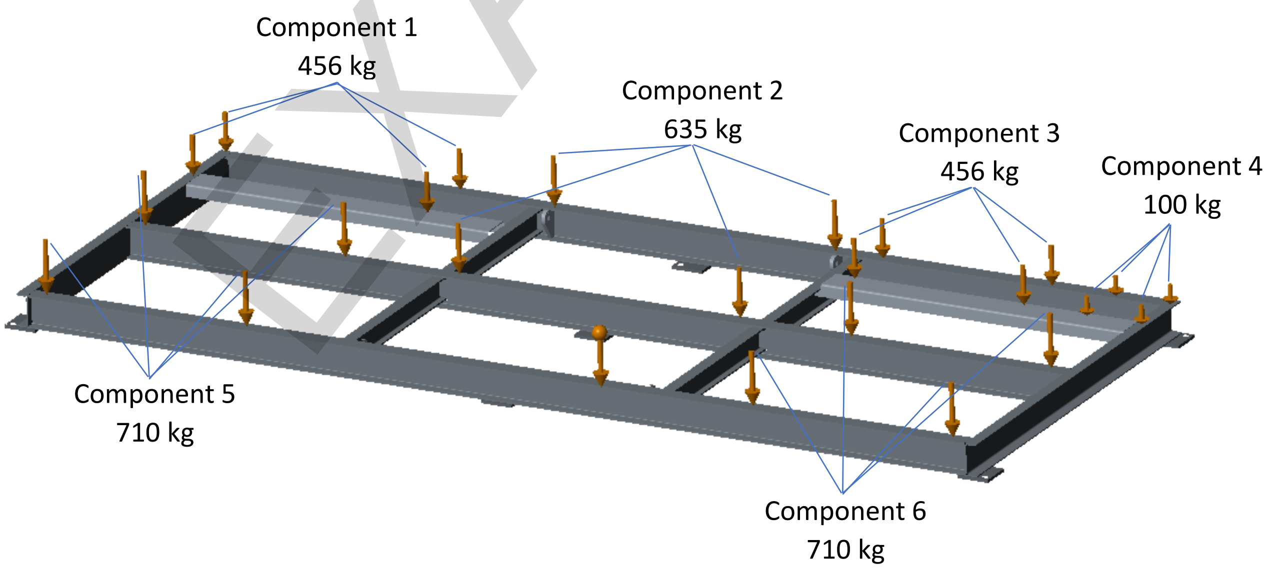
4. Material Properties

Material: A36 low carbon steel per ASTM A36/A36M

$\rho = 7.80 \times 10^{-6}$ kg/mm	Tensile Yield = 250 MPa
ν = .26	Tensile Ultimate = 400 MPa
E = 200 GPa	

