MEEN 459/659– SPRING 2019 Group Homework 3 due March 21, 2019

Figure 1 depicts a schematic view of an automotive (commercial vehicle) turbocharger (TC). The TC comprises of a casing, a rotor: a thin steel shaft connecting a heavy (T) turbine wheel to a light (C) compressor wheel, two floating ring bearings supporting the rotor and an axial thrust bearing. Engine oil lubricates the films made by the floating ring bearings (FRBs), one on the C side and another on the T side. Each FRB makes two fluid films: an inner film between the shaft OD and the FRB ID, and an outer film between the FRB OD and the casing ID. The FRBs rotate with angular speed (Ω_R) at a fraction of the shaft speed (Ω_S) .

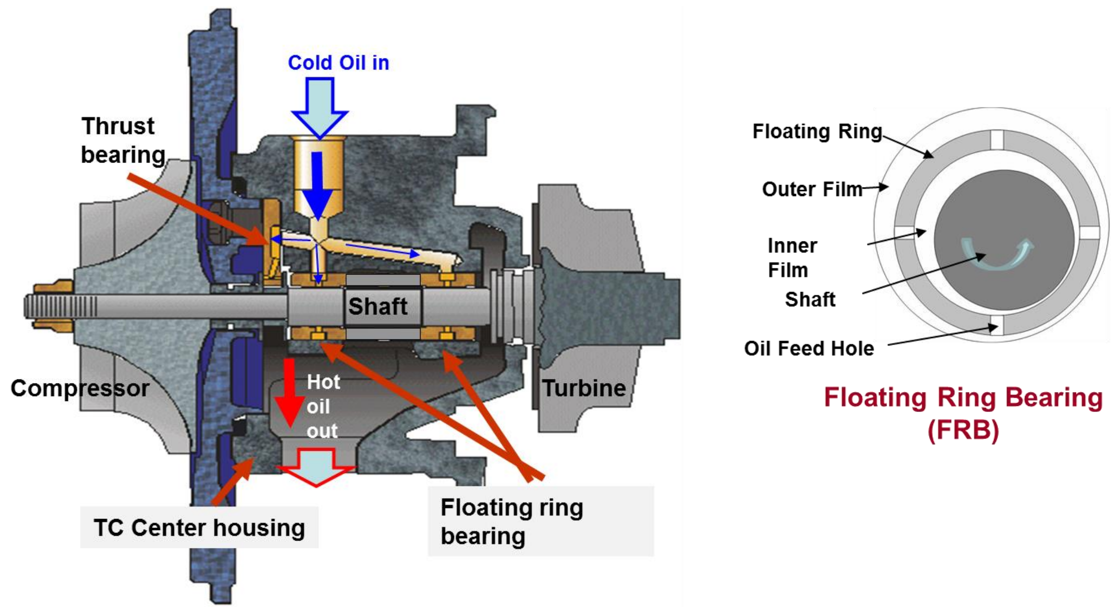

Fig. 1. Cross section of passenger vehicle turbocharger and schematic view of floating ring bearing

The data files attached contain the time response of the TC rotor displacements recorded at the compressor nose and at the turbine nose[1]. *X*, *Y* denote two orthogonal directions facing the rotor or shaft. Eddy current sensors recorded the rotor displacements during a slow acceleration of the TC from a low speed of 12.5 krpm to a high speed of 65.0 krpm. There are a total N_{RPM} = 23 shaft speeds.

Note the following about each ASCII data file:

Header.TXT contains basic information:
Sampling rate = 20,000/s, the number of samples recorded $N_{samples}$ = 2,048 for each channel. Delta_frequency for DFT (Hz), Δf==9.77 Hz, also stated.

Time_start.TXT contains time and corresponding shaft speed (RPM).
column 1: time (s), → column 2 : shaft speed (RPM)

[1] The commercial TC was modified to add targets at the T and C ends so as to measure vibration.

Ring.TXT contains angular speeds in RPM.
column 1: shaft speed → column2: compressor ring angular speed, column3: turbine ring angular speed.
Each of the floating rings has four holes for lubricant feeding into the inner film land (See Fig. 1). Fiber-optic sensors counted the frequency at which a hole passed by the sensor, hence allowing to record the spinning speed of the floating ring. The fiber optic sensor was not always successful in counting an actual speed (hence some are zero).

