Bearings Misalignment Influence on Vibration Level

Introduction:

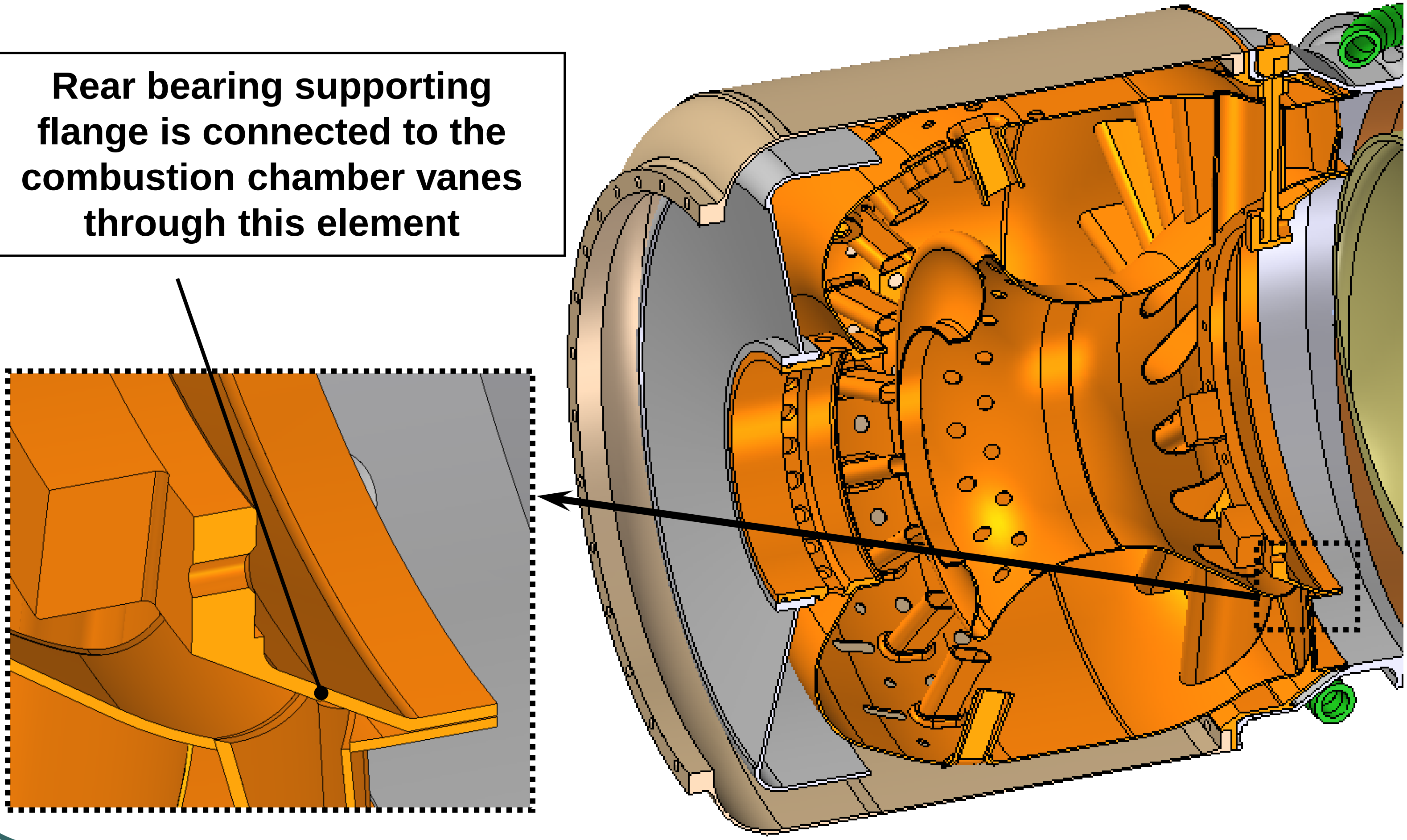
- Testing of engines showed that after a few hours of operation, the vibration level rose above the acceptance limit (V_{max} = 1.6 in/sec).
- Further investigation revealed that the vibration level growth was rather connected to the number of start-operation-shutdown cycles.

