Modeling the torsional dynamics of reciprocating machines: "Pitfalls and Challenges"

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Dynamics of Rotating Machines

ÅF-Sound & Vibrations

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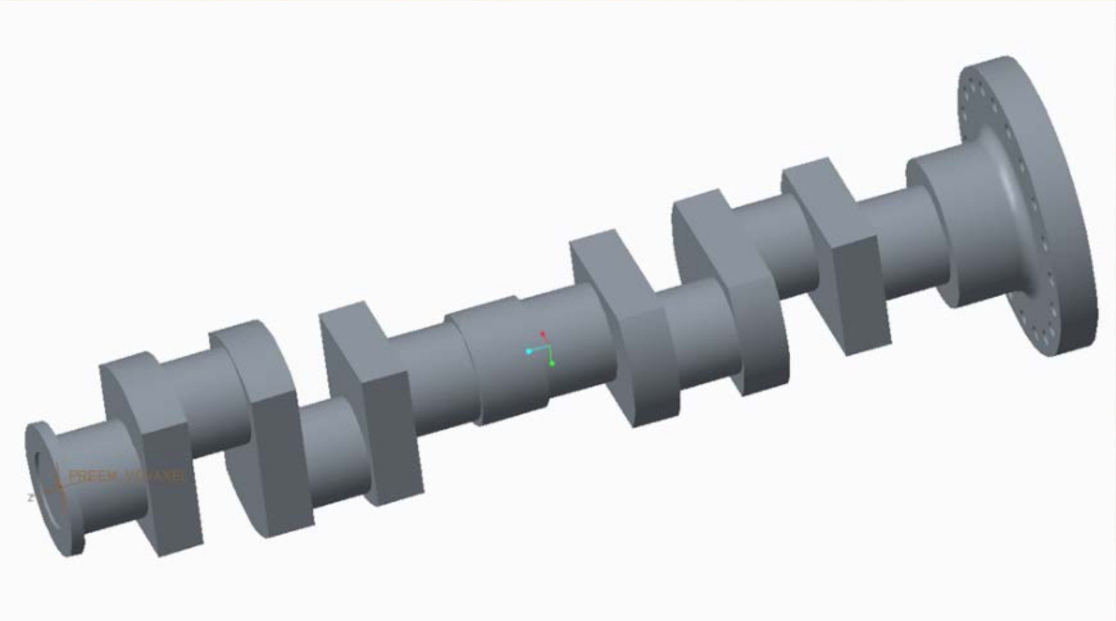
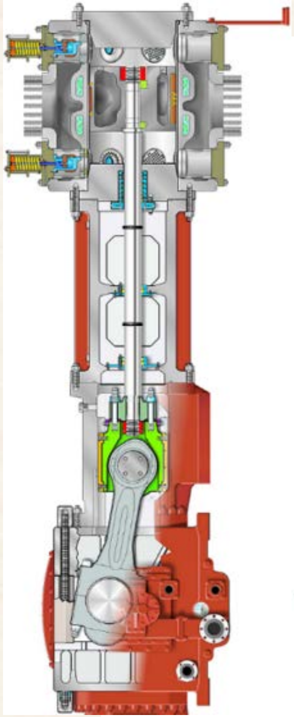
Citycampus - plats för möten

CRANK SHAFTS



TORSIONAL ANALYSIS: <u>Modeling</u>



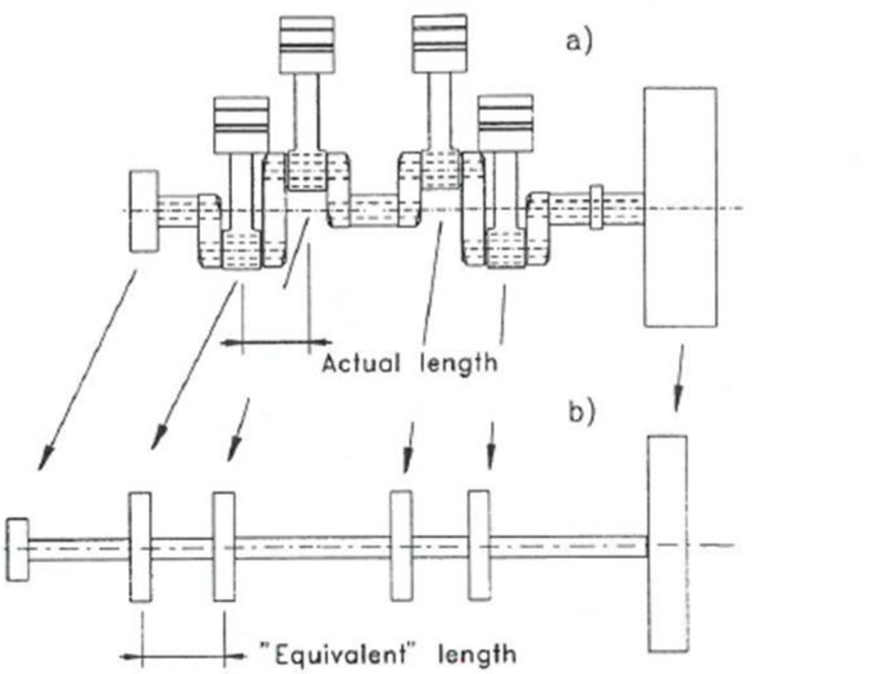


FIGURE 5.1. Sketch of the crankshaft: (a) actual system; (b) equivalent system, lumped-parameters model.

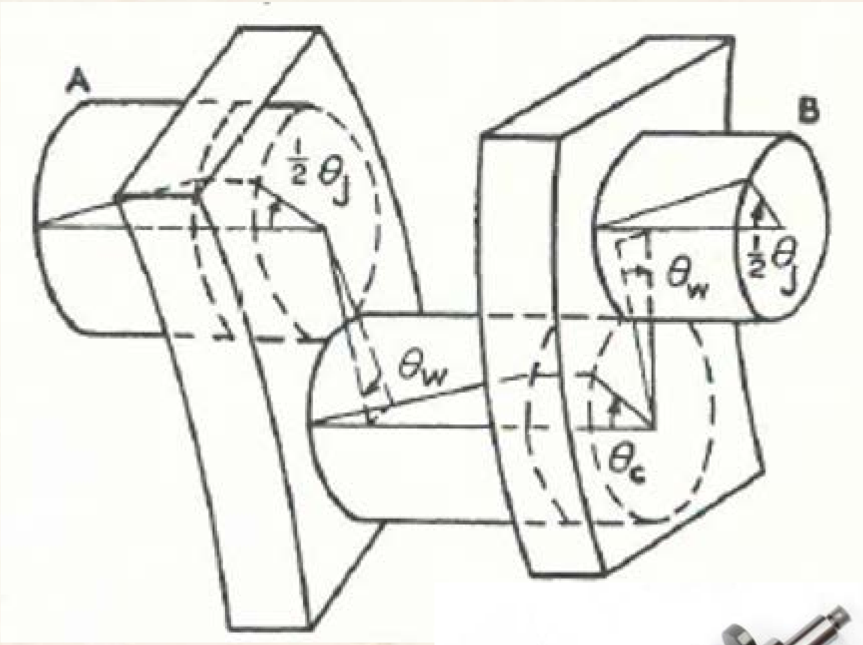
Lumped-parameters model:

