

Design Optimization of Front Bumper System for Low Speed Impact Insurance Industry Impact Test using DFSS and CAE Analysis

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ABSTRACT

In 2006, the Insurance Institute for Highway Safety (IIHS) released a new Low Speed Bumper Test Protocol for passenger cars¹. The new test protocol included the development of a deformable barrier that the vehicle would impact at low speeds. IIHS positioned the new barrier to improve correlation to low speed collisions in the field, and also to assess the ability of the bumper system to protect the vehicle from damage. The bumper system must stay engaged to the barrier to protect other vehicle components from damage. The challenge is to identify the bumper system design features that minimize additional cost and mass to keep engagement to the barrier. The results of the Design for Six Sigma analysis identified the design features that increase the stiffness of the bumper system enable it to stay engaged to the barrier and reduce the deflection.

INTRODUCTION

1. BACKGROUND

One of the missions of IIHS is to reduce the property damage from low speed automotive crashes². Research performed by IIHS of low speed collisions concluded that 81% of the vehicle damage repair involved the front or the rear impact³. Of those collisions, more than half of the vehicle's bumper impact bar did not require replacement. One of the observations made on vehicles where the impact bar was not damaged, was that the bumper impact bars did not stay engaged vertically between the two vehicles causing the striking vehicle to over or under ride the struck vehicle. IIHS developed a Centerline Test to assess the ability of the

bumper system to stay engaged to the deformable barrier and protect the vehicle from damage.

A. The Barrier Test Device

The Barrier Test Device as shown in [Figure 1](#) consists of the following components and is pictured below (construction drawings shown in the Low Speed Test Protocol⁴ found on the IIHS website):

1. Steel Frame Assembly
2. Backstop - 200 mm high steel wall
3. Absorber - Formed plastic located inside the Cover which crushes during the impact
4. Cover - Thin plastic sheet that is formed to simulate the plastic Bumper Fascia used on most vehicles today

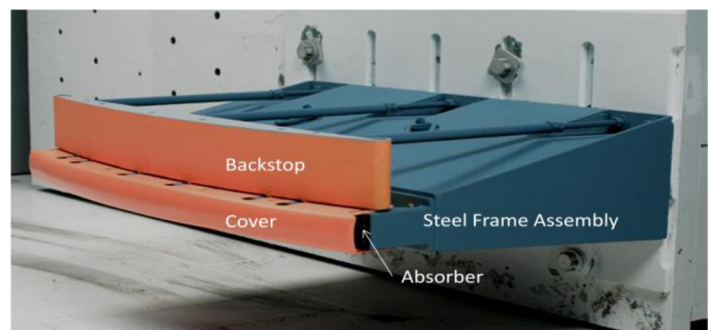


Figure 1. Picture of IIHS Deformable Barrier Assembly

B. The Low Speed Bumper Test Protocol - Centerline Test

Two of the four tests in the IIHS Low Speed Bumper Test Protocol⁴ are the Front and Rear Centerline test. Viewing the

Barrier from the top, the center of the barrier is lined up with the centerline of the vehicle. From the side view, the bottom of the test barrier is positioned at 457 mm (18 inches) to ground. The test speed is 10 kph. An overhead picture of the barrier position to the vehicle is shown in [Figure 2](#). A side view of the barrier position is shown in [Figure 3](#).

