



SURFACE VEHICLE RECOMMENDED PRACTICE

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Engine Cooling Fan Structural Analysis

RATIONALE

Corrections have been made to punctuation, grammar, and spelling where needed. Section 5.2.2.3 has been expanded to include Power Take Off (PTO) mounted parking brakes. Clarifying statements have been added where needed.

FOREWORD

This SAE Recommended Practice is intended as a guide toward standard practice but may be subject to frequent change to keep pace with experience and technical advances, and this should be kept in mind when considering its use.

1. SCOPE

Three levels of fan structural analysis are included in this practice:

- a. Initial structural integrity.
- b. In-vehicle testing.
- c. Durability (laboratory) test methods.

The initial structural integrity section describes analytical and test methods used to predict potential resonance and, therefore, possible fatigue accumulation.

The in-vehicle (or machine) section enumerates the general procedure used to conduct a fan strain gage test. Various considerations that may affect the outcome of strain gage data have been described for the user of this procedure to adapt/discard depending on the particular application.

The durability test methods section describes the detailed test procedures for a laboratory environment that may be used depending on type of fan, equipment availability, and end objective.

The second and third levels build upon information derived from the previous level. Engineering judgment is required as to the applicability of each level to a different vehicle environment or a new fan design.

This SAE Recommended Practice is applicable to any engine cooling fan application including medium and heavy-duty trucks, buses, construction equipment, industrial, and agricultural equipment. Some sections are more applicable to engine-driven fans than to hydraulic-driven or electric-motor-driven fans, especially with respect to speed control. Fan failure modes, however, are generally the same regardless of driving modes.

The usage of non-metallic construction necessitates areas of evaluation not required by metallic designs. Chief among

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these are temperature extremes, moisture content, impact resistance, chemical attack, material purity/homogeneity, and aging/weathering. Areas of evaluation affecting both metallic and non-metallic fans, but requiring somewhat different approaches with non-metallic parts, include natural frequency determination and durability testing.

1.1 Purpose

The purpose of this document is to identify the general methodology for the structural analysis of engine cooling fans, and to provide expanded information on subset practices within the general methodology, such that a user of this practice can adapt specific subsets related to a vehicle¹ class.

2. REFERENCES

2.1 Applicable Documents

The following publications form a part of this specification to the extent specified herein. Unless otherwise indicated, the latest issue of SAE publications shall apply.

2.1.1 SAE Publications

Available from SAE International, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 877-606-7323 (inside USA and Canada) or +1 724-776-4970 (outside USA), www.sae.org.

SAE J1099 Technical Report on Low Cycle Fatigue Properties, Ferrous and Non-Ferrous Materials

SAE J1116 Categories of Off-Road Self-Propelled Work Machines

SAE J1234 Specification Definitions - Off-Road Work Machines

SAE J/ISO 6165 Earthmoving Machinery - Basic Types - Vocabulary

2.1.2 ASTM Publications

Available from ASTM International, 100 Barr Harbor Drive, P.O. Box C700, West Conshohocken, PA 19428-2959, Tel: 610-832-9585, www.astm.org.

ASTM D618 Standard Practice for Conditioning Plastics for Testing

3. DEFINITIONS

3.1 NON-METALLIC FANS

Non-metallic fans can be constructed from a variety of thermoplastic and thermosetting resins, with or without any of the following: reinforcing fibers, fillers, stabilizers, modifiers, and pigments. Non-metallic fan materials in common use include but are not limited to polypropylene, nylon, polyester, and vinyl ester.

3.2 WELD-LINE or KNIT-LINE

The area of a molded non-metallic part formed by the union of two or more streams of thermoplastic flowing together during an injection molding process.

3.3 STRESS WHITENING

An effect noted in non-metallic materials under stress loading occurring as a result of molecular orientation, visible as a white area due to the change in the refraction index of the material.

4. INITIAL STRUCTURAL INTEGRITY

¹ The term "vehicle" as used in this practice is defined as an all-inclusive term.