Moment of inertia per cylinder line includes contributions from reciprocating and rotating parts at the corresponding cylinder position.

<u>Rotating parts</u>: Crank pin, crank web, balance weight, connecting rod (lower part)

<u>Recip parts:</u> Piston, connecting rod (higher part)

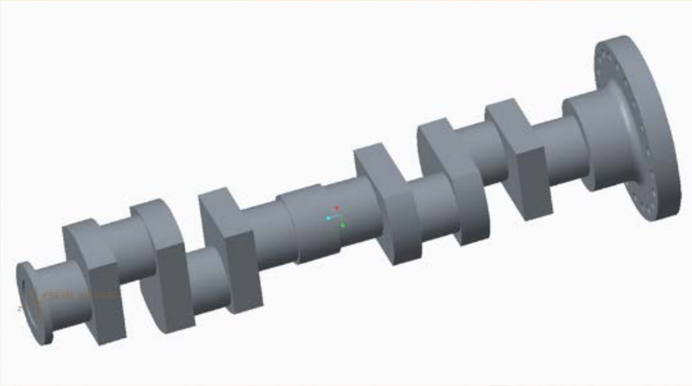
Handbooks provide expressions to evaluate these concentrated moments of inertia for well-defined crankshaft geometries

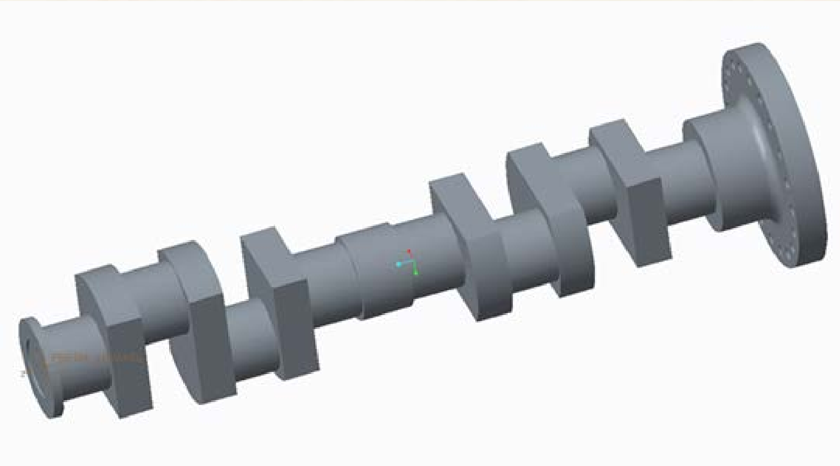


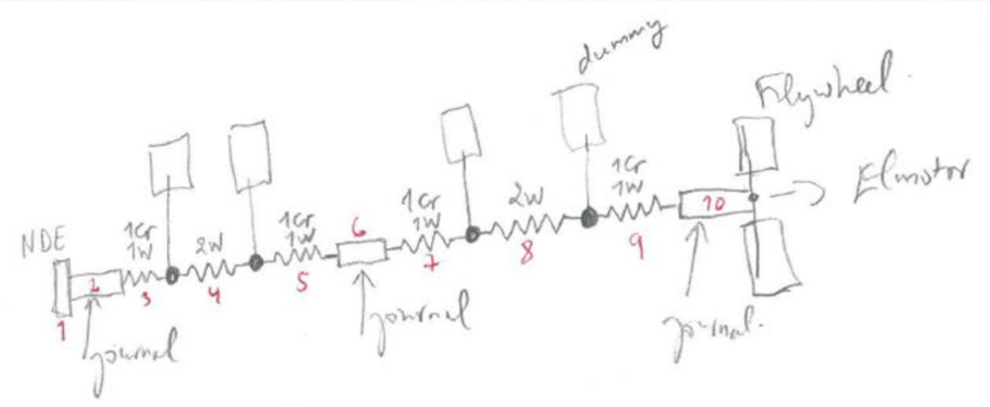
Crankthrow equivalent stiffness (Ke):

Observe that the crankpin is twisted while the crankweb is bended (*Analytical method*)

$$\frac{1}{K_e} = \frac{L_e}{G_e I_e} = \frac{L_j}{G I_j} + \frac{L_c}{G I_c} + \frac{2}{K_w}.$$



