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VECTOR METHOD TO COMPUTE D VALUE FOR HEAVY-ROAD VEHICLES COMBINATIONS

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ABSTRACT

European and Australian regulations indicates the D value computing relations for mechanical coupling components of combinations of vehicles. The aim of this paper is to find the mathematical model to deduce the structure of presented relations and eventually to simplify them.

Keywords: D values, vector method, GMC, adherence factor, truck, trailer

INTRODUCTION

According to literature [1, 2] the D values is the theoretical reference value for the horizontal forces in the towing vehicle and the trailer and is used as the basis for horizontal loads in the dynamic tests. For D, some different formulas are indicated, expressed as a function of prime mover and articulated vehicle combination (with one trailer, B- double, road train prime mover (towing two or three trailers) and road train converter dolly).

The prime mover transmits the load to the towed trailers by king pin and 5^{th} wheel or by turntable or a combination of 5^{th} well – king pin-turntable as is schematically suggested in Fig. 1a and 1b. As a function of the load, the converter dolly can be with one or two axle. The traction force is transferred by the turntable to the semi-trailer, as it is schematically suggested in Fig. 2 and Fig. 3.

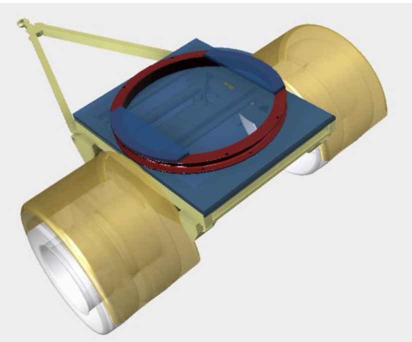


Fig. 1a. Converter dolly with turntable

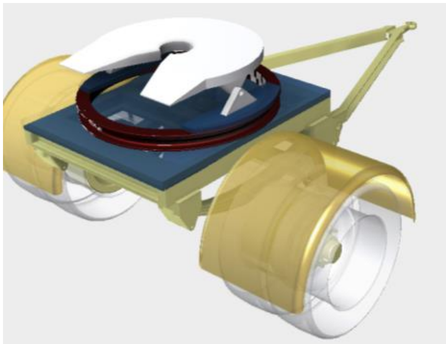
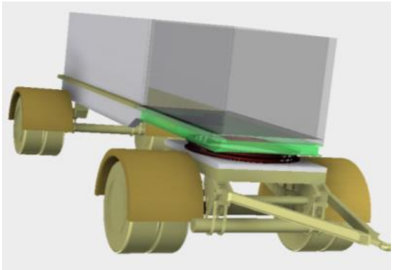
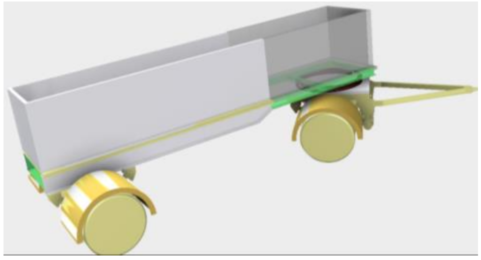


Fig. 1b. Converter dolly with turntable and 5^{th} wheel

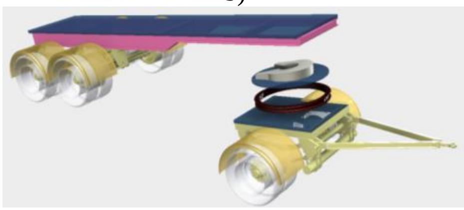


a)



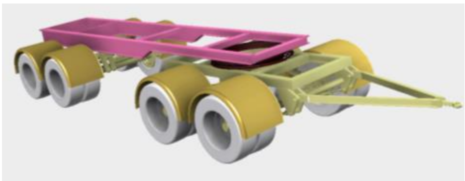
b)

c)



d)

Fig. 2. Converter dolly with a single axes and semitrailer components



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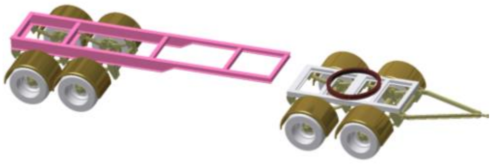