4.1 Scope

It is necessary to identify and attempt to evaluate the characteristics of an application which can have an effect on fan durability. Failures almost always occur in fatigue, so careful attention should be paid to avoid resonance or forced vibration of the fan. This section considers vibrational inputs, fan natural frequencies, and operating speed as part of the initial structural integrity analysis. A fan application fact sheet (Figure 1) is recommended as a form to communicate between user and fan supplier.

- 4.1.1 A resonant condition may occur when the natural frequencies of the fan as determined from 4.3 is coincident with either of the vibrational input frequencies or their harmonics, as calculated in 4.2, or with the effects of airflow obstructions near the fan.
- 4.1.2 It is desirable to separate these frequencies, including the upper and lower harmonics, whenever possible. In addition, torsional vibrations, auxiliary equipment, driveline vibrations, etc., may cause vibratory inputs to the fan which cannot be predicted in equation form.
- 4.1.3 Vibratory inputs to the fan caused by the fan tips rubbing against a shroud should be avoided. Such rubbing is generally accompanied by much noise but can also be easily identified by visual inspection of the fan and shroud. Engine movement and vehicle frame flexure are two conditions that can cause rubbing.

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PART ONE - FAN USER INFORMATION

Customer: _____ Location: _____

Contact Person: _____

Phone Number: _____ E-mail Address: _____

Performance Required

Volumetric Flow Rate: _____ Air Density: _____

Speed: _____ RPM Static Resistance Pressure: _____

Max Fan Power: _____

Limitations

Max Fan Diameter: _____ Max Over-Speed: _____ RPM

Max Projected Width: _____ Max Fan Power: _____

Other: _____

Application (Vehicle) Description

Model Number: _____ Engine: _____

Rated Power: _____ at Engine Speed: _____ RPM

Fan Drive Type: _____

Fan/Engine Speed Ratio: _____ Fan Mounting Location: _____

Fan Rotation: _____ Belt Tension: _____

Pilot and Bolt Circle: _____ Maximum Run-Out: _____

System

Shroud (& Type): _____ Shroud Diameter: _____

Fan Position: _____

Clearance to Obstructions: Front: _____ Rear: _____

Required Testing

Airflow: _____ Spin Burst: _____ Shaker Scan: _____ Impact: _____

Strain Gage: _____ Endurance (Bench Test): _____ Dimensional Check: _____

Material Properties: _____ Other: _____

PART TWO - FAN SUPPLIER INFORMATION

Manufacturer: _____ Location: _____

Contact Person: _____

Phone Number: _____ E-mail Address: _____

Proposal

Manufacturer's Part Number: _____

Drawing and/or Model File Attached: _____

Fan Weight: _____ Max Fan Imbalance: _____

Fan Rotational Inertia: _____ Fan Transverse Inertia: _____

Other: _____

Test Results Attached

Airflow: _____ Spin Burst: _____ Shaker Scan: _____ Impact: _____

Strain Gage: _____ Endurance (Bench Test): _____ Dimensional Check: _____

Material Properties: _____ Other: _____

Figure 1 - Fan application fact sheet

4.2 Vibrational Inputs

4.2.1 Frequency Prediction

Without verification by in-vehicle testing, the potential critical speeds and frequencies that can affect the fan can only be predicted. Two potential frequencies of vibration are the harmonics of the piston firing frequency Equation 1 and the harmonics of the fan rotational frequency associated with obstructions that cause a non-uniform or pulsating flow as the fan rotates (Equation 2). Both full-order and half-order harmonic frequencies should be considered.

$$\text{Piston Firing Frequency} = \frac{(\text{No. of Cylinders})(\text{Engine rpm})}{(30)(\text{No. of Cycles})} \quad (\text{Eq. 1})$$

where:

number of cycles refers to two or four stroke engine

$$\text{Fan Rotational Harmonic Frequencies} = \frac{(n)(\text{Fan rpm})}{60} \quad (\text{Eq. 2})$$

where:

$n = 1, 2, 3, \dots$ obstructions encountered per revolution

4.2.2 Air Pressure

The cooling fan operates with a working pressure gradient across the fan swept area. Local obstructions, side-members, and core (or stacked core) air restrictions all affect fan blade deflections and strain levels.

