COST EFFECTIVE USE
OF CARBON FIBER SMC

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Abstract

Viper demonstrated the capability of carbon fiber SMC and the benefit it offers high performance vehicles. That was an important and necessary first step for the broader use of carbon reinforced composites in the automotive industry. The next critical step for carbon fiber SMC (CFSMC) is to make it cost competitive. Only then can CFSMC move beyond high performance vehicles and into the broader automotive market.

In the broader market, with lower performance requirements, CFSMC is not cost competitive. However, there is a great deal of work being done, all along the supply chain, to address the key cost drivers for CFSMC. Once the competitive cost targets are reached, CFSMC will be able to compete with glass reinforced SMC as well as Aluminum.

In the mean time, there is a cost effective approach for using CFSMC in current parts and new applications, that need increased stiffness. The key is to use CFSMC where it provides the maximum benefit, at the lowest cost.

Cost Drivers

For the carbon fiber supplier, the high cost of the PAN precursor and the slow process of thermal pyrolysis used to convert PAN into carbon fiber, are the main cost drivers for carbon fiber. The price of carbon fiber has dropped dramatically in the last several years. However, "the automobile industry is not interested in using them until the price of carbon fiber drops from $8 to $5 (and preferable $3) a pound."[1] A great deal of research is being done in this area to break through this cost barrier.

For the CFSMC supplier, the main cost drivers are the high cost of carbon fibers, the cost of compatible resin systems and the higher cost of short production runs. Although the cost of CFSMC has dropped along with the cost of carbon fiber, at over $10 / lb., it is not cost competitive for most applications. To address the problem, less expensive resins are being investigated along with lower cost carbon/glass hybrid materials. New, more efficient methods for CFSMC production are also being brought on line.

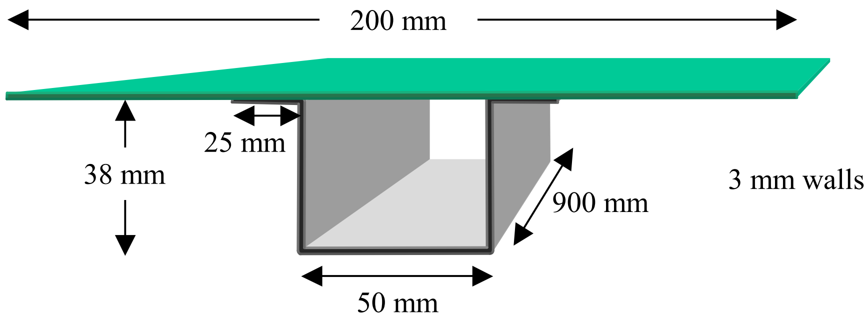
For the molder, the main cost drivers are the high cost of CFSMC, the higher cost of short production runs and the cost associated with additional risk. Increased demand is already addressing the first two issues. The issue of additional risk comes from the fact that commercial molders are not used to molding CFSMC, especially for structural applications. It does not mold the same as glass reinforced SMC. In addition, it costs much more to throw away a scrap part, when it is molded from CFSMC. Experience and the technical support from the material supplier are helping to address this important issue.

Cost Targets for CFSMC

At what price does CFSMC become cost competitive against aluminum? According to the Automotive Composites Consortium newsletter, carbon fiber composites that cost about $2.50 / pound "would place it in contention with aluminum, making it competitive for certain automotive applications" [2].

At what price does CFSMC become cost competitive against glass reinforced SMC? To determine this, a section of a typical bonded assembly was used for analysis. See Drawing A. The assemble is composed of a low density 28% glass SMC skin with an SMC inner support channel bonded onto it.

Drawing A



The COMPAREM™ program [3] is used for the analysis and to determine at what price CFSMC (AMC 8590) would be cost competitive, against low density 28% glass SMC and standard 28% glass SMC. To equalize the performance of the different assemblies, the dimensions of the CFSMC inner channel had to be reduced. In each case, the assemblies have the same stiffness and the assembly with the CFSMC channel is able to carry the same load as the assembly with the glass reinforced channel. This is shown in the Exhibits A and B.

To be cost competitive with low density 28% SMC, CFSMC would have to sell for $2.64 / lb. Refer to Exhibit A.

To be cost competitive with standard 28% SMC, CFSMC would have to sell for $2.83 / lb. Refer to Exhibit B.

These cost targets assume that the entire support channel would be molded from either CFSMC or the 28% glass SMC. Until those competitive cost targets for CFSMC are met, a more efficient approach must be used.

