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Coefficient of restitution of model repaired car body parts

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Analysis and modelling

ABSTRACT

Purpose: The qualification of influence of model repaired car body parts on the value of coefficient of restitution and evaluation of impact energy absorption of model repaired car body parts.

Design/methodology/approach: Investigation of plastic strain and coefficient of restitution of new and repaired model car body parts with using impact test machine for different impact energy.

Findings: The results of investigations show that the value of coefficient of restitution changes with speed (energy) of impact. Moreover, coefficient of restitution is smaller for repaired model parts than for new parts. This could have influence on passive safety of vehicle.

Research limitations/implications: In the investigations aerodynamic resistance, friction in bearing of pendulum, part of impact energy changing to heat and vibrations were disregarded. Moreover, the investigations have been carried out on model of longitudinal. Only one grade of steel has been tested with using one type of welding.

Originality/value: The results of investigation show that repair of post-accident car body parts influences on value of coefficient of restitution and in a result on plasticity of car body and level of passive safety of post-accident vehicle.

Keywords: Computational material science and mechanics; Coefficient of restitution; Impact energy

1. Introduction

Work contains the attempt of the response to the question how is influence of post-accident repair of car body parts on passive safety of vehicle. During car crash very important is absorption of impact energy. The way of energy absorption influences on value and elapsed time of deceleration. Deceleration appears during car crash and depends on velocity of car in moment of crash, elapsed time of crash and construction of vehicle. Moreover, deceleration could be responsible for injuries of driver and passengers of vehicle during collisions.

One of way of impact energy absorption describe is evaluation of coefficient of restitution R. The coefficient of restitution was introduced by Newton. This parameter describes what part of impact energy is recovered in second part of impact, when vehicle reflects from barrier. Moreover, coefficient of restitution describes what part of impact energy is used up to plastic strain and elastic strain. For entirely plastic impact $R = 1$, but for entirely elastic impact $R = 0$. In reality impacts have elastic-plastic character and $0 < R < 1$ [1].

Coefficient of restitution depends strongly on relative impact velocity. This parameter shows what part of relative impact velocity is recovered after impact. When velocity after impact is smaller than velocity before impact it means that decrease of kinetic energy of system. Different of kinetic energy is connected with irreversible using up to plastic deformation, heat and vibrations.

For collisions of cars to fixed barrier with the relative velocities bigger than 20 [km/h] the coefficient of restitution is smaller then 0.1. When the velocity is smaller coefficient of restitution is in range from 0.2 to 0.6 and is marked by big scatter. These values are experimental effects for vehicle like vans and pickups [2]. Figure 1 shows coefficient of restitution in depends on impact velocity for vans and pickups.

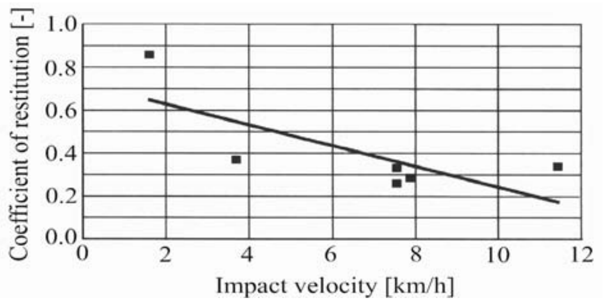

Fig. 1. Coefficient of restitution in depends on impact velocity for vans and pickups [2]

Further information about construction of car bodies, coefficient of restitution, deformations and cars crashes the reader can found in Ref. [3 - 10].

2. Theoretical grounds

Coefficient of restitution can be calculate for a lot of methods. One of them is method in which are registered two height and two mass during free fall (formula 4). On foundation that parameters coefficient of restitution has been calculated [1].

$$M = \frac{m_2}{m_1} \tag{1}$$

$$\lim_{m_2 \to \infty} M = \lim_{m_2 \to \infty} \frac{m_2}{m_1} = \infty \tag{2}$$

$$R = \frac{1}{M} + \frac{1+M}{M}\sqrt{\frac{h_2}{h_1}} \tag{3}$$

$$\lim_{M \to \infty} R = \lim_{M \to \infty} \frac{1}{M} + \frac{1+M}{M}\sqrt{\frac{h_2}{h_1}} = \sqrt{\frac{h_2}{h_1}} \tag{4}$$

where:
M – mass ratio[-],
R – coefficient of restitution [-],
m_1 – mass of pendulum [kg],
m_2 – mass of test piece + mass of test stand + foundation [kg],
h_1 – height of pendulum drop [m],
h_2 – height of pendulum reflect [m].

