Analysis and Evaluation of Minivan Body Structure Finite Element Methods

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Abstract

The paper describes the application of MSC product in Harbin Hafei Motor Co.,Ltd and then describes how the finite element methods can be used for analysis and evaluation of minivan body structure. Including static, dynamic, fatigue, crashworthiness analysis, optimization and sensitivity and so on. In this paper, Author use MSC-NASTRAN calculate the strength and stiffness in both bending and torsion loadcase. Summarized the strength and stiffness evaluation standards for minivan. And then done the normal model analysis in order to consider the influence of tyre unbalance and engine idle excite. The calculations and analysis were verified by test.

Introduction

Automotive companies are focussing on the processes of delivering a new or updated high quality vehicle to the market faster and cheaper. Analytical processes like CAE are extensively used upfront to develop a robust quality product. My company is one of the leading automotive companies in employing CAE tools effectively to speed up the product development process in China. CAE tools have been around for many years and have been used successfully on many vehicle programs within HHFMCL.(Harbin Hafei Motor Co.,Ltd)

As well known, the automotive body structure is very complex. The body is the key assembly of an automotive. Body structure must have enough strength in order to ensure its fatigue life. And enough stiffness ensure assemble and make use of. In the mean time, it had to have reasonable dynamic characteristic in order to control vibration and noise. By means of using finite element methods, we can satisfy the requiring of automotive design, and develop the level of design radically. In addition, shortcut the development period and reduce the cost.

Body structure static analysis

The key of static analysis is to ensure reasonable loads and their standard. The loads of body structure are very complex. But mostly have two kind like below:

(1) Torsion (simulate the wheel run up) the torque can be confirm by axle load , suspension stiffness and the rough of load surface. For minivan it can is equal about 1000N.m.

(2) Bending (simulate the weight of passenger and luggage) the load can be ensure according to the number of passengers and the weight of luggage.

The static analysis can be divided into strength analysis and stiffness analysis. For static strength analysis, the safety factor is 1.3, and the analysis model and result is shown in figure 1 and figure 2. For static stiffness analysis, calculate the torsion loadcase, the analysis model and result is shown in figure 3:

31029 nodes
33017 shell elements
4 rigid elements

Spot welds have been simulated as connections between two different grids of different elements joined together. The weld step varies between 50 to 80 mm according to different zones of minivan.

By our experiences, if the minivan has a very high torsion rigidity, usually it automatically ensures a suitable bending rigidity.

Except control the deform value, we must notice the smooth of stiffness curve and the deform value of peristome. And it is necessary to analysis the connect stiffness between the body and suspension, engine, body attachment, etc.

The dynamic analysis and evaluation of body structure

The body in driving endure a lot of excite. Studying dynamic characteristic can effectively analysis automobile comfortable, and the fatigue life of body. The aim of studying dynamic characteristic is optimal the body structure and control body mode. The frequency of body must stagger excite frequency. Normally, the first step natural frequency of minivan body is varies between 20-40Hz. In the field of the frequency, the source of excite mostly have two kinds: one is the wheel unbalance, frequency varies between 1-30Hz, the other is engine idle excite, frequency varies between 20-40Hz.

The excite frequency of wheel can be ensure by driving speed, in China, it is below 150km/h, quite below 21Hz. So the first step natural frequency must above 23Hz. The excite frequency of engine idle lie on the number of cylinders and idle rotate speed. For example:

(1) four cylinders, idle rotate speed n = 600r/min, the excite frequency of engine idle: f = (600/60)2=20Hz

(2) six cylinders, idle rotate speed n = 600r/min, the excite frequency of engine idle: f =

(600/60)3=30Hz

(3) eight cylinders, idle rotate speed n = 600r/min, the excite frequency of engine idle: f = (600/60)4=40Hz.

The range of body frequency above are body assembly, it is said, body in white add the weight of body attachments, such as seats, doors, engine hood, luggage lid etc. Usually we can simulate those attachments by means of rigid elements, in order to considering their effort. In table 1 , we give some value of modal analysis of one type vehicle my company produce, and conformity with test. Natural mode shown in figure 4,5,6,7, The model has:

51002 nodes

52015 shell elements

TABLE 1. EXCELLENT AGREEMENT BETWEEN THEORY AND EXPERIMENT

Analysis result	Experiment result	Agreement
36.532	35.987	1.51%
43.955	42.579	3.23%
47.377	46.988	0.82%
52.535	51.654	1.71%

Body parts and attachments analysis

Engine hood and luggage lid must have enough torsional stiffness, doors and their outer panel must have enough stiffness, too. The others, such as mirror, steering system, exhaust, had to have reasonable dynamic characteristic, avoid approach body frequency, in the mean time, must stagger the excite frequency of engine idle, too. The example shown in figure 8, 9.

NVH analysis

We using MSC/NVH Manager analysis full automobile nvh characteristic. And we have developed a program to Automesh solid element acoustic cavity model. Vehicle design targets are typically established for the following NVH characteristics based on customer and market objectives. These targets are usually expressed in terms of subjective ratings .

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NVH Characteristic	Frequency Range
Ride	< 5 Hz
Shake	5 - 25 Hz
Harshness	25 - 100 Hz
Boom	25 - 100 Hz
Moan	100 - 150 Hz
Noise	150 - 300 Hz

For interior noise issues, most of the acoustic energy in a typical automobile is below 125 Hz [3]. Noise and vibration concerns below 125 Hz must usually be dealt with by major structural changes such as additional cross members, reinforcements, and beam section sizes. Above 125 Hz, vehicle interior noise is usually the main concern and can be dealt with by local design modifications such as panel beads and damping treatments.