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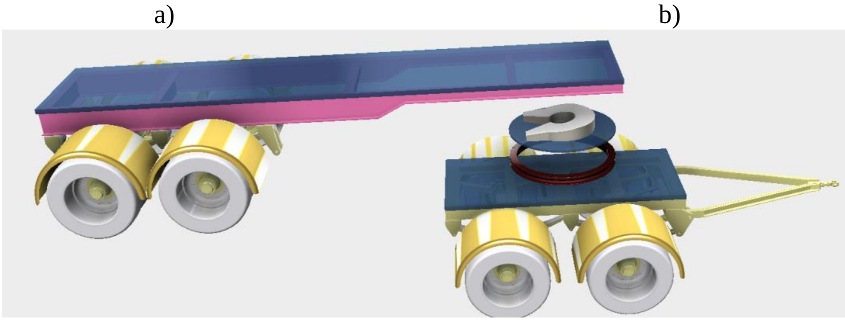

c)

Fig. 3. Converter dolly with two axes and semitrailer components

Mathematical model

A vector method is applied to find the link between the truck and semitrailer masses. If (M1=truck mass) and (M2=towed mass) then the link between the two components is given as center mass vector named rmc, according to Fig. 3.

Analytically, the rmc vector is described as follows:

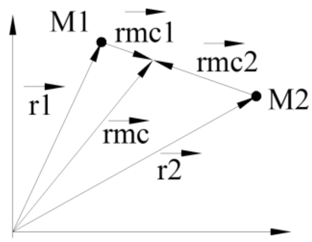

Fig. 3. The link elements between M1 and M2 center mass, as component of the truck semitrailer system

$$\overline{rmc}=\frac{\overline{r1}.m1+\overline{r2}.m2}{m1+m2} \quad (1)$$

$$\overline{r1}-\overline{rmc}=\overline{r1}-\frac{\overline{r1}.m1+\overline{r2}.m2}{m1+m2}=\frac{m2.(\overline{r1}-\overline{r2})}{m1+m2} \quad (2)$$

$$\overline{r2}-\overline{rmc}=\overline{r2}-\frac{\overline{r1}.m1+\overline{r2}.m2}{m1+m2}=\frac{m1.(\overline{r2}-\overline{r1})}{m1+m2} \quad (3)$$

$$\overline{D}=m1.\frac{\partial^2(\overline{r1}-\overline{rmc})}{\partial t^2}=m1\frac{m2}{m1+m2}\frac{\partial^2(\overline{r1}-\overline{rmc})}{\partial t^2}=\frac{m1.m2}{m1+m2}*g*\varphi \quad (4)$$

$$\overline{D}=m2.\frac{\partial^2(\overline{r2}-\overline{rmc})}{\partial t^2}=m2\frac{m1}{m1+m2}\frac{\partial^2(\overline{r2}-\overline{rmc})}{\partial t^2}=\frac{m2.m1}{m1+m2}*g*\varphi \quad (5)$$

where ϕ is the adherence factor; g=9.81 m/s^2.
If:
U is the static load in 5th wheel (slewing ring) between M1 and M2,
m1=M1+U,
m2=M2-U,
and x=(m1+m2)/(2*m1)

D= ϕ*g* (m1*x)*(m1*(1-x)+m2)/(m1+m2) (6)

Because M=m1+m2=M1+M2 and (m1*x)*(m1*(1-x)+m2)=M*M/4, it results

D=ϕ*g*M/4 (7)

According to equation (7), the D value can be computed as a function of GMC (gross mass combination) and the adherence factor between the wheels and the road.

Another case is revealed when the system is composed by a tuck and two semi trailer. Similarly with the anterior case if (M1 =truck) and (M2, M3=towed mass), the link between the 3 elements is the center mass system. All these components are presented in Fig. 4.

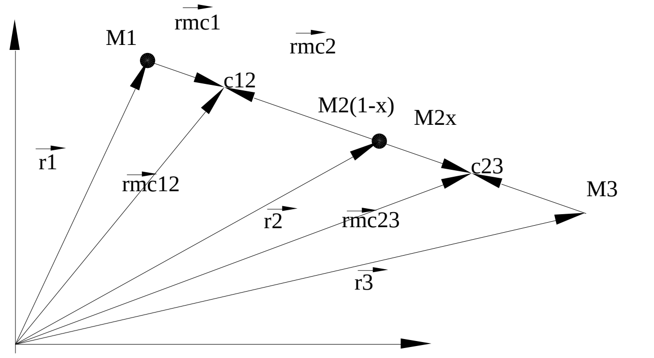

Fig. 4. The link elements between M1, M2 and M3 center masses, as components of the truck semitrailer system.

