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Heavy-Duty Nonmetallic Engine Cooling Fans—Material, Manufacturing, and Test Considerations

Foreword—This Document has not changed other than to put it into the new SAE Technical Standards Board Format. Definitions were changed to Section 3. All other sections have been renumbered accordingly.

This SAE Information Report is intended to serve as a supplement to SAE J1390.

Nonmetallic 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. Among the engine cooling applications commonly described as heavy-duty (trucks, buses, construction equipment, industrial equipment, and agricultural equipment), the most widely used combination has been injection-molded, glass-fiber reinforced nylon. This report will address only that combination, hereinafter referred to simply as “nonmetallic” or “nylon” fans.

The usage of nonmetallic construction necessitates areas of evaluation not required by metal designs. Chief among these are temperature extremes, moisture content, impact resistance, chemical attack, material purity/ homogeneity, and aging/weathering. Areas of evaluation affecting both metallic and nonmetallic fans, but requiring somewhat different approaches with nonmetallic parts, include manufacturing quality assurance, dimensional consistency, assembly integrity, natural frequency determination, and durability testing.

1. Scope—The following topics are included in this report:

Section 2—References
Section 3—Definitions
Section 4—Material Selection
Section 5—Production Considerations
Section 6—Initial Structural Integrity
Section 7—In-Vehicle Testing
Section 8—Laboratory Testing

The Material Selection section lists environmental factors and material properties which should be considered when determining appropriate fan material(s) for a given application.

The Production Considerations section covers various aspects of machine selection, mold design, and process control.

The Initial Structural Integrity section lists factors which should be considered in addition to those covered by Section 3 of SAE J1390.

The In-Vehicle Testing section lists factors which should be considered in addition to those covered by Section 4 of SAE J1390.

The Laboratory Testing section addresses some test considerations and methods for nonmetallic fans which differ from those used with metallic fans or which were not included in Section 5 of SAE J1390.

1.1 Purpose—This report exists to identify general methodology which addresses the areas of evaluation listed previously for injection-molded nylon fans. It is envisioned that those working with other processes and/or materials can use SAE J1390 and this document as starting points in the development of structural analysis methodology pertinent to their particular combination(s).

2. References

2.1 Applicable Publications—The following publications form a part of this specification to the extent specified herein. Unless otherwise indicted the latest revision of SAE publications shall apply.

2.1.1 SAE PUBLICATION—Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096-0001.

SAE J1390—Engine Cooling Fan Structural Analysis Recommended Practice

2.1.2 ASTM PUBLICATION—Available from ASTM, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959.

ASTM D 618—Method for Conditioning Plastics and Electrical Insulating Materials for Testing

3. Definitions—The following terms relating to injection molding of plastics are used:

3.1 Barrel, Liner and Screw—Components of the plasticizing cylinder of an injection-molding machine in which the material is melted and moved forward to the injection nozzle.

3.2 Weld or Knit-Line—The area of a molded plastic part, formed by the union of two or more streams of plastic flowing together.

3.3 Cold Slug Flow—Condition where insufficient heating of plasticizing cylinder results in unmelted pellets appearing in the molded part.

3.4 Flash—The excess plastic material that is forced from a mold cavity during the molding operation. Flash may also occur between worn mold sections.

3.5 Gate—An orifice or opening through which the melted plastic material enters the cavity.

3.6 Surface Drag—Skidding of plastic resin along surface of mold due to improper mold temperatures, injection pressure, or injection speed.

3.7 Stress Whitening—An effect noted in nylon (crystalline 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. *Material Selection*

4.1 Scope—All materials classified as nylons share certain basic characteristics. However, even within the seemingly limited realm of glass-fiber reinforced nylons, many levels and combinations of physical, thermal, and environmental resistance properties are available. These properties result from such factors as the following:

a. Type of nylon (6, 6/6, 6/10, 6/12, etc.)
b. Percentage (by weight) of glass fibers
c. Diameter and length of glass fibers
d. Wetting agent used to promote adhesion between resin and fibers (if present)
e. Heat stabilizer (if present)
f. Impact modifier (if present)
g. Pigmentation (if present)

In order to select a material with appropriate characteristics, the prospective manufacturer and end user should investigate the proposed application thoroughly, and maintain open communication with the various material suppliers.