Introduction:

- It was then concluded that irreversible thermal stress deformation, in the plastic domain caused by the start-operation-shutdown cycle was the cause of the vibration problem.

Cross-section of the combustion chamber

Rear bearing supporting flange is connected to the combustion chamber vanes through this element



Introduction:

- **The rear bearing is attached to the engine combustor inner rear flange. The combustor was thus identified as the prime suspect.**
- **Inspection of the concentricity between the two main bearings of dismantled engines which experienced vibration level growth showed that indeed in all of them the T.I.R. exceeded 0.12 mm (or the eccentricity exceeded 0.06 mm).**

Introduction:

- This condition was found to be the result of a combustor deformation which affected the concentricity of its inner flange to the engine mainframe.
- The combustor installation design provides a clearance enabling unconstrained thermal expansion in the axial direction.

Introduction:

- A calculation of the expected combustor thermal expansion showed that perhaps the provided clearance is not sufficient.
- The clearance was increased on all dismantled engines and experience showed that after this change in design the vibration level growth phenomenon disappeared.
- An analytical study of the bearings misalignment influence upon vibration level was undertaken to further confirm the problem solving method.

In design, operation and troubleshooting of turbojet engines, rotordynamics analysis can help reaching the following objectives:

- **Predict Critical Speeds.** **In order to prevent resonance problems at design stage.**
- **Predict Amplitudes of Synchronous Vibration Caused by Rotor Imbalance.** **It is necessary to assess engine vibration level in engine operation as well as to find the best distribution of imbalance along the rotor so as to minimize reaction forces at the bearing supports. Recommendations about correct elements angular position during assembly process will be presented.**
- **Assess effect of bearing misalignment on engine vibration level. It is necessary to evaluate maximum admissible misalignment for normal engine operation i.e. without excessive vibrations.**

