

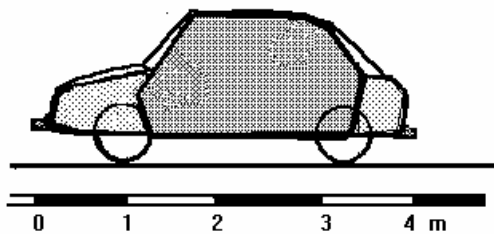
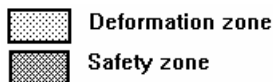
Appendix 1. Carried out calculations of impacts between mathematical models of vehicles.

Ap1.1 Mechanical properties of models used in calculations.

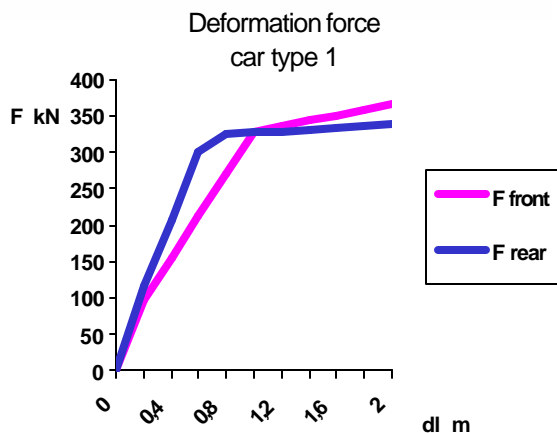
1 In general:

The mechanical properties of the "models" are chosen based on calculated results of impacts involving the full breadth of the «car» between the model and a massive block of infinite weight. The properties are calculated to give the different models a defined depth of deformation and calculated values of acceleration in collisions at different velocities. The **designed mass** is the mass of a loaded condition used in the calculations of impacts.

The design of the "models", either the types of cars or the seats, with defined mechanical properties is made to make it possible to analyse how changes of properties and conditions influence on the acting forces and changes of velocities in impacts.



Car type 1. Weight 1000 kgs.



Maximum acceleration at 80 km/h: approximately. 33,4 g.
 Depth of deformation: approximately. 1,06m

2 Cars and seats.

Car type 1:

Description:

Smaller 3 (5) door combi car. Min. operating weight 850 Kgs. Designed weight (crash-test weight): 1000 Kgs.

Collision strength front:

Depth of the deformation zone: 1,00 m.
 Design velocity without severe damage to the safety coupe: 50 km/h.

Maximum acceleration at 50 km/h: approximately. 23,5 g. Depth of deformation approximately 0,65m

Maximum acceleration at 100 km/h: approximately 35,8 g. Depth of deformation: approximately 1,60 m.

Collision strength rear:

Design velocity without severe damage to the safety zone: 50 km/h

Depth of deformation zone: 0,65 m.

Maximum acceleration at 50 km/h: approximately. 30,5 g.

Depth of deformation: approximately. 0,6 m.

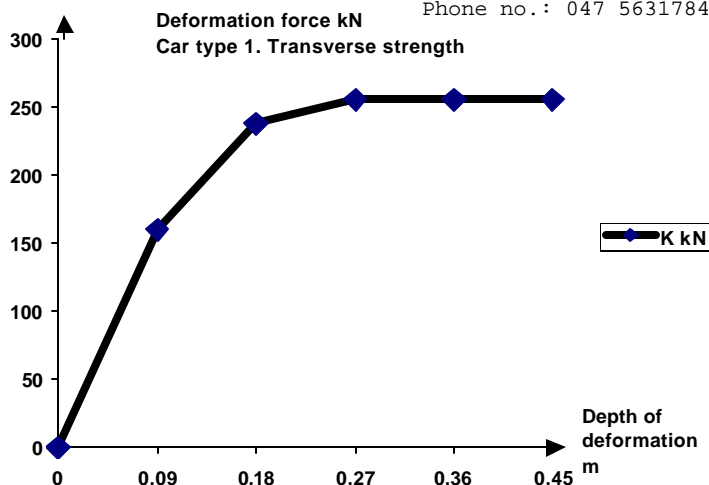
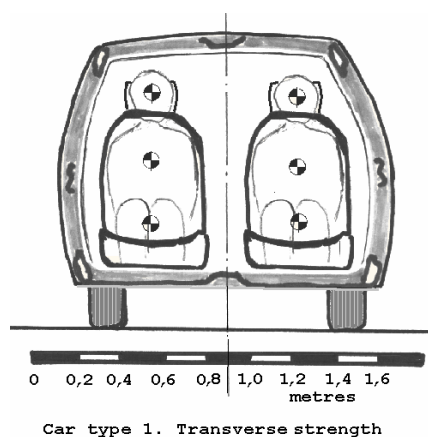
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Strength of bumper zones front and rear:

Depth of bumper zone = 0,08 m both ends. Maximum acceleration at 5 km/h: approximately. 3,9g. Depth of deformation: approximately. 0,05 m. Coefficient of elasticity of bumpers: approximately. 0,5.