Crashworthiness simulation and design

A main goal in automotive development is to achieve an optimum in passive safety, i.e. to protect the car passengers during a crash as well as possible. This goal leads to increasing safety design efforts in the early development phases, synonymous with an increasing use of numerical simulation tools. The successful car body crashworthiness simulations lead to a new partnership between test and analysis teams with the goal to reduce cost and delay of new car model design. Except simulate front and side crash, extended simulation, such as occupant, airbags, steering wheel design, seat and seat belt design, kheebolster design, bumper design, etc. In our company, we have simulated full frontal 48.3km/h crash against a rigid barrier, the model and result are shown in figure 10, 11.

Design sensitivity and optimization

The aim of the car design is to get an optimal construction under different constraints. Design sensitivity analysis computes the rates of change of structural responses with respect to changes in design parameters. These design parameters are usually referred to as design variables and can be used to represent shell thickness, beam cross sectional dimensions, journal bearing sizes, and so on. Design optimization analysis is a formal plan or algorithm, that is used to search for a "best" design. Such as in automotive chassis design, we may want to investigate changes in cabin resonant frequencies given changes in panel thickness. These rates of change are called design sensitivity coefficients. once these rates of change are known, optimization analysis can find the optimal set of panel thickness which yield the lowest level of cabin resonant frequencies. The other example: one part of vehicle's frame structure was found to be overstressed. Unfortunately, it is too expensive to redesign that particular frame component at this stage in the engineering cycle. However, other structure component nearby can be modified without severe cost increases. There are nearly 90 structure design parameters can be manipulated. The design goal is to reduce the magnitude of the stresses by reducing the internal load to the overstressed member.

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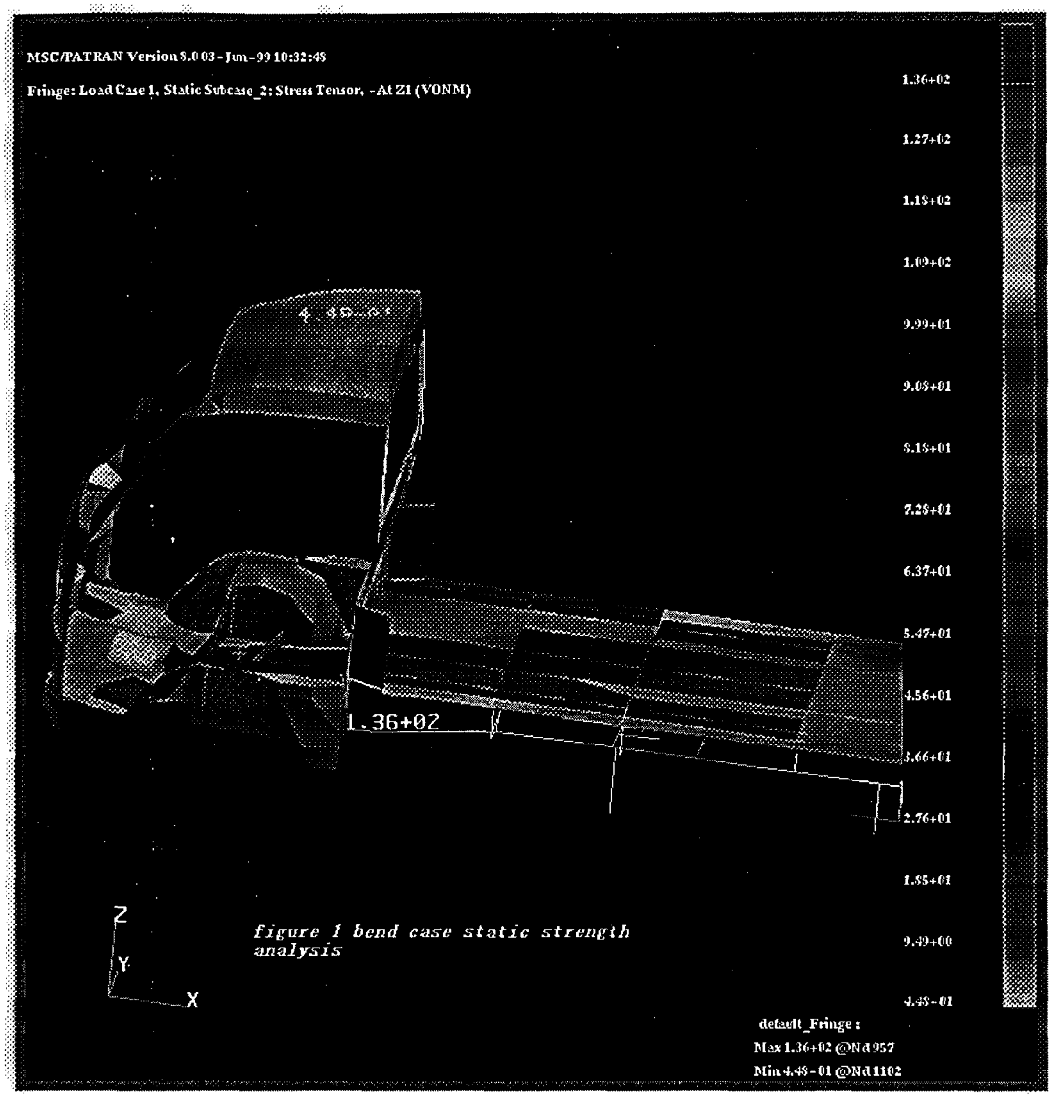
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1.18+02
1.09+02
9.99+01
9.08+01
8.18+01
7.28+01
6.37+01
5.47+01
4.56+01
3.66+01
2.76+01
1.85+01
9.49+00
4.49-01
1.36+02
Z
Y
X
figure 1 bend case static strength analysis
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Min 4.49-01 @Nd 1102