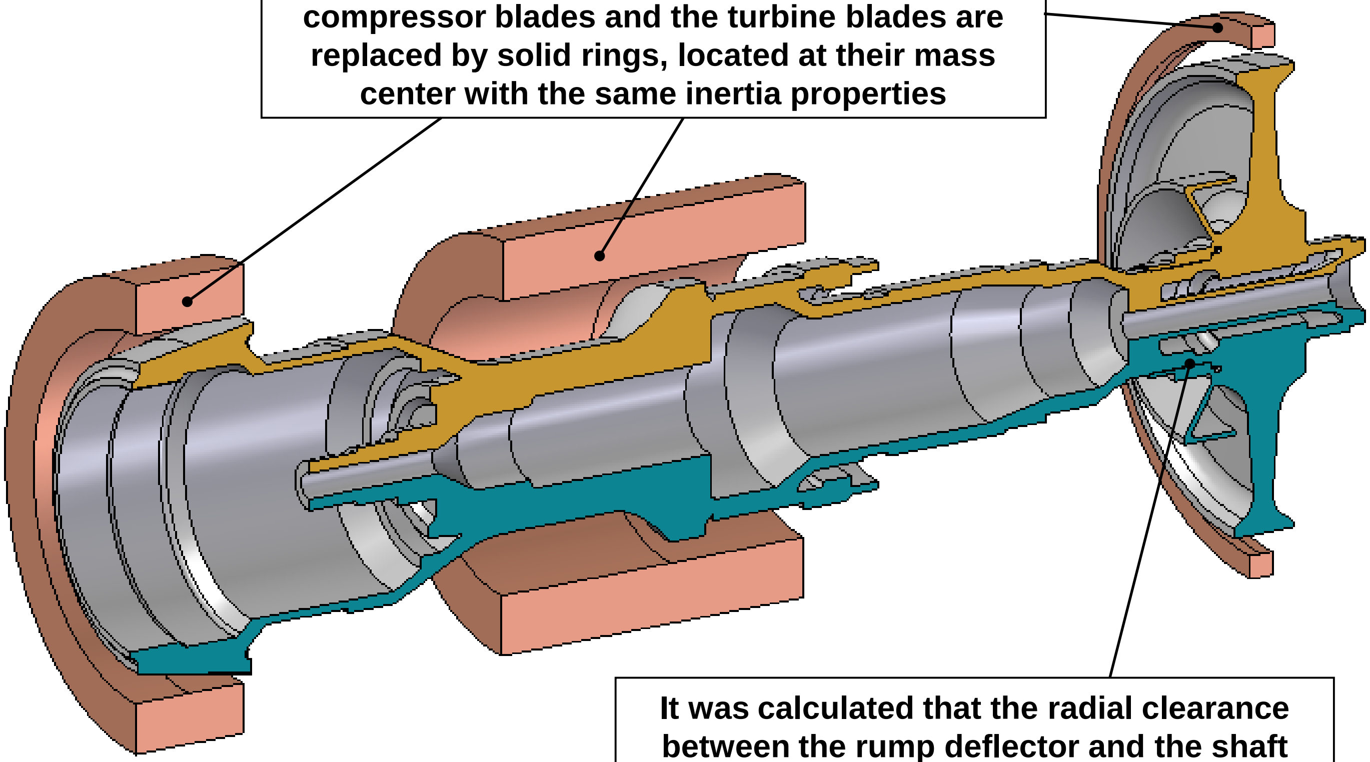
Rotordynamics Analysis

Prediction of rotordynamic response with high accuracy degree depends on the following aspects:

- **Correct and accurate modeling of the detailed rotating assembly structure**
- **Taking into account gyroscopic effect**
- **Taking into account nonlinear effects (stress stiffening & spin softening)**