4.3 Fan Natural Frequencies

4.3.1 The resonant frequencies and location of the node lines of the fan should be measured for each mode of vibration. This can be done by using a shaker table, accelerometers, strain gages, or by observation. The resonant frequencies may be for both rectilinear and torsional modes of vibration. Each resonant frequency of a fan can be affected by the following:

4.3.1.1 The shape of the fan mounting surface, which may affect the relative spring constant of the system and should be duplicated as closely as possible.

4.3.1.2 The torque of the mounting bolts may also affect the relative spring constant.

4.3.1.3 Dimensional variations from fan to fan, including material tolerances, may affect both the relative spring constant and the vibrating mass.

4.3.1.4 When using means other than the actual installation for driving the vibrating mass, caution should be exercised with the excitation level as the natural resonant frequencies can be masked by the high excitation levels of an over-driven forced vibration.

4.3.1.5 Temperature and moisture content of a non-metallic fan, since tensile modulus and flexural modulus vary with both temperature and moisture content.

4.3.1.6 Orientation of reinforcing fibers of a non-metallic fan (if present).

4.3.1.7 Material homogeneity of a non-metallic fan due to molding process variations.

4.3.2 The maximum stress may not occur at the resonant frequency. It may occur at a frequency between the resonant frequencies of two different modes of vibration, i.e., a combination of rectilinear and torsional excitation.

4.3.3 Finite element analysis methods may be used as a supplement to the previous test methods. Mode shapes and frequencies, and relative stress gradients can be numerically predicted and compared to vehicle vibrational inputs.

4.4 Operating Speed

4.4.1 As fan operating speed increases, so does stress due to centrifugal force. Also, a broad speed range increases the exposure of the fan structure to potential resonant frequency input whether from engine shake inputs or airflow disruption. While it may be desirable to keep the fan operating speed as low as possible to minimize stresses, fan speed is dictated by vehicle cooling requirements.

4.5 Log Sheet

4.5.1 The fan user and supplier may wish to establish a fan application fact sheet. This can be used to identify design parameters that affect fan performance for their particular application and to record the basic fan characteristics. It must be remembered, however, that one cannot anticipate all of the factors that will affect fan durability while early in the design stage. No itemized list will be all-inclusive, and no algorithm is possible. A sample fact sheet is provided as Figure 1. Users and suppliers should feel free to modify it as mutually desired.

5. IN-VEHICLE TEST

5.1 Scope

In-vehicle tests can be used to complement the Initial Structural Integrity section of this document because the forces on a fan are determined by a combination of the fan's operating environment and the engine/vehicle operational duty cycle conditions. A fan designed for a specific vehicle application and having satisfactory structural strength in its intended application may have unsatisfactory durability in a different application. The following sections will aid in the selection of a suitable test vehicle, in the preparation and instrumentation of the vehicle for test, and in conducting the actual test.

5.2 Test Vehicle Selection

This subsection considers the kinds of standard and optional vehicle equipment which can impose forces, vibrations, and frequencies on the subject fan. The vehicle equipment environment influences the fan by three different methods. First, equipment obstructions ahead of, behind, and around the fan disturb the air flow passing through the fan. This air flow disturbance imposes forces and vibrations on the fan. Second, the engine and other equipment are sources of mechanical vibrations. These vibrations can propagate and be transmitted to the fan through its mounting attachment. Third, the fan drive that determines the plane-of-rotation, the center-of-rotation, and the rotational speed directly affects inertial forces and vibrations in the fan. Consideration of these factors will permit the tester to specify the appropriate optional equipment for the test vehicle.

5.2.1 Package Obstructions

Equipment located in the near vicinity of the fan that restricts and obstructs the fan air flow.

5.2.1.1 Radiator Core

Consider the variation in air flow restriction due to optional radiator cores with a different number of tube rows, core depth, fin densities, and fin designs. Radiator tanks, side structures, and cross-reinforcing rods can be significant obstructions if the fan partially "sweeps" any of these items.

5.2.1.2 Heat Exchanger Core

Any finned core located ahead or behind the fan will restrict air flow. Examples are air conditioning condenser and coolers for engine lubricating oil, power steering fluid, automatic transmission fluid, hydraulic PTO fluid, and charge air coolers.