3. Research

Before investigation have been selected three things about evaluation of coefficient of restitution. There are test stand, test pieces and impact conditions.

3.1. Test stand

The investigations have been carried out on single-blow impact testing machine with modified pendulum form. Weight of test stand was about 700 [kg] and the mass of pendulum was 20 [kg]. Test stand has been fixed to the foundation (Fig. 2). During investigation two height have been registered: height of pendulum drop (h_1) and height of pendulum reflect (h_2).

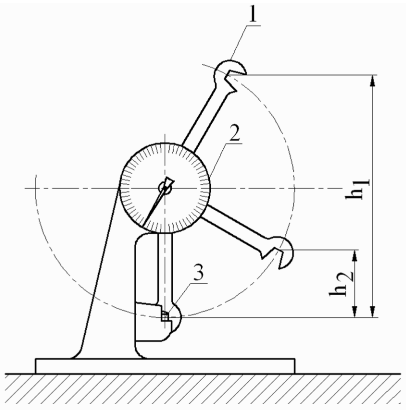

Fig. 2. Test stand: 1–pendulum, 2–registration device, 3–test pieces, h_1–height of pendulum drop, h_2–height of pendulum reflect

3.2. Test pieces

A large majority of car bodies are made by steel. Today they are HSS, HSLA, DP, TRIP steels, but a few years ago car bodies has been made by simplier steel grades.
Further information about materials for car bodies the reader can found in Ref. [9 - 11].

One of them is S235 and the test pieces have been made with this steel [11]. Chemical constitution of this steel has been shown in Table 1. In Table 2 have been shown mechanical properties of steel used in investigation.

Table1.
Chemical constitution of steel used in investigation [12]

No.	Chemical element	Content [%]
1.	C	0.17
2.	S	0.035
3.	P	0.035
4.	Si	0.10 - 0.35
5.	Mn	1.40
6.	Cu	0.55
7.	Ni	0.12

Table 2.
Mechanical properties of steel used in investigation [12]

No.	Property	Value
1.	Yield stress[MPa]	235
2.	Tensile strength[MPa]	380 - 520
3.	Elongation A_{50}[%]	16

Three kind of pieces had been made for investigation:

- pieces which model new, not repaired car body parts,
- pieces which model repaired parts with using straightening,
- pieces which model repaired parts with using TIG welding (Fig. 3).

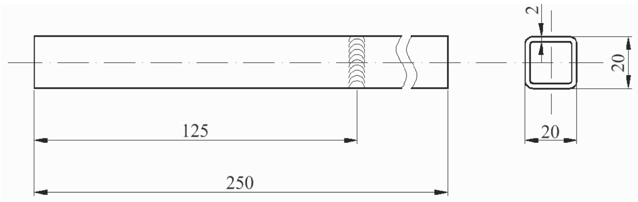

Fig. 3. Test pieces which model repaired parts with TIG welding

That three kind of test pieces have modeled not repaired and repaired car body parts. Post-accident car body parts are repair with straightening (with plastic deformation) or with exchange damaged part of car body element (witch welding). Further information about post-accident car repairs the reader can found in Ref. [13 - 16].

One on the most important thing during car crash is deformation of car body because impact energy among other things has been used to plastic strain of car body elements during car crash. Fig. 4 shows way of measurement of plastic deformation of model car body part.

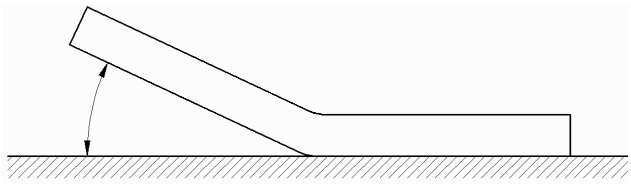

Fig. 4. The way of plastic deformation measurement

3.3. Impact conditions

During test pendulum has been drop from height h_1. Pendulum has hit on central part of test pieces. Size of deformation test pieces depends on impact energy. In next step pendulum of test stand has reflected and returned to height h_2. Heights h_1 and h_2 have been registered during investigations. In table 3 have been shown value of impact energy and velocity of pendulum during investigation.