Recorded displacements (mils): time based and amplitude of DFT for each sensor are in
Channel2.tim & **Channel2.fre** → Compressor nose (*X)*
Channel3.tim & **Channel3.fre** → Compressor nose (*Y)*
Channel6.tim & **Channel6.fre** → Turbine nose (*X)*
Channel7.tim & **Channel7.fre** → Turbine nose (*Y)*

***.tim** file contains N_{RPM} = 23 ROWS (one for each rotor speed) and $N_{samples}$ = 2,048 COLUMNS (each corresponding to a time step: 0 Δt, 1Δt, ….

***.fre** file contains N_{RPM} = 23 ROWS and ½ $N_{samples}$ = 1,024 COLUMNS (each corresponding to a frequency step, Δf==9.77 Hz)

Please note that the **time data** for shaft displacements is obscured with (electrical) noise showing frequencies above 150 krpm (2.5 kHz). Filter such data!

Tasks:

Select a FRB: compressor or turbine; and analyze the time and DFT data to show and to discuss:

A) Shaft speed vs. time.

B) Ring speed Ω_R vs shaft speed Ω_S

C) Ring speed/shaft speed ratio (Ω_R/Ω_S) vs. shaft speed Ω_S.

D) Shaft orbits (Y vs X) vs shaft speed RPM. The clearance circle (max amplitude motion =8 mil). – Make a video and explain what you see. [You will have to use first take the DFT of a signal, then set=0 components of frequency (say) above 2.0 kHz, and calculate the Inverse DFT to produce a new time signal not affected by electrical noise from probes] –See figure 4.

<u>Select a *X* or a *Y* shaft displacement:</u>

E) Produce waterfalls of shaft motion (DFT amplitude vs frequency vs shaft speed). See Figure 2, for example.

F) Show amplitude of DFT vs order of rpm (i.e. divide frequency/shaft speed in Hz). See Figure 3, for example.

G) Dissect amplitude of DFT to extract information on its frequency content. That is find amplitude components synchronous (1X) with shaft speed, 2X, as well as SSV (sub synchronous) at ½ ring speed and ½ (ring + shaft speed). Plot the results in a meaningful form and discuss them!

H) Use the data to determine: is the TC response linear or nonlinear? What do subsynchronous motions mean (what do they represent)? what components of vibration are important? Why did the test stop at 65 krpm?

The zipped folder includes two technical papers for you to browse (perhaps even read) and gather knowledge. In addition, http://rotorlab.tamu.edu includes a page with a tutorial on past research at the TurboLab. Do you know that we are starting to study TCs for UAVS? Visit http://cup.illinois.edu

The homework intends to show you a typical engineering analysis (after collecting the data) that can reveal important trends on the performance of a mechanical system.

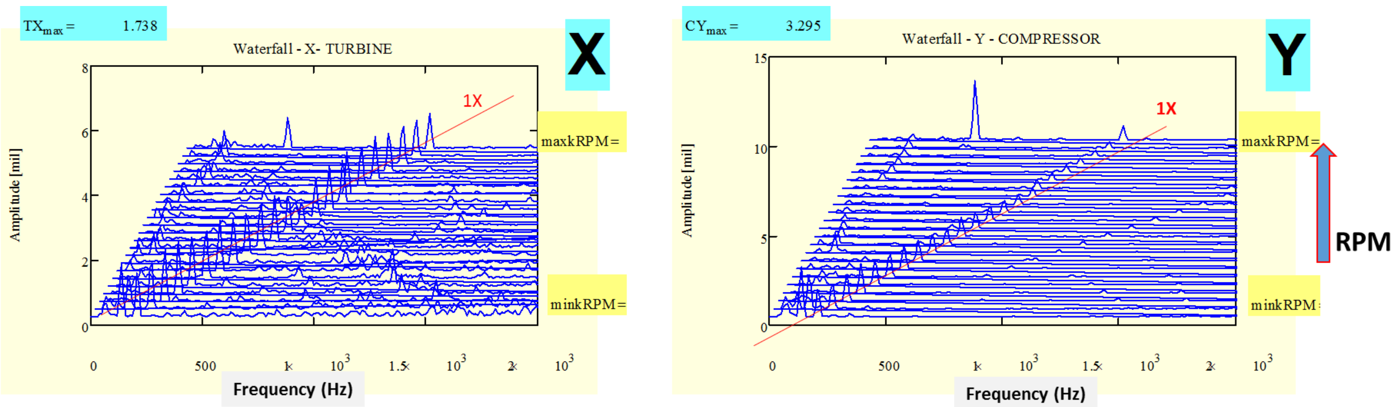

Fig. 2. *Waterfalls of* shaft motion amplitude at C and T ends.