4.2 Application Factors—Evaluate the following characteristics, as applicable, for all materials used in the fan assembly:

4.2.1 Temperature extremes—highest and lowest

4.2.2 Relative humidity (relative to material moisture content)

4.2.3 PHYSICAL PROPERTIES

4.2.3.1 Tensile strength

4.2.3.2 Tensile fatigue strength

4.2.3.3 Tensile modulus

4.2.3.4 Flexural fatigue strength

4.2.3.5 Flexural modulus

4.2.3.6 Low-temperature impact resistance

4.2.3.7 Ignition temperature

4.2.3.8 Noncombustibility or self-extinguishing

4.2.3.9 Flame propagation

4.2.3.10 Any other depending on application

4.2.4 THERMAL PROPERTIES

4.2.4.1 Heat distortion temperature

4.2.4.2 Expansion characteristic

4.2.5 CHEMICAL RESISTANCE

4.2.5.1 Petroleum products

4.2.5.2 Coolant

4.2.5.3 Other vehicular fluids

4.2.5.4 Cleaning solvents

4.2.5.5 Paint(s)

4.2.5.6 Molded-in component(s)

4.2.5.7 Salt spray

4.2.5.8 Any others depending on application

4.2.6 AGING/WEATHERING

4.2.6.1 Exposure to sunlight

4.2.6.2 Exposure to ozone

4.2.6.3 Heat cycling

4.2.6.4 Abrasion

4.2.6.5 Storage and shipping

4.3 Manufacturing Factors—Evaluate the following characteristics of the material and process:

4.3.1 Dimensional stability

4.3.2 Melt temperature

4.3.3 Abrasiveness (tool wear)

4.3.4 Sensitivity to moisture content

4.3.5 Molded-in stresses

4.3.6 Any others of concern to manufacturer

5. Production Considerations

5.1 Scope—The fan mold and injection-molding machine used must be properly designed or selected to manufacture a consistent product. Similarly, the manufacturing process must be capable of yielding a consistent product. Unless this consistency can be assured, further testing would be fruitless.

5.2 Machine Selection—The type of material to be processed will determine certain machine characteristics which are critical to consistent production. These include:

5.2.1 MECHANICAL OPERATION OF THE MACHINE

5.2.1.1 Proper barrel, liner, and screw for material type

5.2.1.2 Temperature control

5.2.1.3 Injection pressure, stroke, and rate

5.2.1.4 Shot capacity versus shot size

5.2.1.5 Clamping force (machine "tonnage")

5.2.2 SUPPORT EQUIPMENT

5.2.2.1 Material driers

5.2.2.2 Chillers or heaters to regulate mold temperature

5.3 Mold Design—Part design and material selection will determine mold design. Factors considered include:

5.3.1 Physical stability of the mold is essential.

5.3.1.1 No deflection in the mold base during operation

5.3.1.2 No shifting of molded-in components (inserts) during molding

5.3.1.3 Proper ejector pin operation and location

5.3.1.4 General fit and proper shut-off in all areas

5.3.1.5 Proper construction and hardening to reduce wear

5.3.2 Gate location can be important due to several factors:

5.3.2.1 Material flow and fiber orientation

5.3.2.2 Knit lines

5.3.2.3 Cold slug flow

5.3.2.4 Type of gate and size for material and reinforcement

5.3.2.5 Aesthetics

5.3.3 Proper venting

5.3.4 Material shrinkage characteristics

5.3.5 Proper control of temperature in all areas of the mold

5.3.6 Cavity pressure and temperature sensors can be installed for process control.

5.3.7 Simulation of mold filling using mold flow analysis software is recommended as a methodology for early detection of molding problems.

5.4 Process Control—Every step of the manufacturing process should be closely monitored.

5.4.1 MATERIAL CONTROL

5.4.1.1 Inspect containers for shipping damage and possible contamination.

5.4.1.2 Obtain material lot certification.

5.4.1.3 Infrared spectrophotometry can supply a quick check of material purity.

5.4.1.4 Consider molding test bars for evaluation of physical properties.

5.4.2 Establish a policy regarding the use of reground material.

5.4.3 Assure proper drying of materials.

5.4.4 Assure proper purging of machines to eliminate contamination of materials in the machine.

5.4.5 Assure proper screw/liner clearance to minimize destruction of reinforcing material (glass fibers).

5.4.6 Assure proper barrel and nozzle temperature.

5.4.6.1 For proper cavity fill

5.4.6.2 To avoid material degradation

5.4.7 Monitor material residence time at high temperatures to avoid degradation.

5.4.8 Monitor material flow indications on the molded part.

5.4.8.1 Note slug flow.

5.4.8.2 Check for surface drag.

5.4.8.3 Check for glass fiber dispersion and orientation.

5.4.8.4 Check for burned or scorched material.

5.4.8.5 Check for flash on edges, ejector pins, or molded in holes.

5.4.8.6 Check knit or weld lines.

5.4.8.7 Check match to molded-in components.

5.4.9 Assure proper gate trim.

5.4.10 Monitor any secondary part trimming.

5.4.11 Assure proper date coding.

5.4.12 Assure molded-in components are properly prepared.

5.4.12.1 Precise location in the mold

5.4.12.2 Fit

5.4.12.3 Surface preparation

5.4.12.4 Temperature compatibility

5.4.12.5 No other detrimental effects on the molded part

5.4.13 Monitor part weight and maintain within acceptable variation. Part weight is a good indicator of process stability.