Transverse strength:

Design criteria: Withstand a transverse impact towards a massive block with a width of 1,6 m and a height 1,0 m in a velocity of 50 km/h without a larger depth of deformation than 25 % of the breadth of car i.m. approx. 0,45 m.

Maximum transverse acceleration: approximately 26g.

Car type 2:

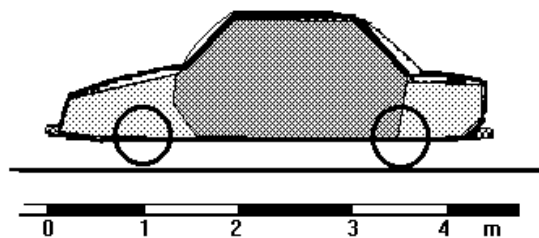
Description:

Larger sedan. Min. operating weight 1350 Kgs. Designed weight: 1500 Kgs.

Collision strength front:

Design velocity 80 km/h without severe damage to the safety zone.

Depth of deformation zone: 1,25 m.



Maximum acceleration at 80 km/h: approximately. 35,9 g.

Depth of deformation approximately 1,15m

Maximum acceleration at 120 km/h: approximately. 73,3g.

Depth of deformation approximately 1,70 m.

Collision strength rear:

Design velocity 75 km/h without severe damage to the safety zone.

Depth of deformation zone = 1,00 m.

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Maximum acceleration at 75 km/h: approximately. 39,7g. Depth of deformation: approximately. 1,00 m.

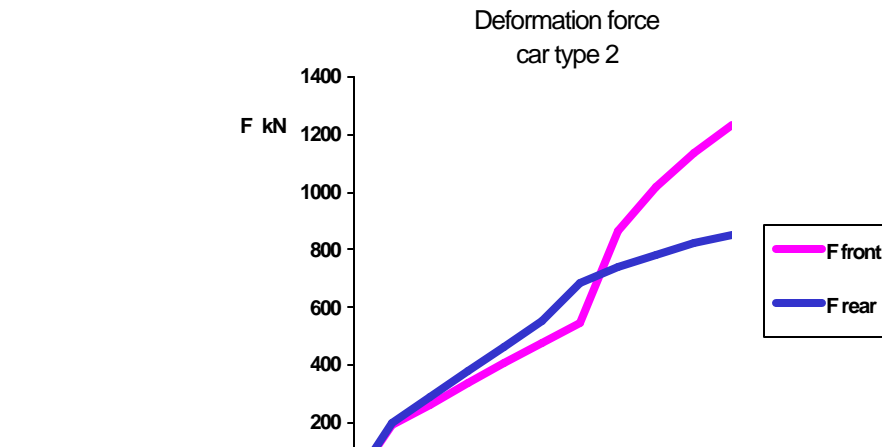
Maximum acceleration at 120 km/h: approximately. 54,5g. Depth of deformation approximately. 1,70 m



Strength of bumper zones front and rear:

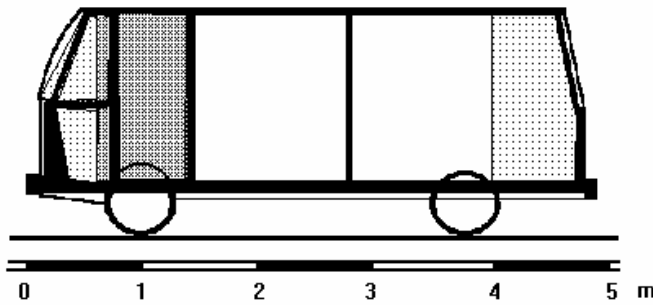
Depth of bumper zone = 0,10 m both ends. Maximum acceleration at 8 km/h: approximately. 7,6g.