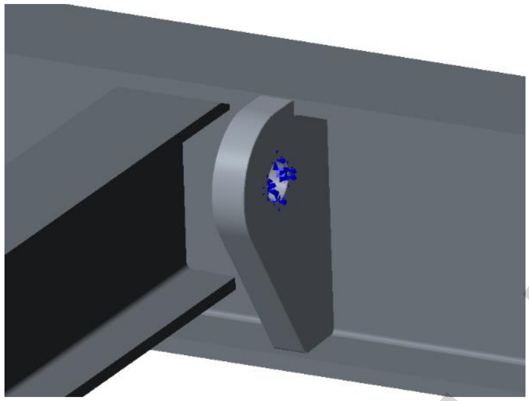
5. Loads and Constraints

5.1 Loads



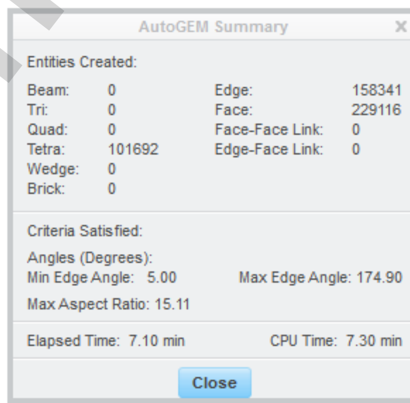
5.2 Constraints

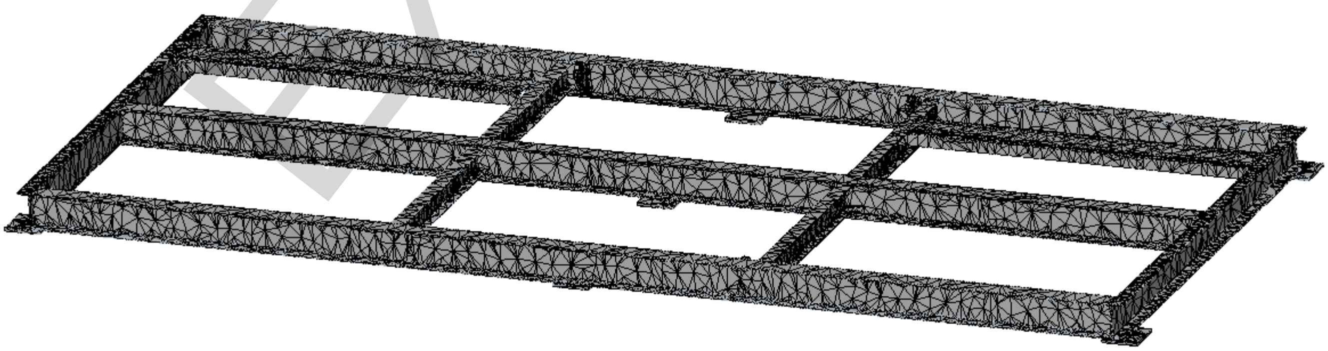
Model constraints represent a typical lifting scenario: Loaded pallet assembly suspended from the 4 lifting lugs. Each hole in the lugs is fixed in the x, y, and z axes. The 3 rotational degrees of freedom are maintained.



6. Model Mesh

By default, Creo Simulate created 101,692 tetrahedral elements for the analysis. No diagnostic warnings were reported.