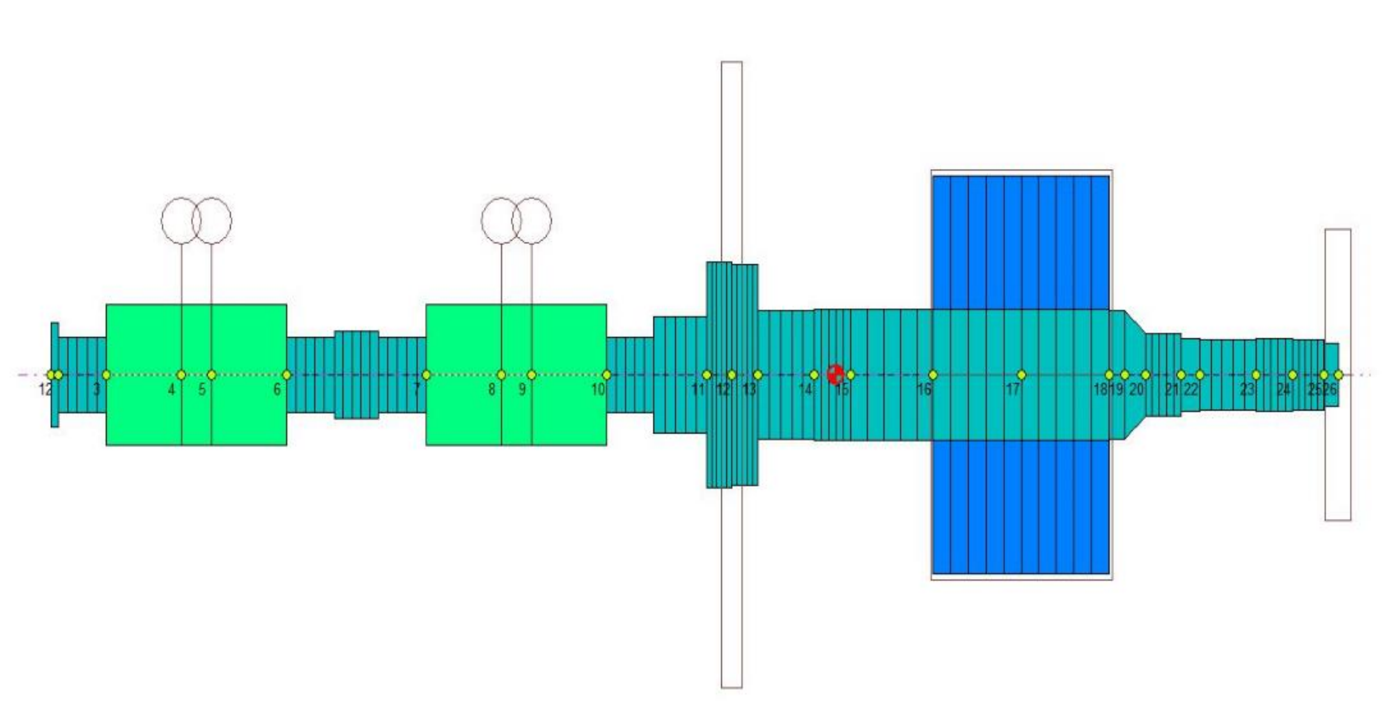




Inclusion of journal inertia and stiffness (FE modeling)

Hybrid model: Lumped and descretized system

“Case Example modelled in DyRoBeS”



1·25 Stiffness of driven machines

This section provides information and methods for assessing the point of rigidity, equivalent length and stiffness of driven-machine shafts.

Numerical values of stiffness of various types of Heenan & Froude dynamometer shafts are given together with the corresponding values for moments of inertia in section 1·15 (pp. 33 and 34).

1·251 *Point of rigidity of armatures and other driven machines*

As previously stated on p. 52, the 'point of rigidity' of a shaft is defined as the point at which the moment of inertia of a distributed mass (such as that of an armature core) is concentrated.

Although the stiffening effect of a mass on the shaft upon which it is mounted is gradual along most of the shaft length, for simplicity of calculation it is assumed (*a*) that no stiffening effect is felt by the shaft supporting the mass up to a certain point on the shaft axis, viz. the point of rigidity, and (*b*) that the shaft ends at this point (and becomes 'infinitely rigid' beyond it).

The following information in regard to points of rigidity of shaft portions supporting an armature core is based on vibration tests of pairs of identical generators coupled back-to-back, which were carried out by B.I.C.E.R.A.

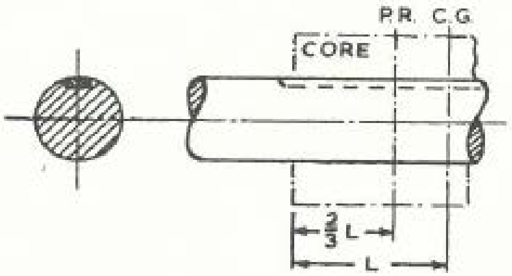


Fig. 1.

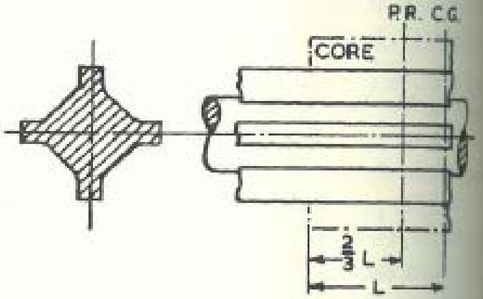


Fig. 2.

Plain keyed shafts (Fig. 1)

Point of rigidity is situated at two-thirds of the distance from the beginning of the armature core to the centre of gravity of the armature (including commutator).

Shafts with solid cruciform cross-section (Fig. 2)

Point of rigidity at two-thirds of the distance from the beginning of the armature core to the centre of gravity of the cross-section (including commutator).

Shaft with press fit or shrunk fit spiders (Fig. 3)

Point of rigidity at one-third of the distance from the beginning of the armature core to the centre of gravity of the armature (including commutator).

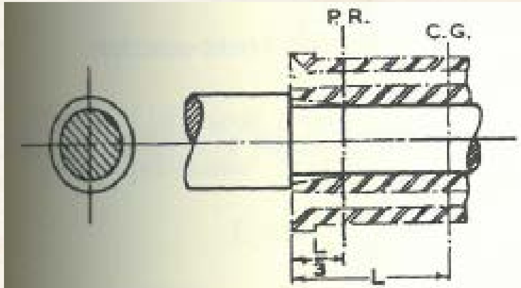


Fig. 3.

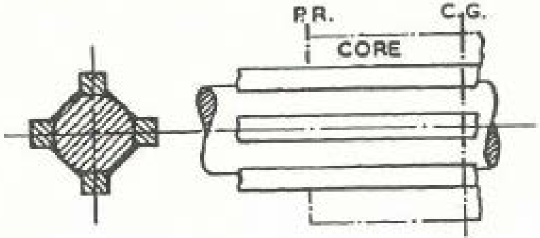
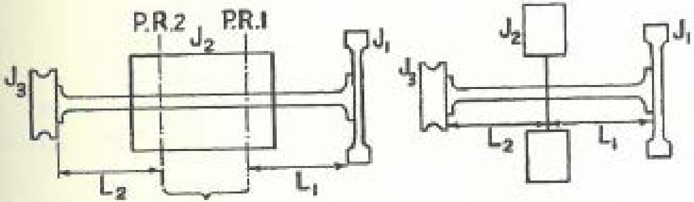


Fig. 4.