5.2.1.3 Shroud

Optional fan shroud or hand guards. As with radiator tank obstruction, fan shroud design relative to the fan sweep path may significantly impact air loading of the fan structure.

5.2.1.4 Radiator Shutters

Mounting location (in front or behind radiator) and type (modulating or full open-full closed).

5.2.1.5 Winter Front

Optional grille mounted winter fronts.

5.2.1.6 Blockage

Frame member or body sheet metal obstructions, belt pulleys and crankshaft damper can present blockages when in proximity to the fan.

5.2.1.7 PTO Shafts

Front crankshaft driven power take-off shaft.

5.2.1.8 Deflector

Optional fan blast deflector.

5.2.2 Vibration Sources

Equipment that generates mechanical vibrations. Because these equipment items are commonly located in the immediate vicinity of the fan, they also cause fan air flow obstruction effects.

5.2.2.1 Engine

Design parameters and/or data permit the tester to consider engine vibration magnitudes and fundamental forcing frequencies.

5.2.2.1.1 Type

Gasoline or diesel, two-stroke cycle or four-stroke cycle, number of cylinders, in-line or Vee, turbocharged or naturally aspirated, uniform or uneven cylinder firing interval.

5.2.2.1.2 Size

Displacement, bore, stroke, and power rating.

5.2.2.1.3 Crankshaft Damper

Determine if a damper is provided, and location of fan drive pulley with respect to damper (is fan driven from crank or damper inertia member?).

5.2.2.1.4 Speed

Governed or rated engine speed; fast idle or sub-idle.

5.2.2.1.5 Vibration Data

Review any available vibration test data for magnitudes and frequency. Crankshaft torsional data is important.

5.2.2.2 Accessories

Power steering pump, water pump, air brake compressor, air conditioning compressor, alternator, emissions air pump, vacuum brake pump, and hydraulic brake booster pump.

5.2.2.3 Driveline

Optional sizes, lengths, and types (one-piece or two-piece). Any driveline variant that effects first mode bending frequency can impact fan structural response. For example, a transmission or Power Take Off (PTO) mounted parking brake that is unique to a particular axle ratio or vehicle weight rating may produce an input to the fan structure that differs from that of vehicles without the parking brake.

5.2.3 Fan Drive

The drive ratio and clutch, if used, control fan rotational speed. Additionally, the drive acts as the path to transmit mechanical vibration to the fan.

5.2.3.1 Type

Gear or belt, fixed or clutch (on-off, modulated engagement or viscous including electro-viscous), hydraulic motor, electric motor (variable or incremental speed changes).

5.2.3.2 Ratio

Fan speed to engine speed ratio.

5.2.3.3 Position

Fan mounting position on end of crankshaft, on water pump shaft, or remote mounted fan spindle.

5.2.3.4 Fan Mounting

Fan mounting surface or spacer configuration.

5.2.3.5 Lumped-Mass Effect

The lumped-mass effect of a fan and clutch assembly can produce water pump or fan accessory drive bearing vibration inputs due to mounting offsets or imbalance.

5.3 Instrumentation

This section considers the preparation and instrumentation of the subject fan and the selected test vehicle.

5.3.1 Strain Gage Location

It is important that strain gages are placed at all of the highly stressed locations on the subject fan. Several methods exist for determining gage location. The best procedure is to employ multiple methods of gage location and to use a generous number of gages. This will reduce the risk that a highly stressed location has been overlooked. The fully strain gaged fan becomes in effect a "master fan." It should be handled carefully during the in-vehicle test and should be safely stored after test completion. Retention of the "master fan" will allow for its use in future in-vehicle tests or to correlate bench durability tests. In the case of an electric cooling fan (ECF) the fan, motor, and shroud frame is identified as the "master fan assembly" and is retained as an assembly.

5.3.1.1 Brittle Lacquer

Strain gage locations are determined by crack patterns developed in a brittle lacquer coating. The brittle coating can be patterned in the test vehicle and/or on a bench test stand. The bench procedure can use rotational and/or axial excitation.