Using CFSMC to Increase the Stiffness of <u>Current</u> Parts

The stiffness, weight and material cost of the assembly shown in Drawing A were compared, using different materials. The weight and material cost of each assembly was determined, using the COMPAREM™ program. Some of the assemblies to be compared, have different mechanical properties along its length. Therefore a beam program was used to determine the deflection of the assemblies under the same uniform load of .172 MPa / 25mm. Assembly strength was not compared since higher strength SMC replaced lower strength 28% SMC in the channel.

The need to reduce vehicle weight and better gas mileage has driven the broader use of low density SMC. Chart A shows that low density SMC offers not only a significant reduction in weight but a reduction in material cost as well. However, there has also been a reduction in panel stiffness, due to the lower modulus of the low density SMC. The change in stiffness and mass has changed the natural frequency of the assembly. This has increased the road noise for some vehicles.

The goal of this paper is to determine the lowest cost approach to increase the stiffness of an existing assembly, without increasing its weight -- using CFSMC. The weight and material cost of the low density 28% SMC assembly will be used as a baseline. The performance goal is to make the low density SMC assembly as stiff as the assembly molded from the standard 28% SMC. Material properties and prices, used in this study, are shown in Chart B. The prices in this study are used for <u>comparison only</u>. Below is the deflection, weight and material cost for the assembly in Drawing A, when molded from low density 28% SMC and standard 28% SMC.

Chart A

	Deflection	Weight	Mtl. Cost
LD 28% SMC Skin **LD 28% SMC** Channel	22.6 mm	1.276 kg	$3.10
Std 28% SMC Skin **Std 28% SMC** Channel	16.0 mm	1.868 kg	$3.50

Chart B

Material	Price / lb.	Specific Gravity	Compression Modulus	Compression Strength	Tensile Modulus	Tensile Strength
LD 28% SMC	$1.10 / lb.	1.30	6,900 Mpa	100 Mpa	7,575 Mpa	72 MPa
Std 28% SMC	$0.85 / lb.	1.90	8,905 Mpa	160 MPa	11,000 Mpa	72 MPa
AMC 8570 (55% Glass & Carbon)	$7.00 / lb.	1.66			35,850 MPa	240 MPa
AMC 8590 (55% Carbon)	$13.50 / lb.	1.48			55,150 MPa	235 MPa

In this paper, CFSMC refers to the AMC 8590 material as well as the glass/carbon hybrid material AMC 8570.

Replacing the 28% SMC channel with a CFSMC channel is not a cost effective approach, as shown below. The stiffness of the assembly has increased significantly, by using CFSMC. However, the material cost has increased significantly as well. Assembly weight increased because the CFSMC has a higher Specific Gravity than the low density SMC. The assemblies with the CFSMC are much stiffer than necessary. The calculated deflection with the AMC 8570 channel is 7 mm & 5 mm with the AMC 8590 channel. The maximum deflection target is 16 mm.

	Deflection	**Weight**	**Mtl. Cost**
LD 28% SMC Skin **AMC 8570** Channel	7.0 mm	1.438 kg	$13.60
LD 28% SMC Skin **AMC 8590** Channel	5.0 mm	1.358 kg	$21.29

The key is to place CFSMC where it provides the most benefit, at the lowest cost. In the case of the Viper Inner Door, the AMC 8590 was only in the critical hinge area. In the case of an assembly like this, the two critical areas are: 1) The bottom of the support channel and 2) The center of the span, between its supports.

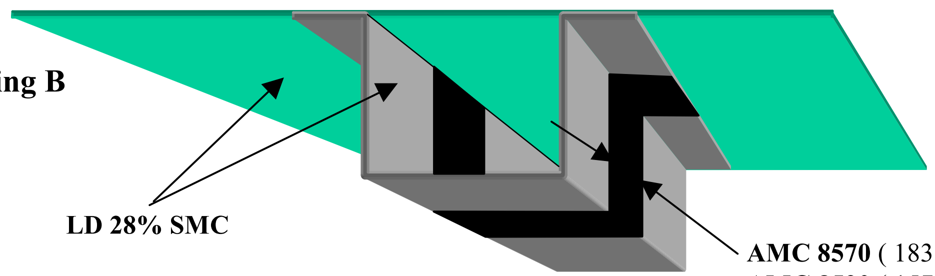
Approach #1) Use CFSMC Along the Entire Bottom of Channel.

The CFSMC and low density SMC are co-molded, with the CFSMC located at the bottom of the channel. The wall thickness is still 3 mm, since the existing molds are being used. The material cost for the assembly using the AMC 8590 has dropped from $21.29 to $9.47, with this approach. However, both assemblies are still much stiffer than necessary. The results are shown below.