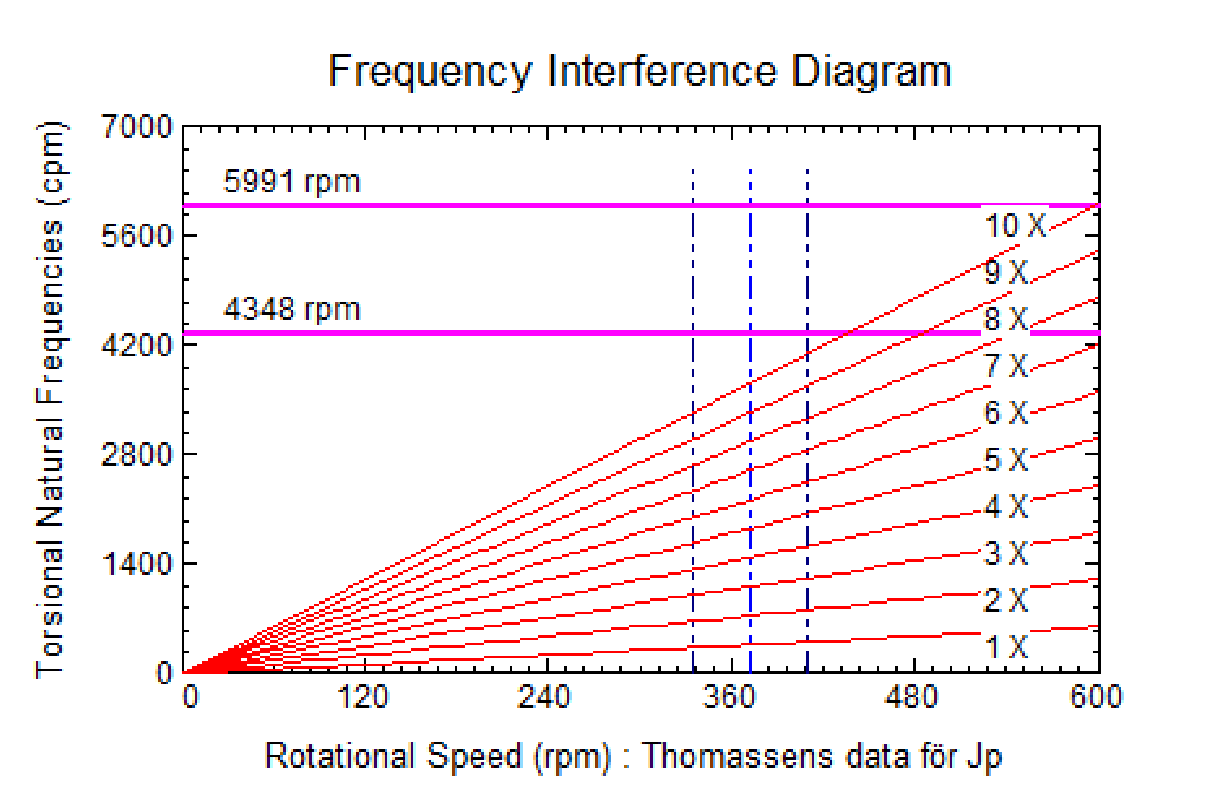
(*a*) Original system. (*b*) Equivalent system.

Fig. 5.

Typical reported Data for torsion analysis

Description	mass no.	Inertia I kgm^2	Stiffness K MNm/rad
CRANK1	1	97.00	210.56
CRANK2	2	81.15	83.62
CRANK3	3	101.40	210.41
CRANK4	4	79.00	194.44
FLYWHEEL	5	2414.15	491.59
LAMINATIONS	6	2643.60	1150.80
LAMINATIONS	7	2495.69	40.99
EXT. FAN	8	61.42	-

CASE1: GIVEN ”JP 4 CYLINDERS”



Reported results

Node	System natural torsional frequency	Margins from			
		Operating speed		Power frequency	
	Cycles/ min.	1 times	margins/multiple	1 times	2 times
1	4043 68	-	8.7% / 10	34.8%	-32.6%
2	5304 88	-	42.6% / 10	76.8%	-11.6%
3	7812 130	-	-	-	30.2%
4	>15000	-	-	-	-

Note: Large margins (>100%) are not presented in this table and are indicated with -.

Operating speed driver: 372 RPM

Operating speed compressor: 372 RPM

Electrical power frequency: 50 Hz (3000 CPM)

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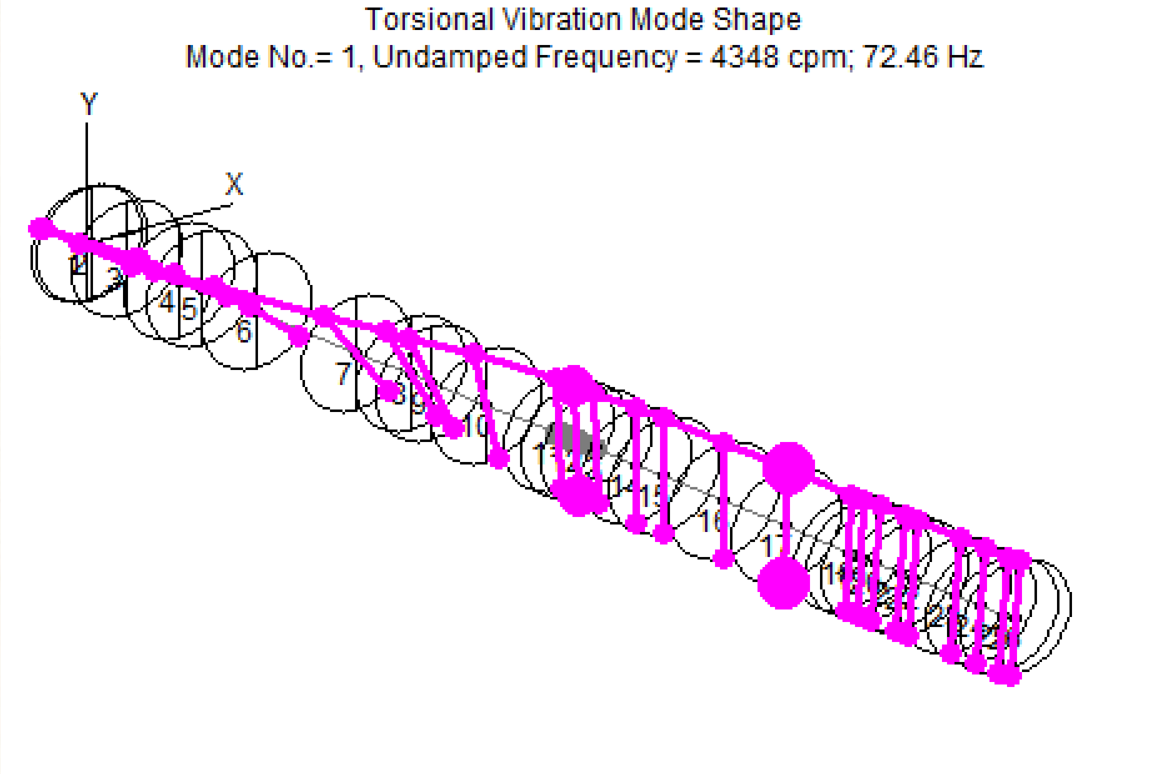