- **Chosen method of rotordynamic analysis**
- **Numerical results accuracy**

The Rotor Model

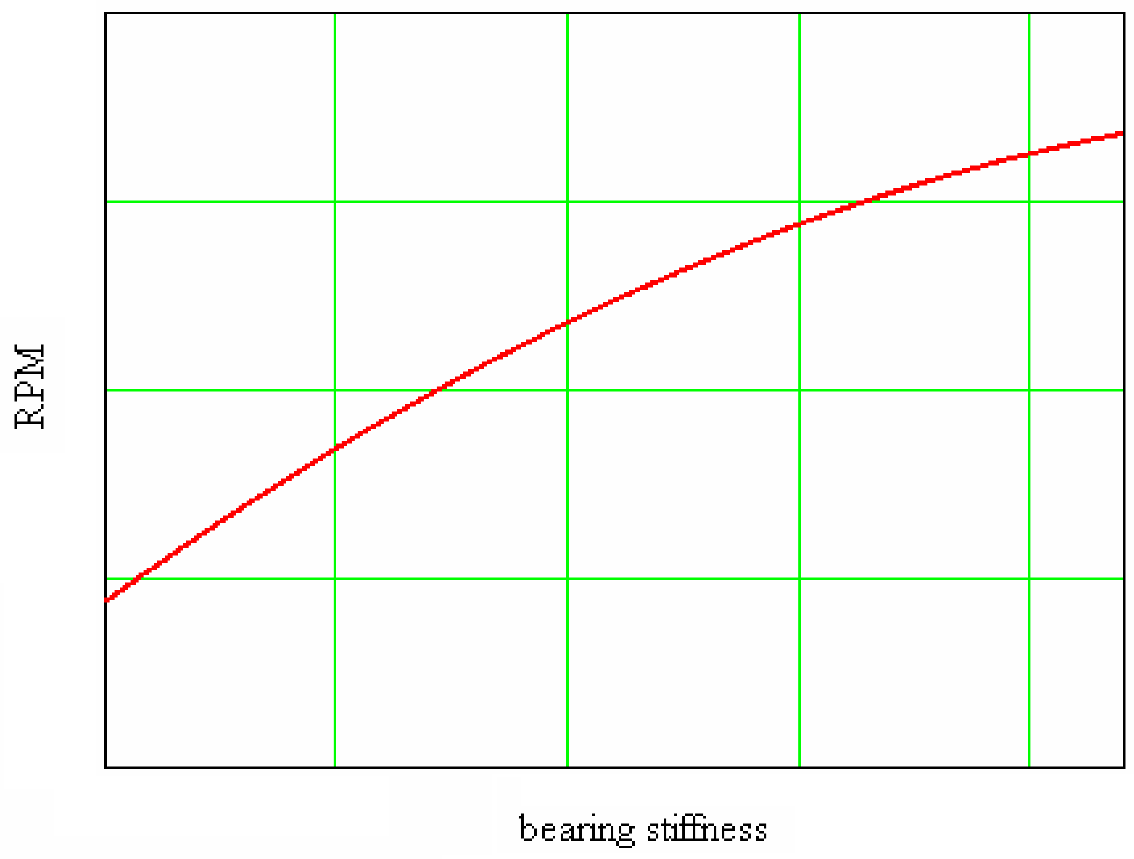
The axial compressor blades, the centrifugal compressor disc portion, the centrifugal compressor blades and the turbine blades are replaced by solid rings, located at their mass center with the same inertia properties



