CAR BODY FRAMEWORK OPTIMIZATION FOR FRONTAL IMPACT BY USING LINEAR STATIC METHODS

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It proposes a method of car body framework optimization for frontal impact by using full finite element model of the car and linear static methods. The method based on single crash-test simulation and creating a calculation model for linear optimization. It was developed a calculation scheme, which allows to bring non-linear dynamic problem to linear static problem. Optimization of the framework was executed for linear static problem. Such methodology reduces calculation time for optimization of passenger compartment.

At present for calculation of car frontal impact it is necessary detail finite element models of the car (on JSC AvtoVAZ models with 400 000 – 1 000 000 finite elements are used). Optimization of the car body framework requires frequentative impact simulations. Also detail model is necessary for analysis such problems like noise, vibration, harshness. It requires to include corresponding linear static problems in optimization cycle. All this problems require big computational power.

One may to divide the problem of car body framework optimization on two relative independent problems: designing of front elements, which deforms during impact, and designing of passenger compartment. For estimation of these part groups the different criteria are used. For front elements the maximal absorption of energy for given deformations is important. A passenger compartment must ensure absence of plastic deformations and saving of initial geometry for given loads ideally.

The main idea of the approach is single simulation of frontal impact, loads (which load the passenger compartment during impact) calculation and subsequent optimization of passenger compartment by using calculated loads by static linear methods. For all that the correctness of problem solving is defined by follow main aspects:

1. Defining of the time moments for maximal loads
2. Correct calculation of the calculation loads
3. Creating of adequate calculation scheme

Definition of the time moments for maximal loads.

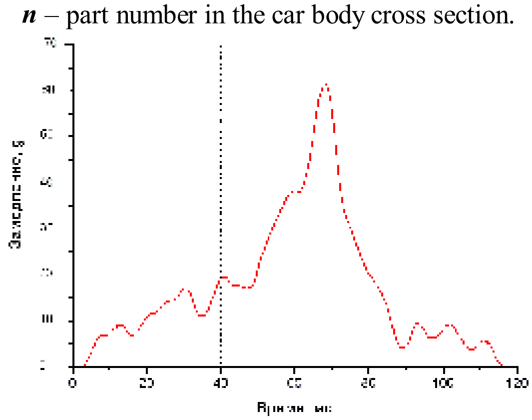
On picture 1 it can see several peaks of car deceleration (for example, on 30, 40 and 70 ms of the impact). It is necessary to examine all peaks of deceleration, because higher deceleration does't mean higher force as mass of moving parts is decrease during the impact. For our example the loads for 12, 30, 40, 58, 70 ms were taken. For estimation of loads the follow value was used:

$$Ps_j = \sum_i F_{i,j}, i = 1, n,$$

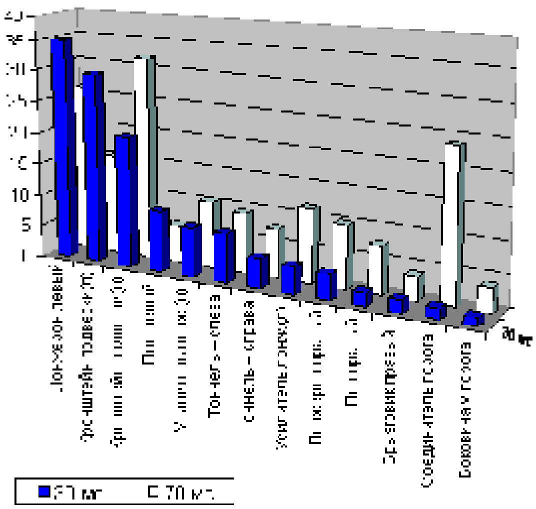
where $\boldsymbol{Ps_j}$ – summary force in j-th time moment;

$\boldsymbol{F_{i,j}}$ – summary force for i-th part cross-section and j-th moment time;

$\boldsymbol{n}$ – part number in the car body cross section.

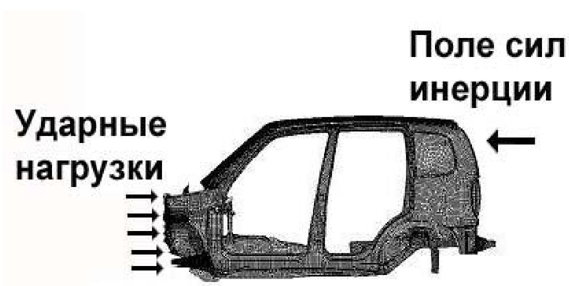


Calculation of the calculation loads.
It is necessary a special preparation of the car model. In this model the cross-section of all parts, which are near chosen car body cross-section, are described. On picture 2 all forces for parts are described. It is necessary the same table for all time moments.