5.3.1.2 Judgment

Gage locations can be determined by past experience with similar fan designs or by analysis of the subject fan design. Contact fan supplier for gage location information.

5.3.1.3 Modal Analysis

Gage locations are along the node lines of the principal modes that are expected to receive the largest amounts of vibrational energy.

5.3.1.4 Finite Element

Gage locations are determined from the computer analysis of a finite element model.

5.3.1.5 Photoelastic

Gage locations are determined from the bi-refrigent pattern in a photoelastic coating on the subject fan.

5.3.1.6 Failures

Gage locations determined by the fatigue crack pattern in a failed fan.

5.3.2 Strain gage life is an important consideration when materials exhibit strain levels much higher than those for which the gage is designed to measure. Typically, a gage provides an accurate indication of strain levels several times above its rated high cycle life, but only for a limited number of cycles, and then typically with a zero shift and a gage factor shift. It is important to understand these characteristics of the gage in use.

5.3.3 Recorded Data

Suitable instrumentation is required to record engine speed, fan speed except when fan is solidly driven on the crankshaft, and strain gage output magnitude and frequency. For a viscous drive, sensor air temperature and clutch housing temperature may be recorded. For a plastic fan (non-metallic) the adjacent air temperature, plastic material temperature and temperature of fan mount material in contact with fan are required.

5.3.3.1 Instruments for speed measuring shall have a demonstrated accuracy within 1.0% of the value being measured or within 10 rpm, whichever is greater.

5.3.3.2 Instruments for temperature measuring shall have a calibrated accuracy within 3 °C and shall have scale divisions of 1 °C or smaller.

5.3.4 Vehicle Measurements

Specific measurements may be made on the selected test vehicle so that the following factors will be known.

5.3.4.1 Fan Drive Break-In

New friction disks in fan drives may require a break-in period.

5.3.4.2 Belts

Adjust belt tension on all accessory drives including the fan drive to the specified maximum. New V-belts may require a break-in period. For serpentine belts with spring tensioners, consider the effects of low limit and high limit springs.

5.3.4.3 Fan Mounting

Record the axial runout of the fan drive mounting surface and the radial runout of the fan drive pilot.

5.3.4.4 Fan to Shroud

Record radial tip clearances at top, bottom, and both sides. Record the axial position of fan in fan shroud. Record the fan to radiator clearance.

5.4 Vehicle Test

The intent of the in-vehicle fan test is to record fan strains while vehicle operational duty cycle conditions and the fan operating environment are varied in a systematic way. This will determine the combination of factors that cause the highest fan strains.

5.4.1 Vibration Sources

Determine the effect on fan strains for different vibration input conditions.

5.4.1.1 Engine Load

Test with engine at full load, partial load, and no load conditions.

5.4.1.2 Engine Speed

Test condition of maximum speed (governed speed or rated speed and a specific over speed) and speed transients due to automatic or manual transmission shifting including the effects of down-shifting. Test engine start-up, shut-down, idle, and specific below idle speed conditions. Scan the engine operating speed range in a continuous sweep mode in each transmission gear position to identify fan resonances and maximum fan strain amplitudes.

5.4.1.3 Accessories

Test the effect of the on-off duty cycle of various accessories.

5.4.1.4 Fan Clutch

Determine the effect of the fan clutch operating modes: fully engaged, disengaged, mechanically locked, and/or on-off transients. Note also that the speed of clutch engagement can impart an inertial impulse loading to the fan blades.

5.4.1.5 Fan Drive

Test with fan mounting components (water pump, spacer, fan drive) that produce the maximum allowable radial and axial runout.

5.4.1.6 V-Belts

Test with both a "loose" belt tension condition and with an over-tightened belt tension condition. This is applicable to the fan drive belts and to all accessories.

5.4.2 Obstructions

Determine the effect on fan strains caused by obstruction changes.

5.4.2.1 Accessories

Selectively remove individual accessories to determine their obstruction effect on fan strains.

5.4.2.2 Radiator Core

Determine effects of change in air flow restriction caused by an optional core. Simulate the restriction increase due to core clogging in service.

5.4.2.3 Radiator Shutters

Effects of shutters open, closed, and partially open if the modulating shutter type is used.