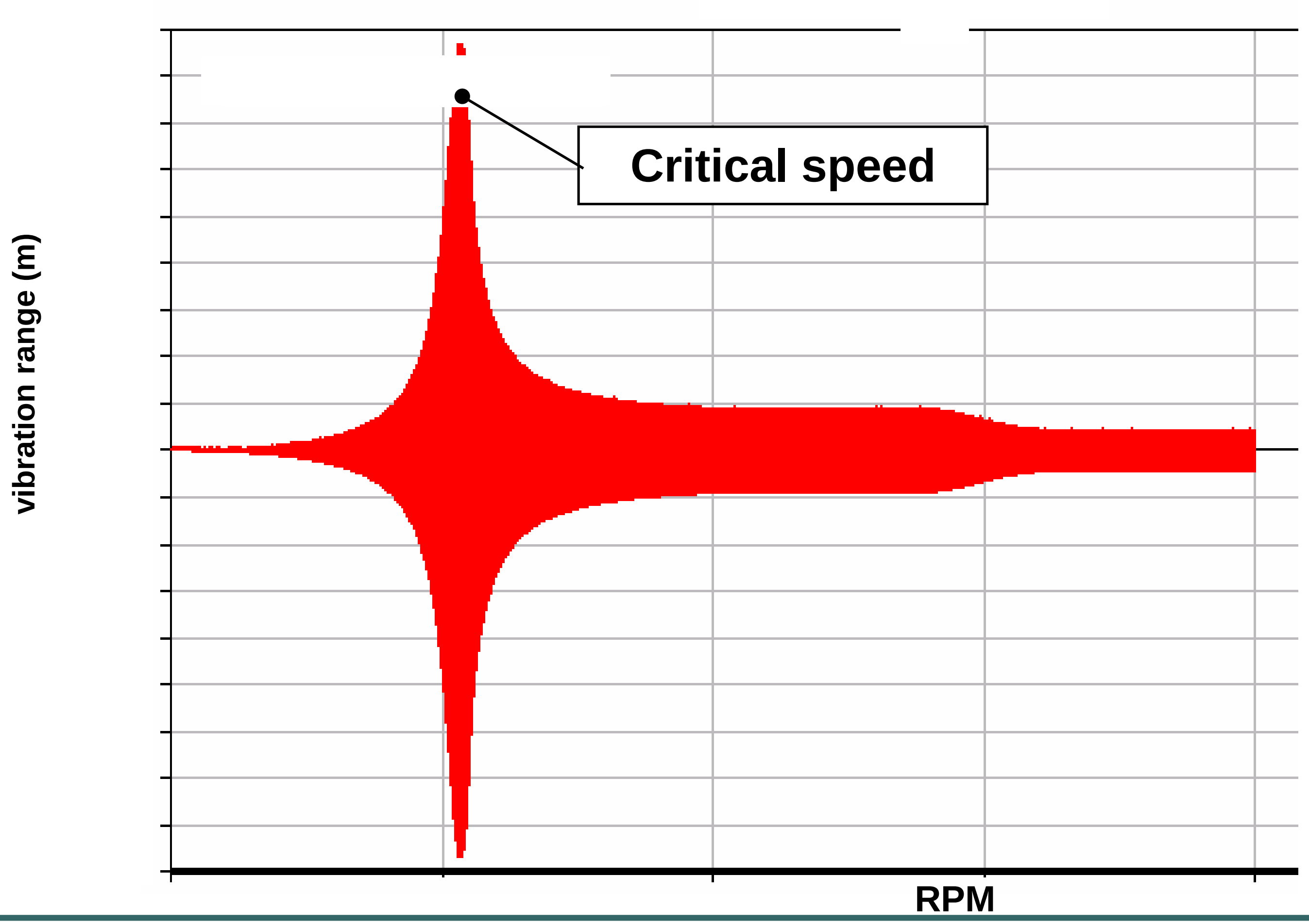
It was calculated that the radial clearance between the rump deflector and the shaft was more than 0.01 mm. This cylindrical fit was non assumed as integral connection.

