UDK 621.91

TĂNĂSOIU A., "Aurel Vlaicu" University, Arad, Romania
COPACI I., "Aurel Vlaicu" University, Arad, Romania
NICOLA A., University of Petrosani, Romania

ON THE BUFFING PROCESS CAUSED BY THE SHOCK THAT APPEARS IN THE USE OF RAILWAY VEHICLES

The paper presents an experimental study on the appreciation of the values of forces that strain the bearing structures of railway vehicles during the shock caused by collision. For this purpose, a force transducer was designed and executed that measures force on three orthogonal directions, which was inserted on the king-pin bearing beam of the railway car's bogie. The theoretical computation methods for the forces that appear on the car during the shock caused by collision were verified through experimental measurements, with the resulting conclusions.

1.Theoretical Considerations

During the shock caused by collision, the longitudinal force F, applied through the shock insulators (buffers, central coupling dampeners) acts on the vehicle. At the same time, due to the accelerations transmitted to the vehicles, the following inertia forces appear [1], [2], [3], [4], [6], [8], [10] figure 1:

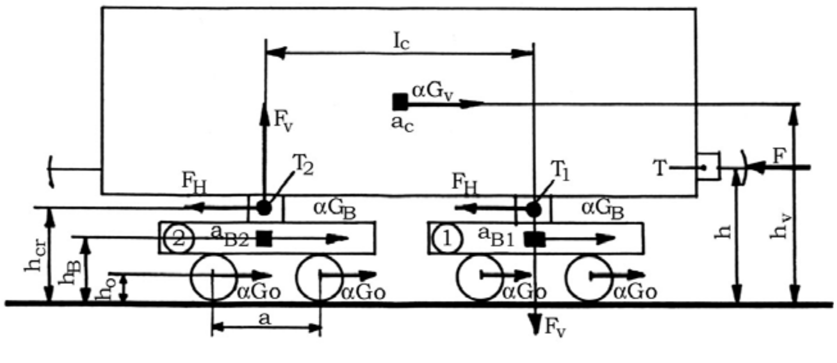

Figure 1 – Forces that act on the vehicle during the collision and transducers used for experimental determinations (T, T1, T2 – force transducers; aC, aB1, aB2 acceleration transducers)

1. F_{iV} – inertia force of the mass and weight G_V of the carbody and load of the vehicle:

$$F_{iV} = \alpha\ G_V \tag{1}$$

2. F_{iB} – inertia force of the mass and suspended weight of the bogie G_B :

$$F_{iB} = \alpha\ G_B \tag{2}$$

3. F_{iO} – inertia force of the mass and weight of the axle G_O:

$$F_{iO} = \alpha\, G_O \tag{3}$$

Theoretically, α is considered as being a proportionality coefficient equal to:

$$\alpha = \frac{a}{g} \tag{4}$$

where:

- a is the transmitted acceleration;
- g is the gravitational acceleration.

The magnitude of the proportionality coefficient α depends on the specific energy factor 2β, in the sense that its values decrease with the increase of 2β. The energy factor 2β is defined as [4]:

$$2\beta = \frac{W_e}{E_p} \tag{5}$$

where:

- W_e – potential deformation energy stored by the shock insulators (buffers, central coupling);
- Ep – total stored potential deformation energy.

$$E_p = \frac{m_1 m_2}{m_1 + m_2}\frac{v^2}{a} = W_e + W_{eo} + W_{ev} + W_{eB} \tag{6}$$

where:

- Weî – potential deformation energy stored by the freight;
- Wev – potential deformation energy stored by the bearing structure of the vehicle;
- WeB – potential deformation energy stored by the bearing structure of the bogies.

Thus, the equation becomes:

$$1 = \frac{W_e}{E_p} + \frac{W_{eo}}{E_p} + \frac{W_{ev}}{E_p} + \frac{W_{eB}}{E_p} \tag{7}$$

The proportionality coefficient α is obviously dependent on the value of the energy factor 2β, consequently on the quantity of potential deformation energy stored by the shock insulators that serve the purpose of diminishing the response of the considered mechanical system (transmitted acceleration and forces) to the shock caused by collision.

Figure 1 shows the inertia forces applied in their gravity centers and their distances from the railway.

The force transmitted during shock, F, is equal to:

$$F = F_{iV} + 2F_{iB} + 4F_{iO} \tag{8}$$

On each bogie there acts:

a) a horizontal component F_H and a vertical one F_V of the force that represents the reaction of the carbody in the bogie-chassis connection.

$$F_H = F_{iB} + 2F_{iO} \tag{9}$$

and:

$$F_V = \frac{F_{iV}(h_V - h) - 2F_{iB}(h - h_B) - 4F_{iO}(h - h_O)}{l_C} \tag{10}$$

where:

- h is the distance of the force F from the railway;
- h_V, h_B, h_O are the distances of the gravity centers of the carbody and freight, suspended part of the bogie and vehicle's axles from the railway;
- l_C vehicle axle base.