	Deflection	**Weight**	**Mtl. Cost**
LD 28% SMC Skin **LD 28% SMC** Mid Channel **AMC 8570** Channel Bottom	9.7 mm	1.327 kg	$6.13
LD 28% SMC Skin **LD 28% SMC** Mid Channel **AMC 8590** Channel Bottom	8.0 mm	1.303 kg	$9.47

Approach #2) Use CFSMC Along the Center Section of the Channel
The CFSMC and low density SMC are co-molded with the CFSMC located across the center of the channel. Refer to Drawing B. The wall thickness is still 3 mm. The length of the CFSMC strip was adjusted until the deflection of the assembly was 16.0 mm. This approach is more cost effective than the first approach and the assembly deflection target has been met. The results are shown below.

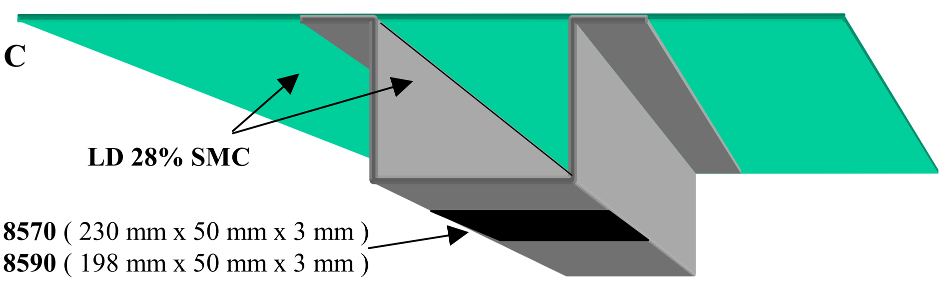
Drawing B



	Deflection	Weight	Mtl. Cost
LD 28% SMC-- LD 28% SMC-- LD 28% SMC LD 28% SMC— AMC 8570 ---LD 28% SMC	15.8 mm	1.340 kg	$5.13
LD 28% SMC-- LD 28% SMC-- LD 28% SMC LD 28% SMC— AMC 8590 ---LD 28% SMC	15.9 mm	1.292 kg	$6.26

Approach #3) Use CFSMC Along the Bottom Center Section of Channel
The material cost for both assemblies can be reduced even more, by combining the first two approaches. The length of the CFSMC strip was adjusted, so the assemblies would meet the deflection target of 16.0 mm. The diagram and results are shown below.

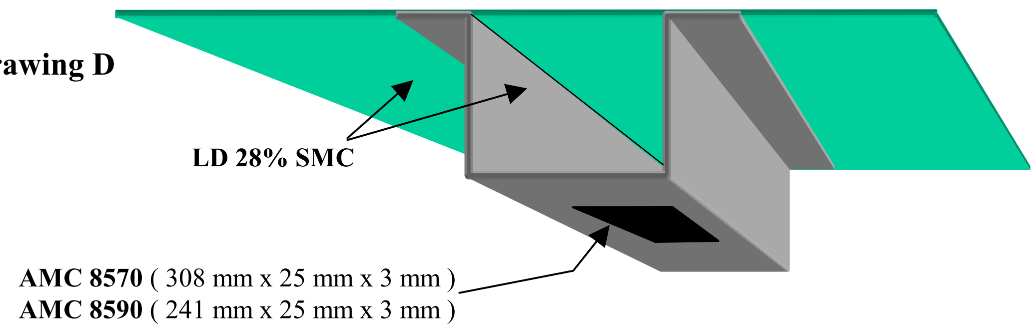
Drawing C



	Deflection	Weight	Mtl. Cost
LD 28% SMC-- LD 28% SMC-- LD 28% SMC LD 28% SMC-- LD 28% SMC—LD 28% SMC AMC 8570	15.8 mm	1.291 kg	$3.88
LD 28% SMC-- LD 28% SMC-- LD 28% SMC LD 28% SMC-- LD 28% SMC—LD 28% SMC AMC 8590	15.8 mm	1.292 kg	$4.47

Approach #4) Use CFSMC Only Along the Bottom Center Section of the Channel – Best Approach
The CFSMC and low density SMC are co-molded, with the CFSMC placed along the bottom center of the channel. The strip of AMC 8590 is longer than the previous approach (241 mm vs 198 mm) but it is only half the width (25 mm vs 50 mm). This approach is by far the most cost effective way to increase the stiffness of an existing assembly -- using CFSMC. This assembly, has the stiffness of the standard 28% assembly with essentially the same weight as the low density 28% SMC assembly. The material cost is only $0.84 higher than the low density SMC assembly. The diagram and results are shown below.