Graph 1

1st critical speed dependence on front bearing stiffness.

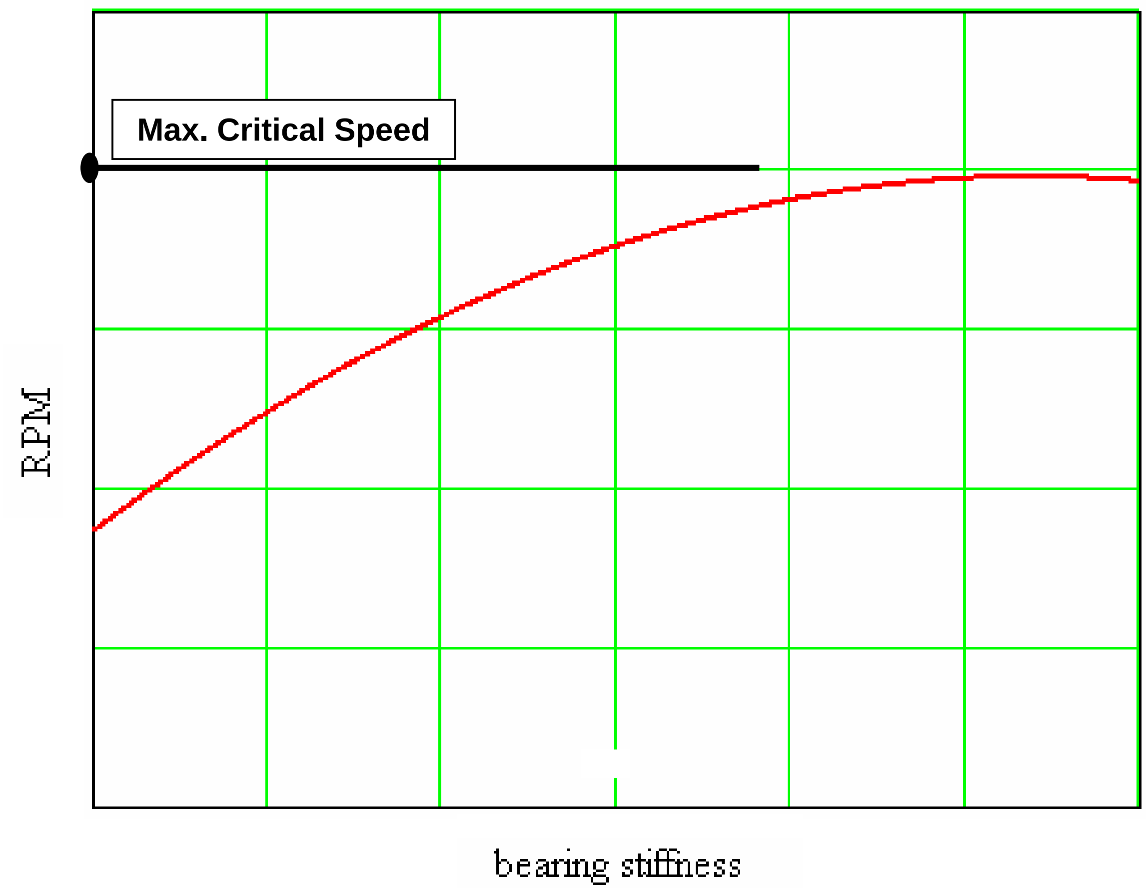


The time-transient results which show lateral vibration amplitude versus time during constant rotor acceleration taken at the front bearings center