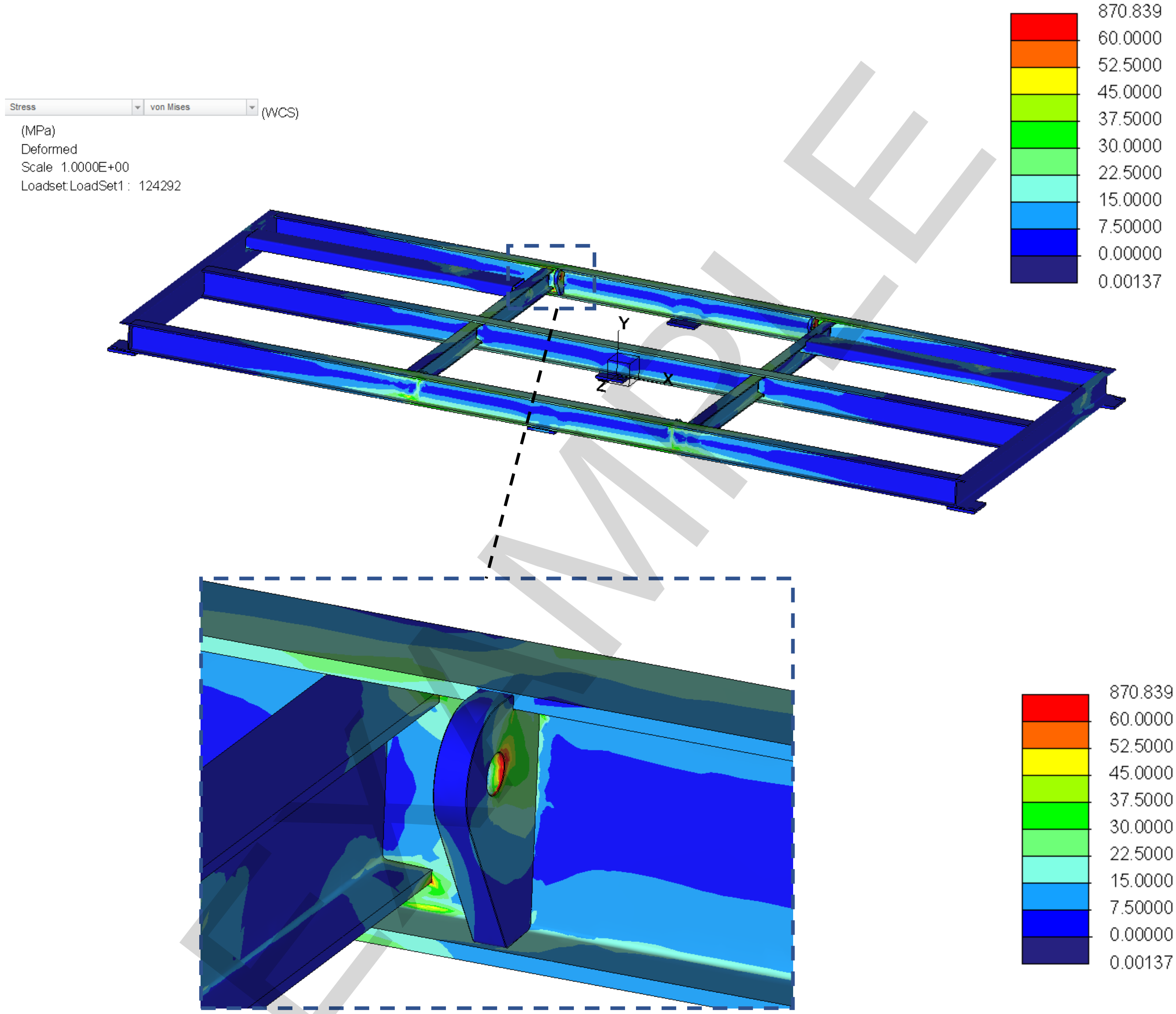




7. Results

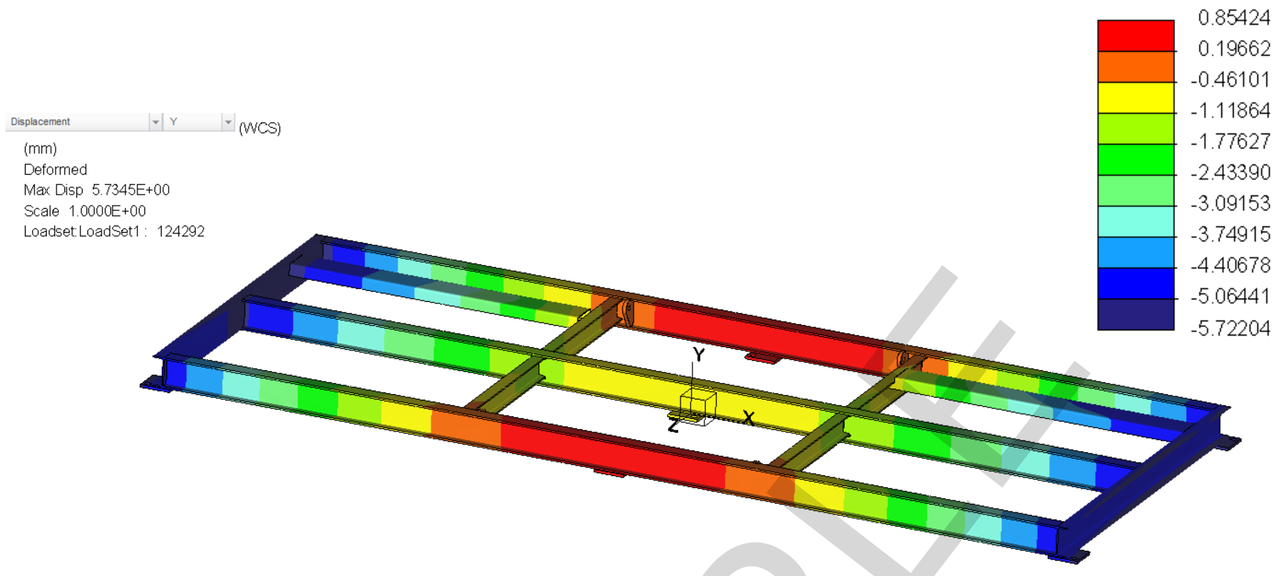
7.1 Pallet Frame

Results of the analysis indicate a maximum stress in the pallet frame induced by the intended loading of approximately 52.5 MPa. Yield strength of the material is 250 MPa giving the design a safety factor of 4.5.*