5.4.2.4 Winter Front

Test the effect on fan strains caused by the use of winter fronts or cardboard.

5.4.2.5 Shroud

Test for the effects of an optional fan shroud.

5.4.2.6 Heat Exchanger Core

Test for the obstruction effect on fan strains by selectively removing optional heat exchanger cores.

5.4.3 In-Service Evaluation

Simulate special conditions occurring during typical vehicle operation.

5.4.3.1 Shock

Effects on road, cargo loading, or auxiliary equipment caused shock inputs.

5.4.3.2 Water Splash or Fording

Can be significant source of low cycle or non-fatigue fan destructive stresses.

5.4.3.3 Dirt Build-Up

Can cause vibration due to rotating imbalance of fan.

5.5 Analysis

5.5.1 The strain data gathered during in-vehicle testing must be analyzed to be useful to the engineer. SAE J1099 provides information that is useful in the analysis of service load and/or strain data. It also contains a list of references that have proven useful in the analysis of fatigue data.

5.5.2 Particular attention should be paid to the fact that properties of non-metallic materials vary significantly with temperature, humidity, environmental factors, and manufacturing conditions. Any analysis should consider the effect of these variations on both measured strain levels and product suitability.

6. DURABILITY (LABORATORY) TEST METHODS

6.1 Scope

Durability tests in a laboratory environment can be used to complement in-vehicle strain gage testing. Conditions which might be impossible to obtain during testing in the application can be simulated somewhat more easily in laboratory tests. Historically, durability tests have been used to “prove” that a fan will survive for some acceptable length of time under the worst conditions recorded while testing in the application. Testing can also evaluate areas inaccessible to conventional strain gage measurements. Durability testing, with the ability to control and increase strain levels, can demonstrate design factors at loads greater than anticipated service. Bench testing allows evaluation of the fan at a greatly accelerated rate compared to the rate of most in-vehicle testing.

6.2 Methods

A variety of bench tests are used to evaluate fans. It is difficult for any one test to accurately reproduce every operating characteristic. The user must select the method(s) that satisfy his/her durability criteria. Since it is accepted that fan durability considerations are associated with fatigue, the methods outlined are generally designed to evaluate endurance characteristics. Consider that combined stresses may be more damaging than what an individual test may indicate. Therefore, sometimes a vehicle durability test is advised.

In most cases, the goal of the test setup would be to reproduce the “worst case” in-application strain condition (magnitude, direction, frequency). This should be accomplished while reasonably duplicating the in-application test conditions of speed, temperature, and humidity. With non-metallic fans, given the damping characteristics of some molded materials, difficulty may be encountered in simulating engine-induced vibrations with aerodynamic obstructions.

6.2.1 Non-Rotational Resonant Test

The test fan is mounted at the pilot and bolt circle and loaded axially through the range of amplitude and frequencies of interest. This method may not accurately reproduce all modal conditions and will not include strains produced by centrifugal loading.

6.2.1.1 Equipment (Shaker Table)

The vibrator should be capable of accepting various fan mounting arrangements with normal input loading from 50 to 500 N and a frequency range of 25 to 500 Hz, preferably in all directions (x-, y-, and z-directions).

Heating and cooling provisions should be made for maintaining the temperature of a non-metallic fan during a test since resonant frequency can change with material temperature.

6.2.1.2 Instrumentation

A method of monitoring frequency and strain amplitudes that will accurately relate the test conditions to the in-vehicle conditions is required. Additionally, the use of a strobe light and frequency analysis may aid in the test evaluation.

6.2.1.3 Fan Attachment Method

The fan mounting should be a close representation of that found in the vehicle (that is, hub, spacer, clutch, etc.). This assembly is mounted to the driving member of the loading source. If the test assembly must be suspended, use caution to minimize the frequency effects on the test results.

6.2.1.4 Durability Test

Mount the “master fan” used in the vehicle analysis and set the test stand to simulate the frequency mode of vibrating and the highest dynamic strain level observed during the vehicle test. Because the minor variations of physical conditions of nominally identical parts can cause small changes in resonant frequencies, each test fan should be gaged to insure operation at the required test condition. Replace the “master fan” with the test fan and adjust frequency if necessary to maintain peak resonance. Other than frequency, all test conditions must remain as set up with the master fan. Monitor equipment to ensure that conditions remain stable during testing. Strain levels higher than anticipated can also be tested.