Table 3.
Impact conditions during investigations

No.	Height of pendulum drop (h_1) [m]	Impact energy [J]	Impact velocity [m/s] ([km/h])
1.	0.91	178	4.2 (15.2)
2.	1.22	239	4.9 (17.6)
3.	1.41	277	5.3 (18.9)
4.	1.56	306	5.5 (19.9)
5.	1.61	316	5.6 (20.2)

4. Results

This work has introduced value of coefficient of restitution for model post-accident car body parts. Plastic deformation of test pieces after impact has been measured too. The investigations have been carried out with five level impact energy. Figure 5 shows plastic strain in depend on impact energy for three kind of test pieces. Results are average from three tests.

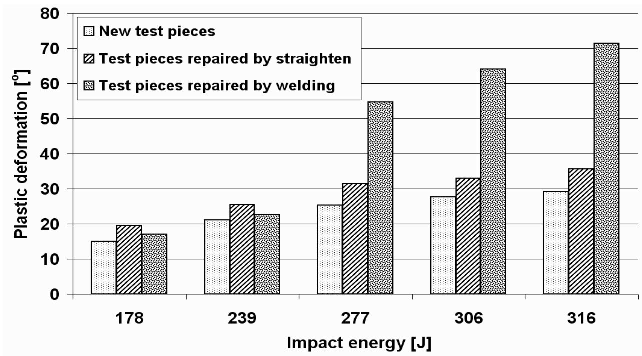

Fig. 5. Plastic deformation for new and repaired test pieces after test for different values of impact energy

For the smallest impact energy plastic strain has been characterized by similar value apart from kind of test pieces. The same situation has been observed for second value of impact energy. Larger plastic strain has been observed for larger impact energy. Plastic strain has increased with impact velocity and of course impact energy. Not repaired model test pieces have had the smallest plastic strain. The biggest plastic strain has been reached for pieces which model repaired parts with using TIG welding. Moreover, cracks of test pieces have been observed during investigation for test pieces repaired by welding. Cracks have appeared for fourth and fifth impact energy. Cracks have been observed in heat-affected zone.

Figure 6 shows value of coefficient of restitution in depend on impact energy for new and repaired test pieces. Results are average from three tests.

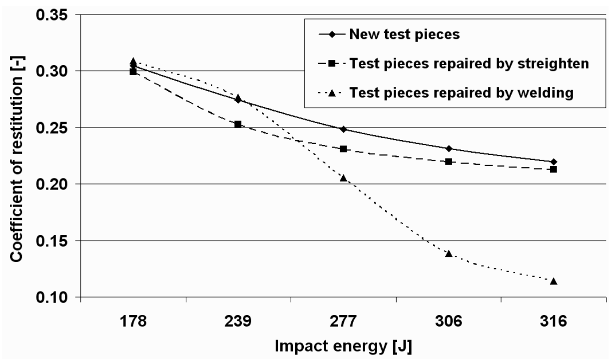

Fig. 6. Coefficient of restitution in depend on impact energy for new and repaired test pieces

Generally value of coefficient of restitution has decreased with increase of impact energy for all kinds of test pieces. The first value of impact energy has been characterized by similar value of coefficient of restitution for all kinds of test pieces. Similar situation has been observed for second impact energy. For impacts from third to fifth height drop coefficient of restitution of repaired by welding test pieces has decreased. The smallest values of coefficient of restitution has been observed for the largest impact energy. Moreover, the smallest coefficient of restitution has been observed for test pieces which have been cracked during investigations.

5. Conclusions

In this work has been shown simlpy way to computation of coefficient of restitution. In this way three kind of model car body parts have been tested. Results of investigations show that kind of post-accident repair has influence on deformation of car body during next car crash. Moreover, coefficient of restitution of repaired car body parts during repeated car crash depends on repair technology. Plastic strain is larger for larger impact energy, but for repaired test pieces differences are more visible. New test pieces have the smallest plastic strain. Test pieces repaired by welding have the largest plastic strain. When the impact energy is small that difference in value of coefficient of restitution not so large for different kind of test pieces. The difference in value of coefficient of restitution is larger for larger impact energy. Further than cracks have been observed during investigation of test pieces repaired by welding. Summary, for the same level of impact energy repaired test pieces have bigger deformation than new test pieces. Repaired test pieses have smaller plasticity and ability to absorption of impact energy. This is a reason of decrease of passive safety level.

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