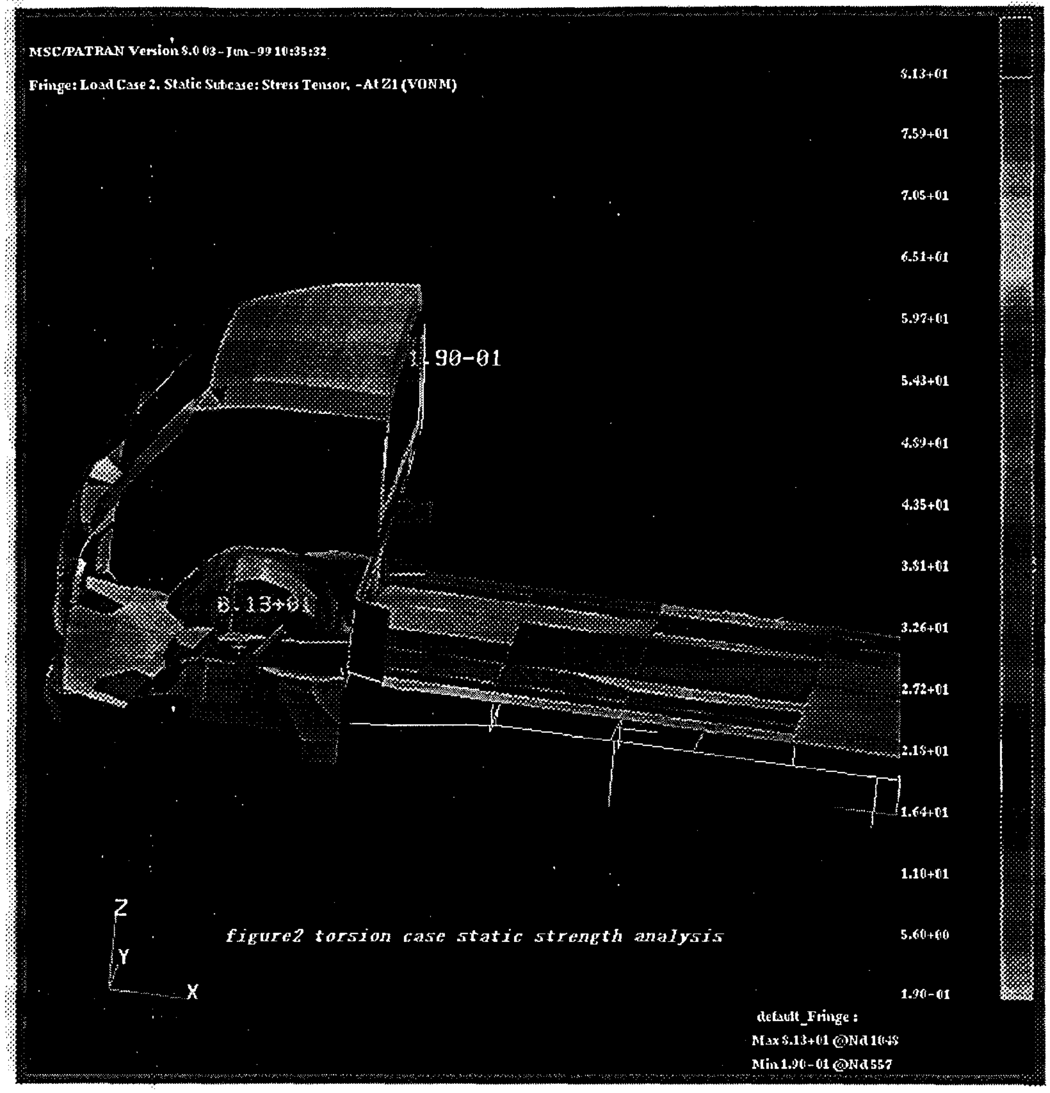

figure2 torsion case static strength analysis

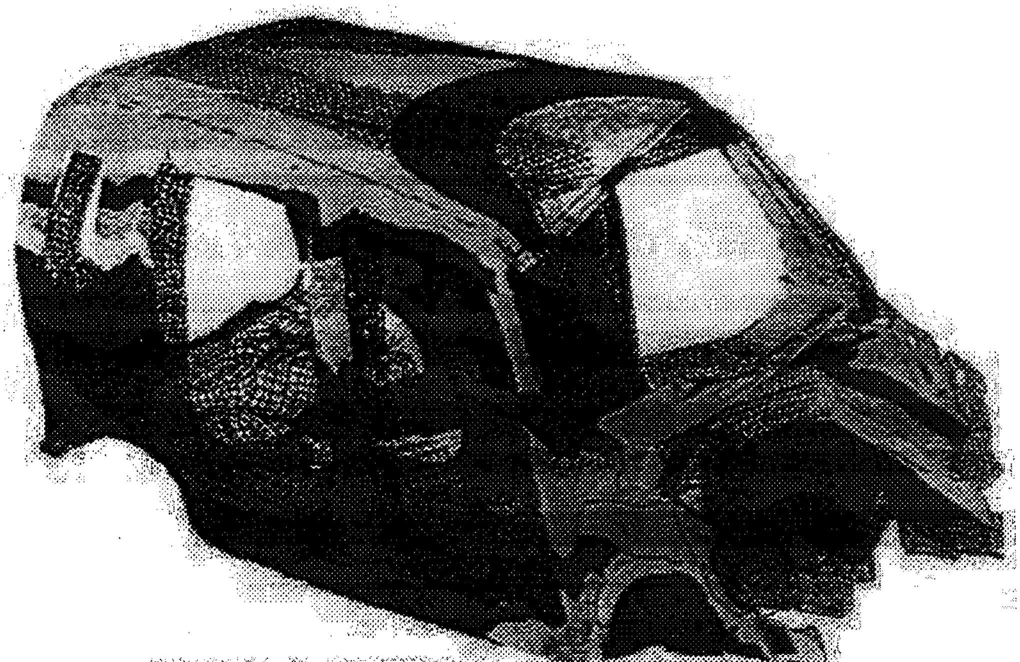