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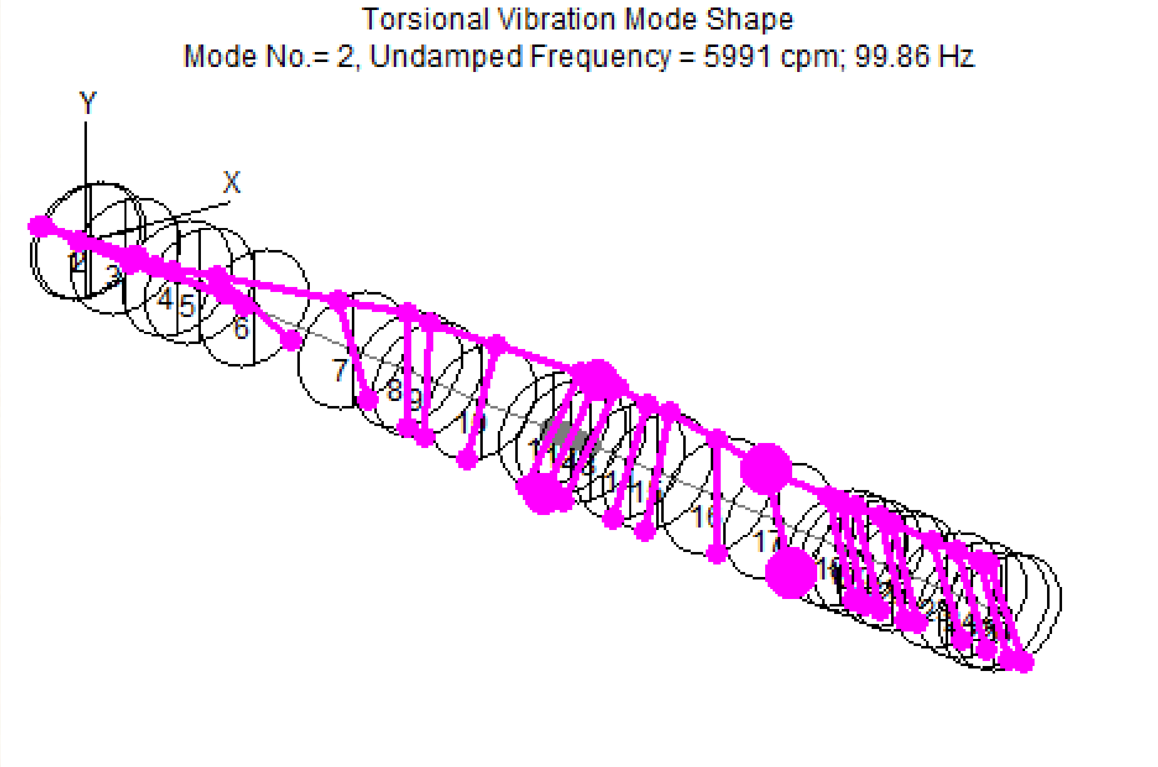