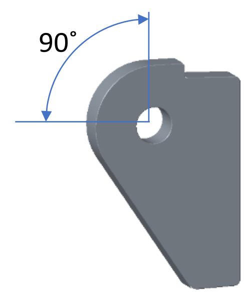
*The pallet frame fringe plot below contains singularities caused by abrupt changes in geometry and the boundary conditions. Singularities occur when infinitesimally small areas are stressed, such as the sharp corners between the end of the cross-members and the web of the side rail to which it is rigidly attached. Physically, such small areas do not exist. Mathematically, Creo Simulate is mapping elements exactly as modeled which results in erroneously high stresses or displacements at these locations and can safely be ignored.

Displacement results of the loaded pallet frame yield reasonable and expected deflections.



7.2 Lifting Lugs

4 lifting lugs are incorporated into the pallet frame for lifting purposes. The lugs are 25 mm thick, A36 plate steel. The lifting hole is concentric with the outer radius of the lug and a constant cross-section between the two is maintained for lifting angles between 0˚ and 90˚. When a shackle pin bears on the ID of the lifting hole, the lug will be in double shear. The stress calculations for this condition are as follows;



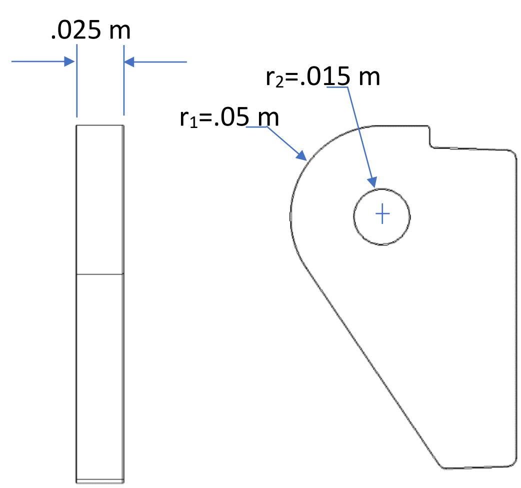
$t_{lug} := .025 \cdot m$ $\quad P_{TOT} := 41190\ N$

$r_1 := .05 \cdot m$ $\quad P_{LUG} := \frac{P_{TOT}}{4}$

$r_2 := .015 \cdot m$ $\quad P_{LUG} = (1.03 \cdot 10^4)\ N$

$A_S := t_{lug} \cdot (r_1 - r_2)$

$A_S = (8.75 \cdot 10^{-4})\ m^2$



And, shear (V) is;

$V := \frac{P_{LUG}}{2 \cdot A_S}$

$V = (5.884 \cdot 10^6)\ Pa$

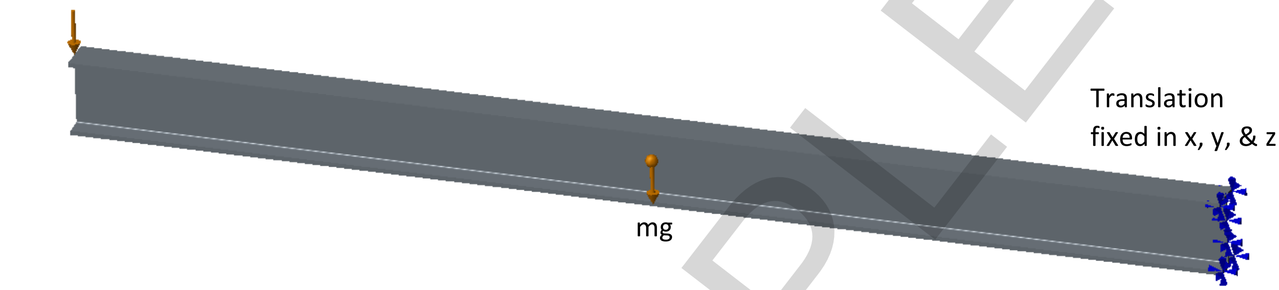
Allowable shear stress is typically taken as ½ Yield, or

