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IMPROVING THE AXLE DRIVE SYSTEM FOR THE 3400 KW ELECTRIC LOCOMOTIVE

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Abstract: The CFR's class 43 and 46 electric locomotives (3400 kW) are built in the early 1980's using a very reliable solution from ASEA.

The axle drive system though, which is appropriate to a DC traction motor, doesn't meet the actual needs for high speeds. Thus, a new system using AC traction motors and a different mechanical approach is much more suitable, reliable and cost effective.

The solution of complete suspended traction motor and gear is successfully used in railway applications, such as OBB's Taurus locomotives. This study reveals the advantages of using a similar solution on class 43 locomotives.

First, the forces occurring in both situations (actual drive system and improved one) are calculated. As a result, the values indicate the advantage of the complete suspended axle drive system.

Then, a series of practical comparisons based on tests performed by the DB are presented. The tests involved a classic BR locomotive and the 'EuroSprinter'. In this case too, the tests revealed the advantage of using the complete suspended axle drive system.

Using this mechanical solution, the additional axle loads are eliminated and the use of the AC traction motors will help reducing the un-suspended mass and also improving the traction performances.

The solution is cost effective, as the locomotive chassis and bogie frames will remain the same.

Key words: electric locomotive, axle drive system, bogie, drive, gear.

1. Introduction

The CFR's class 43 and 46 electric locomotives (3400 kW) are built in the early 1980's using a very reliable solution from ASEA.

The axle drive system though, which is appropriate to a DC traction motor, doesn't meet the actual needs for high speeds. Thus, a new system using AC traction motors and a different mechanical approach is much more suitable, reliable and cost effective.

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2. The bogie

The locomotive has two bogies, each one the two-axle type. The actual bogie is shown in figure 1.

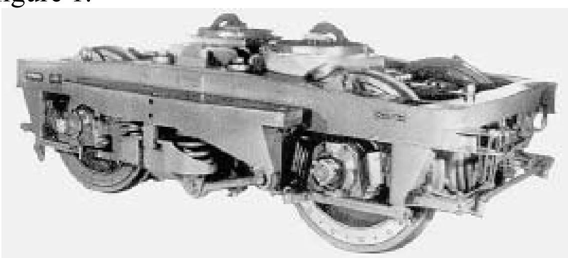

Fig.1. The bogie

The axle drive system consists in two suspended traction motors and two half suspended gearboxes. The axle drive system is presented in figure 2.

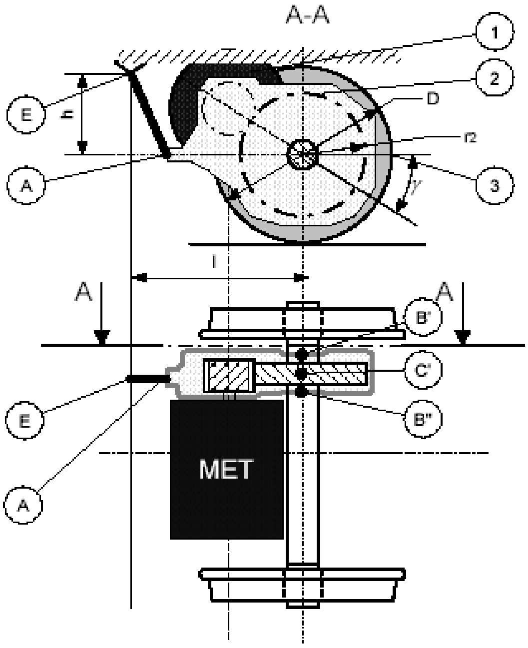

Fig. 2. The axle drive system
1 – traction motor (MET); 2 – gear box; 3 – mounted axle.

3. The forces in the actual drive system

The traction motor is suspended completely to the bogie frame and the gearbox is half suspended to the bogie frame through the AE bar. The other side of the gearbox's case is mounted directly on the axle, in the points B' and B''. In order to determine the forces occurring in point C, the situation in which the axle moves from left to right is considered. Thus, the traction motor is situated behind the axle.

