REXNORD RTS[SM] - Rexnord Technical Services
Mechanical & Material Engineering Services

Technically Speaking

RESONANCE IS THE TENDENCY OF A SYSTEM TO OSCILLATE WITH HIGH AMPLITUDE WHEN EXCITED BY ENERGY AT A CERTAIN FREQUENCY . THIS FREQUENCY IS KNOWN AS THE SYSTEM'S NATURAL FREQUENCY OF VIBRATION OR RESONANT FREQUENCY.

Vibration Resonance fatigue testing of crankshafts:

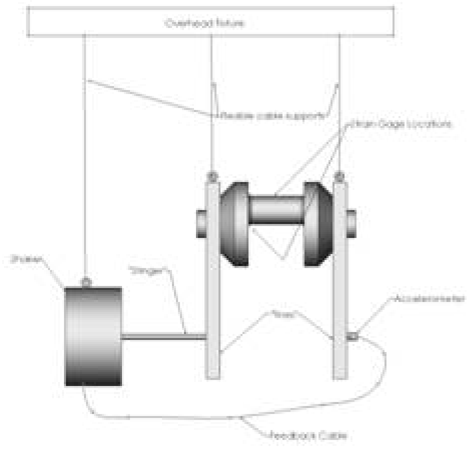
The gas pressure and inertia forces acting on crankshafts generate both bending moments and torsional moments. Because the magnitude and phase relationships between the maximum bending moment and maximum torsional moment vary with speed and torque, it is typical to analyze the stresses due to maximum bending and maximum torsion separately. Validation of separate bending and torsion analyses requires separate bending and torsion tests.

RTS has the capability and expertise to perform crankshaft testing with combined or separate bending and torsion loads. Crankshaft tests are performed using either servo-hydraulic or electrodynamic excitation; servo-hydraulic generally with loads greater than 6,000 lbf at frequencies below 1,800 RPM (30 Hertz) and electrodynamic for loads less than 6,000 lbf at frequencies above 30 Hertz.

Servo-hydraulic actuators often act directly on the crankshaft. Although electrodynamic shakers may also act directly on the crank, resonance techniques such as the “tuning fork method” described below are commonly employed to allow performance of high frequency fatigue tests at stress / strain levels that would require higher direct acting loads than can be generated with available electrodynamic shakers.

TUNING FORK METHOD

In the tuning fork method, the crankshaft or a section of the crankshaft is assembled with two plates that become “tines” of the tuning fork as shown in the picture below. Careful selection of the length and mass of the tines results in a first bending natural frequency of the crankshaft / tine assembly of 50 to 150 Hertz or higher. The assembly is easily excited at its natural frequency by an electrodynamic shaker.



As with any test method, analysis is required to assure that the stress / strain distribution during testing is similar to the stress / strain distribution during actual use. Finite element analysis is useful prior to testing to determine both the optimum mass of the tines and the distribution of stress during testing. Stress distribution of the first bending mode of the crankshaft / tine assembly is usually very similar to the stress distribution in actual use.

Because the crankshaft is tested at the resonant frequency of the assembly, the force applied by the shaker is not easily correlated to equivalent force at the crank-pin. Rather, one or more strain gages applied to the crankshaft are used to calibrate the test setup and, in some cases, to control the test. The highest strain is usually in a fillet. A strain gage in a fillet with high strain may fail or the bond to the test sample may fail before the crankshaft fails, so additional strain gages placed in flat areas with lower strain than in the fillet are used for control.

In addition, an accelerometer may be placed on one of the tines and the acceleration level may be correlated to strain.

The crank / tine assembly is hung from a supporting structure. A small shaker can also be suspended from the same structure or can be floor mounted. A "stinger" attached to both the shaker and one of the tines is set to excite the tuning fork at its resonant frequency and its amplitude is controlled to provide the required strain in the fillet.

Depending on the controller used, a failure or crack will either be evident because the frequency can no longer be controlled, or the frequency necessary to maintain the assembly in resonance will drop.

BENEFITS

Forces generated in reciprocating engines and compressors can be much higher than the maximum force rating of most electrodynamic shakers. Resonance techniques such as the tuning fork method allow crankshafts to be tested at the high frequencies attainable by electrodynamic shakers even when the required force is greater than can be generated by available electrodynamic shakers.

The frequency range of electrodynamic shakers is 5 Hertz to at least 2,000 Hertz while the maximum operating speeds of most crankshafts is between 1,800 RPM (30 Hertz) and 9,000 RPM (150 Hertz). Therefore tests may be run on an electrodynamic shaker at the maximum operating speed of the crankshaft or higher, thereby accumulating test cycles at a higher rate than on running engines or compressors. Faster tests may allow more samples or more design variations to be tested in the same period of time. The cost of testing with the tuning fork method may also be lower than other methods.

DISADVANTAGES

The disadvantage of the tuning fork method is that the excitation must be purely sinusoidal. If the response of the tuning fork assembly to a purely sinusoidal excitation is significantly different than the response of the crankshaft to operating forces, then a test with direct acting forces must be used.

Internal combustion engines will create a large compression load, and a much smaller inertial load will occur as the piston reverses direction. When performing a servohydraulic test, it is possible to reproduce this difference between compression and inertial loads. Vibration resonance fatigue testing, by its nature, produces a fully reversed sinusoidal loading. If the proper analysis is done prior to testing, the test components
may be designed so that the bending moments encountered in testing closely resemble the bending moments encountered in an operating engine.

RTS has the capability to perform this type of testing in the vibration testing laboratory, as well as the traditional servohydraulic testing in the fatigue lab.

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