Depth of deformation: approximately. 0,05 m. The bumpers to be considered as self repairing within 8 km/h.

Coefficient of elasticity of bumpers: approximately. 0,95.



 Deformation zone
 Safety zone



Car type 3. Weight 3000 kgs.

dl m

Car type 3:

Description:

Smaller cargo van. Min. operating weight 2000 Kgs. Designed weight: 3000 Kgs.

Collision strength front:

Design velocity 50 km/h without severe damage to the safety zone. Depth of deformation zone = 0.80 m.

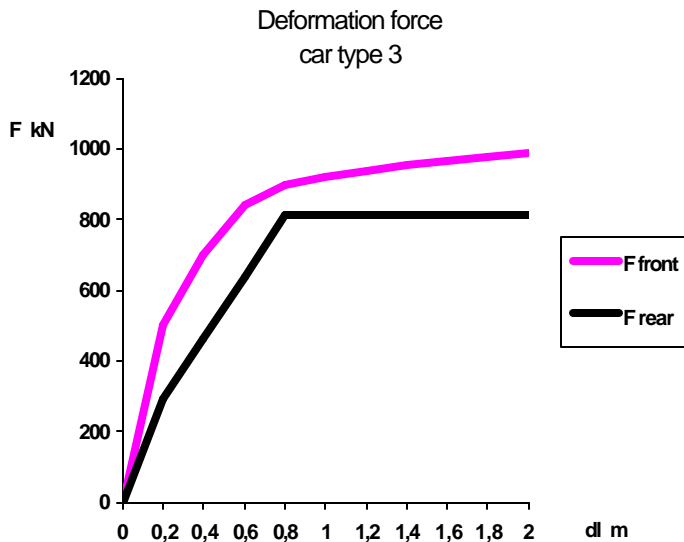
Maximum acceleration at 50 km/h:

approximately. 27,5g.

Depth of deformation: approximately. 0,55m

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Maximum acceleration at 100 km/h:
approximately. 32,6g.
Depth of deformation: approxi-
mately. 1,50 m.

Collision strength rear:

Design velocity 75 km/h without se-
vere damage to the safety zone.
Depth of deformation zone = 1,00 m.
Maximum acceleration at 50 km/h:
approximately. 24,6g.
Depth of deformation: approximately
0,70 m.
Maximum acceleration at 100 km/h:
approximately. 27,6g.
Depth of deformation: approxi-
mately. 1,78 m

Strength of bumper zones front and rear:

Depth of bumper zone = 0,08 m.
Maximum acceleration at 5 km/h: approximately. 3,9g.
Depth of deformation: approximately. 0,05 m.
Coefficient of elasticity of bumpers: approximately. 0,5.

Car type 4:

Description:



Distribution van. Min. operating weight 3500 Kgs. Designed weight: 6000 Kgs.

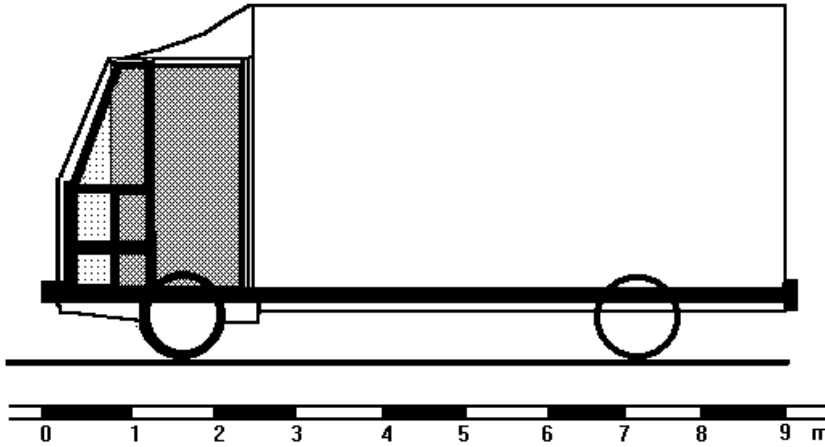
Collision strength front:

Design velocity 50 km/h without severe damage to the safety zone.
Depth of deformation zone = 0.65 m.
Maximum acceleration at 50 km/h approximately. 24,4 g. Depth of deformation approximately 0,60m
Maximum acceleration at 100 km/h approximately. 43,7 g. Depth of deformation approximately 1,40m.