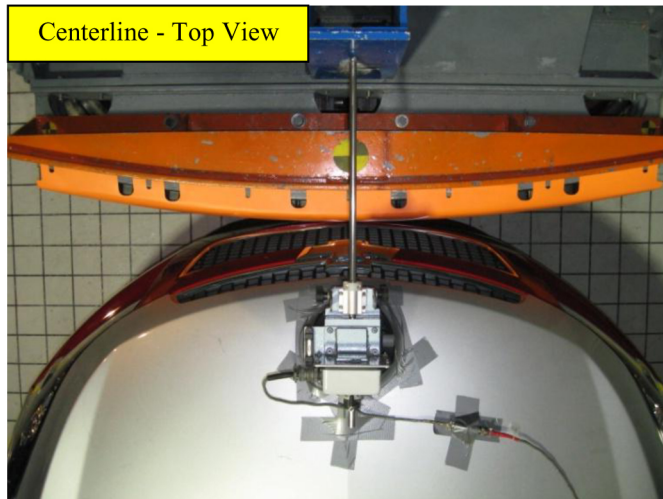


Figure 2. Overhead view of vehicle position to IIHS Deformable Barrier

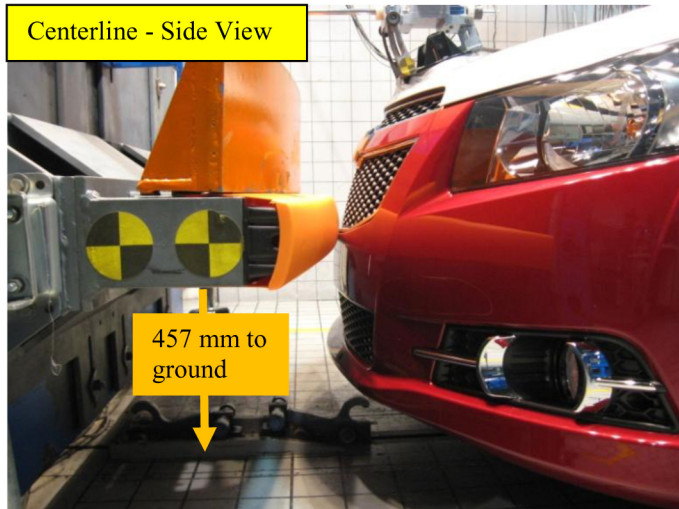


Figure 3. Side view of vehicle position to IIHS Deformable Barrier

2. FOCUS

The study was focused on the front Centerline hit to optimize the design parameters of the Bumper System. These same features would apply to the rear Centerline hit also. The design features are listed below and shown in the [Figures 4](#), [5](#), and [6](#). Design Features #1-6 are shown in [Figure 4](#), with #7 shown in [Figure 5](#) and #8 shown in [Figure 6](#).

Design Features:

1. Energy Absorber Foam Depth
2. Energy Absorber Foam Density
3. Vertical Engagement of the Bumper Beam to the Barrier
4. Impact Bar Material Thickness
5. Impact Bar Material
6. Angle of the surface of the vehicle to vertical
7. Energy Absorber Shape - D or P section
8. Impact Bar Shape - D or B section

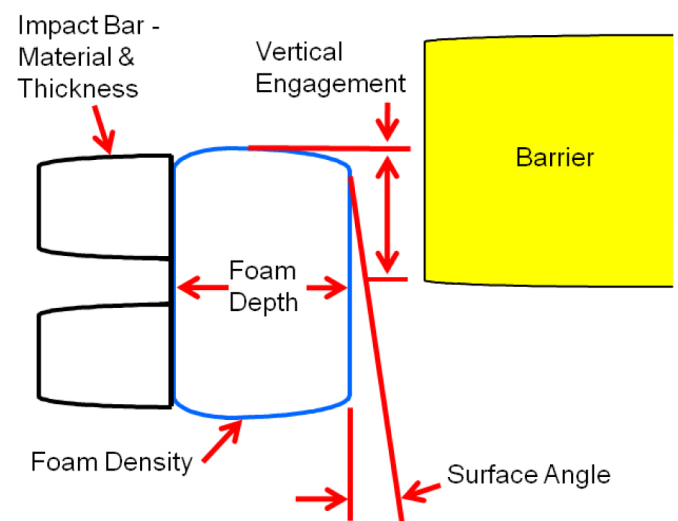


Figure 4. Graphic for Bumper Features 1 to 6

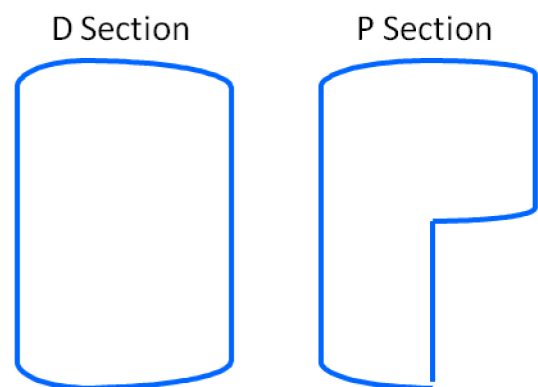


Figure 5. Energy Absorber Shape - D or P Section

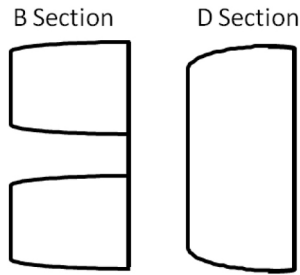


Figure 6. Impact Bar Shape - B or D Section

In addition to the bumper design parameters, there are vehicle factors which will affect the deflection of the bumper system. These are called Noise Factors. Noise factors are not able to be changed as they are vehicle factors outside of the bumper system. However, the analysis will use these parameters to determine the degree they affect the bumper system performance. These vehicle factors are:

1. Vehicle Mass
2. Vehicle Height Position relative to the Barrier - caused by body and chassis dimensional variation
3. Impact Bar Sweep - usually determined by the exterior styling

3. OPTIMIZATION PROCESS

A. CAE Model

A CAE model (Dyna 3D) was developed of the Bumper Impact Bar and RCAR/IIHS Deformable barrier as the tool to optimize the system. This model was designed to be able to easily modify the bumper system parameters to perform the multiple iterations for the optimization process. The Bumper Impact Bar was mounted onto a vehicle front end structure, which was mounted onto a virtual test cart. This kept the size of the CAE model small (in comparison to a full vehicle CAE model) enabling quicker run times for each iteration.

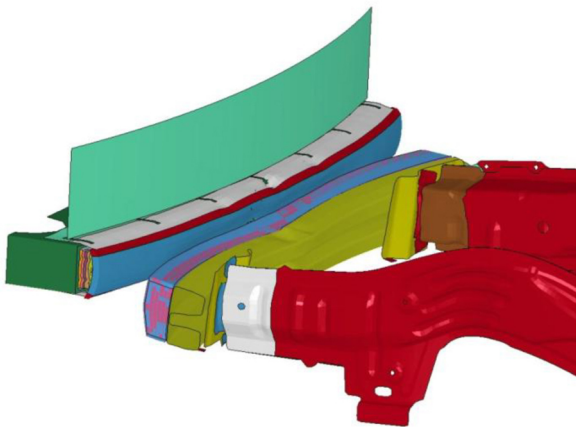


Figure 7. CAE Model of Barrier, Impact Bar, Energy Absorber, and Mounting Structure

B. Design for Six Sigma (DFSS)

The DFSS process was chosen to optimize the bumper system as it will determine which Control Factors of the Bumper System and Noise Factors of vehicle have the most influence on the Bumper System deflection. The advantage of using DFSS is that is able to determine the optimization results with minimizing the number of CAE iterations.

1. Parameter Diagram

A graphical representation of the Control Factors, Noise Factors and inputs is shown below:

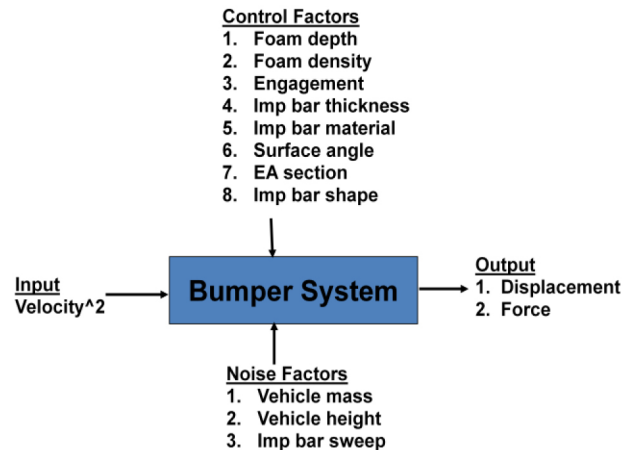


Figure 8. Parameter Diagram showing Inputs, Control Factors, Noise Factors and Outputs

2. Ideal Function

IIHS damageability test is conducted to assess damage done to the vehicle during an impact with a deformable barrier. During this impact event, kinetic energy of the vehicle will be absorbed by the bumper system. To reduce damageability, minimum deflection is desirable to enable less damage to the vehicle. The vehicle speed for the IIHS Low Speed Center hit is 10 kph. In order to understand what Control Factors of the bumper system affect deflection most, three different velocities of 7, 10, and 13 kilometers per hours will be used. This is represented by this graph below where velocity is on the X axis and displacement is on the Y axis. The optimal set of Control Factors will lower the slope of the line graphed for displacement at the 3 different velocities.