Drawing D



	Deflection	Weight	Mtl. Cost
LD 28% SMC-- LD 28% SMC-- LD 28% SMC LD 28% SMC-- LD 28% SMC—LD 28% SMC AMC 8570	16.0 mm	1.287 kg	$3.61
LD 28% SMC-- LD 28% SMC-- LD 28% SMC LD 28% SMC-- LD 28% SMC—LD 28% SMC AMC 8590	16.0 mm	1.278 kg	$3.94

Using CFSMC to Increase the Stiffness of New Applications

The best approach for using CFSMC in new applications is shown below. Again, the CFSMC and low density SMC are co-molded, with the CFSMC located in the bottom center of the channel. The channel width in this area was reduced to the width of the CFSMC. Low density SMC in this area does not add that much to the stiffness of the assembly. The wall thickness remained 3 mm, for all of the areas with the low density SMC. The wall thickness for the critical area along the bottom center of the channel is 3 mm with the AMC 8970 material. This area is only 1.5 mm thick when the AMC 8590 material is used.

The assemblies with CFSMC, are as stiff as the standard SMC assembly, with a weight that is slightly less than the low density SMC assembly.

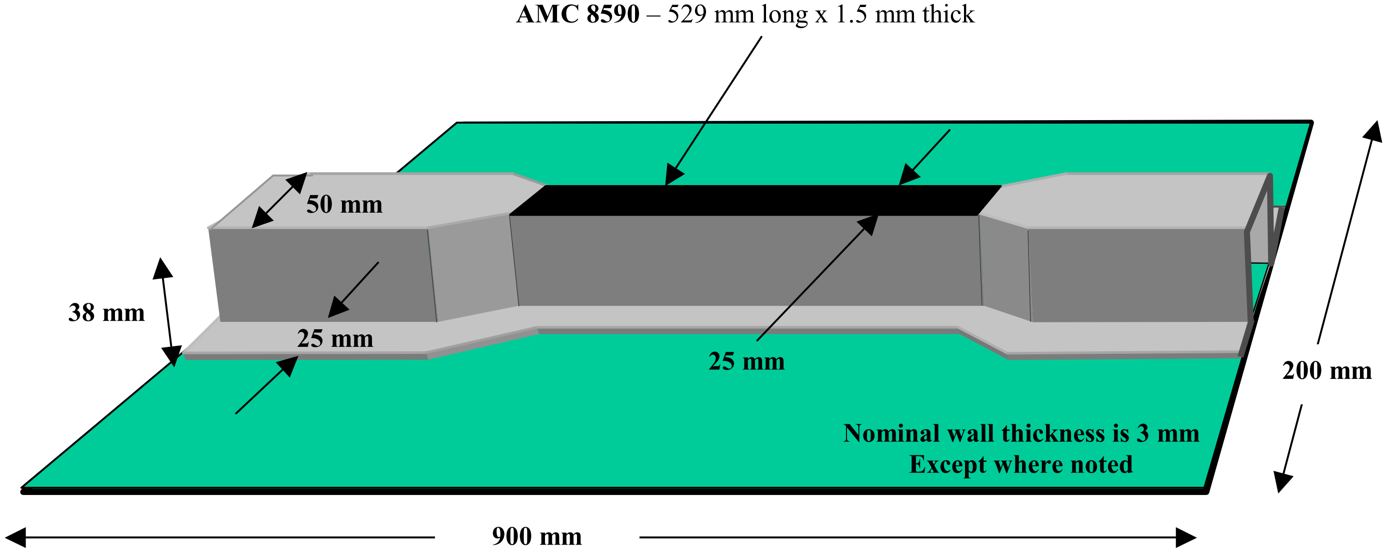
The material cost for the assembly using AMC 8570, was $0.53 higher than the material cost for the low density SMC and only $0.13 higher than the material cost for the standard SMC assembly.

The material cost for the assembly using AMC 8590, was $0.73 higher than the material cost for the low density SMC and only $0.33 higher than the material cost for the standard SMC assembly.

The results and channel design are shown below.

