

Material Selection During Early Design Phase Using Simplified Models

2011-01-0526

Published
04/12/2011

Raj Sohmshetty and Rakshit Ramachandra
Ford Motor Co.

Radhakrishan Mariappasamy and Senthil Karuppaswamy
Detroit Engineered Products Inc.

Copyright © 2011 SAE International

doi:[10.4271/2011-01-0526](https://doi.org/10.4271/2011-01-0526)

ABSTRACT

Optimal material selection for a part becomes quite challenging with dynamically changing data from various sources. Multiple manufacturing locations with varying supplier capabilities add to the complexity. There is need to balance product attribute requirements with manufacturing feasibility, cost, sourcing, and vehicle program strategies. The sequential consideration of product attribute, manufacturing, and sourcing aspects tends to result in design churns.

Ford R&A is developing a web based material recommender tool to help engineers with material selection integrating sourcing, manufacturing, and design considerations. This tool is designed to filter the list of materials for a specific part and provide a prioritized list of materials; and allow engineers to do weight and cost trade-off studies. The initial implementation of this material recommender tool employs simplified analytical calculators for evaluation of structural performance metrics of parts. The intent of the material recommender tool is to identify directionally correct material choices for individual parts to complement the assembly level design optimization using detailed finite element models.

The study presented in this paper work compares the structural performance typical automotive parts simplified models with that of the detailed finite element analyses on the actual models. The study is made for various load cases considering variation of material and geometric properties. This paper compares performance trends between simple calculation and FEA based approach results for typical

automotive parts; and provides a justification for using the simple calculators in the material recommender tool.

INTRODUCTION

It is well known that the automotive industry is highly competitive and there is a need to continually improve product cost and weight efficiencies as well as engineering efficiency. The recent volatility and rise in commodity prices increases the significance of material cost saving initiatives. New and advanced materials are being constantly developed to aid automakers meet increasingly higher structural performance requirements while maintaining or reducing the weight of the vehicle body structure.

Extensive efforts are being made at Ford to conceptualize and develop product design guidance tools that integrate sourcing, manufacturing, and assembly considerations upfront in the design cycle to achieve engineering efficiency, cost, and product attribute improvements. This approach includes a flexible software environment that can grow in functionality and usability over time.

One of the tools designed to help in guiding the early design stage is a material recommender which integrates material, purchasing, and program strategies to address the challenges created by global vehicle platforms with regional manufacturing. This web based tool provides customizable strategy enforcements & what-if/trade-off studies. The criteria for suggesting an optimal material is determined by various “Filters” which include binary and fuzzy types. The part to be analyzed is approximated to the closest standard geometry and a performance analysis of the part can be carried out by the user.



Documents

Document Sharing Hub

This paper shows how simplified load analysis on the approximated standard geometry of a complex part compares with the FEA on the part itself. Although today's increasing product and part complexity drive the need for FE based model evaluation and simulation tools, simplified engineering equations with assumed section geometry and end conditions are sufficient to predict performance metric during early design stages.

As the product design of a part or assembly matures, it undergoes multidisciplinary optimization (MDO) to determine an optimal shape or size of the part. To perform an MDO, the problem needs to be well defined, which is not practical during the early design stage due to the dynamically changing information. Hence, this process generally occurs when the project advances and design freedom reduces. MDO does not optimize for material selection and the entire process may take several weeks to provide results.

An effort has been made to determine and compare the performance trends between Simple Calculation and FEA while the problems analyzed are contained to "one part" response of automotive body structure.

TECHNICAL APPROACH

The technical approach followed for this study is shown in [Figure 1](#). First, the parts and the various load cases were identified. This study has been performed on 5 different materials and their properties are listed in [Table 1](#). The identified parts were then modeled and analyzed using a commercial FE package. Each of these parts were treated as simple standard sections and calculated for performance using analytical calculators. Since the data was not exact

between the FE and simplified models, the absolute results could not be compared directly. Instead, the results were plotted on an XY plot and a trend was determined using regression analysis.