During the shock, the first bogie is additionally loaded with the value F_V, while the seccond is correspondingly unloaded.

b) inertia forces applied in the axis of each beam of the bogie $F_{iB}/2$ and in each axle box $F_{iO}/2$.

c) forces that represent the vertical reaction transmitted to the suspension from each wheel.

$$F_S = \frac{F_V}{4} \pm \frac{F_H(h_{Cr} - h_O) - F_{iB}(h_B - h_O)}{2a} \tag{11}$$

where:

- h_{Cr} is the distance of the bogie-chassis connection in relation to the railway;
- a bogie axle base.

For the vertical reaction transmitted to the suspension, the minus sign is adopted for the first and the plus sign for the second.

2.Experimental Testing

In order to experimentally determine the proportionality coefficient α and the components F_H and F_V collision testing was conducted under the following conditions [4], [8], [9]:

1. Colliding car with mass m_1 = 80t collided a car with mass m_2 = 25,5t, resting and unbraked, at collision velocities between (6,0 - 11,6)km/h.

2. The collided car had two bogies equipped with specially constructed force transducers, of own design [2], [5], [7], [11] fig. 2, mounted on the king-pin beam, fig. 3 and fig. 4. The force transducers T_1, T_2, which measure the force on three orthogonal directions, where placed in such a manner as to determine the forces on the longitudinal direction F_{H1}, F_{H2}, and vertical F_{V1}, F_{V2}, of the first and second bogie.

3. Figure 2 shows the used transducers.

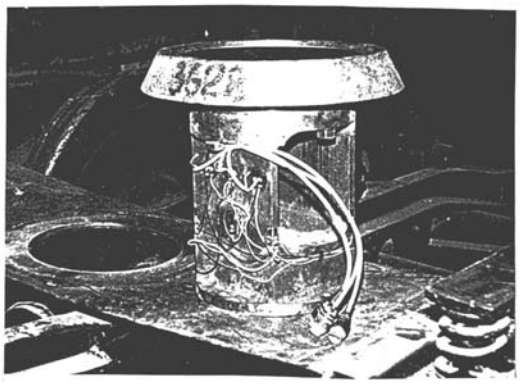

Figure 2 – Force transducer for three orthogonal directions

Figure 3 – Moment from the assembly of the force transducer in the king-pin bearing beam

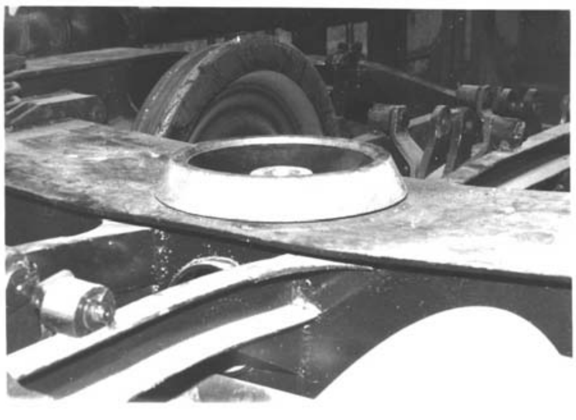

Figure 4 – Moment from the assembly of the force transducer in the king-pin bearing beam

For example, for the case of the collision at velocity v=11,6km/h the determined parameters were:

- force transmitted through buffers F = 1060,5KN;
- longitudinal acceleration of bogie 1 and 2 a_{B1} = 6,01g and a_{B2} = 6,31g, respectively;
- acceleration of the carbody a_C = 6,15g;
- vertical component of bogie 1 and 2 F_{V1} = 135KN; F_{V2} = 80KN, respectively;
- horizontal component of bogie 1 and 2 F_{H1} = 160KN; F_{H2} = 100,8KN, respectively.

3.Conclusions

1. From the measurements of the longitudinal accelerations of the bogies, the proportionality coefficient results as α_{B1}=6,01 for the first bogie, and α_{B2}=6,31 for the second. Since the weight of the bogie was G_B=4550kg, the values of the horizontal forces result as F_{H1}=273,4KN, and F_{H2}=287,0KN.

2. The experimentally determined values, using the force transducers T_1 and T_2, for the horizontal components F_{H1} and F_{H2} are significantly lower than those resulting from using the proportionality coefficients α_{B1} and α_{B2} determined by measuring the accelerations on the longitudinal direction a_{B1} and a_{B2}. It is observed that $F_{H1} > F_{H2}$.

3. The values of the vertical forces determined experimentally, confirm the supplementary vertical loading of the first bogie by F_{V1}=135KN and the almost complete unloading of the second bogie by F_{V2} = - 80KN.

4. Using the proportionality coefficients α_{B1} , α_{B2} of the bogies, and α_C=6,15 of the carbody, the vertical component F_V = 58,24KN was determined using equation (10). A large difference is observed between the values of the vertical forces measured experimentally with force transducers and the values determined with the proportionality coefficients α_{B1}, α_{B2} and α_C .