	Deflection	**Weight**	**Mtl. Cost**
LD 28% SMC-- LD 28% SMC-- LD 28% SMC **LD 28% SMC-- LD 28% SMC—LD 28% SMC** **AMC 8570**	16.0 mm	1.247 kg	$3.63
LD 28% SMC-- LD 28% SMC-- LD 28% SMC **LD 28% SMC-- LD 28% SMC—LD 28% SMC** **AMC 8590**	16.0 mm	1.206 kg	$3.83

Drawing E



Conclusion

Carbon reinforced SMC is not cost competitive with glass reinforced SMC, at this time. Significant reductions in mass, that are possible with carbon fiber SMC, will have to wait for the price of carbon fiber SMC to fall below $2.75 / lb.

Carbon fiber SMC can be very cost effective, when used in critical areas to increase the performance of new applications or existing parts. For parts already in production, co-molding carbon fiber in key areas may be less expensive than molding the entire part out of a higher performance / higher cost material or to change the mold. For new applications that need additional stiffness, but have a limited design envelope, co-molding with carbon fiber SMC in key areas may be less expensive than shifting over to a higher performance / higher cost material for the entire part.

References

(1) "Carbon-Fiber Composites for Cars", Oak Ridge National Laboratory Review, Vol. 33, No. 3, 2000.
(2) "Carbon Fiber Composite Structures: Very Light, Very Strong, Very Costly", Automotive Composite Consortium Newsletter, Summer/Fall 1996.
(3) B. Hull, "Analytical Tool to Determine the Best Composite & Design Combination for Structural Automotive Applications", Composite Fabricators Association Conference 2001.

Exhibit A

SKIN MATERIAL	**LD 28% SMC**	**LD 28% SMC**
Modulus & Strength in psi or Mpa	Mpa	MPa
Compression Modulus	6,900	6,900
Compression Strength	100	100
Specific Gravity	1.30	1.30
Material Price / lb.	$1.10	$1.10
CHANNEL MATERIAL	**LD 28% SMC**	**AMC 8590**
Modulus & Strength in psi or Mpa	Mpa	MPa
Tensile Modulus	7,575	55,150
Tensile Strength	72	235
Specific Gravity	1.30	1.48
Material Price / lb.	$1.10	$2.64
PART		
Dimensions in mm or inches	mm	mm
Skin Section Width	200	200
Skin Section Thickness	3	3
Total Channel Footing Width	50	50
Channel Footing Thickness	3	1.5
Channel Width at Bottom	50	12
Channel Thickness at Bottom Wall	3	1.5
Channel Height	38	32
Total Thickness of Channel Sidewalls	6	3
Radius	.75	.50
Length of Assembly (span between supports)	900	900
Total Height of the Assembly	41	35
Maximum Loading (Moment) of Current Part	35	35
Flexural Stiffness of the Assembly	3,962	4,254
Tensile Stress at Channel Bottom	72	55
Stress as % of Material's Tensile Strength	*100%*	*24%*
Compressive Stress at the Skin	27	24
Stress as % of Material's Compressive Strength	*27%*	*24%*
Material Cost of Total Assembly	**$3.10**	**$3.10**
Weight of Total Assembly (kilograms)	**1.278**	**0.942**

Exhibit B

SKIN MATERIAL	**LD 28% SMC**	**LD 28% SMC**
Modulus & Strength in psi or Mpa	Mpa	MPa
Compression Modulus	6,900	6,900
Compression Strength	100	100
Specific Gravity	1.30	1.30
Material Price / lb.	$1.10	$1.10
CHANNEL MATERIAL	**Std 28% SMC**	**AMC 8590**
Modulus & Strength in psi or Mpa	Mpa	MPa
Tensile Modulus	11,000	55,150
Tensile Strength	72	235
Specific Gravity	1.90	1.48
Material Price / lb.	$0.85	$2.83
PART		
Dimensions in mm or inches	mm	mm
Skin Section Width	200	200
Skin Section Thickness	3	3
Total Channel Footing Width	50	50
Channel Footing Thickness	3	1.5
Channel Width at Bottom	50	12.5
Channel Thickness at Bottom Wall	3	1.5
Channel Height	38	35
Total Thickness of Channel Sidewalls	6	3
Radius	.75	.50
Length of Assembly (span between supports)	900	900
Total Height of the Assembly	41	38
Maximum Loading (Moment) of Current Part	50	50
Flexural Stiffness of the Assembly	5,243	5,364
Are the competing parts as stiff as the current part?		Yes
Tensile Stress at Channel Bottom	72	67
Stress as % of Material's Tensile Strength	*100%*	*28%*
Compressive Stress at the Skin	34	29
Stress as % of Material's Compressive Strength	*34%*	*29%*
Material Cost of Total Assembly	**$3.28**	**$3.28**
Weight of Total Assembly (kilograms)	**1.544**	**0.955**