COMPARING SIMPLIFIED CALCULATION AND FINITE ELEMENT ANALYSIS UNDER VARIOUS LOAD CASES

Load Case 1: Bending Stiffness

The model shown in [Figure 2](#) (left) was used to analyze the bending stiffness using FEA. The model was meshed with element size of 10mm constrained in all degrees of freedom at one end and unit load applied on the other end (along the y-axis direction). The model was then simplified into a cantilever beam with a hollow square section to calculate the bending stiffness ([Equation 1](#)) under similar loading conditions as in FE model ([Figure 3](#)). The dimensions of the simplified model are approximated to the dimensions of the FE model as shown in [Figure 3](#).

Bending Stiffness of Cantilever Beam= $3 * I * E / l^3$

[4] ([Equation 1](#))

Where I is the moment of inertia (mm^4); and E is the elastic modulus of the material (MPa).

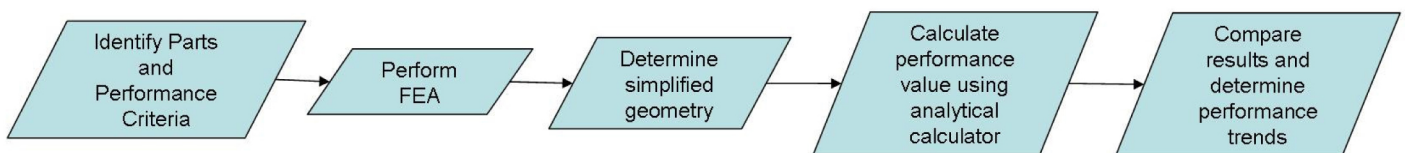


Figure 1. Technical Approach

Table 1. Materials Used for the Study

Properties	Material A	Material B	Material C	Material D	Material E
Yield Strength (MPa)	360	170	945	645	350
Young's Modulus (GPa)	210	210	200	210	68
Poisson's Ratio	0.3	0.3	0.3	0.3	0.33
Density (g/cc)	7.8	7.8	7.83	7.85	2.7



Documents

Document Sharing Hub

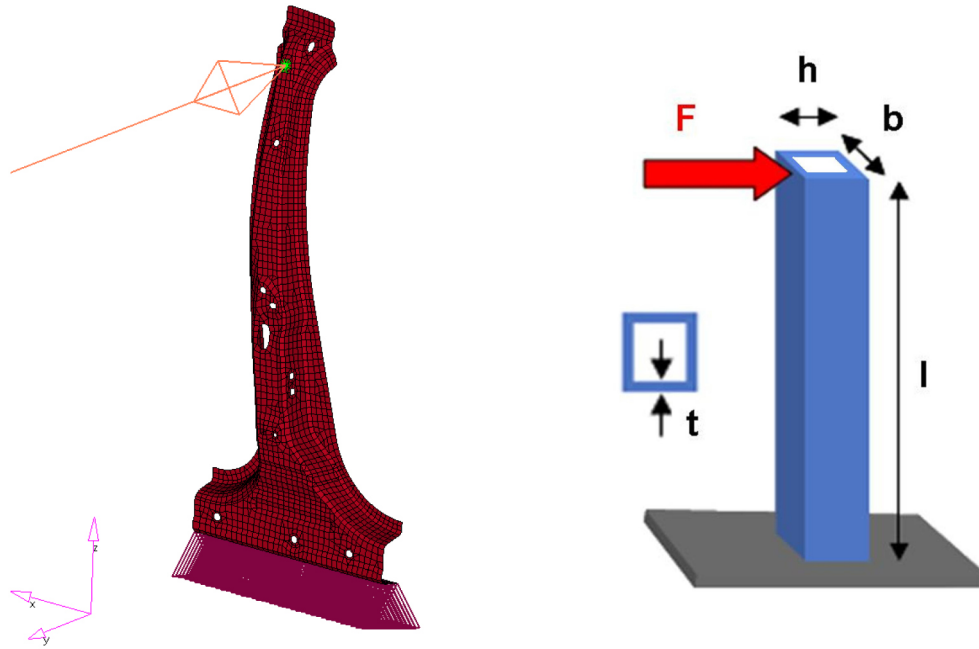


Figure 2. FE Model (left) and Simplified Model (right)