Some different cases were identified. To describe and coding these a list of symbols were presented according to figure 5.

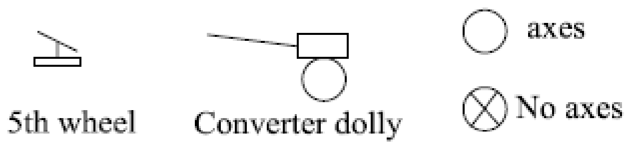

Fig. 5. List of symbols

According to Fig. 5, the following cases were identified and coded:
Case 00 00 00, presented in Fig. 6,

Case 01 -10 00, presented in Fig. 7,
Case 01 -11 -10, presented in Fig. 8.

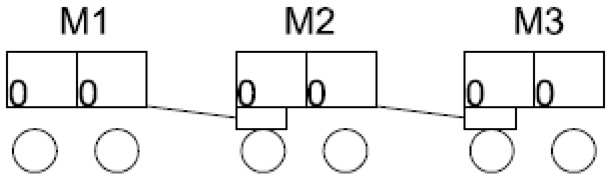

Fig. 6. Case 00 00 00 with converter dolly between M1, M2 and M3

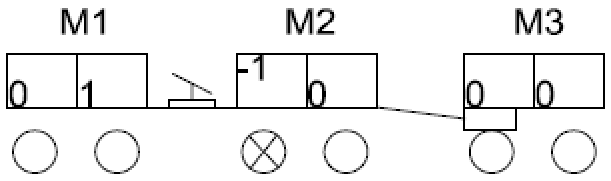

Fig. 7. Case 01 -10 00 with 5th wheel between M1 and M2, and converter dolly between M2 and M3

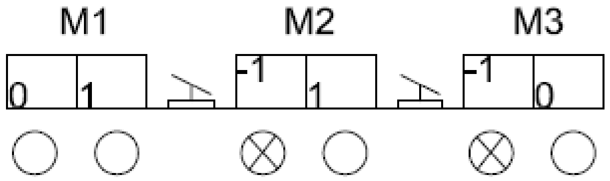

Fig. 8. Case 01 -11 -10 with 5th wheel between M1 and M2, and 5th wheel dolly between M2 and M3

In Figures 6, 7 and 8, the values 0, 1 and -1 indicate the effect of the transferred load U, in the mass modification. According with these notations, it results:
M1:=M1+(0 or 1)*U12
M2:=M2+(-1 or 0)*U12+(0 or 1)*U23
M3:=M3+(0 or -1)*U23
with
U12=static load in 5th wheel (slewing ring) between M1 and M2
U23=static load in 5th wheel (slewing ring) between M2 and M3

We note :
T=M1
M=M1+M2+M3 represents GMC (gross mass combination);
R=M-T;

To find the D formula, 3 intermediary values are introduced, as following:
x=(M1+M2-M3)/(2*M2)
A2=M2/R
A3=M3/R

According with the vector method, it results:

$$D=\phi*g*[M1+M2*(1-x)]*[M2*x+M3]/M \quad (8)$$

equivalent with

$$D=\phi*g*R/M*[T*(A2*x+A3)+R*A2*(1-x)*(A2*x+A3)] \quad (9)$$

Because (A2*x+A3) is a common variable, it results:

$$D=\phi*g*R/M*(A2*x+A3)\ [T+R*A2*(1-x)] \tag{10}$$

Because A2*x+A3=M/ (2*R) and A2*(1-x) =(R-T)/ (2*R), it results:

$$T+R*A2(1-x)=T+R*(R-T)/(2*R)=M/2$$

The formula for D will be:

$$D=\phi*g*M/\ (2*R)*(R/M)*(M/2)=\ \phi*g*M/4 \tag{11}$$

CONCLUSION

A simply equation is developed to describe D values and it completes the Regulation No 55 and ISO-TC-22. It takes into account the GMC (gross mass combination) and the adherence coefficient between wheel and road. The ϕ*g*GMC/4 formula works also for extended truck-trailer configuration.

REFERENCES

1. AS/NZS 4968.1:2003. Heavy road vehicles—Mechanical coupling between articulated vehicle combinations. Part 1: Design criteria and selection requirements for fifth wheel, kingpin and associated equipment
2. Regulation No 55 of the Economic Commission for Europe of the United Nations (UN/ECE) — Uniform provisions concerning the approval of mechanical coupling components of combinations of vehicles.