The motor torque drives the whole system and may be written as a couple of two opposing forces, marked as P_t. The gear and the forces are presented in figures 3 and 4.

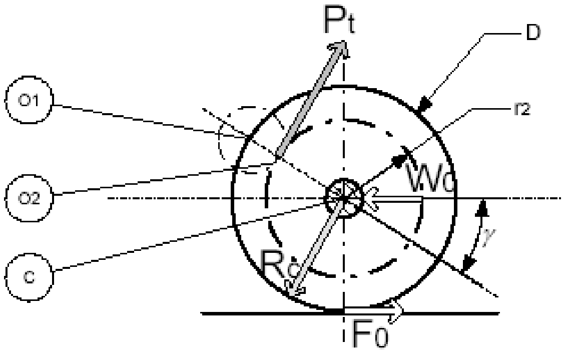

Fig. 3. The gear and the forces

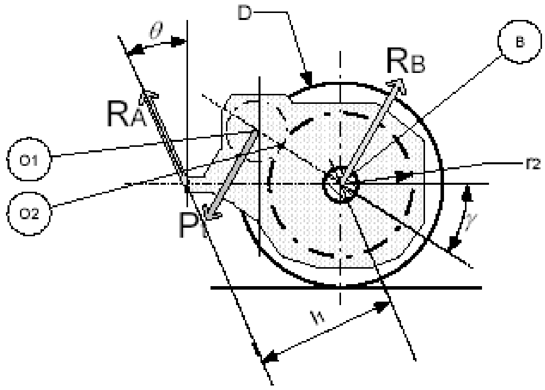

Fig. 4. The gear casing and the forces

The force occurs in O_1 and O_2 points situated on the gear casing and in gear contact point.

The equilibrium conditions at axle level (see fig. 3) are:

$$\left.\begin{array}{l} F_0 = W_0 \\ P_t \cdot r_2 = F_0 \dfrac{D}{2} \end{array}\right\} \Rightarrow P_t = F_0 \frac{D}{2r_2}$$

$$R_C = P_t = F_0 D / 2r_2$$

where F_0 is the traction force, W_0 is the mechanical drag, D is the wheel diameter, R_c is the reaction force in the C point, Pt is the loading force deriving from the motor torque and r_2 is the radius of the axle gear.

The equilibrium conditions for gear casing (see fig. 4) are:

$$\begin{aligned} V:&\quad R_{BV} - P_t\cos\gamma + R_A\cos\theta = 0\\ H:&\quad R_{BH} - P_t\sin\gamma - R_A\sin\theta = 0 \end{aligned};$$

$$\sum M_{B'=B''} = 0 : R_A l_1 = P_t(r_1 + r_2)$$

Considering these equilibrium conditions, the horizontal and vertical reaction forces at axle level result:

$$\begin{cases} \rightarrow R_A = P_t(r_1+r_2)/l_1 = \\ = F_0\dfrac{D}{2r_2}(r_1+r_2)/l_1 = \dfrac{F_0D}{2l_1}\left(1+\dfrac{1}{r_2/r_1}\right) = \dfrac{F_0D}{2l_1}\left(1+\dfrac{1}{i}\right) \\ \rightarrow R_{B_V} = P_t\cos\gamma - \dfrac{P_t}{l_1}(r_1+r_2)\cos\theta \\ = P_t\left[\cos\gamma - \dfrac{r_1+r_2}{l_1}\cos\theta\right] = \\ \dfrac{F_0D}{2r_2}\left[\cos\gamma - \dfrac{r_1+r_2}{r_2}\dfrac{r_2}{l_1}\cos\theta\right] = \\ = \dfrac{F_0D}{2r_2}\left[\cos\gamma - \left(1+\dfrac{1}{i}\right)\dfrac{r_2}{l_1}\cos\theta\right] \end{cases}$$