figure 3 stiffness analysis result

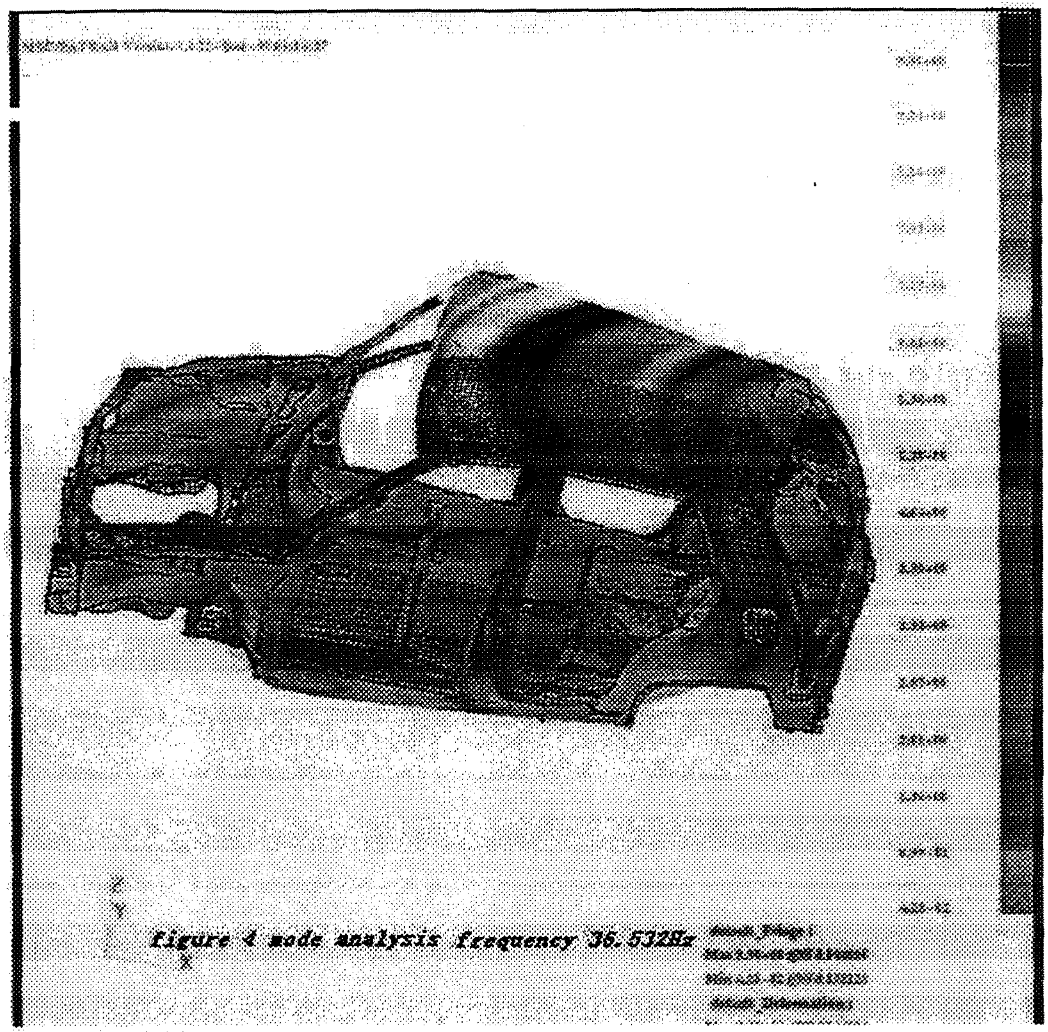

figure 4 mode analysis frequency 36.53Hz

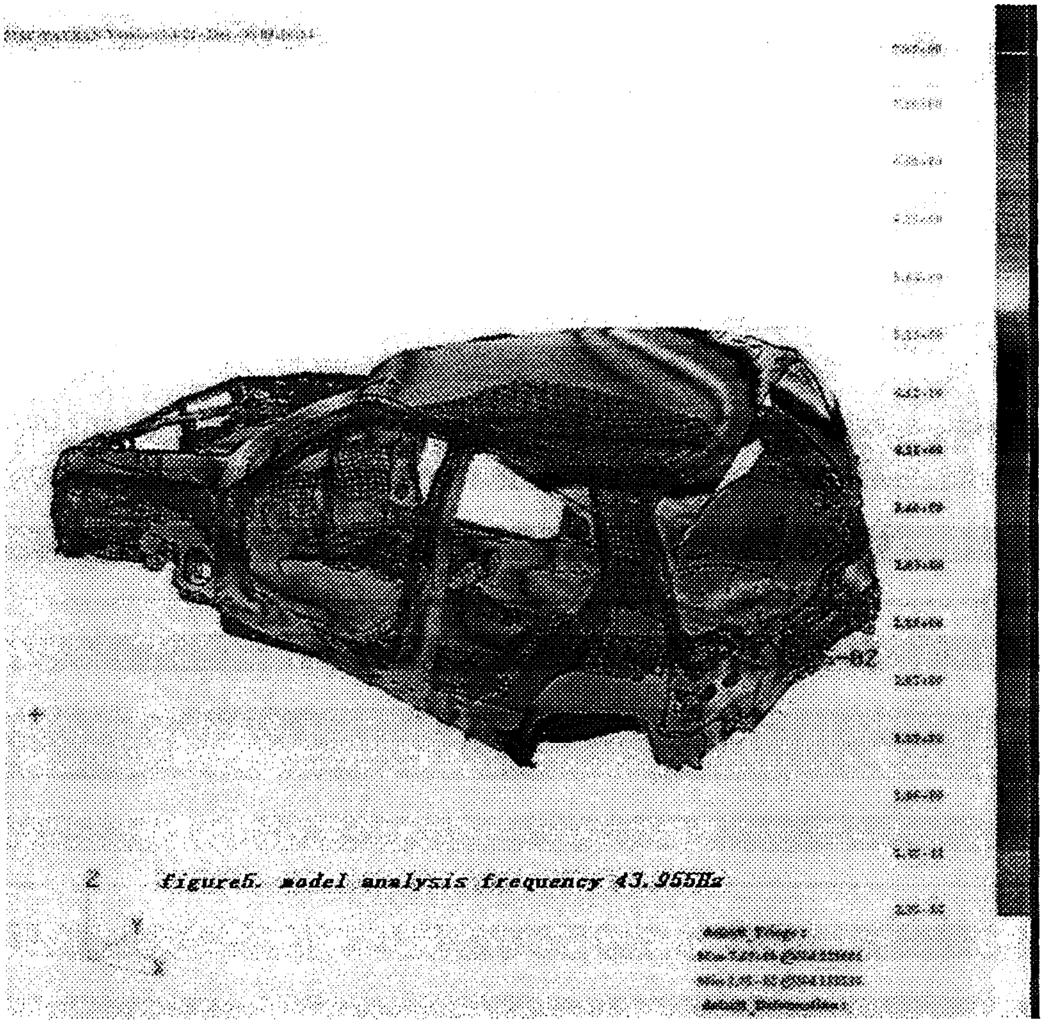

