



Idle Combustion Forcing Function Evaluation Procedure

1 Scope

Note: Nothing in this standard supercedes applicable laws and regulations.

Note: In the event of conflict between the English and domestic language, the English language shall take precedence.

1.1 Purpose. This test quantifies the low frequency combustion (gas pressure) torque excitation from an internal combustion engine across a standard range of possible steady state idle speeds. It is used to set and measure Subsystem Technical Specifications (SSTS) in conjunction with the Engine Level Allocable Test (ELAT) procedure as referenced in GMW14007.

The current procedure separates measured combustion torque data into its random and periodic components using the Cyclic Averaging Separation Method (CASM). First, cylinder (cyl) pressures are acquired on a combustion data acquisition system, typically sampling 360 times per crankshaft revolution, which are then stored in raw crank angle based files. They are then post processed using the CASM method, the results combined with inertial loads for the engine, and then saved as a forcing function set in a universal file. This forcing set is used to drive standard Finite Element Analysis (FEA) idle vibration simulations.

Within General Motors North America (GMNA), the acquisition is currently performed by Combustion Analysis System (CAS), and the post processing is done on a personal computer (PC) in Matlab, using the program Internal Combustion Engine Fundamental Loads (ICEFLo). The inertial loads are brought into ICEFLo from a General Motors Powertrain (GMPT) Analysis program called Gas and Reciprocating Inertia Torque Simulation (GRITS), and ICEFLo stores the forcing set in the standard universal file format. This is used to drive the FEA idle vibration simulation per Vehicle Synthesis, Analysis and Simulation (VSAS) Procedure Number 0C-02-014.

This procedure could be used for other operating conditions, but is most applicable to idle because

of the relative high amount of random combustion torque produced at low loads and speeds.

The CASM portion of the post processing is to calculate dynamic gas pressure torque traces from the individual cylinder pressures, which are then summed to find the engine's total gas pressure torque. This torque trace is cyclically averaged (calculating the average of n cycles), to find its periodic or repetitive component (two (2) revolutions long). This two (2) revolution trace is then replicated n times to form a periodic trace equal in length to the original data trace. This periodic trace is then subtracted from the total torque trace, producing the random torque trace (the deviation from the periodic). Each component trace is then also interpolated to the time domain by using the time stamp recorded for each sample.

The random torque component is then processed in the time domain to produce a frequency based power spectral density (the data being hanned and amplitude corrected, with 1 Hz resolution). The periodic part is processed in the crank angle domain to produce a complex order spectrum (in zero peak amplitude form) with 1/2 order resolution.

Together, the data from the various speed/load combinations form a combustion excitation set spanning likely conditions of steady state idle.

Note: The CASM data processing technique relies on the operating condition being nominally constant, i.e., no gross changes in engine speed or loads from accessories (i.e., air conditioner (A/C) compressor clutching in/out), fan engagement, etc. If nominally steady conditions are not met, the periodic torque will change, and some of the periodic torque content will improperly be put into the random (non steady) content. This will lead to misinterpretation of the data. The only idle speed variation during the run should be the random fluctuations during normal idle speed control operation.

1.2 Foreword. This test is intended to provide a standard combustion torque excitation source (to be combined with engine inertial excitations in the program ICEFLo, Powertrain Analysis Capability

GM Confidential

© Copyright 2013 General Motors Company All Rights Reserved

April 2013

Page 1 of 11



Documents

Document Sharing Hub

ES184) for vehicle system modeling, as well as specification setting and validation, diagnostics and development. Because idle speeds vary with application, and high idle might be of interest, speeds from 500 rpm to 1200 rpm are measured representing warm idle. In addition, the cold start idle is measured at calibration dependent elevated speeds (see 4.2.2.2.1).

The test is evolutionary in nature, and changes to its content and processing are expected to occur. The vehicle and powertrain operating conditions may also change as test capabilities and experience develop. Some engines and powertrains do not allow operation at all standard test conditions, in which case the dataset is reduced accordingly.

1.3 Applicability. This test procedure applies to multipurpose passenger vehicles and light duty trucks.

2 References

Note: Only the latest approved standards are applicable unless otherwise specified.

2.1 External Standards/Specifications.

None

2.2 GM Standards/Specifications.

GMW14007

2.3 Additional References.

ES184, Powertrain Analysis

SARR0204, Gas and Reciprocating Inertia Torque Simulation Program

VSAS 0C-02-014, Idle Loads for Noise and Vibration

3 Resources

3.1 Facilities. The standard test facility is a flat surface in a test room with exhaust extraction, although a chassis dynamometer with locked rolls is also acceptable. The test facility should have the capability of maintaining a constant ambient temperature between 18 °C and 29 °C (65 °F to 85 °F). Excessively high or low humidity levels affect the idle characteristics of engines. Avoid acquiring data under such conditions, unless nonstandard conditions are specifically required.