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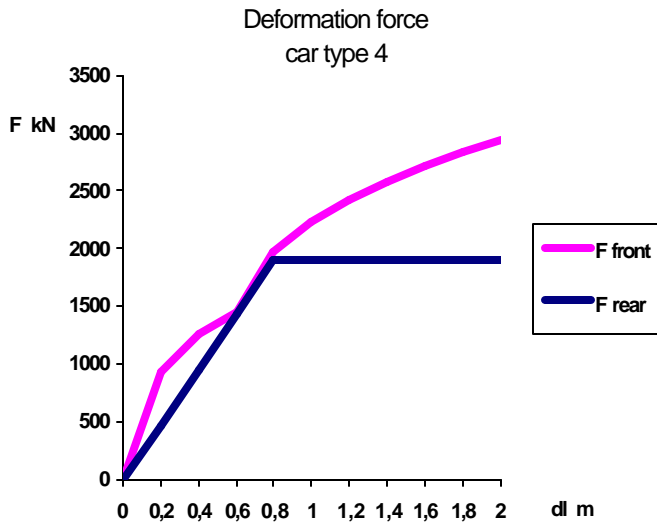
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 Deformation zone
 Safety zone



Car type 4. Weight 6000 kgs.

Depth of bumper zone = 0,08 m both ends.



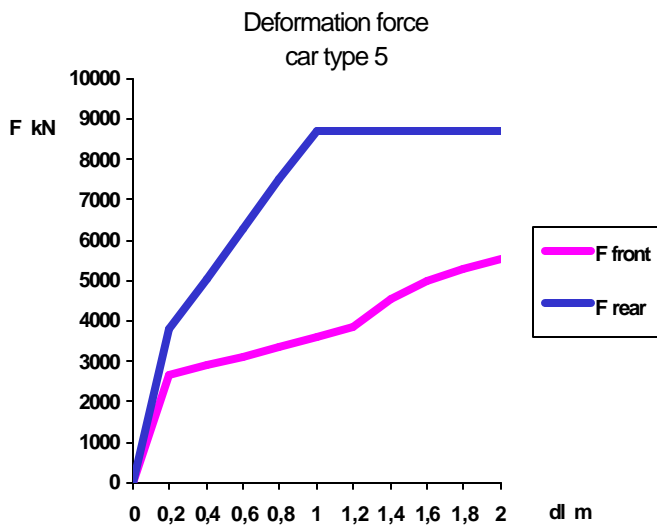
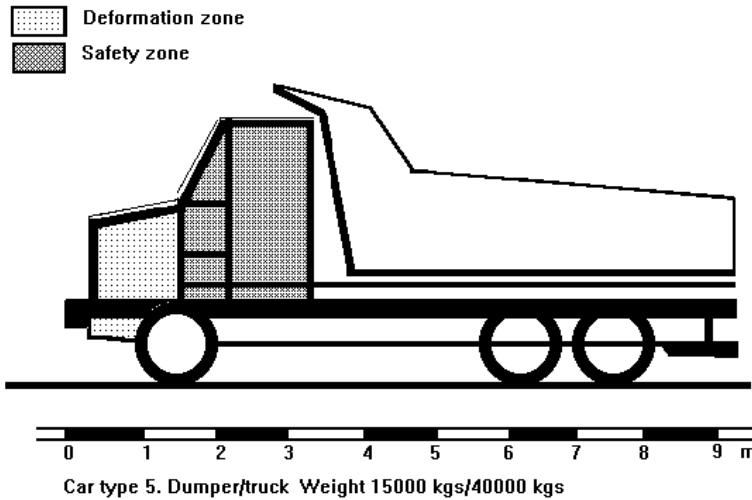
Collision strength rear:
 Design velocity 50 km/h without severe damage to the safety zone.
 Depth of deformation zone = 0,80 m.
 Maximum acceleration at 50 km/h: approximately. 28,2 g.
 Depth of deformation: approximately. 0,70 m.
 Maximum acceleration at 100 km/h: approximately. 32,3 g.
 Depth of deformation: approximately. 1,62 m

Strength of bumper zones front and rear:

Maximum acceleration at 5 km/h: approximately. 3,9 g.
 Depth of deformation: approximately. 0,05 m.
 Coefficient of elasticity of bumpers: approximately. 0,5.

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Car type 5:

Description:

Heavy truck/dumper. Min. operating weight 7500 Kgs. Designed weight: 15000 Kgs. Maximum weight with trailer 40000 Kgs.

