

GM MOVES TOWARD COMPOSITE TRANSMISSION CROSS-MEMBER FOR FULL-SIZE TRUCKS

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Abstract

General Motors' next generation full-size truck frames are currently 80 pounds over their targeted weight. By replacing the current steel transmission cross-member on General Motors' full-size trucks through the application of a composite material transmission cross-member, a substantial weight reduction will be achieved. Reducing the weight of General Motors' full-size trucks will consequently increase the fleet-wide fuel economy for the company's truck line, allowing CAFE requirements to be met more easily.

Problem Topic

Distributing lighter products to customers is a concern for many automobile manufacturers. Lighter vehicles reflect increased performance, fuel economy, and overall customer awareness. This project was designed to determine the feasibility of applying a composite material transmission cross-member on full-size light-duty trucks.

A composite material has never been chosen for the fabrication of a full frame structural component on General Motors' full-size trucks. A composite material transmission cross-member will be lighter than the current cross-member, which is constructed out of steel.

Benefits

By establishing a mass reduction on full-size trucks, General Motors can advertise attractive aspects such as increased performance and fuel economy. Other benefits may include savings in piece cost and tooling investments.

The most beneficial result, by reducing vehicle weight, is the increase in that program's fuel economy, accomplishing a higher fleet-wide average fuel economy for light-duty trucks. With a higher fleet-wide average fuel economy, the Corporate Average Fuel Economy (CAFE) standards will be easier to meet. It is important to meet CAFE standards to avoid penalizations.

Criteria and Parameter Restrictions

Transmission cross-members are evaluated and restricted from many different aspects, for many different reasons. This list includes, but is not limited to, the following areas of evaluation: stiffness, fatigue, mobility, vibration, interior noise, heat deflection, and durability. The scope of this project is limited to the evaluations of stiffness, vibration, noise, and heat deflection. Standards and requirements for newly designed composite material transmission cross-members will not change from the current specifications.

Selecting a Composite Material

Composite materials are attractive to the automotive industry because they are lightweight and provide strength. Decreasing a vehicle's weight could reduce emissions and require less fuel. Composites can be made with increased material stiffness and decreased mechanical deformation. Vehicle components, made of structural composites, reduce weight and still provide strength to that component. Compared to steel structures, composites provide high stiffness-to-

weight and strength-to-weight ratios. Composites can be configured into complex shapes at lower costs, and maintain functionality during the duration of component life due to high corrosion resistance.

Recently composites have been growing in many different industries replacing various materials. Reinforced with stiff fibres and particles, composites are a polymer matrix. Although composites are stiff and strong, they are capable of becoming weak in increasing temperatures because they are bound by polymers. Understanding that fibres and particles are used to reinforce the polymer matrices to make composites, it is important to understand both, the different possible polymer matrices and the different possible reinforcements that can be used to assemble a composite. These polymer matrices are formed as either thermoplastics or thermosets.

Due to the structural advantage provided by thermosets, a glass reinforced polyester application has been chosen for evaluation. This application is in the form of sheet moulding compound (SMC). Glass fibre reinforcement has been chosen because it provides adequate strength and stiffness and mechanical properties are retained at higher temperatures. Competitive pricing of glass fibre has allowed the use of this application to be more feasible than using carbon fibre reinforcement.

SMC

Sheet Moulding Compound (SMC) is a composition of glass fibres, resin, and filler. It is an integrated, ready-to-mold composition. This particular SMC was fabricated using a metering polyester resin on a thin plastic film. This film acts as the carrier for the polyester. The polyester resin system includes a catalyst to enhance curing, a filler, and thickening and mold release agents. Adjustable blades control the thickness and width of the resin on the film. Continuous glass fibres are fed into a chopper assembly and deposited onto the resin paste. Then the resin paste is conveyed on the plastic carrier film. A second layer of resin on another carrier film is then placed on top creating a sandwich of polyester resin. This sandwich is fed through compaction rollers to uniformly distribute the resin and to ensure wetting of the glass.

Applications of SMC are specified by engineers who prefer the material's cost-performance advantages over steel. SMC allows the consolidation of several parts, reducing the need for subassemblies. SMC can provide one single, molded unit. The engineer's design of the composite material transmission cross-member requires the production of two separately molded units. This is still an advantage from the current design, which requires the welding of three separate steel units.

Sheet Moulding Compound is lightweight, stiff, and strong all at the same time. It offers high strength-to-weight and stiffness-to-weight ratios.

Less expensive SMC tooling can also be made faster than tooling for sheet steel. Automotive companies have found this to be most attractive when looking for ways to differentiate the appearances of car and truck models.

Glass Fibres

Glass-reinforced composites are commonly engineered using E-glass fibre and thermoset polyester resin. The primary purpose of adding glass fibre to thermoset plastics is to increase the polymer matrix's tensile strength, flexural strength, modulus, and impact strength. For the purpose of this project the engineer has chosen to use E-glass to fabricate the transmission cross-member.

Reinforcement is achieved by transferring the stress, under an applied load, from the weak polymer matrix to the much stronger glass fibres. Under stress, the elongation of the glass fibres

must be less than that of the polymer matrix to acquire an efficient reinforcement. While also under stress, the modulus or stiffness must be higher than that of the polymer matrix.