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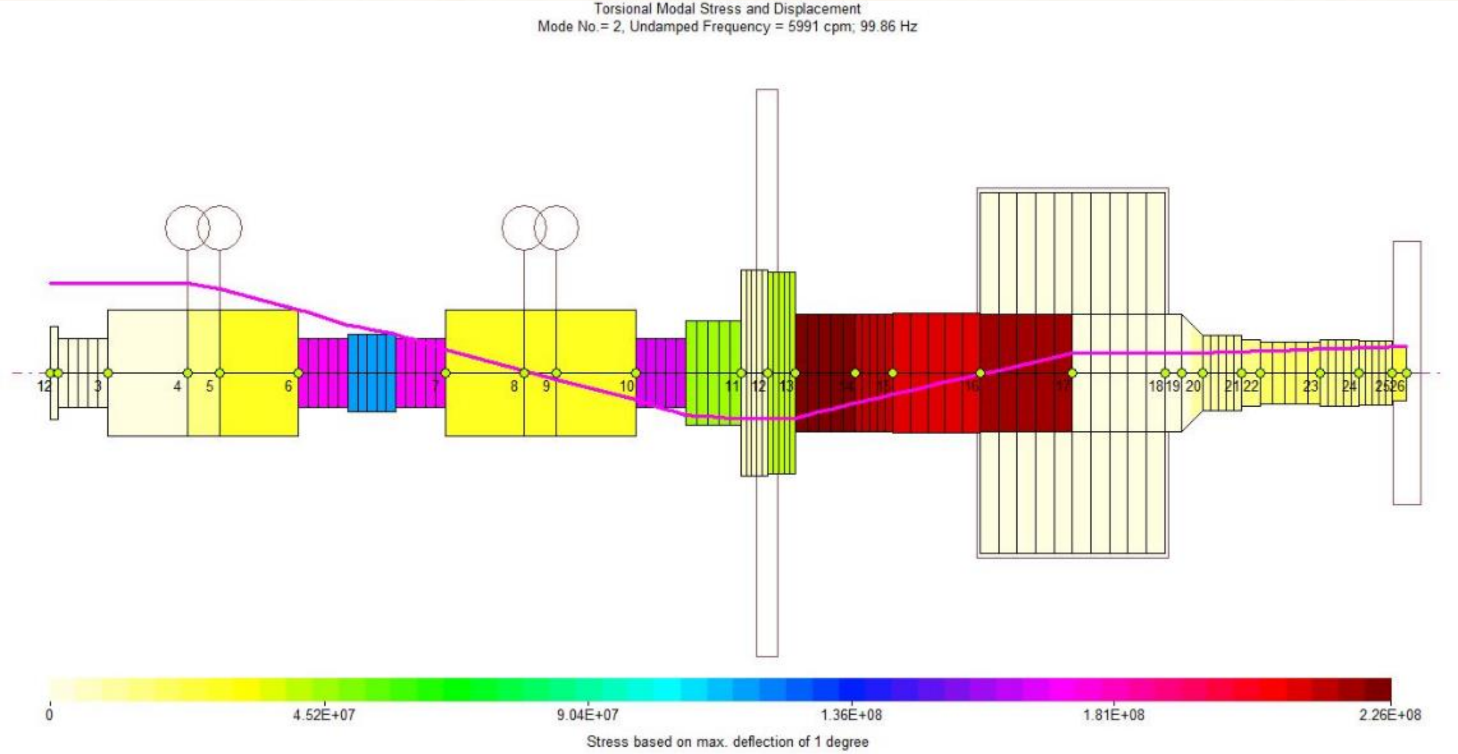
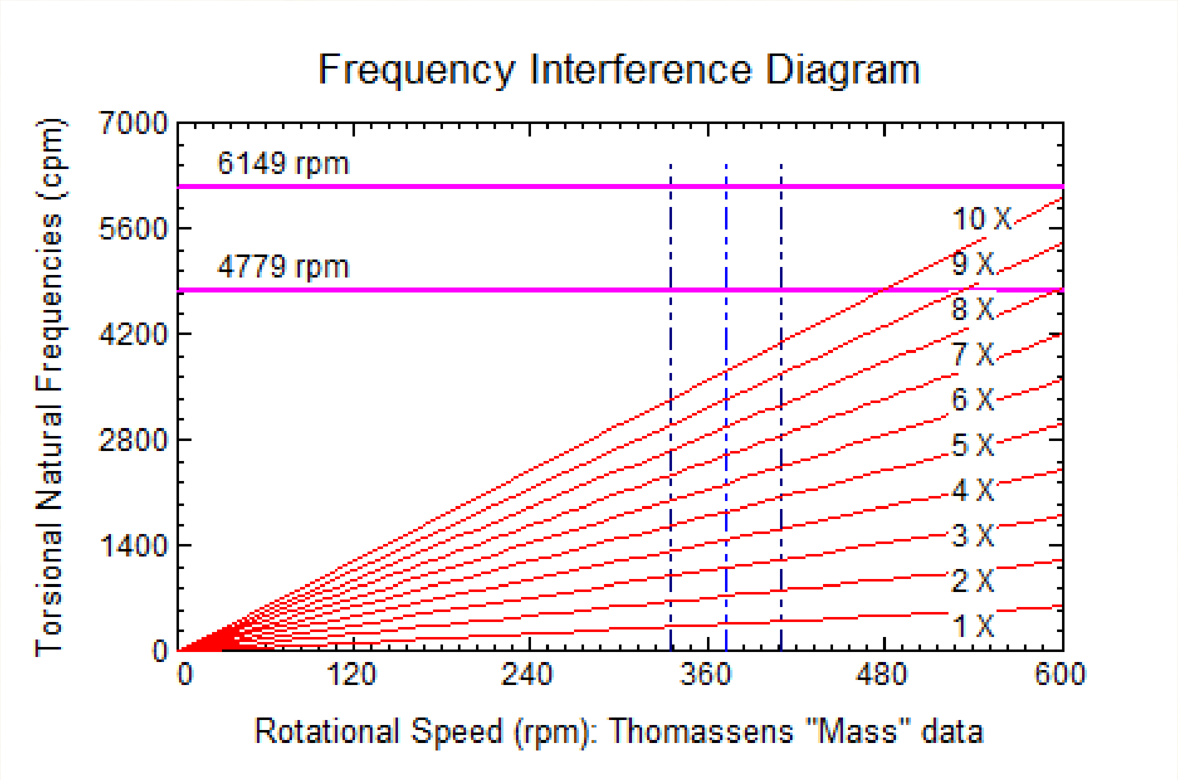


CASE2: GIVEN ”RECIP MASS”



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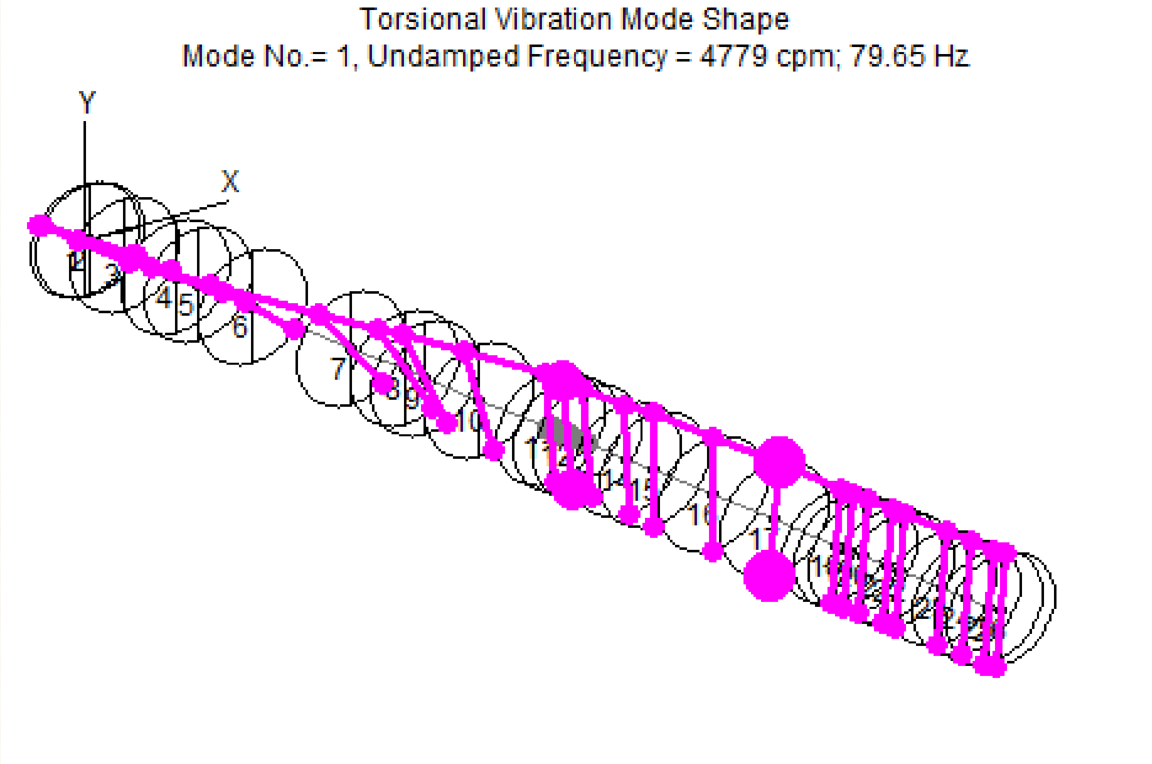