figure5. model analysis frequency 43.955Hz

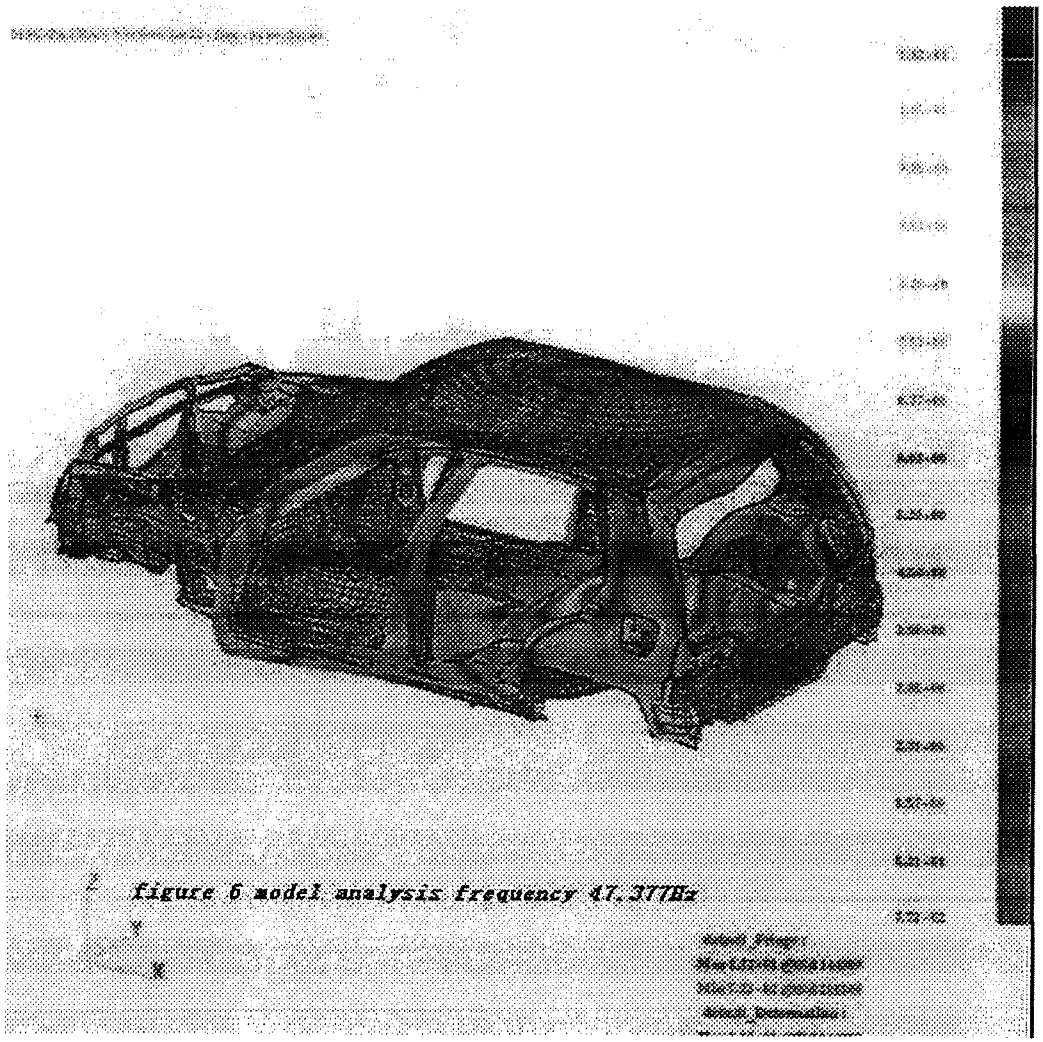

figure 6 model analysis frequency 47.377Hz