$$\begin{cases} \rightarrow R_{B_H} = P_t\sin\gamma + R_A\sin\theta = \\ = P_t\left[\sin\gamma + \dfrac{r_1+r}{l_1}\sin\theta\right] = \dfrac{F_0D}{2r_2}\left[\cos\gamma - \left(1+\dfrac{1}{i}\right)\dfrac{r_2}{l_1}\sin\theta\right] \end{cases}$$

$$\begin{cases} R_{C_V} = R_C\cos\gamma = P_t\cos\gamma = \dfrac{F_0D}{2r_2}\cos\gamma \\ R_{C_H} = R_C\sin\gamma = P_t\sin\gamma = \dfrac{F_0D}{2r_2}\sin\gamma \end{cases}$$

The real forces are:

$$\begin{cases} R_{C_V} = R_C\cos\gamma = P_t\cos\gamma = \dfrac{F_0D}{2r_2}\cos\gamma \\ R_{C_H} = R_C\sin\gamma = P_t\sin\gamma = \dfrac{F_0D}{2r_2}\sin\gamma \end{cases}$$

where i is the gear ratio.

Due to the fact that the B' and B'' points are very close, the PBV and PBH forces are considered to occur in the C point, also marked as "O". Figure 5 shows the forces occurring in the O point.

The horizontal and vertical components are the sum of the forces occurring in the B and C points, as written below:

The reaction induced to the bogie frame appears in the E point (see fig. 1 and 6).

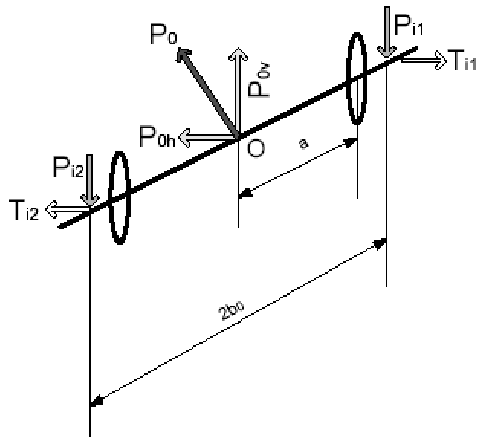

Fig. 5. The forces in the O point – the driving point

$$\begin{cases} P_{CV} = -(R_{CV}) = -\dfrac{F_0D}{2r_2}\cos\gamma \\ P_{CH} = -(-R_{CH}) = \dfrac{F_0D}{2r_2}\sin\gamma \end{cases};$$

$$P_{B'_V} = P_{B''_V} = R_{B_V}$$
$$= \frac{F_0D}{2r_2}\left[\cos\gamma - \left(1+\frac{1}{i}\right)\frac{r_2}{4}\cos\theta\right]$$
$$P_{B_H} = -R_{B_H}$$
$$= -\frac{F_0D}{2r_2}\left[\sin\gamma + \left(1+\frac{1}{i}\right)\frac{r_2}{4}\sin\theta\right]$$

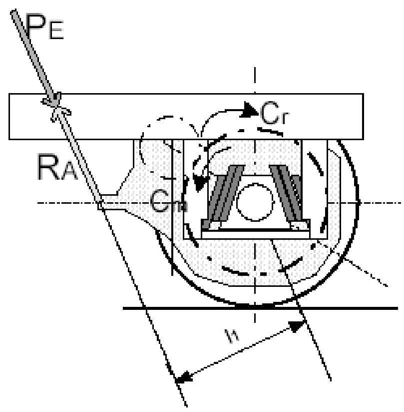

Fig. 6. The reaction induced to the bogie frame

$$P_E = -(R_A) = \frac{F_0D}{2l_1}\left(1+\frac{1}{i}\right)$$
$$C_r = -C_m = P_t r_1 = \frac{F_0D}{2l_1}r_1 = \frac{F_0D}{2l_1}\frac{1}{i}$$

4. The forces in the new drive system

The proposed new drive system is used mainly in Europe for powerful high speed locomotives

, such as Siemens' Taurus. The entire axle drive system is suspended to the bogie frame. The Siemens system is presented in figure 7.