225 MPa, well above V.

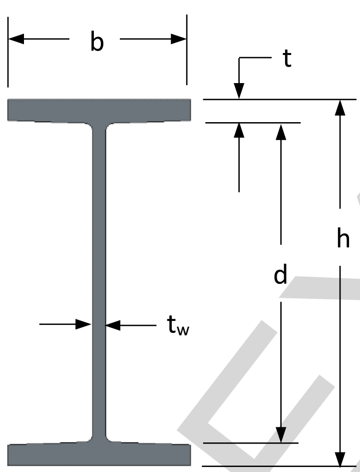
8. Self-Checks and Uncertainties

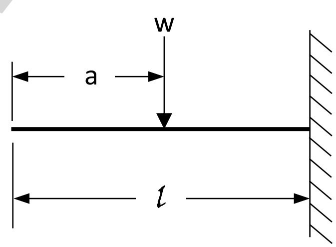
A comparison between calculated and FEA results for a simple beam loading scenario is carried out below to serve as verification of the parameters used in the analysis of the pallet frame and the reasonableness of those results. The beam modeled has the same cross-section and material properties as the W8 x 15# main I-beam used in the design of the pallet frame. The beam is fixed at one end with a 4905 N (500 kg) load applied at the other.

Loads and Constraints:



Moment of inertia, I_x, von Mises stress, σ_{vm}, and displacement, δ, calculations:





From beam model, cross-sectional area is;

$b := .100 \cdot m$
$d := .1772 \cdot m$
$t := .0114 \cdot m$
$t_w := .007 \cdot m$

$w := 4905\ N$
$E := 166.3 \cdot 10^9\ Pa$
$a := 0\ m$
$l := 3.049\ m$

$$c := \frac{d}{2} + t$$

$A_{beam} := 3.716 \cdot 10^{-3}\ m^2$

Moment of Inertia is;

$$I_x := \frac{b \cdot (d + 2 \cdot t)^3 - (b - t_w) \cdot d^3}{12}$$

$$I_x = (2.355 \cdot 10^{-5})\ m^4$$

Stress due to bending is;

$$\sigma := \frac{w \cdot l \cdot c}{I_x}$$

$$\sigma = (6.352 \cdot 10^{7})\ Pa$$

and, shear stress in the beam is;

$$\tau_{xy} := \frac{w}{A_{beam}}$$

$$\tau_{xy} = (1.32 \cdot 10^{6})\ Pa$$

Von Mises stress is calculated from the following equation;

$$\sigma_{vm} := \sqrt{\frac{1}{2} \cdot \left((\sigma_{xx} - \sigma_{yy})^2 + (\sigma_{yy} - \sigma_{zz})^2 + (\sigma_{zz} - \sigma_{xx})^2 \right) + 3 \cdot \left(\tau_{xy}^{\ 2} + \tau_{yz}^{\ 2} + \tau_{zx}^{\ 2} \right)}$$

Where,

$$\sigma_{xx} := \sigma \qquad \sigma_{yy} := 0\ Pa \qquad \sigma_{zz} := 0\ Pa \qquad \tau_{yz} := 0\ Pa \qquad \tau_{zx} := 0\ Pa$$

