



Automotive Turbocharger Model Validation and Turbocharger Housing Acceleration Analysis



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Introduction

The trend in the automotive turbocharger (TC) industry is to develop virtual tools to predict TC performance, thereby reducing/eliminating costly test rigs and product qualification. The work conducted demonstrates a method for validating a TC rotor structural finite element (FE) model. In addition, TC center housing and compressor housing accelerations are analyzed to identify effect of engine excitation frequency. Test data for input into a nonlinear rotordynamics model to predict effect of engine excitation on TC rotor performance.

Research Methodology

Free-Free mode testing (Fig. 1) is conducted on a TC rotor to measure its natural frequencies and mode shapes. Measurements are compared to FE structural model predictions to validate computational tool.

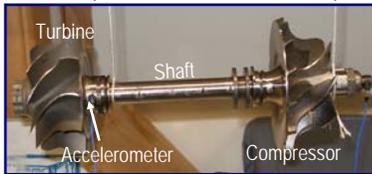


Fig. 1: Setup for free-free mode testing

Analysis of TC housing acceleration test data (Fig. 2 & Fig. 3) using Fast Fourier Transformation (FFTs) to evidence operating regions where engine excitation is important.

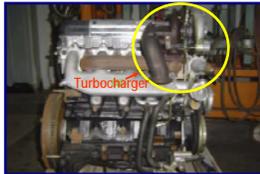


Fig. 2 Typical IC engine with turbocharger

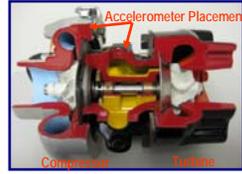


Fig. 3 Locations of acceleration measurements

Results

Table 1 Comparison of measured and predicted free-free mode natural frequencies

	Measured [Hz]	Predicted [Hz]	% difference [--]
First Freq.	832	850	2.22
Second Freq.	2400	2737	14.07

Table 1 compares predicted TC rotor free-free model natural frequencies to test data. The predicted first frequency corresponds well with the test value. The predicted and measured second frequency agree within allowable limits. Figures 4 and 5 show the excellent correlation between predicted and measured first and second free-free mode shapes, respectively.

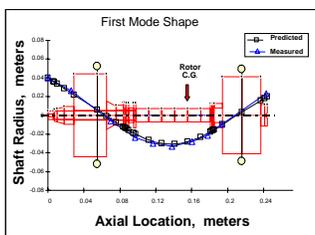


Fig. 4 First free-free mode shapes overlaid on rotor model

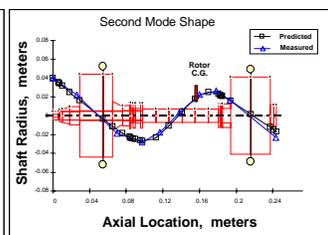


Fig. 5 Second free-free mode shapes overlaid on rotor model

Results (Continued)

Figures 6 and 7 show waterfalls of recorded compressor housing and center housing accelerations in the X and Y directions, respectively. Three engine loads were analyzed (25%,50%,100% of full engine load). Analysis results for 25% engine load shown. Note that waterfalls presented are in terms of orders of engine frequency (engine main speed).

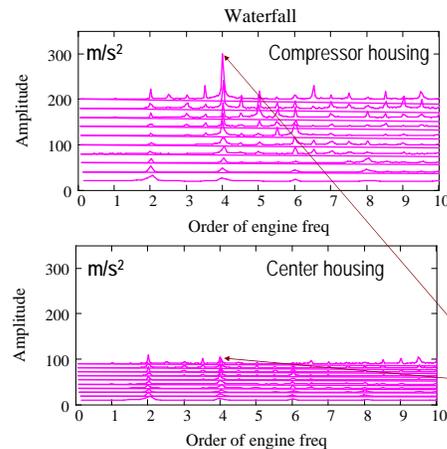


Fig. 6 X direction Acceleration waterfall plots of compressor housing (top) and center housing (bottom).

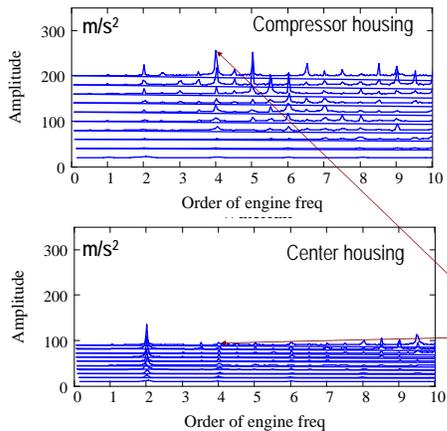


Fig. 7 Y direction Acceleration waterfall plots of compressor housing (top) and center housing (bottom).

- Compressor housing acceleration amplitudes are larger than center housing amplitudes
- Large motion amplitudes appear at 2x,4x, and 6x orders of engine frequency
- As engine load increases, amplitudes of acceleration increase

Conclusions

- Free-Free Modal Testing is a proven method to validate FE structural model of actual TC rotor
- Measured TC housing accelerations show TC casing and compressor casing do NOT move as single rigid body.
- TC virtual software tool must account for casing and compressor housing flexibility.

Acknowledgement

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