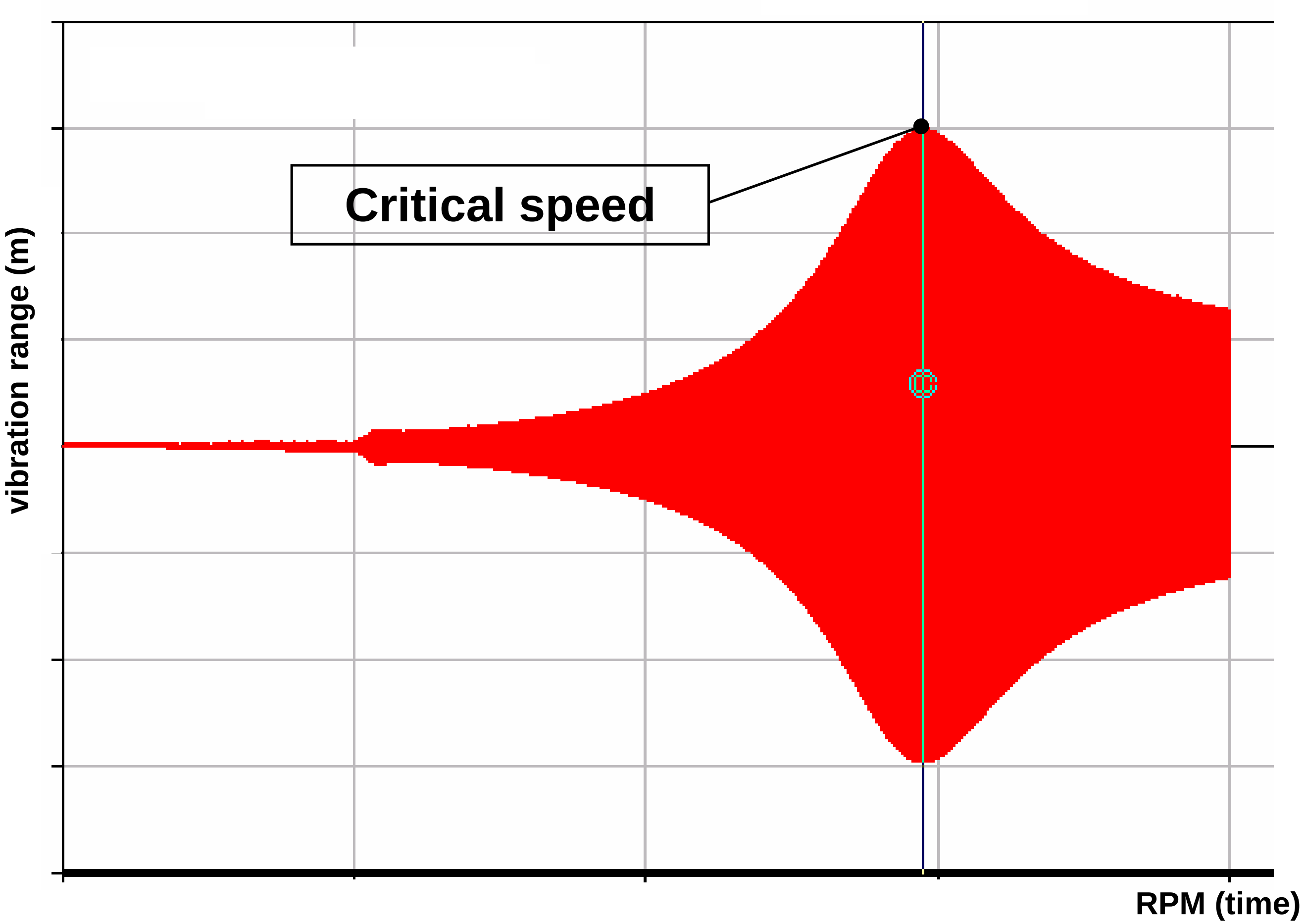


Graph 2

1st critical speed dependence on front bearing stiffness.



The time-transient results which show lateral vibration amplitude versus time during constant rotor acceleration taken at the rear bearings center



Bearings Misalignment Response Analysis

The goals of the study were:

- **To confirm analytically that increased vibrations take place when misalignment exceeds a specific value.**
- **To obtain this threshold value of misalignment.**

Bearings Misalignment Response Analysis

The dynamic response due to rotor misalignment was simulated in the following order:

- **A rotor start was simulated until the rotating assembly reached steady-state operation at given speed when no misalignment was present.**
- **The misalignment level was gradually increased from 0 to 0.5 mm during steady-state engine operation at constant RPM.**
- **The resulting rear bearing reaction force as a function of time was recorded and results presented.**