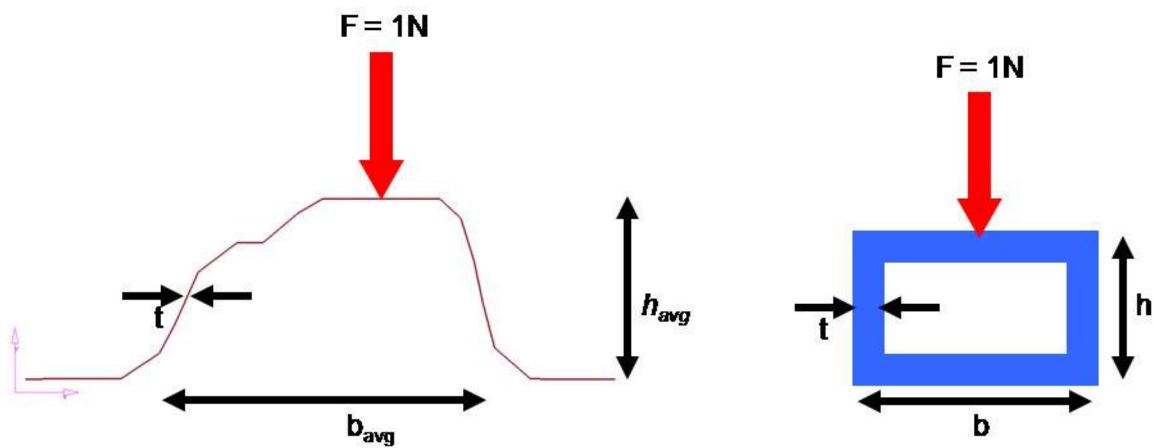


Figure 3. Cross-sections of FE and Simplified Models

Table 2. Bending Stiffness Comparison between FE and Simplified Models

Material	Thickness (mm)	Bending Stiffness (N/mm)	
		FEA	Simple Calculation
Material A; Material B	1.25	0.15	25.85
	1.5	0.25	30.5
	1.75	0.38	34.9
Material C	1.25	0.14	24.61
	1.5	0.24	29.19
	1.75	0.37	33.25
Material D	1.25	0.15	27.72
	1.5	0.25	30.3
	1.75	0.38	34.7
Material E	1.25	0.05	8.48
	1.5	0.08	9.99
	1.75	0.13	11.45

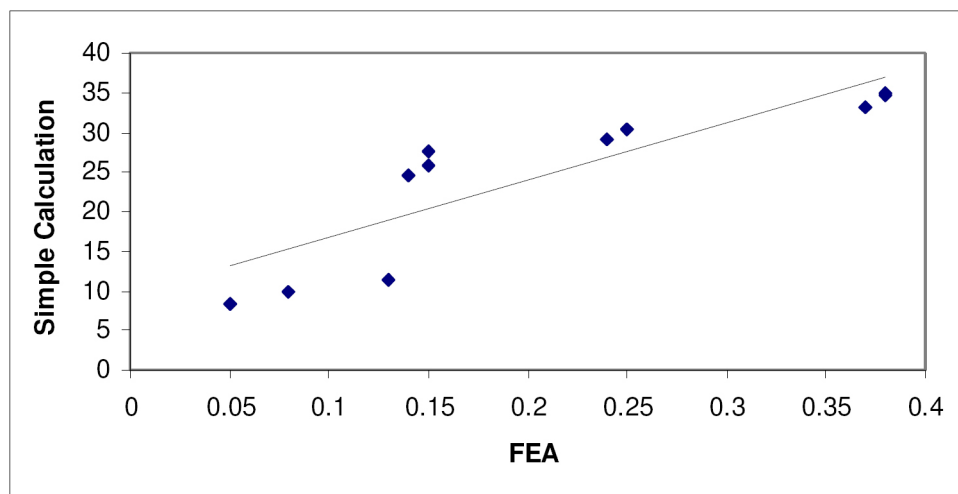


Figure 4. Bending Stiffness Results Trend Plot