Collision strength front:

Design velocity 80 km/h without severe damage to the safety zone.

Depth of deformation zone = 1,30 m.

Maximum acceleration at 80

km/h: approximately. 26,3 g. Depth of deformation: approximately. 1,25 m

Maximum acceleration at 100 km/h: approximately 34,9 g. Depth of deformation: approximately. 1,70 m.

Collision strength rear:

Design velocity 80 km/h without severe damage to the safety zone.

Depth of deformation zone = 1,00 m. Maximum acceleration at 80 km/h: approximately 50,89 g. Depth of deformation: approximately. 0,80 m.

Maximum acceleration at 100 km/h: approximately 59,2 g. Depth of deformation: approximately. 1,050 m

Strength of bumper zones front and rear:

Depth of bumper zone = 0,15 m both ends. Maximum acceleration at 10 km/h: approximately 7,85 g. Depth of deformation: approximately 0,10 m. Coefficient of elasticity of bumpers: approximately. 0,5.

The seats:

In the calculations I have used a specific deflection of the seat. This simplified way of calculating the forces between the seat and the body is based on an assumption of a certain proportionality of the projected area of a body and the weight.

In the calculations it's used two type of seats with different mechanical properties.

Type a: Deflection dl at an acceleration of 5 * g: 0,010 m

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Type b: *Deflection dl at an acceleration of 5 * g: 0,025 m*

The deflections are measured with a specific pressure based on the projected area of a normal male body, age 21, weight approximately 80 Kgs and a height 180 cm.

Carried out measurements shows the type a to be corresponding to a seat considered to be a seat with a good and firm support.

A comparison with the result of the same measurements on an ordinary mattress of foamed plastic gives a deflection of 10 times more. A stiffness of 1/10 gives a reduction in the calculated acceleration forces of 50 %.

In fact the deflection and the elastic properties of the seat structure will depend of the loads the seat is exposed to. To consider them as a specific deflection only dependent of the acceleration is a rough simplification.

A light and slim female body will probably cause deflections following such a deflection rate better than a taller male body.

As soon as more of the structural strength members of the seat becomes deflected, a specific deflection will diverge from the reality. And the more the structures are deflected, the more will the elastic abilities of the seat diverge from the elasticity of the upholstery alone.

Friction between seat and person.

I have done a test measuring the friction between the seat and the person seated by testing a cloth of the type of jeans onto a seat covered with a clothing of velour. I have found the coefficient of friction m to be about 0,9. Adding an effect of the deflection of upholstery due to the pressure the coefficient of friction is assumed to be about $m = 1,0$ giving a frictional force of:

$$F = m \times g \quad N.$$

Ap1.2 Calculated examples of rear-end collisions.

1 Description of programs used in calculations.

The contents of this compendium is based on a large number of calculations of impacts between different types of cars at different velocities and with changing loads.

These calculations are done in four computer programs of my own design:

- a: IMPACT2.PGM. Giving accurate acceleration values of a defined body. Used to «design» the mathematical models of cars. Gives values for a graphic presentation of the results.
- b: IMPACT1.PGM. Calculating the change of velocity and energy in centric impacts between bodies with different elastic properties.
- c: IMPACT3.PGM. Calculating accurate deformation values and accelerations of any centric impact between two defined bodies as well as how long the impact lasts together with the distance object A will run during the impact. Gives approximate values for a graphic presentation of the impact.
- d: IMPACT4.PGM. Calculating acceleration values of any body inside the stroked object B, depending of the velocity of C as the impact B-C starts, the distance x between B and C and the stiffness and the elastic ability of impact B-C. Gives min./mean./max. acceleration values of C

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APPENDIX 1

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together with simultaneous acceleration values of B in impact A-B. Gives approximate values for a graphic presentation of the impact.

The programs are designed in the «Work sheet» program Plan Perfect 3.0.