Note: This test is written assuming in vehicle operation, but may also be run on an engine dynamometer if the proper loads and calibrations are known for the various operating conditions. Vehicle specific instructions, such as parking brake settings, should then be ignored.

3.1.1 Calibration. The test facilities and equipment shall be in good working order and shall have a valid calibration label.

3.1.2 Alternatives. Alternative test facilities and equipment may also be used. However, all measuring variables as specified in this standard shall be determined correctly with respect to their physical definition.

3.2 Equipment.

3.2.1 Thermometer, (optional) hygrometer (for relative humidity).

3.2.2 Multichannel combustion data acquisition system. It must have capability to index the crank shaft encoder accurately to cylinder one piston position, to allow accurate torque calculations based on cylinder pressure. In GMNA, CAS data acquisition systems have normally been used.

3.2.3 One (1) pressure transducer for each cylinder (spark plug transducers acceptable).

3.2.4 Optical encoder on crankshaft nose (normally 360 pulses per revolution (ppr). If this is not possible, a magnetic pickup can be set up to produce a pulse train from the flywheel starter teeth. It is recommended to put a signal from a magnetic pickup through a frequency doubler to increase resolution.

3.2.5 External cooling fan, preferably the centrifugal design used in the Noise and Vibration Integration building, since these provide the smoothest airflow. Smaller fans may be used if the hood is off.

3.2.6 Brake applicator kit and weight.

3.2.7 Windows-compatible PC with Matlab (used in GMNA) or equivalent. 2 GHz, 512 MB RAM minimum recommended.

3.2.8 Tire pressure gauge.

3.3 Test Vehicle/Test Piece. The powertrain and accessory drive system must be qualified to ensure that they represent desired design intent (accessory drive must provide the correct load). Deviations must either be corrected or noted. This is, however, subject to the specification of the test requester if obtained for nonstandard use.

3.4 Test Time.

Calendar time: 3 to 5 days

Test hours: 2 to 3 days

Coordination hours: 1 to 2 days

Note: Calendar Time is normally two to three days total for setup, test and teardown. One to two days is normally required for data post processing. It is

GM Confidential

© Copyright 2013 General Motors Company All Rights Reserved

April 2013

Page 2 of 11

advantageous to machine the encoder adapter and establish capability to alter idle command speed (in a representative manner) prior to the test date, in order to save test cell time.

3.5 Test Required Information.

3.5.1 Engine Parameters: The number of cylinders, firing order, firing intervals, number of strokes in cycle (2 or 4), bore, stroke, rod length, piston pin offset, and compression ratio.

3.5.2 Vehicle/Condition Parameters: Record as needed to distinguish the conditions.

3.6 Personnel/Skills. This test requires one engineer and one technician skilled in CAS and noise and vibration data acquisition/processing.

4 Procedure

4.1 Preparation.

4.1.1 Vehicle Preparation. Note that vehicle vibration considerations are included to be consistent with similar tests which include vibration measurements. While these considerations are not essential to cylinder pressure measurements, vibration measurements are often taken simultaneously, and it is best to use a consistent technique for both types of test.

4.1.1.1 Battery should be at a minimum of 80% state of charge, in order to provide a steady alternator load. If it is low, charge it before testing with an external charger or by running the engine.

4.1.1.2 Set steel safety pole in front of vehicle.

4.1.1.3 If vibration data is also being taken, Install a brake pedal bracket and 9 kg (20 lb) mass.

Install wheel chocks on the front wheels, not letting the tire touch the face of the chock.

Adjust cold tire pressure to the manufacturer's specifications (allow tires to cool if the vehicle has been recently operated).

Close or remove hood. Do not place transducer amps on the powertrain.

4.1.1.4 If vehicle vibration data is not being taken, set the parking brake.

4.1.1.5 Allow time for the vehicle to adjust to test lab ambient temperature before testing.

4.1.1.6 Record requested information in test data log (see Appendix A).

4.1.1.7 Place the exhaust extraction inlet(s) in line with the exhaust exit(s) two inches away from the tailpipe(s). It is essential not to create excessive vacuum in the vehicle exhaust system (idle

combustion could be significantly affected) or change its dynamic properties by contacting it.

4.1.1.8 Set up an external cooling fan directed toward the engine cooling. This will prevent vehicle fans from operating and powertrain mounts from getting too hot. Alternatively, the hood may be removed for equipment clearance and improved mount cooling, using small external fans.

4.1.1.9 Check A/C system for proper operation (i.e., cold air delivery). Charge if necessary.

4.1.1.10 Turn off vehicle radio and Heating Ventilation and Cooling (HVAC) system.

4.1.2 Instrumentation Preparation.

4.1.2.1 Using CAS System for Data Acquisition

Use the Combustion Analysis System for Data Acquisition.