Therefore,

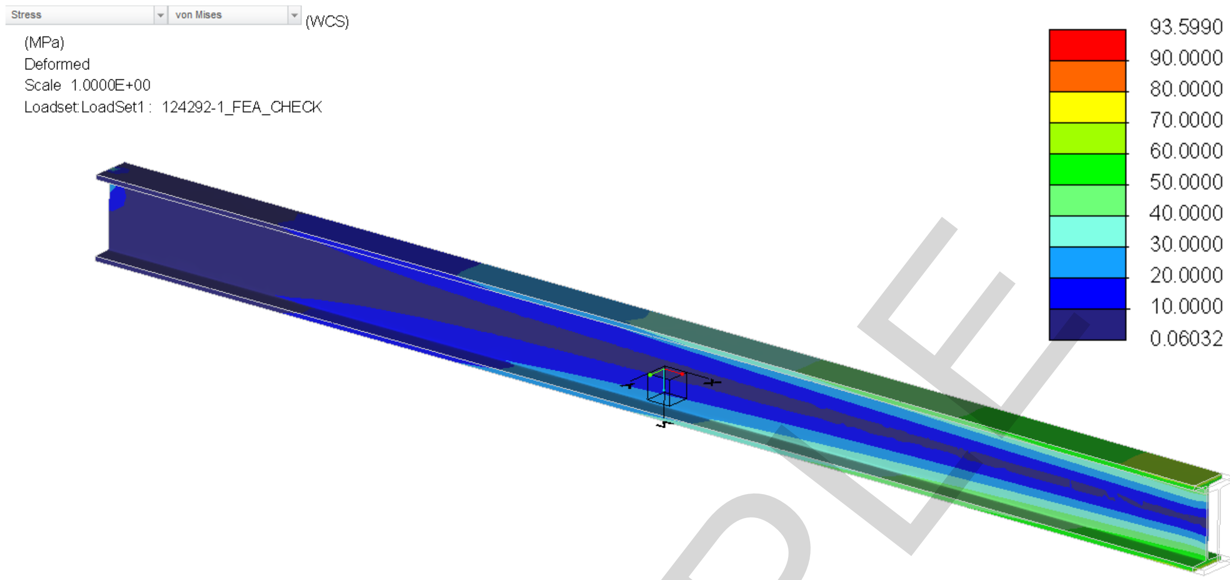
$$\sigma_{vm} = (6.356 \cdot 10^{7})\ Pa$$

Maximum deflection of the beam is calculated from the following equation;

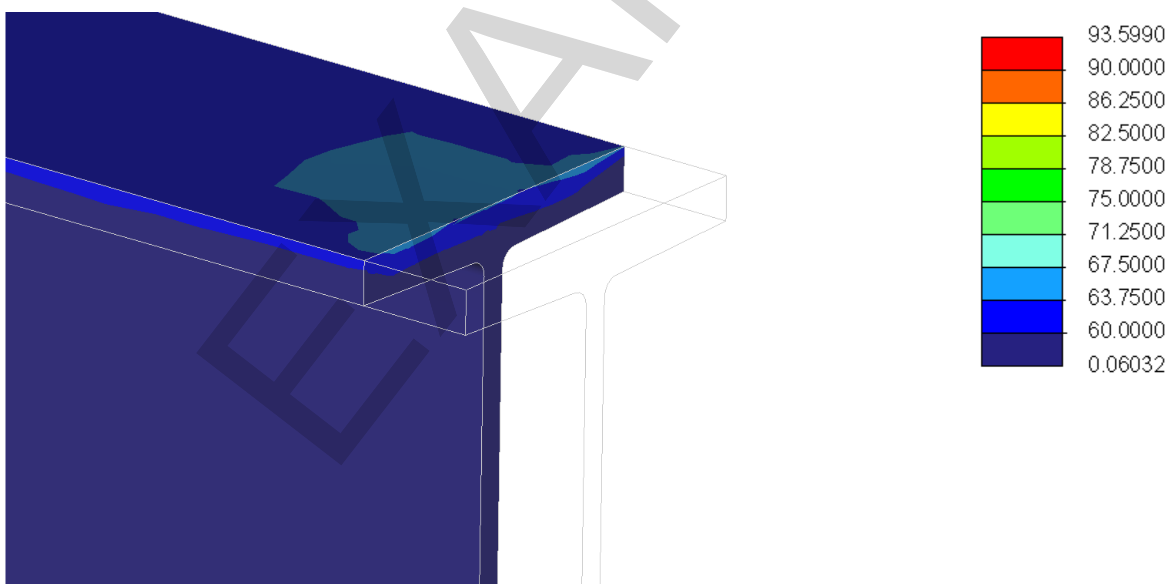
$$\delta := \frac{w}{6 \cdot E \cdot I_x} \cdot \left(2 \cdot l^3 - 3 \cdot l^2 \cdot a - a^3\right)$$