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2 Diagrams

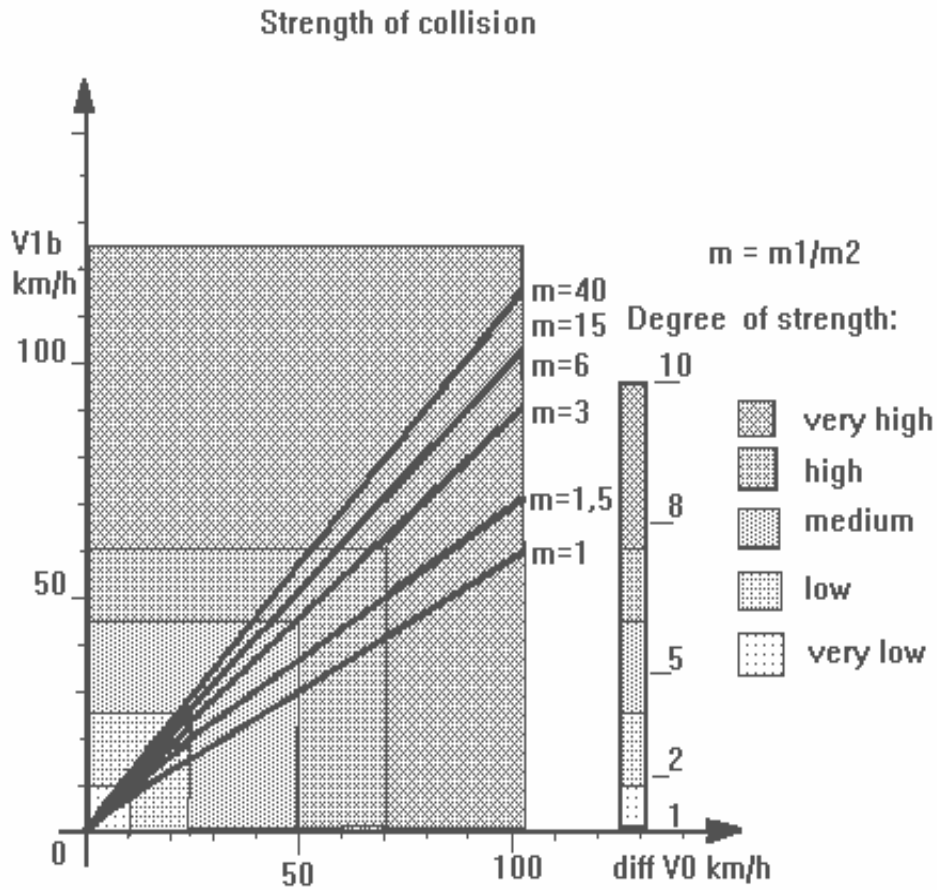
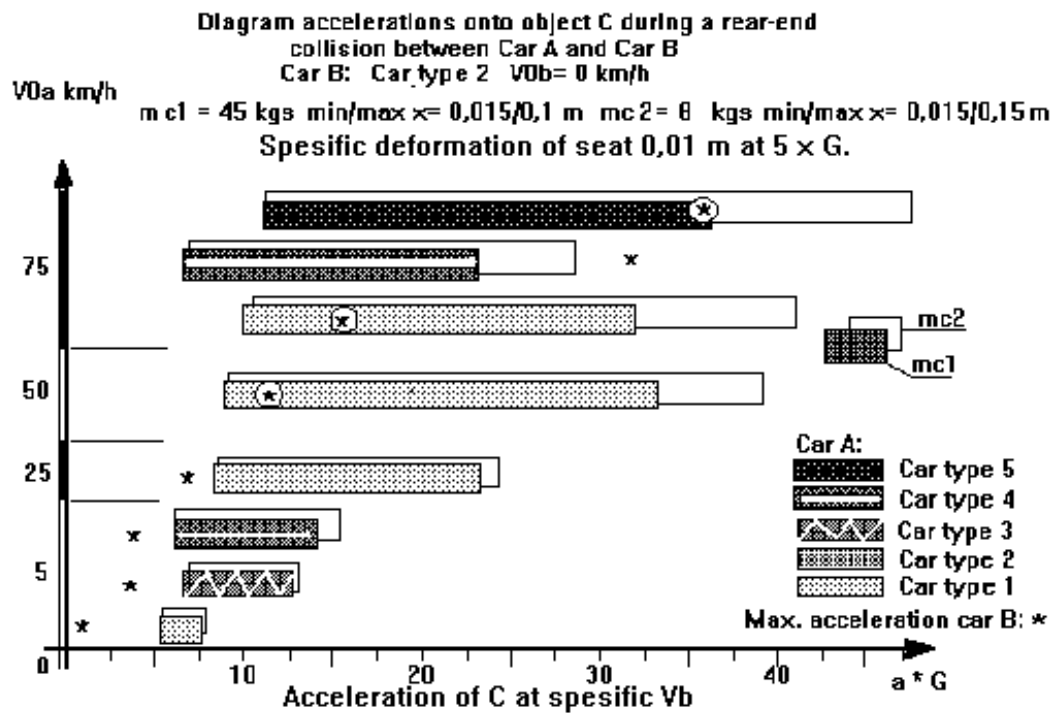