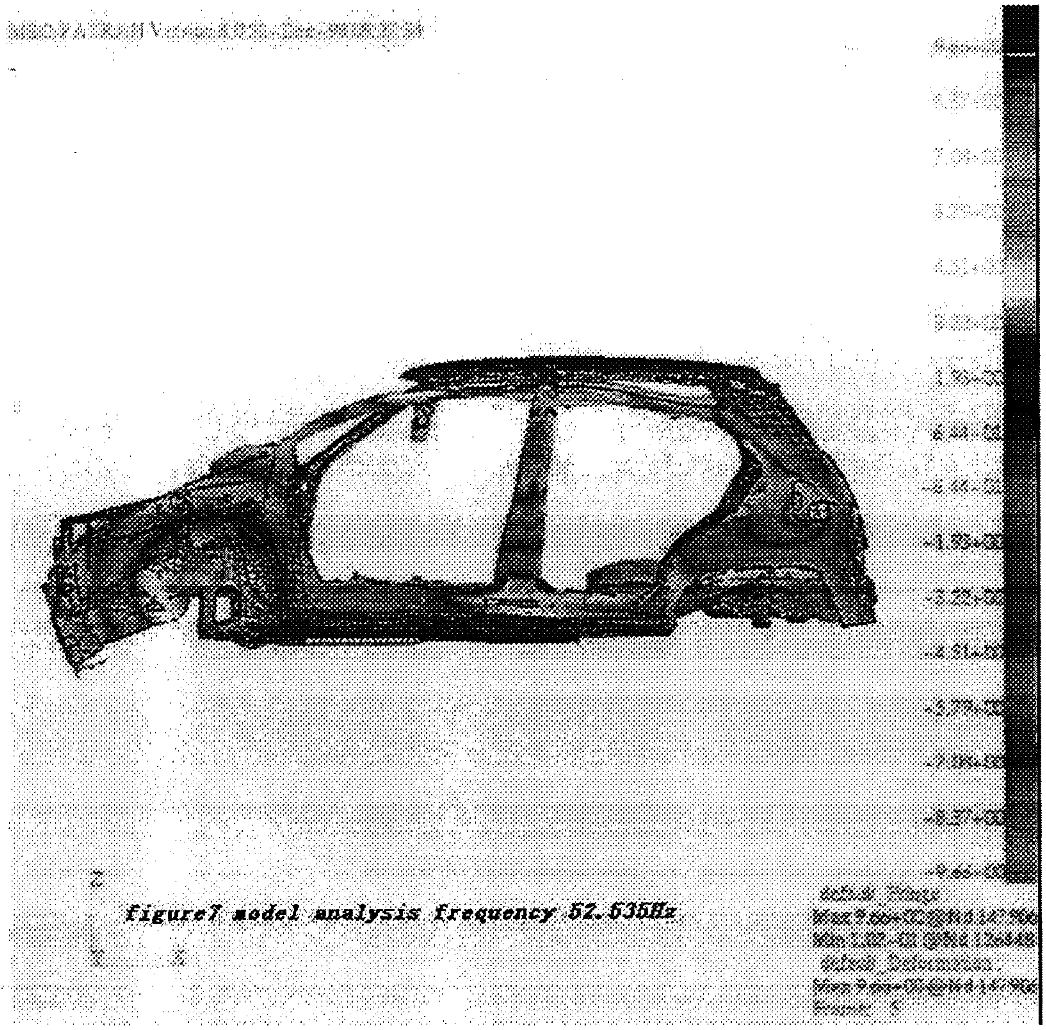

figure7 model analysis frequency 52.635Hz

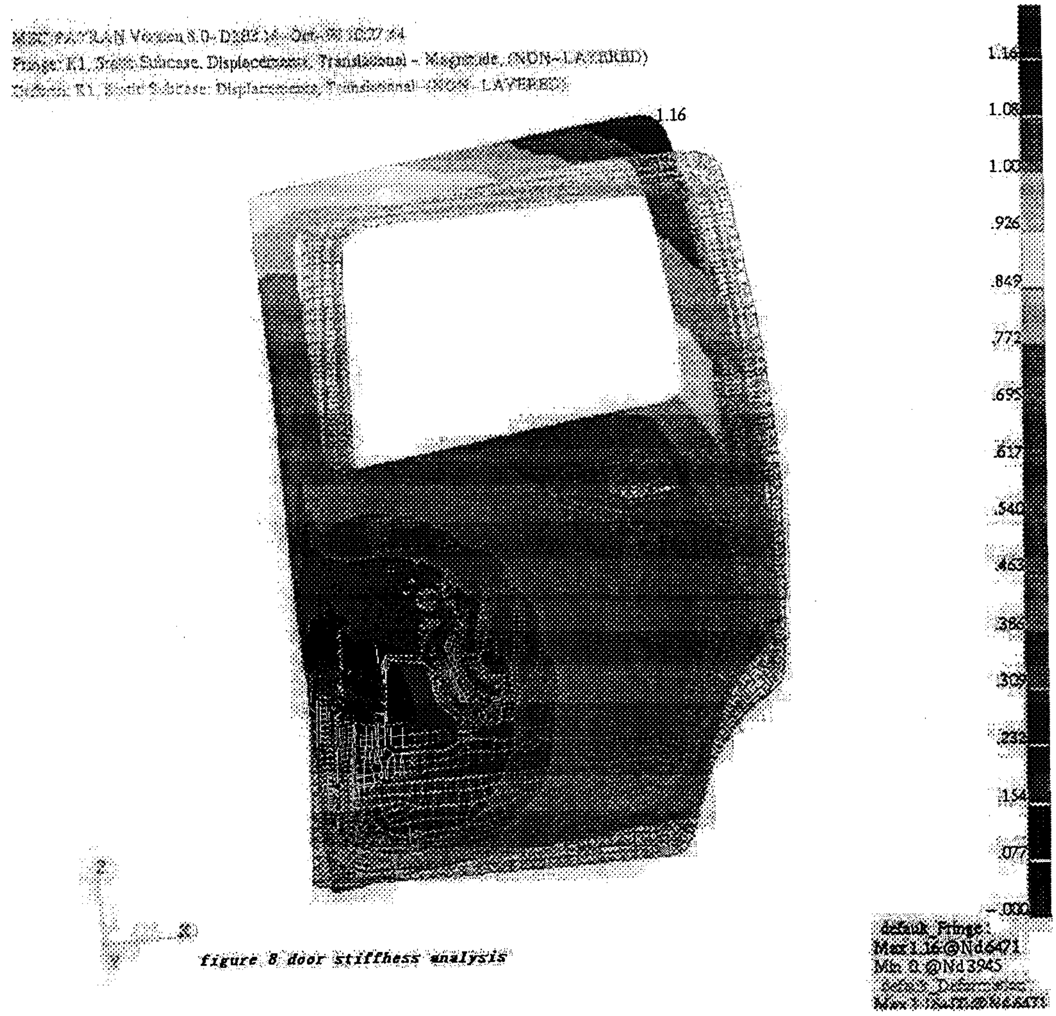