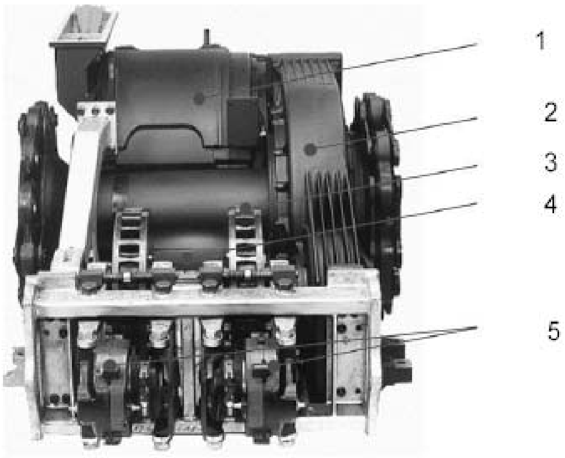

Fig. 7. The Siemens axle drive system
1 – traction motor; 2 – gear; 3 – brake discs; 4 – fake axle; 5 – brake cylinders.

The schema of the axle drive system is presented below, in figure 8.

This system has the advantage that the gear is completely integrated in the traction motor assembly. The gear that actually drives the axle is mounted on a tubular device that surrounds the axle. The tube is mechanically linked directly to the wheels.

The force that drives the system is marked as Pt and is generated by the motor torque delivered by the traction motor.

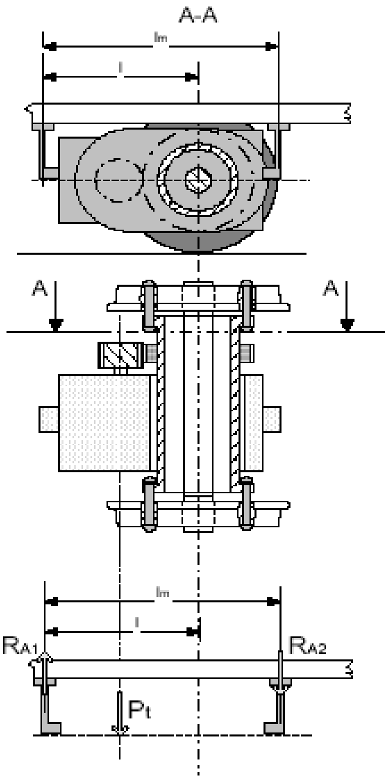

Fig. 8. The complete suspended axle drive system

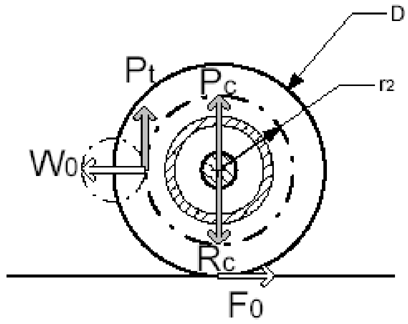

Fig. 9. The equilibrium of the axle

The forces and the torques are:

$$P_C = -R_C = \frac{F_0 D}{2r_2}$$

$$C_r' = Pt(r_1 + r_2)$$

$$C_r'' = P_t r_1$$

$$C_r = C'_r - C''_r = P_t r_2 = \frac{F_0 D}{2}$$

The Pc and Pt forces are generating an additional torque, C_r'. Also due to assembly reasons, an additional opposing torque occurs, marked as C_r''. The resulting additional torque is C_r. This torque is transmitted to the bogie frame through the axle drive system assembly, in the A_1 and A_2 points, thus generating corresponding reactions (see fig. 8).

$$R_{A_1} = R_{A_2} = \frac{F_0 D}{2 l_m}$$

$$\begin{cases} P_{A_1} = -(-R_{A_1}) = R_{A_1} \\ P_{A_2} = -R_{A_2} \end{cases}$$

5. Argument

The complete suspended axle drive systems are preferred on electric locomotives, combined with the use of tri phase asynchronous traction motors.

