Applied Finite Element Analysis

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Units in FEA

Finite element software requires the use of a consistent set of units.

A good choice of units is usually based on an appropriate length scale for your problem—for example, use units of mm or inches for handheld objects. You may need m or feet for large objects.

Example Unit System: N-mm SI

length: mm
Force: N

stress = force/area = N/mm^2 = MPa

This means when stresses are displayed, the unit will be MPa.
The modulus of elasiticity will need to have units of MPa.

The choice of units has additional implications.

density in N-mm SI

Suppose we need to use the density of steel in our model.
density = 7.75 g/cm^3

****be very careful****

We need to derive the units of mass in our N-mm system.
F = m a (a = gravity when F = weight)

density in N-mm SI

$F = m\,a$

N = mass mm/s^2

mass = (N * s^2)/mm

N = kg m/s^2

mass in our system = kg m/s^2 *s^2/mm = kg m/mm = 1000 kg

1000 kg = tonne

for us, density needs to be in 1000 kg/mm^3 = tonne/mm^3

density in N-mm SI

7.75 g/cm^3

= 7.75 * 1 kg/1000 g * 1 cm^3/1000 mm^3

= 7.75 x 10^{-6} kg/mm^3 = 7.75 x 10^{-6} * 1 tonne/1000 kg

= 7.75 x 10^{-9} tonne/mm^3

density in in-lb system

Things get really tricky in Imperial Standard Units

density of steel = 490 lbs/ft^3

Two issues:

- lbs is not mass!
- we need in^3 and not ft^3

490 lbs/ft^3 = 490 lbs/ft^3* 1 ft^3 / 12^3 in^3 = 0.2836 lb/in^3

density in in-lb system

F = m a
a = gravity = 32.2 feet/s^2

1 cubic inch of steel should weigh 0.2836 lbs

0.2863 lbs = mass 32.2 ft/s^2 = mass * 32.2 * 12 in/ft ft/s^2

mass = 0.2863/(32.2*12) lbs s^2/in = 741 x 10 $^{-6}$ snails

(1 slug = lbs s^2/ft)
(1 snail = lb s^2/in)

density in in-lb system

Finally, since we were considering 1 cubic inch of steel, the density value we need to use is:

7.41×10^{-4} snails /in^3

or

7.41×10^{-4} lbs s^2/in /in^3

Other Units

You only need to input the types of materials properties that are used for the analysis.

Be extremely careful in heat transfer with energy units, heat flux units, etc.

Fortunately, someone has made a “cheat sheet” for us: (refer to Endurasim website).

Recommendation

Most journals will expect SI units.

Most objects can be modeled appropriately with a mm length scale.

Therefore, I recommend using the N-mm system all the time, unless there is a good reason to not use N-mm.

In any event, always be careful.

Single or Double Precision?

Along with your choice of unit system if your choice of machine representation of your numbers.

IEEE-Std 754: IEEE Standard for Floating Point Arithmetic defines the bit resolution of floating point number for computers.

The single precision IEEE FPS format is composed of 32 bits, divided into a 23 bit mantissa, M, an 8 bit exponent, E, and a sign bit, S.

16, 32 or 64 bit representations may depend on the computer you use.

$$7.75 \times 10^{-9} \frac{\text{tonne}}{\text{mm}^3} * \underset{(\text{mm}^3)}{\text{Volume}} = \underset{(\text{tonne})}{\text{Mass}}$$

$$\underset{(\text{tonne})}{\text{Mass}} * \underset{\left(9.81 \frac{\text{m}}{\text{s}^2} \frac{1000\,\text{mm}}{\text{m}}\right)}{g} \Rightarrow \underset{N}{\text{FORCE}}$$

N

mm

Stress $\frac{N}{mm^2}$ = MPa

Material Properties need to be consistent with this choice.

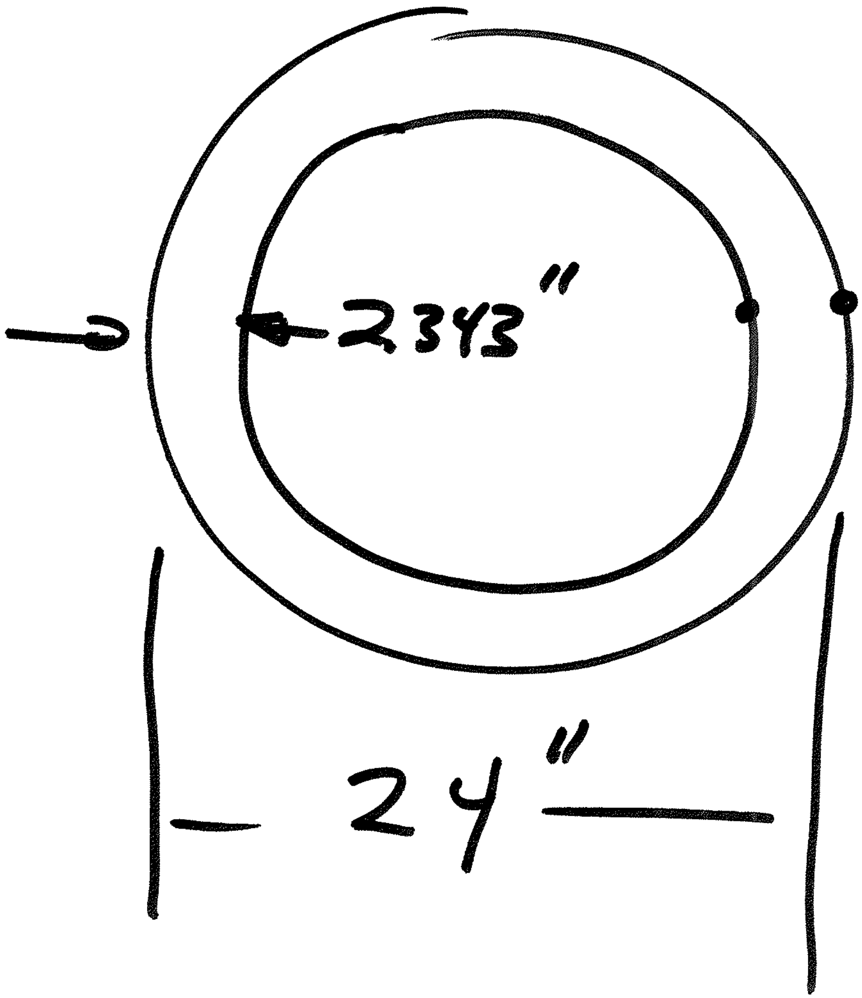
E_{steel} = 210 GPa

= 210,000 MPa

210 000.0 — Input into code

$\nu = 0.3$ no units, just use this number

1 in = 25.4 mm



2.343 X 25.4

24 x 25.4 =

$R_o = 304.8$

$R_i =$