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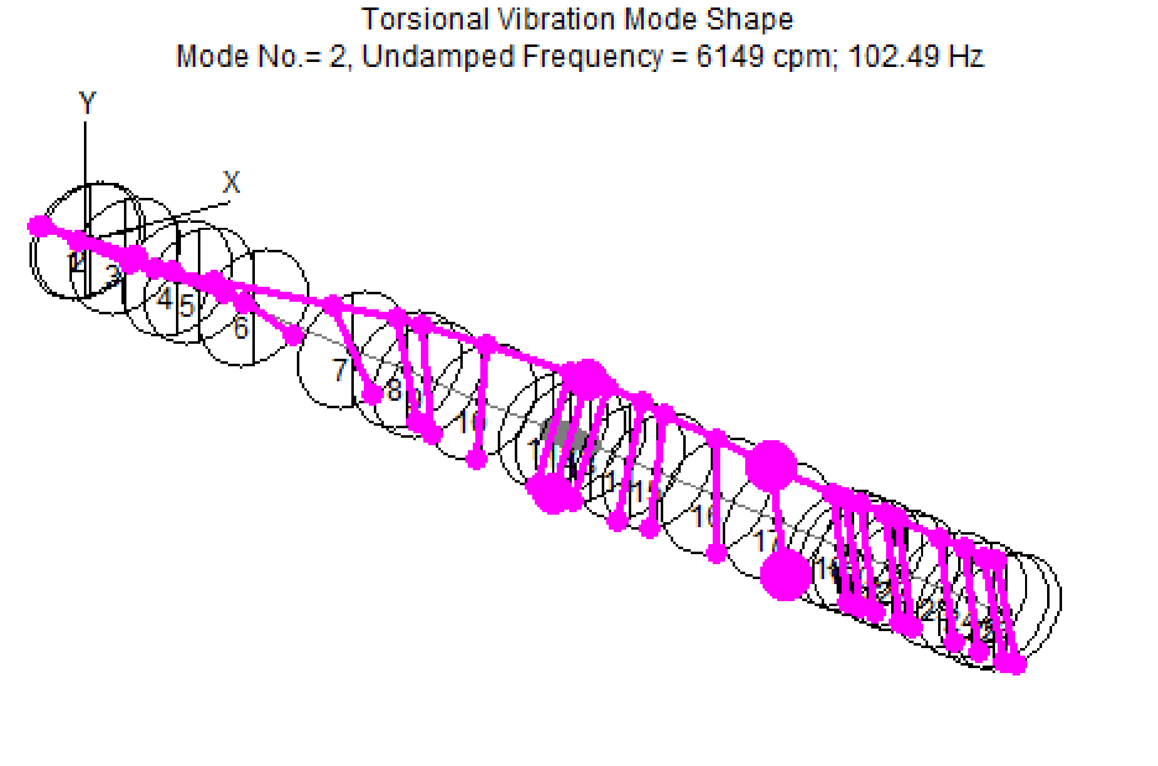