5.4.14 Monitor part balance and maintain within drawing tolerance. Balance is a good indicator of process stability.

5.4.15 Penetrating dyes, x-rays, sectioning, etc., can be used to check for voids or fit of molded-in components.

5.4.16 Dimensional checks should be performed at the start of each production run, and thereafter on a sampling basis in accordance with customer requirements.

5.4.17 Statistical process control techniques are encouraged wherever applicable.

6. Initial Integrity

6.1 Same as SAE J1390 with the following additions:

6.1.1 ADDED TO PARAGRAPH 4.3.1—Natural frequencies of a nonmetallic fan can also be affected by variations in the following:

e. Ambient temperature
f. Moisture content
g. Orientation of reinforcing fibers (if present) and
h. Material homogeneity due to molding process variations

7. In-Vehicle Testing

7.1 Same as SAE J1390 with the following additions:

7.1.1 ADDED TO PARAGRAPH 4.3.2—Relative humidity and temperature of air at the fan inlet and fan material temperature should be recorded for nonmetallic fans.

7.1.2 ADD PARAGRAPH 4.4.3.4—Varying degrees of moisture content of nonmetallic test fan.

7.1.3 ADDED TO PARAGRAPH 4.4.3.5—Varying operating temperature, which affects natural frequencies and mechanical properties of nonmetallic materials.

7.1.4 ADDED TO PARAGRAPH 4.5—Particular attention should be paid to the fact that properties of nonmetallic materials vary significantly with temperature, humidity, environmental factors, and manufacturing conditions (Reference Section 4). Any analysis should consider the effect of these variations on both measured strain levels and product suitability.

7.2 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 can give a good indication of strain levels several times 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.

8. Laboratory Testing

8.1 Scope—Laboratory testing can serve several purposes in the validation of a fan for an application. Historically, it has 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. Laboratory tests can be configured to subject the fan to loads above anticipated use.

Conditions which might be impossible to obtain during testing in the application can be simulated somewhat more easily in laboratory tests. Finally, laboratory testing usually allows evaluation of fan characteristics in a shorter time than is possible with field testing.

8.2 General Test Concerns

8.2.1 Conditioning of nonmetallic fans prior to a test can be as important as the test procedure itself. In the Dry as Molded (DAM) state, some properties are at their maximum value while others are at their minimum. At the other extreme, when saturated with moisture, these physical property values can change by large percentages. In actual fan applications, neither of these conditions is likely to exist.

Depending on the particulars of a given operating environment (ambient temperature, average relative humidity, duty cycle, etc.), a nonmetallic fan will tend to stabilize somewhere between these extremes. It should be recognized, when designing a laboratory test, that conditions which subject the test fan to very high or very low relative humidity (hence moisture content) add severity to the test.

8.2.2 Temperature also plays an important role, since important physical properties of the material vary greatly with test ambient. Percent changes in property values can be several times as large as those due to moisture content changes. Test severity is sensitive to small changes in test temperature, particularly at elevated temperatures.

8.2.3 Test length must also be considered, since the deformation characteristics of plastics include elastic, viscoelastic, and viscous components, the latter two of which are time dependent.

8.2.4 Strain rate dependence of the material in question, how the strain is induced to the part, and its magnitude with respect to material fatigue characteristics are all very important to understand prior to undertaking any accelerated testing. Accelerated testing may give erroneous results by understating material life.

8.2.5 Combination of the factors outlined previously must be considered.

8.2.6 Sequencing of tests may be considered.

8.3 Humidity Soak—Dynamic testing of nonmetallic fans should preferably be conducted using conditioned fans, since the Dry As Molded (DAM) condition is unlikely to occur in any application. Conditioning in accordance with (or equivalent to) ASTM D 618A is suggested as an absolute minimum. Longer exposure to ambient humidity, or conditioning in water (such as ASTM D 618D), is preferred. Prior to using an alternate moisture conditioning routine, it is necessary to understand the potential hydrolysis effects on the material in question. Saturation moisture content, for example, can be obtained by boiling in water until part weight stabilizes. The rate of moisture absorption is temperature dependent, with hot water being absorbed more quickly than cool water. Similarly, hydrolysis effects (if present) vary with conditioning temperature and rate.