Fig. B.20

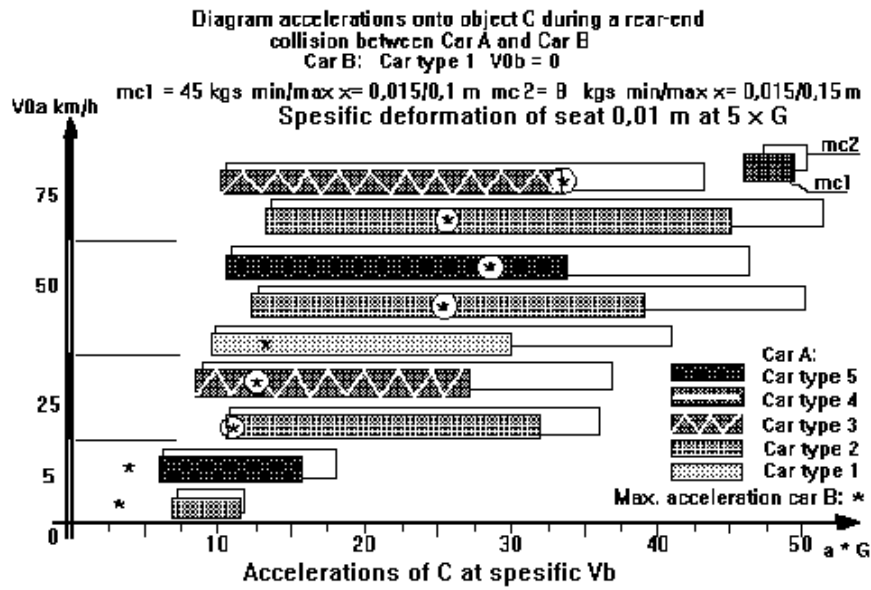
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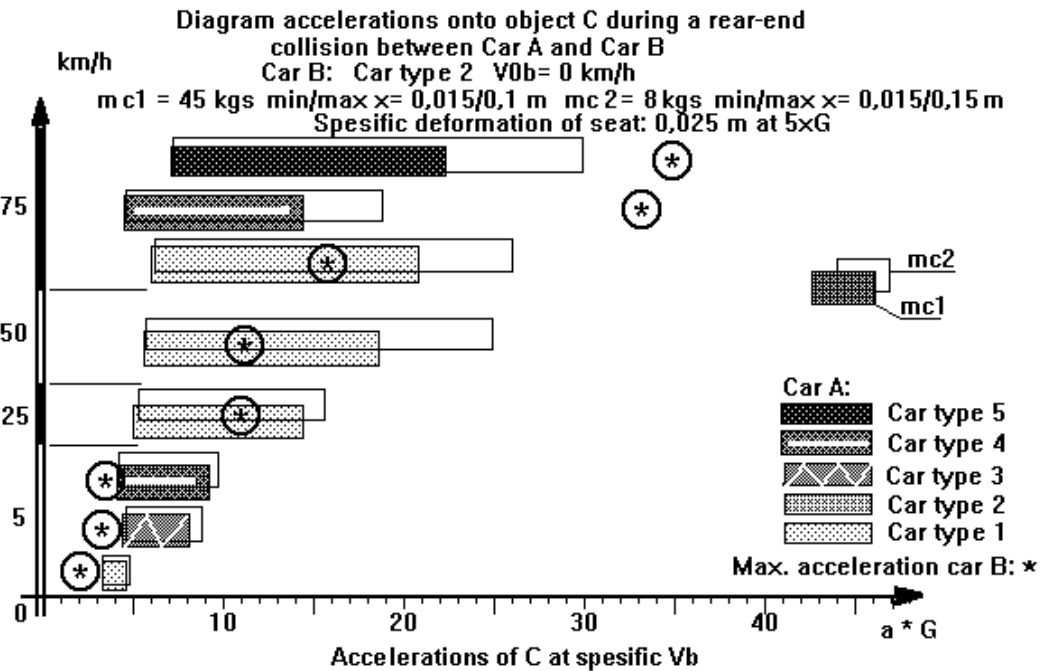
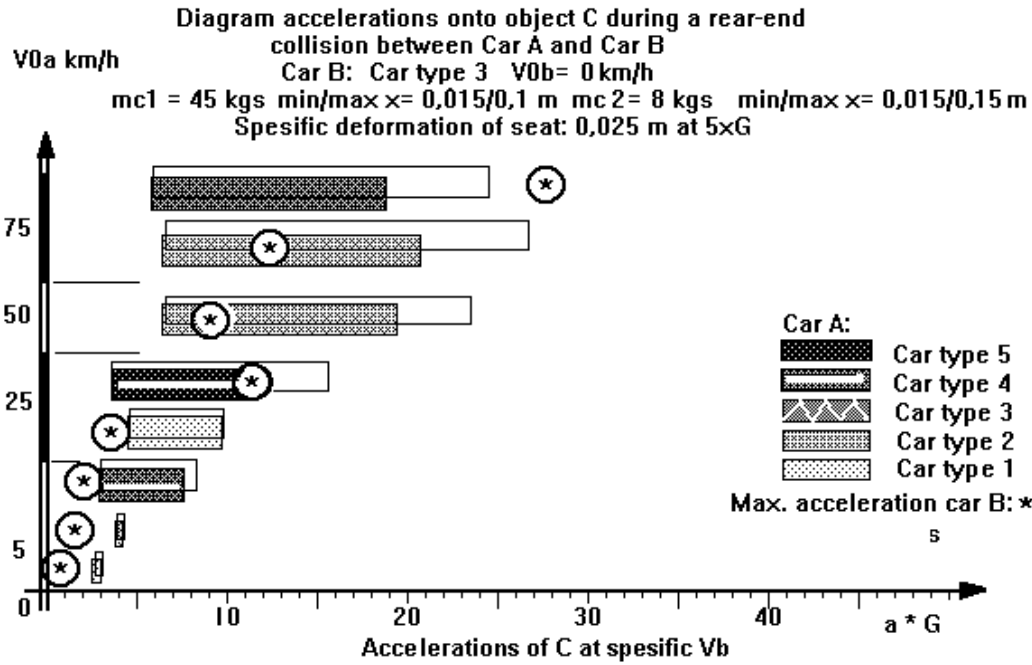
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Tables of calculated results.