figure 8 door stiffhess analysis

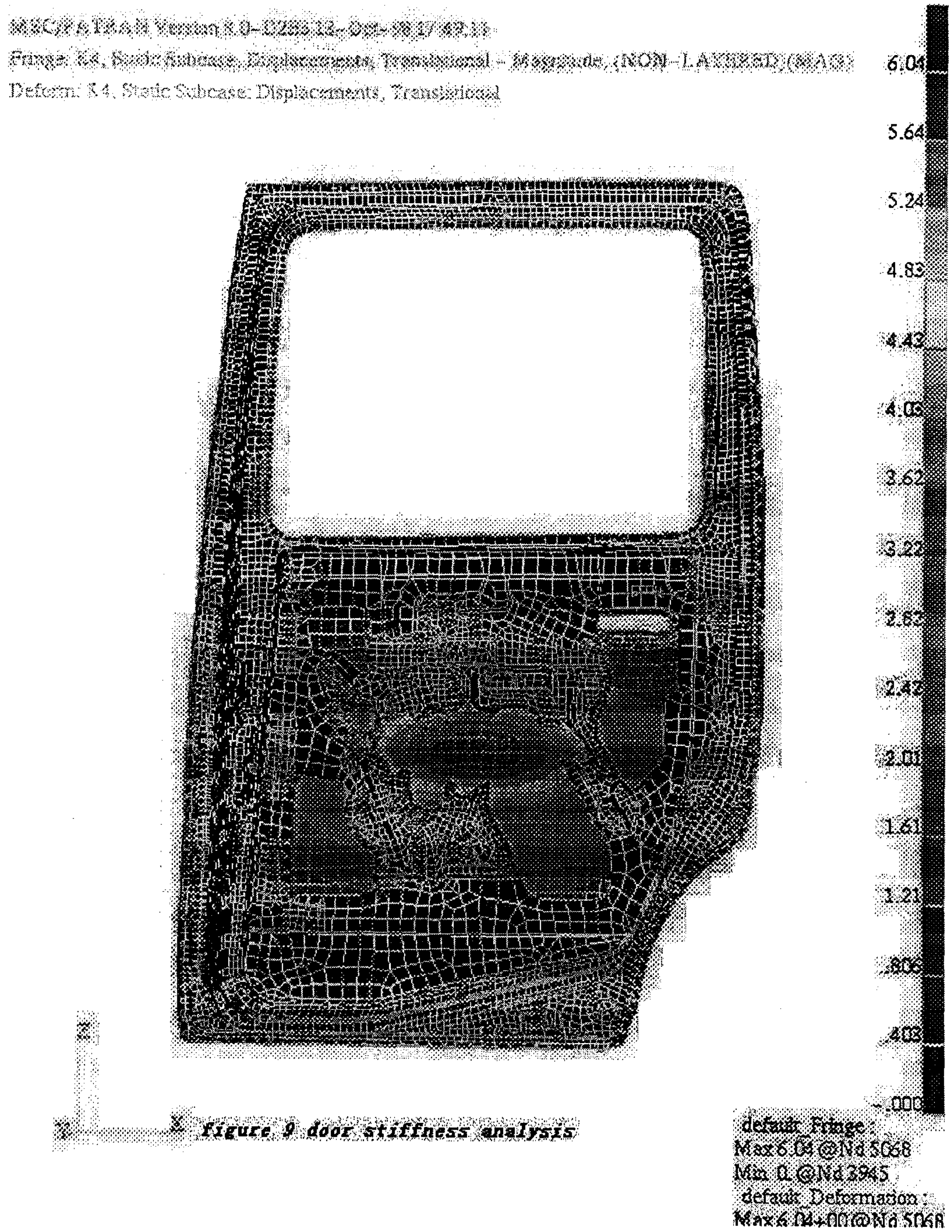

figure 9 door stiffness analysis

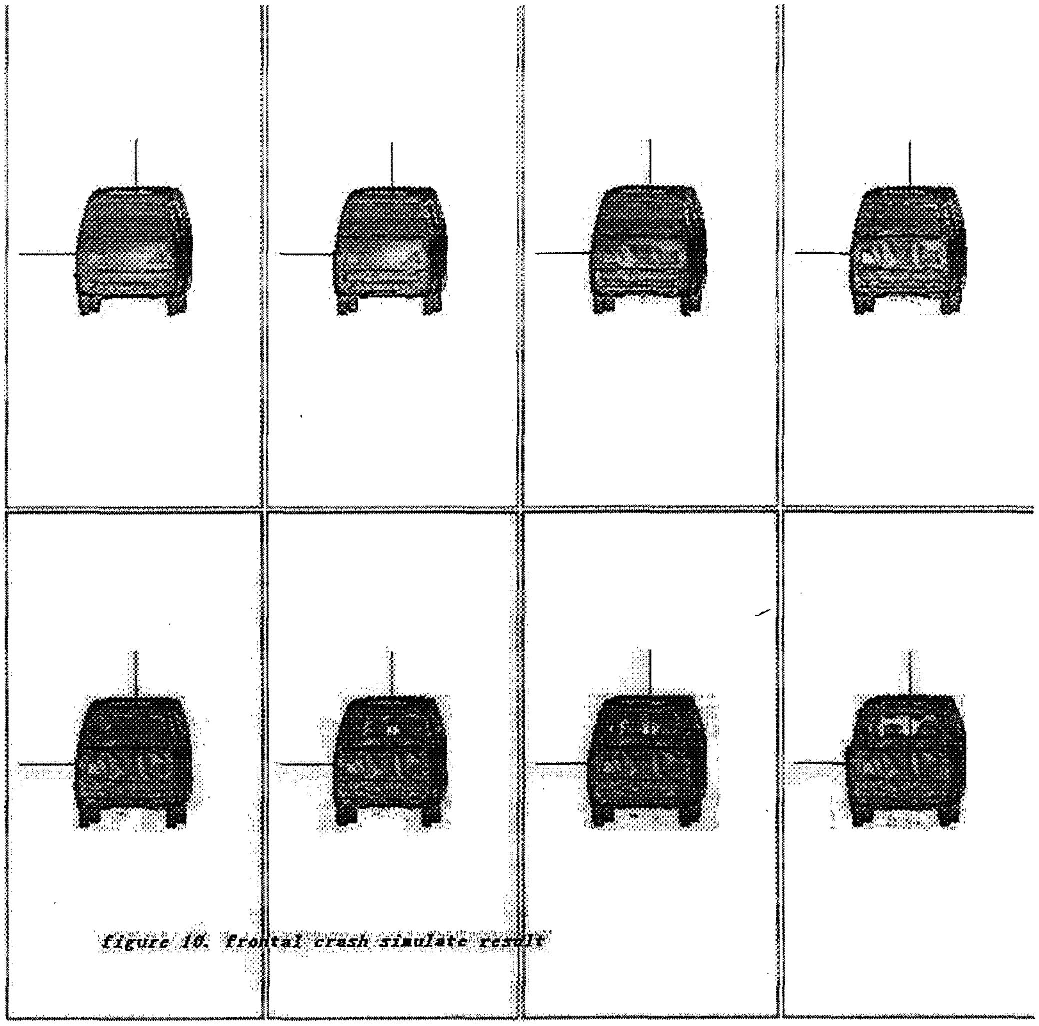