$$\delta = 0.012\ m$$

FEA Results:

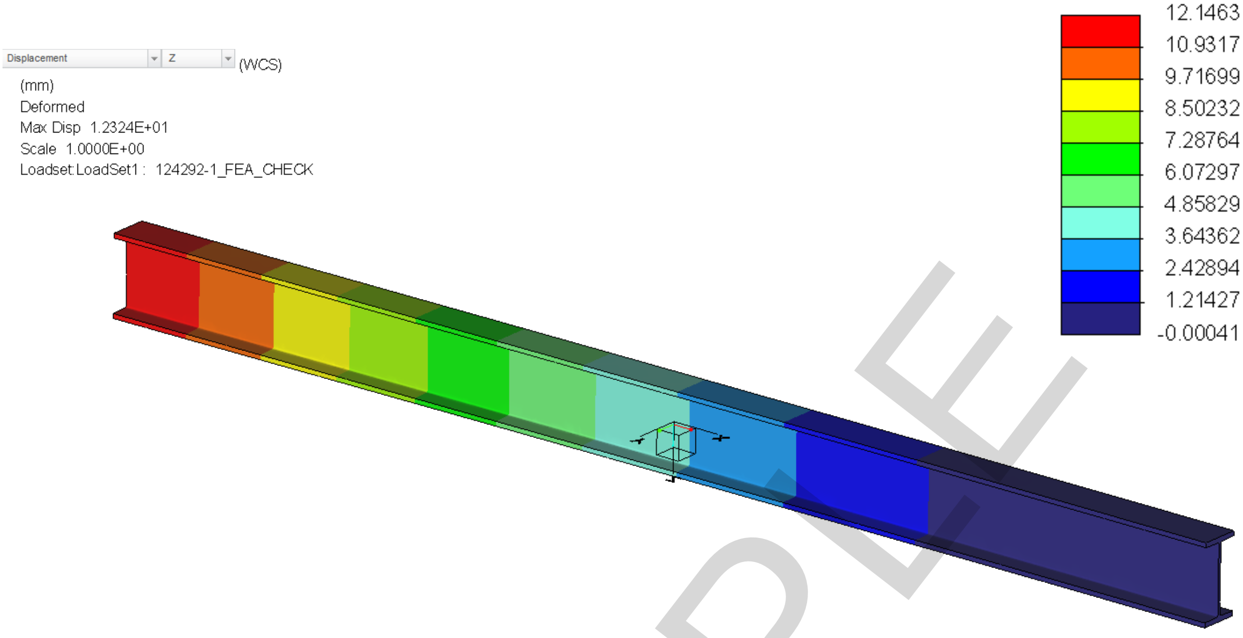


Zooming in and adjusting the scale, maximum von mises stress at the extreme outer fiber is approximately 64.0 MPa which agrees with the calculated stress within 1%.*



*As discussed in Section 7.1, the results of this analysis contain singularities due to the boundary conditions that constrain the model. The fringe plots above are adjusted to display stress results 10 mm from the fixed end of the beam to remove them. As the beam is 3.049 m long, the stress state that exists at this location is not appreciably different than at the extreme end.

Maximum deflection of the beam was calculated to be 12 mm which agrees with the FEA within 1%.



9. Conclusion

The results of the FEA and self-check calculations show that, as designed, the structural integrity of the pallet frame is maintained with a safety factor greater than 4 during lifting and handling operations when the applied load is maximum.