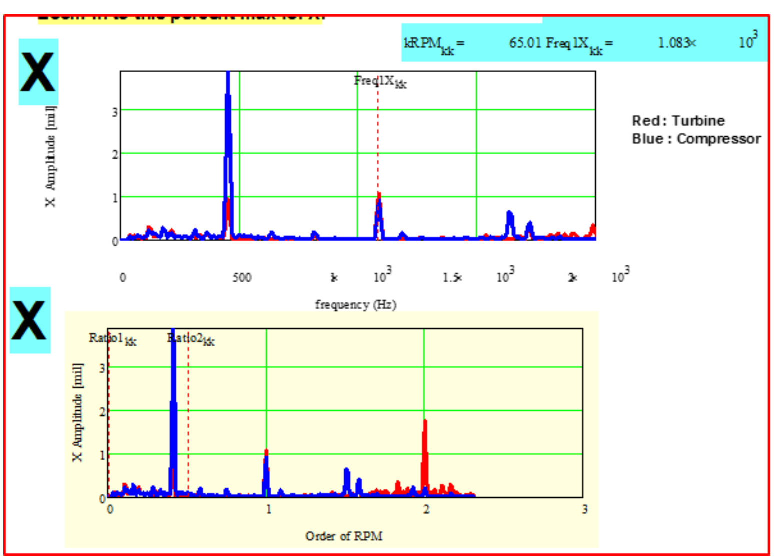

Fig. 3. *X-a*mplitude of DFT vs frequency (top) & vs order of RPM (bottom) recorded at shaft speed=65 krpm (1083 Hz).

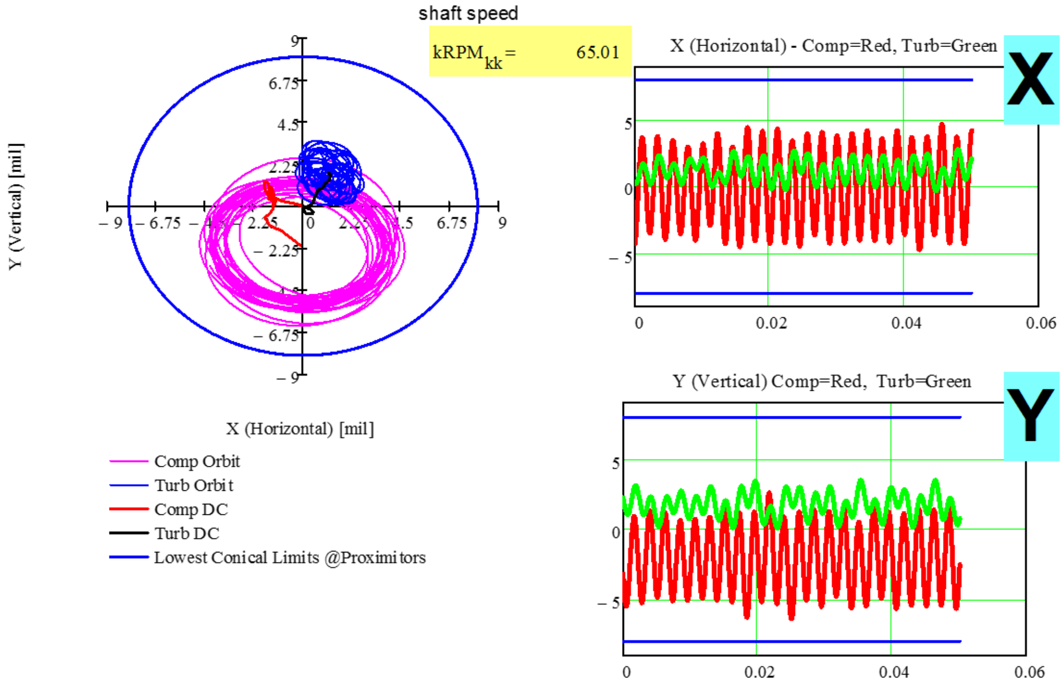

Fig. 4. Example: Orbital motion of TC rotor at C and T ends. Shaft speed=65 krpm (1083 Hz).