figure 10. frontal crash simulate result

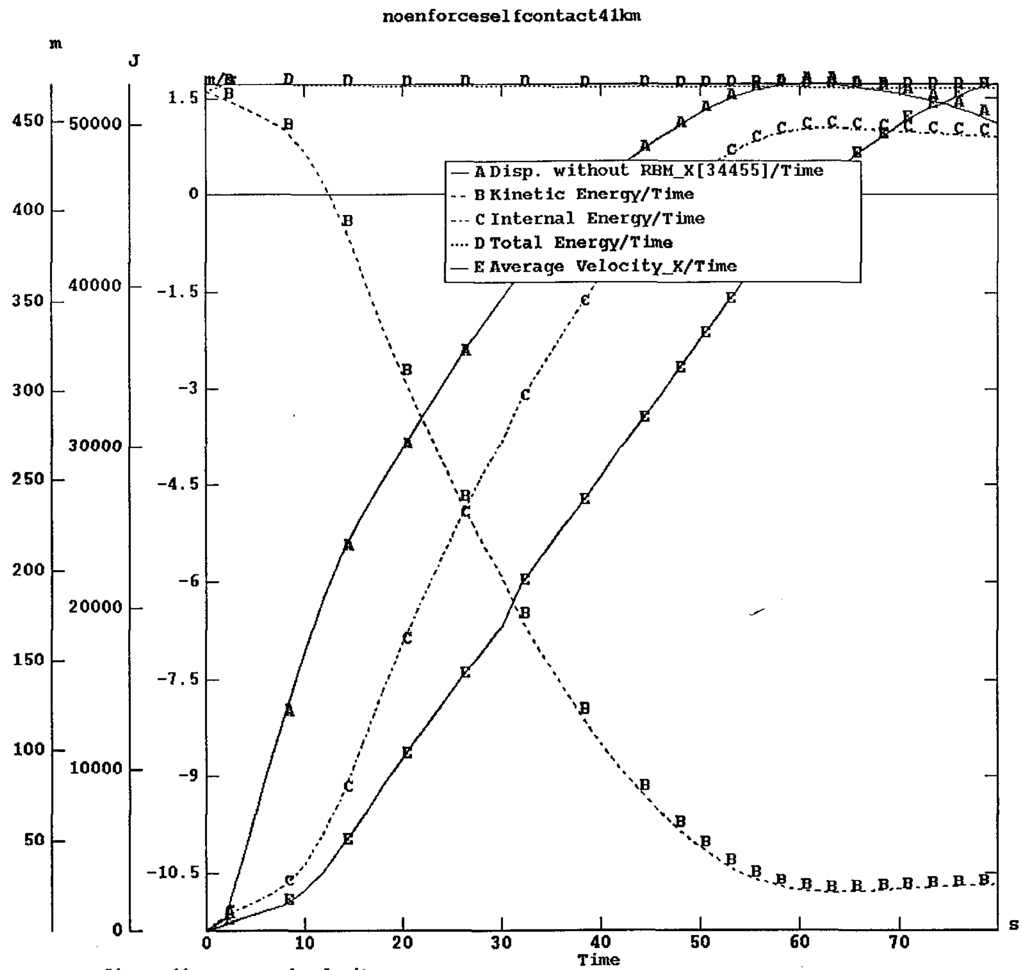

figure 11 energy and velocity curve