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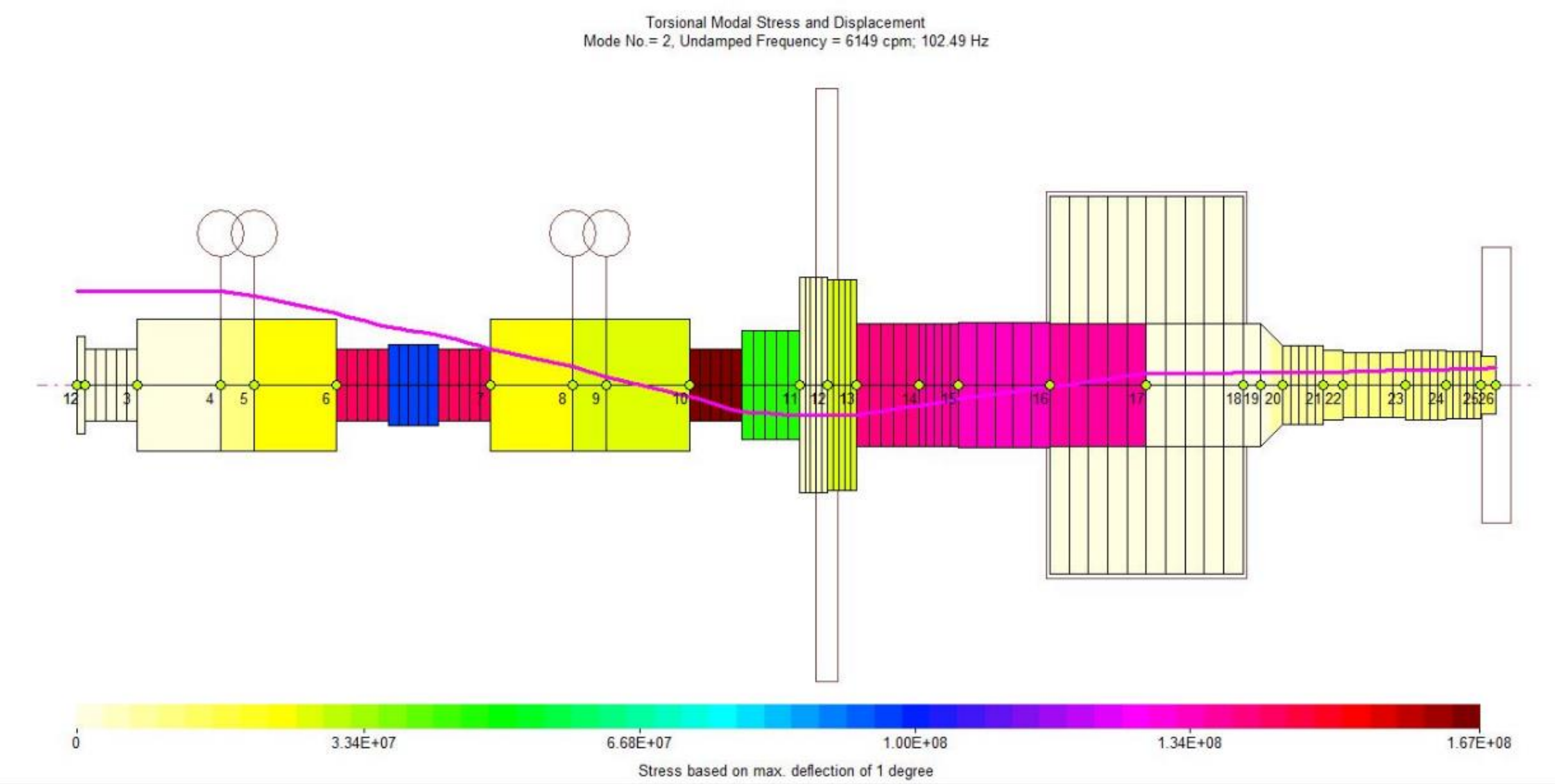
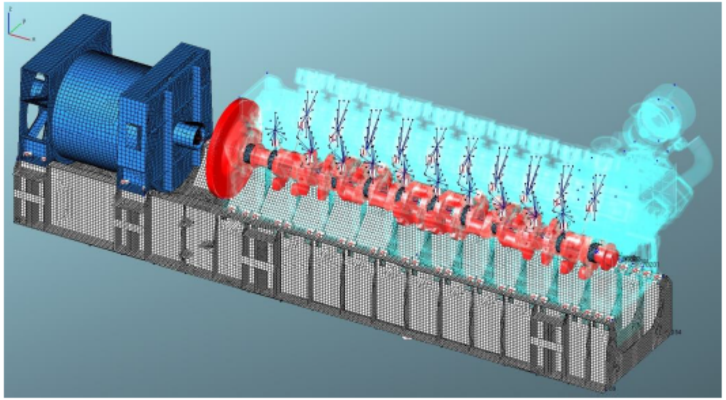
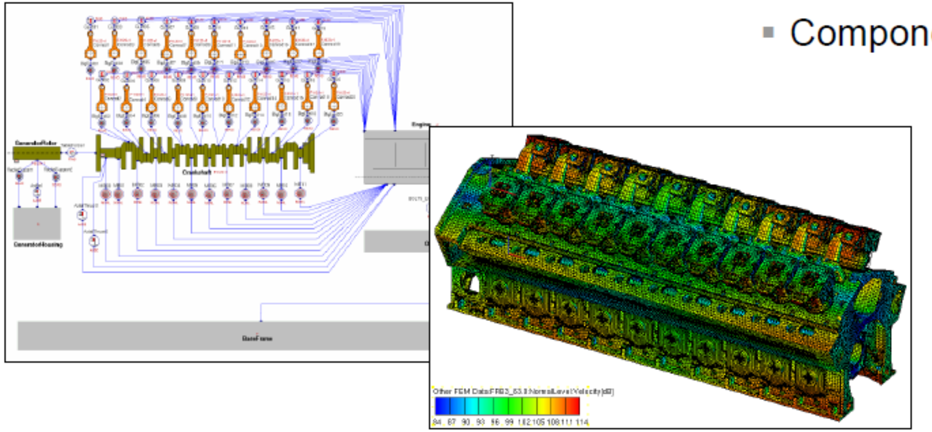


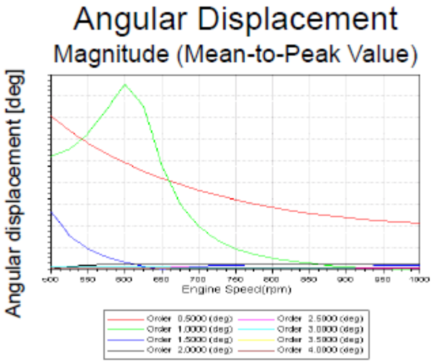
HB has started partnership with AVL (Excite & Fire)



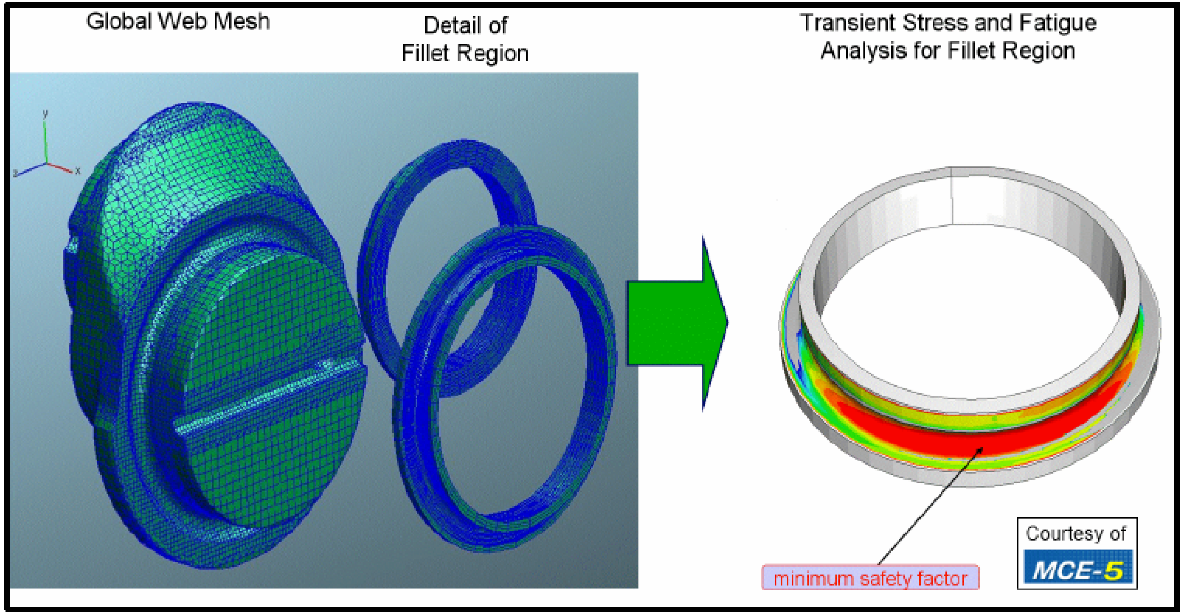
Analysis Targets:

- Shaft Vibrations
- Base frame vibrations
- Acoustics
  - structure borne noise
  - air borne noise
- Component strength





AVL excite + Ansys/Abaqus: Stress analysis



Fillet Modeler – automated mesh generation
for crankshaft durability analysis