4.1.2.1.1 Channel Assignments. Connect all transducers to the CAS system for recording. Use the following recommended channel assignments:

Table 1: Channel Assignments in CAS

Channel	Description
1 thru n	Cylinder pressures up to number of cylinders n
33	Crankshaft encoder, normally 360 ppr

4.1.2.1.2 Set up CAS system to record required Torque (TQ) files (raw crank angle based data traces) sampled at ppr pulses/rev:

Table 2: TQ Files in CAS

File Name	Description	Units
TQ01.001 thru TQ0 n .001	Cylinder pressures cylinders 1 to n	kPa
TQTIME.001	Time stamp for each sample	ms
TQENCD.001	Angle of cylinder 1 relative to Top Dead Center (TDC) firing	degree
TQRPM.001	Trace of 60 degree averaged rpm.	rpm

4.1.2.1.3 Continue setup for idle measurements per CAS manual. This includes accurately indexing the crankshaft encoder to cylinder 1 TDC.

GM Confidential

© Copyright 2013 General Motors Company All Rights Reserved

April 2013

Page 3 of 11

4.1.2.2 Using Alternative System for Data Acquisition.

4.1.2.2.1 Channel Assignments. Connect all transducers to the data acquisition system for recording. Use the appropriate channel assignments for the system:

Required Input Channels:

1. Cylinder pressures up to cylinder n .
2. Crankshaft encoder, normally 360 ppr.

4.1.2.2.2 Set up the data acquisition system to create an encoder signal trace recording the crankshaft position (in degrees relative to TDC cylinder 1 firing) for each data sample, starting as close as possible to -180 degrees.

4.1.2.2.3 Set up the data acquisition system to create a time stamp list recording the time (in milliseconds) for each data sample.

4.1.2.2.4 Set up the data acquisition system to create an engine speed trace recording the rpm for each data sample averaged over 60 degrees of crank rotation.

4.1.2.2.5 Set up the data acquisition system to record the following raw crank angle based data traces at ppr (pulses/revolution):

Table 3: Required Raw Traces

Required Raw Traces	Units
Cylinder pressures cylinders 1 to n	kPa
Time stamp for each sample	ms
Angle of crankshaft relative to TDC cylinder 1 firing	degrees
Trace of 60 degree averaged rpm	rpm

4.1.3 Instrumentation Calibration.

4.1.3.1 Acquisition System Calibration. The appropriate instrumentation group should perform periodic calibration of the data acquisition system according to lab standards.

4.1.3.2 Pressure Transducer Calibration. The appropriate instrumentation group should perform periodic calibration of the pressure transducers according to lab standards.

4.1.4 Transducer Placement/Installation.

4.1.4.1 Crankshaft Encoder Installation. Install so that the housing is constrained to rotate with the engine block. Do not attach to the vehicle cradle or frame. If a magnetic pickup is used, it must be attached to the powertrain structure.

4.1.4.2 Cylinder Pressure Transducers. Spark plug or flush mount transducers may be used, with spark plug transducers being preferable due to ease of installation. Since high frequency (≥ 500 Hz) data is not desired, flush mounting is unnecessary, but permissible. If flush mount transducers are used, check the frequency range of the data. In extreme cases, low pass filtering may be necessary if there is significant signal strength above 500 Hz. Usually, however, the only high frequency component at idle is cross talk from neighboring spark plug wires. These effects are of short duration and low total energy, and what little extraneous data they produce is at frequencies beyond our range of interest.

4.2 Conditions.

4.2.1 Environmental Conditions. Test facility should have a constant (within reason) ambient temperature between 18 °C and 29 °C (65 °F and 85 °F), preferably between 21 °C and 27 °C (70 °F and 80 °F). If it is out of this range, make a note in the deviation section of the test data log.

4.2.2 Test Conditions. Deviations from the requirements of this standard shall have been agreed upon. Such requirements shall be specified on component drawings, test certificates, reports, etc.

4.2.2.1 For warm idle tests, a maximum of 44 standard test conditions are run. The four loading conditions,

- Park, accessories off.
- Park, accessories on.
- Drive, accessories off.
- Drive, accessories on.

are each normally run at eleven different speeds:

1. 500 rpm
2. 550 rpm
3. 600 rpm
4. 650 rpm
5. 700 rpm
6. 775 rpm
7. 850 rpm
8. 925 rpm
9. 1000 rpm
10. 1100 rpm
11. 1200 rpm

Exclusion of Conditions:

1. The higher speeds may not be realistic to measure in Drive, depending on the torque

GM Confidential

© Copyright 2013 General Motors Company All Rights Reserved

April 2013

Page 4 of 11