Table A:

Results of calculations: Rear-end collisions between «models»

Car A strikes car B from behind.

Number of cases: 82.

Calculation program: IMPACT3.PGM

Table B:

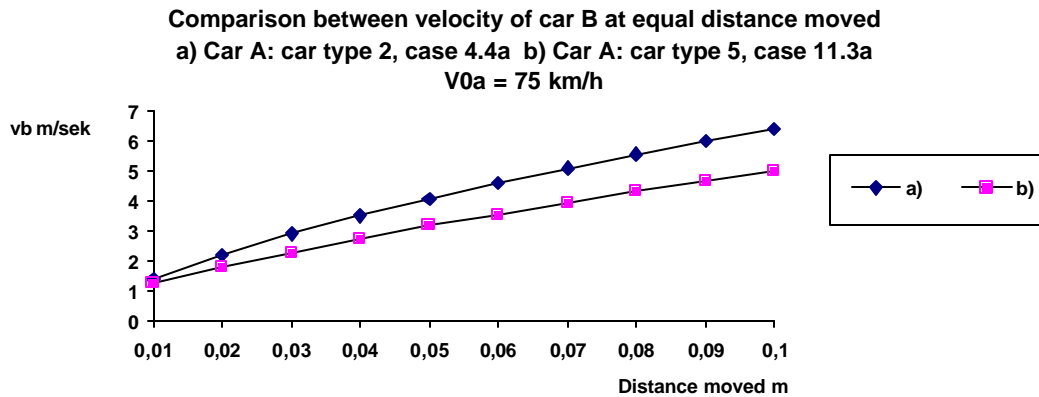
Results of the calculations of a body C in a selected number of the impacts in table A.

Number of cases: 63.

Calculation program: IMPACT4.PGM

Conversion factor for changing of the seats stiffness:

dl = 0,01m: f = 1; dl = 0,02m: f = 0,71; dl = 0,025m: f = 0,63; dl = 0,04m: f = 0,5



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