Many mechanical properties of SMC can vary depending on the amount, length, and orientation of the glass fibres in the resin mixture. Generally the isotropic oriented glass fibres are 25 to 30 percent of the SMC by weight. For increased strength, the transmission cross-member is 50 percent glass by weight.

The glass fibres chosen for the fabrication of the transmission cross-member are chopped and randomly oriented. For developmental research, this decision was made to discover which directions could use more fibrous reinforcement if necessary.

Sizing efficiency, fibre content, length, orientation, and diameter of the glass fibres are responsible for the mechanical properties of reinforced composite materials. As glass fibre content increases, material strength will increase. As indicated earlier, the glass fibre content was increased to 50 percent of the SMC by weight. This has increased the composite material's stiffness and strength.

Longer lengths in any given direction will generally allow greater continuity of stress transfer in that particular direction. The engineer has chosen to use long glass fibres for the reinforcement of the composite material. The lengths of the glass fibres were increased to two inches, which has also increased the material's strength.

Enhancing the transfer of stress along the fibre-matrix interface can be accomplished by the use of chemically coating the individual glass fibres. Decreasing the diameter of the glass fibres can also increase the amount of stress transfer. Smaller diameter glass fibres provide increased fibre surface area, which maximizes the stress transfer for any given reinforcement content.

Ideally the direction and orientation of the fibres should be arranged in the same direction of induced stress. This will optimize load-carrying capabilities. Unfortunately, this information is not yet available to the engineer. For this reason, the use of randomly oriented chopped fibres have been chosen.

Thermoset Polyester

Unsaturated polyesters are versatile in properties and are widely used in many different applications. It was the polymer matrix chosen to manufacture the composite material transmission cross-member. The actual material name given by Quantum Composite is QPC-1977.

QPC-1977 is a modified polyester engineered structural composite (ESC) molding compound that is designed for applications requiring high strength, fire retardance, and resistance to elevated temperatures. QPC-1977 offers fast molding cycles and adequate surface appearance.

Unsaturated polyester resin is dissolved in a crosslinking monomer, which contains an inhibitor to prevent crosslinking until the resin is ready to be used for fabrication. Using different ingredients will determine the properties of the resin.

Unsaturated polyester is the condensation product from an unsaturated dibasic acid and a glycol. This unsaturated dibasic acid is usually maleic anhydride. By adding a saturated dibasic acid such as isophthalic acid, adipic acid, or phthalic anhydride, the degree of unsaturation will vary. Commonly the type of glycol used is either propylene glycol, ethylene glycol, diethylene glycol, dipropylene glycol, or neopentyl glycol (G. R. Bell • Kettering University, personal communication, February 2003).

As for the crosslinking monomer, styrene is most commonly used. However, vinyl toluene, methyl methacrylate, alpha methyl styrene, and diallyl phthalate could also be used as the crosslinking monomer (G. R. Bell • Kettering University, personal communication, February 2003).

To achieve flame-retardance chlorendic anhydride, tetrabromophthalic anhydride, and dibromoneopentyl glycol is used. To obtain chemical resistance isophthalic acid, neopentyl glycol, trimethylpentanediol, and hydrogenated bisphenol A is used. To achieve weathering resistance neopentyl glycol, methyl methacrylate, and ultraviolet absorbers are used. Common ultraviolet absorbers are benzophenone and benzotriazole (G. R. Bell • Kettering University, personal communication, February 2003).

Newly Designed Transmission Cross-member

To optimize the composite transmission cross-member's structural performance, the engineer redesigned the geometrical shape of the current process. The new design of the cross-member allows simple manufacturing techniques to fabricate the entire application. The new cross-member is fabricated using two separate pieces: an upper section and a lower section, which replaces the current three-piece application. These two sections are designed to be adhered using an epoxy adhesive system called 5300 Black/5330.

Additional strength and stiffness were made possible by increasing the wall thickness of the upper section of the composite transmission cross-member. Due to clearance issues, most of the exterior geometrical shape could not be changed. Except for increasing the height of the cross-member, most of the increased wall thickness was added to the interior cross section of the transmission cross-member. The height of the upper section could be increased because there is no stiffener plate added to the top of the engineer's new design. This allowed the top of the upper section to be positioned where the stiffener plate was located on the current design.

Additional strength and stiffness were also made possible by increasing the wall thickness of the lower sections of the transmission cross-member. Due to clearance issues, most of the exterior geometrical shape could not be changed. Most of the increased wall thickness was added to the interior cross section of the transmission cross-member.

Aluminum spacers and pads were added to replace the steel binocular bushings on the current design.

Weight Evaluations

The total weight of the steel transmission cross-member is 19.5 pounds. The total weight of the composite transmission cross-member is 8.5 pounds. The engineer has accomplished an eleven-pound savings in one single component through the application of a composite material.

Conclusions

After reviewing the vibration results, the engineer observed minor fore/aft, lateral, and vertical vibration differences between the current transmission cross-member and the composite material cross-member. Although only minor vibration differences were discovered between the steel and composite cross-members, component will be refined to continuously improve and enhance the quality of GM's products.

When the composite transmission cross-member is refined to improve vertical characteristics, the cross-member will be more resistant to vertical deflection. This will reflect compatible vibration behavior, and General Motors will proceed to execute durability performance.

Introducing composite materials to automotive frame applications is very exciting to General Motors. This composite transmission cross-member is very appealing to GM, and the company desires to advance in the development of more weight efficient frame applications.