6.2.2 Rapid Cycle Test

This test rotates the fan from zero or a low speed to some predetermined maximum speed and back again. The test has limited applications, but can be used for flex fans and to simulate some unusual in-vehicle situations primarily encountered with viscous drives and other add-on clutches.

6.2.2.1 Equipment

Test stand can be driven with an electric motor and should be capable of adjusting the acceleration, maximum speed, deceleration, and dwell time. Test stand power requirements may be substantially higher than the in-vehicle rating of the fan.

For non-metallic fans, a “closed loop” air path should be included, with means for heating and cooling the contained air, plus a temperature monitor and control system. Facility to maintain moisture level in the test part may be required.

6.2.2.2 Instrumentation

A method of monitoring frequency and strain amplitudes that will accurately relate the test conditions to the in-vehicle conditions is required. The use of a strobe light and frequency analyzer may aid in the test evaluation. Additionally, methods of measuring speed and acceleration/deceleration will be required.

6.2.2.3 Fan Attachment Method

The fan mounting should be a close representation of that found in the vehicle (that is, hub, spacer, clutch, etc.). This assembly is mounted to the driveshaft. Use caution to minimize the frequency effects of the slip ring or adapters on the test results.

6.2.2.4 Durability Test

Mount the “master fan” used in the vehicle analysis and adjust the test stand to duplicate both frequencies and highest strain levels observed during the vehicle test. Replace the “master fan” with a test fan before testing. Monitor acceleration, speeds, and deceleration to ensure that conditions remain stable during the test.

6.2.3 Torsionally Loaded Rotating Test

This test rotates the fan at some constant operating speed while applying a torsional vibration to the driveshaft. The test can accurately duplicate centrifugal loads while accumulating stress cycles very rapidly. Durability of the test equipment can be a problem.

6.2.3.1 Equipment

The test stand can be driven with an electric motor. The fan shaft may be driven through “U” joints or off-center pulleys or other methods to produce the torsional loads. Hydraulically driven, torsional actuators are also available with load and frequency capabilities suitable for fan testing. Speed and power capabilities should reproduce all possible vehicle conditions. It should be noted the “U” joint excited tests may be limited to lower fan speeds because of joint durability problems.

6.2.3.2 Instrumentation

A method of measuring speed, frequency, and strain amplitude that will accurately relate the test conditions to the in-vehicle conditions is required.

6.2.3.3 Fan Attachment Method

The fan mounting should be a close representation of that found in the vehicle (that is, hub, spacer, clutch, etc.). This assembly is mounted to the driveshaft. Use caution to minimize the frequency effects of the slip ring or adapters on the test results.

6.2.3.4 Durability Test

Mount the “master fan” used in the vehicle analysis and set the test stand to simulate the frequency and speed at the highest strain levels observed during the in-vehicle test. Because the minor variations of physical conditions of nominally identical parts can cause small changes in resonant frequencies, each test fan should be gaged to insure operation at the required test conditions. Normally one to four gages are sufficient. Replace the “master fan” with a test fan and adjust the speed, if necessary, to maintain peak resonance. All other conditions must remain as established with the “master fan.” Monitor equipment to maintain stability during testing. Strain levels higher than anticipated service can also be tested.

6.2.4 Obstruction Loaded Rotating Test

This test rotates the fan at some constant operating speed while applying air loaded vibrations by placing obstructions in front and/or behind the fan. The test can accurately duplicate centrifugal loads while accumulating stress cycles very rapidly.

6.2.4.1 Equipment

The test stand can be driven with an electric motor. Radiators, shutters, shrouds, and other vehicle components can be evenly or unevenly spaced and used to further increase strain levels. Speed and power capabilities should reproduce all possible vehicle conditions.

For non-metallic fans, a “closed loop” air path should be included, with means for heating and cooling the contained air, plus a temperature monitor and control system. Facility to maintain moisture level in the test part may be required.