5. The proportionality coefficient, theoretically accepted as being the ratio between the acceleration transmitted to the vehicle and the gravitational acceleration, can not be used under this form for the theoretical computations of the forces F_H, F_V, F_{iV}, F_{iB}, F_{iO}, F_S, F.

6. Experimentally, a superior loading is observed vertically F_{V1} and horizontally F_{H1}, for bogie 1. Bogie 2, upoon application of the force transmitted to the car, F, during collision, has the tendency to completely unload vertically, being necessary to investigate the behaviour of the bogie-chassis connection for the collision of the empty car state. In this situation, the weight of the car acting on the bogie $G_V/2$ can be cancelled by the vertical component F_{V2} that acts in the opposite direction.

7. The strains of the bearing structures of the bogies during the collision process are determined by:

- Horizontal force F_H, applied in the bogie-chassis connection;
- Vertical force ($G_V/2 \pm F_V$), applied in the bogie-chassis connection;
- The moment due to the inertia forces of the suspended masses of the the bogie F_{iB} and the force F_H, which vertically load the second axle of the bogie while unloading the first one, in the support of the bogie frame on the suspension, with the value:

$$F_S^* = \pm \frac{F_H(h_{Cr} - h_O) - F_{iB}(h_B - h_O)}{2a} \tag{12}$$

8. The strains of the resistance structure of the carbody during the collision processare determined by:

- Weight of the carbody and freight $G_V = G_C + G_Î$;
- force F transmitted through the shock insulators to the carbody;
- inertia force F_{iV} due to the weight of the carbody G_C and the transported freight $G_Î$;
- forces F_H and F_V, applied in the bogie-chassis connection.

Further studies will establish the dependency relationship between the proportionality coefficient α and the energy factor 2β.

References: [1] Burada C. ; Buga M. et. al. Elemente şi structuri portante ale vehiculelor de cale ferată. Editura Tehnică , Bucureşti - 1980. [2] Copaci I. – Contribuții asupra comportării structurilor vagoanelor la solicitările provocate de şocul longitudinal produs la tamponare. Conducător Ştiințific: Prof. univ. dr. ing. Hoancă Vasile, Universitatea „Politehnica" Timişoara, 200 pg.,1996. [3] Copaci Ion, Bălaş Marius, The study upon the transmitted forces and stresses which appear during the freight car buffing, 7th Conference on Vehicle System Dynamics, Identification and Anomalies "VSDIA 2000" ISBN 963-420-704-9, 6-8.11.2000, Budapest, Hungary, pag. 211-218. [4] Sebeşan I. Copaci I. – „Teoria sistemelor elastice la vehiculele feroviare" Editura Matrix Rom, Bucureşti, 2008, 445 pagini, ISBN 978-973-755-372-0. [5] Copaci Ion, Bocîi Liviu Sevastian, Determinarea experimentală prin metoda tamponării vehiculelor feroviare a caracteristicilor dinamice ale amortizoarelor cuplei centrale, Analele Universității "Aurel Vlaicu" din Arad 2000, seria Mecanică,Fascicola: Rezistența materialelor, Material Rulant de Cale Ferată ISSN 1582-3407, pag. 69-78. [6] Tănăsoiu Aurelia – Asupra rezistenței şi fiabilității amortizorului ce echipează aparatul de tracțiune a vagoanelor de călători, Sesiunea de comunicări ştiințifice cu participare internațională „Cercetare ştiințifică şi educație în forțele aeriene", pag. 410 – 417, AFASES – 2008 Braşov 16 – 17 mai, [7] Copaci Ion, Bocîi Liviu Sevastian, Sârb Mihai, Determinarea experimentală a forței longitudinale la vehiculele feroviare echipate cu cuplă centrală, The First International Railway Vehicles Symposium, 25-26 november 2005, Bucharest, ISBN 973-755-038-2, pag.109-112. [8] Copaci Ion, Tănăsoiu Aurelia, Olaru Stelian, Potoceanu Alexandru - Vehicle-Railway Interaction, - Buletinul Ştiințific al Universității „Politehnica" din Timişoara, Seria Mecanică, Tom 52 (66), Fasc. 7, pag. 139 - 143ISSN 1224-6077, 2007. [9] Copaci Ion, Bocîi Liviu Sevastian, Bele Ioan, Olaru Stelian, Asupra comportării în exploatare a vagoanelor de marfă la solicitările de şoc ce apar datorită tamponării, Lucrările ştiințifice ale simpozionului multidisciplinar "Universitaria ROPET 2004", Ingineria Mecanică, 15-16 octombrie 2004, Petroşani, ISBN 973-8260-69-8, pag. 31-36. [10] Copaci I.,Olaru S., ş.a-"Rezistența la solicitări variabile ce apar în exploatarea vehiculelor feroviare"- Editura Mirton, Tmimişoara 2005; 232 pagini, ISBN 973-661-708-4. [11] "Dinamometru pentru măsurarea forțelor de aşchiere la prelucrarea cu scule de tip ascuțit " Invention Patent nr. 86.897/ 1985 , I.V.Arad.