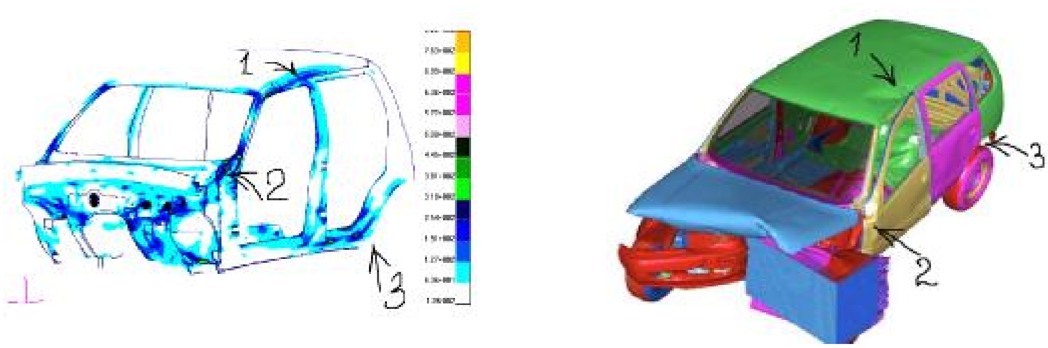
Pic.2. Distribution of the forces ***Fi*** in front element cross-sections for 30 and 70 ms.

Calculation scheme and optimization problem formulation. Calculation scheme is consist of detail finite element model of the car body. In the front part of the body the impact loads are applied. The impact loads are balanced by inertia field, which simulates a deceleration during impact (Pic. 3).



Pic.3.

On the pic.4 the comparison between stress picture for described before methods and results of impact simulation for 70 ms are showed. By arrows the places of buckling failure are showed. The pictures are similarity in a quantitatively and in a qualitative sense.



Pic.4.

Therefore the aim of static calculation of the body for decrease of stress, which produce a buckling failure, is correctness. :

$$\min(\sigma_{max}),$$

$$M \geq (\sum_{k} m_k, k = 1,l),$$

$$(t_{k,i} = t_{k,j} = t_k, i = 1,n), j = 1,n$$

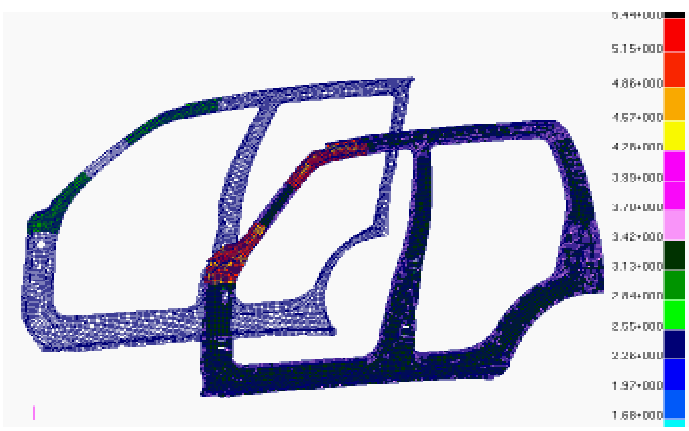
$$T_{min} \leq t_k \leq T_{max}, k = 1,l,$$

$$\theta_k \in \Theta, k = 1,l$$

where $\boldsymbol{\sigma_{max}}$ – maximal stress in the parts for all loadcases (for all chosen time moments);
$\boldsymbol{M}$ – maximum permissible mass;
$\boldsymbol{T_{min}}$, $\boldsymbol{T_{max}}$, – low and high boundary for part thickness;
$\boldsymbol{m_k}$ – added mass for the k-th part;
$\boldsymbol{t_{k,i}}, \boldsymbol{t_{k,j}}$ – thicknesses for the i-th and j-th finite elements of the k-th part;
$\boldsymbol{\Theta}$ – permissible lay out space, which is defined by technologic and ergonomic constraints.,
$\boldsymbol{\theta_K}$ – new geometry of the k-th part;
$\boldsymbol{l}$ – number of the modified parts.

Let examine this approach for finite element car model with 400 000 elements. On the first stage the simulation of the frontal impact was executed. After this all calculated loads are used for passenger compartment optimization for linear static problem.

The most dangerous parts are elements of the side strip. On the pic 5 the results of the optimization are showed.



Pic. 5.

After design and technology studies of the modified parts the examination is executed by static calculations and impact simulation.

Unfortunately now there is’t formal application of the described methodology, because high complexity of description of the lay-out and technology constraints on the first stage of the problem. Nevertheless the application of this method with others design workups allowed to improve the mark of the car for frontal impact by EuroNCAP scale from 4.5 to 12 points.

Summary

The main advantage of the proposed methodology:

- Using of unified full-size finite element model of the car both for impact simulation and stress analysis. It reduces the laboriousness of preparation model.
- Exclusion of impact simulation from the optimization cycle. It allows to use linear methods for optimization and to provide the solution for several tens hors of calculation on the modern workstation (not by using cluster).
- Correctness of the definition of loads on the car body, what is impossible for coarse models.