Bearings Misalignment Response Analysis

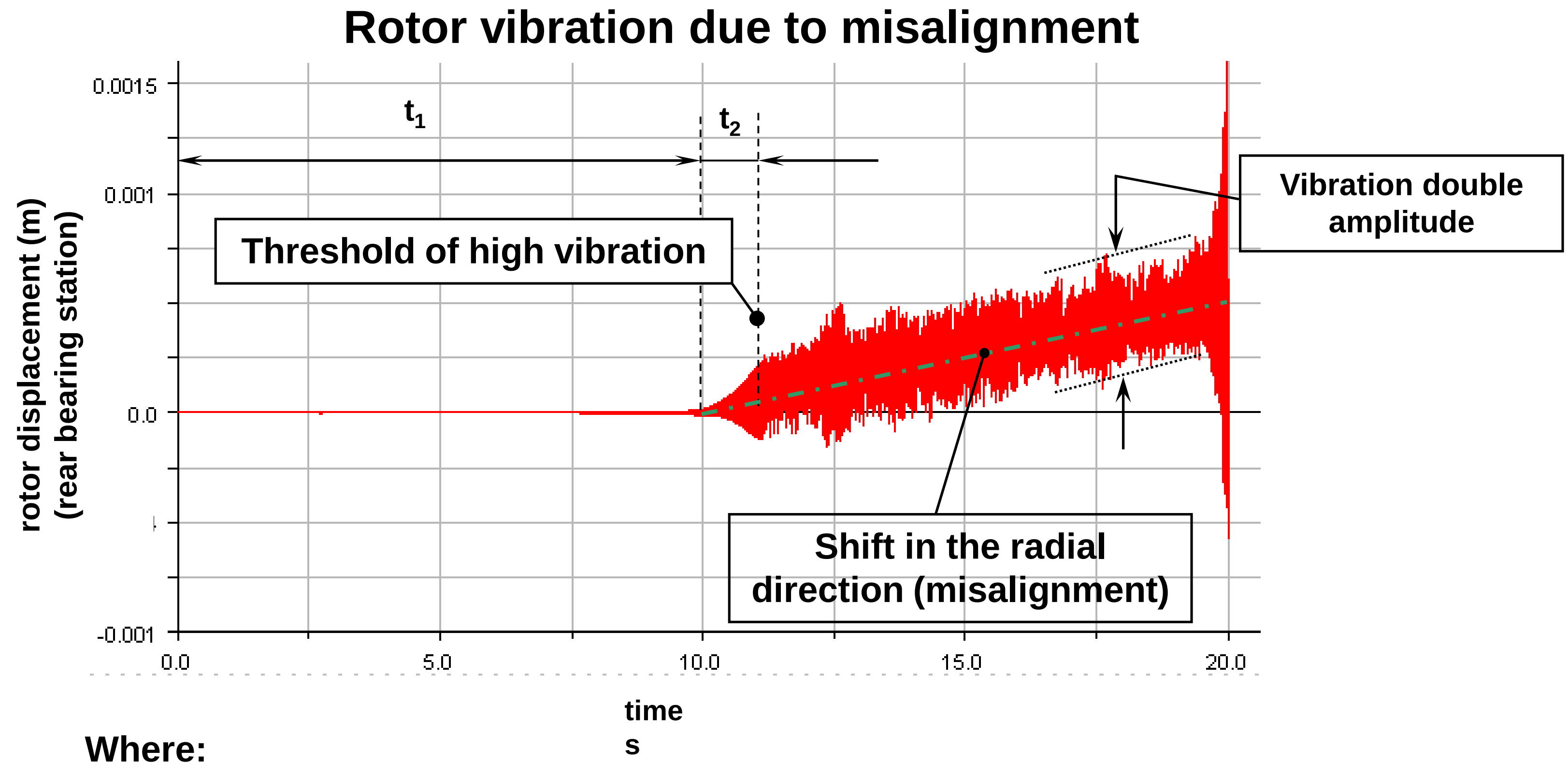
When a misalignment value is over a certain value increased unstable rotor lateral vibrations occur:

- **The main reason for this is the angular stiffness of rolling bearings which creates additional destabilizing load in the rotor axis plane.**
- **The angular stiffness value for the rear bearing was estimated by modeling of Hertzian contact between the bearing rollers and the inner and outer cages. The calculated value was about 3.75x104 N/(m x rad).**

Bearings Misalignment Response Analysis

- **The rotor vibration results were taken at the rear bearing. They are shown below.**
- **The dashed line shows the radial shift performed between 10 and 20 sec of transient simulation. It appears that rotor vibrations envelope midline coincides with the "radial shift" line.**
- **We observe a gradual increase of rotor vibration amplitude during until the vibrations became unstable. The stability threshold corresponds to 0.06…0.07 mm shift of the rear bearing in radial direction. The 0.06 eccentricity corresponds to the 0.12 mm T.I.R experimental result.**

Bearings Misalignment Response Analysis



Where:

t1 - the time where the rotor was accelerated until it reached constant steady state RPM
t2 - the time where we observe gradual rotor vibration increase due to misalignment

CONCLUSIONS

The rotordynamics analysis results may help defining:

- **Safe margins of the engine RPM range to avoid engine operation near the dangerous RPM interval.**
- **Rotor shaft regions where it is recommended to change flexural stiffness to perform critical speed values shift.**
- **Allowable misalignment in assembly.**
- **Desired positioning of rotor elements imbalance during the rotor assembly process to reduce engine vibration level.**
- **Bearing load due to imbalance for bearing life calculations.**