DB tested two locomotives, the BR 152 (suspended motor and half suspended gearbox) and Euro-Sprinter (complete suspended axle drive system).

The results were clearly in favour of the Euro-Sprinter, which achieved the best results in matters of additional axle load, vibration and bogie frame additional load.

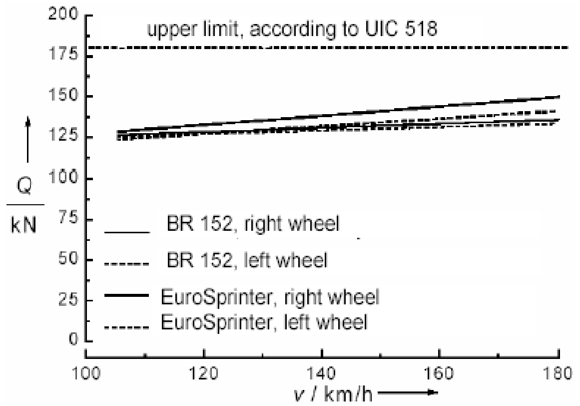

Fig. 10. The axle load variation for both locomotives in the speed domain

The time domain variation of the axle load for both situations (BR 152 and Euro-Sprinter) is presented in figure 11.

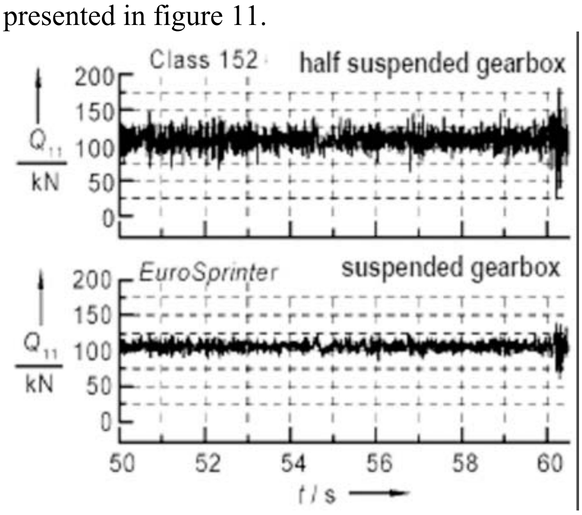

Fig. 11. The axle load variation for both locomotives in the time domain

The comparison between tests and empiric studies revealed that the complete suspended axle drive system has a better behaviour especially at high speeds.

Thus, the issue of modernizing the class 43/44 locomotives is actual and according to the current trend of modernizing the railway infrastructure.

In early 2009, the passenger trains operator CFR Calatori will have the opportunity of running its intercity service to Constanta at speeds of 160 km/h and above. But it will need locomotives able to deliver that kind of speeds and 100% safety as well.

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ПОДОБРЯВАНЕ НА ЗАДВИЖВАЩАТА СИСТЕМА ЗА ОСИ НА ЕЛЕКТРИЧЕСКИ ЛОКОМОТИВ С МОЩНОСТ 3400 KW

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Резюме: *Електрическите локомотиви на CFR, серия 43 и 46 (3400 kW) са произведени в началото на 80-те години на XX век чрез използването на много надеждно решение на ASEA. Задвижващата система за осите, която е подходяща за постояннотоков мотор, обаче не може да отговори на съвременните потребности от високи скорости. Поради това е много по-подходяща, надеждна и икономически ефективна новата система , използваща мотори за променлив ток и различен механичен подход.*

Решението за допълнен окачен тягов мотор и предавателен механизъм се използва успешно в железопътните приложения, като при локомотивите на Taurus на OBB. Това изследване разкрива предимствата от използването на подобно решение при локомотивите от серия 43.

Ключови думи: *електрически локомотив, система за задвижване на осите, талига, задвижване, мотор.*