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Research of Innovations of Diesel Locomotives and Bogies

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Abstract

During manufacturing of diesel locomotives, their basic parameters must be adapted to the requirements of that specific environment. One of the central issues is the choice of bogies. The article present the examples of selecting a bogie by using multi-criteria optimization methods. The methods are adapted for Siemens bogies models SF1, SF2, SF3 and SF6. The solutions obtained by different methods were compared, and shortcomings of certain multi-criteria optimization methods for selection of a bogie model according to its parameters were established.

Keywords: locomotive; bogie models; characteristics of bogies; multi-criteria optimization; ratings method.

1. Overview of different diesel locomotive researches

Despite of economic or political situation, transport remain one of the most important branches of the economy.

Stable global demand in diesel locomotives is observed (Fig. 1a) (Мировой рынок … 2010; Мямлин 2014). Market growth is determined by new technical solutions and the need of the majority of the countries to renew their existing electric traction rolling stock (Fig. 1b).

During the past several years there was a significant general increase in the portion of the electric traction rolling stock, however locomotives comprise no more than 30% of the total locomotive stock, while diesel locomotive are continued to be most frequently used (Мировой рынок … 2012; Myamlin et al. 2015).

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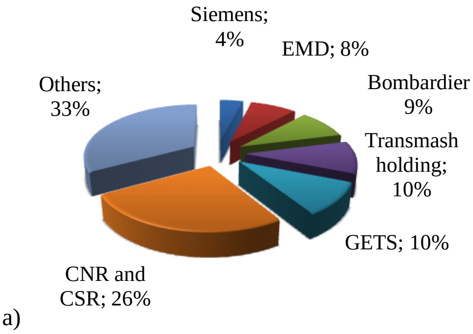


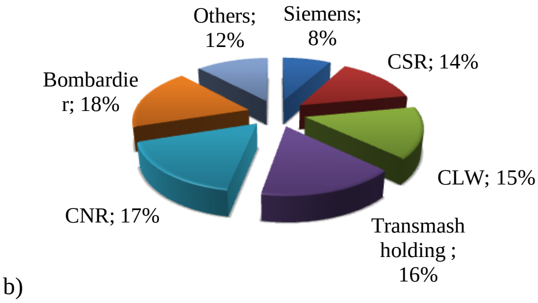


Fig. 1. Distribution of the production quantitate of the main world manufacturers: a) new locomotives; b) new electric trains.

In the past years production of new locomotives was continuously increased by two Chinese corporations: China North Locomotive and Rolling Stock (CNR) and China South Locomotive & Rolling Stock (CSR), who became the main suppliers of diesel locomotives and electric trains (Мировой рынок … 2010; Мямлин 2014). Aside from CNR and CSR, dominating position on the electric trains market (Fig. 1, b) is sustained by Bombardier, while Alstom and Siemens are among the largest suppliers. These three companies together take up one third of the market (Мировой рынок … 2012; Мямлин 2014).

The well-known manufacturer Siemens is increasingly active in offering its products, and its role on the European market (Fig. 1, a, b) is continuously growing. Let us analyse the improvement tendencies (Fig. 2) of the locomotive structure of this company, which is the world's leader of one railway product.

Figure 2 demonstrates that Siemens is among top ten largest manufacturers of railway machinery suppling not only rolling stock, but also control systems and services.

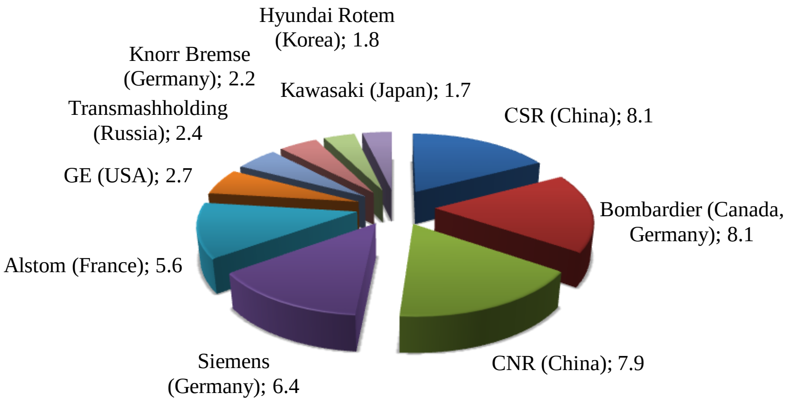


Fig. 2. Top ten largest manufacturers of railway machinery, billion euro.

2. Examples of structural features of diesel locomotive bogies

We will now analyse peculiarities of technical solutions applied in the structures of locomotives of the Siemens company, as one of the leading manufacturers, by focusing on the structural parts of the bogies.

Bogie SF1 (Fig. 3) was created for electric locomotives with the highest speed of 230 km/h, which can be used to transport passengers and freight (Мямлин 2014). Here is an example of their application: Austrian railway locomotive Taurus. The bogie is designed for European railroads and areas with a large number of curves. Geometric characteristics of this series of bogies are presented in figure 3.

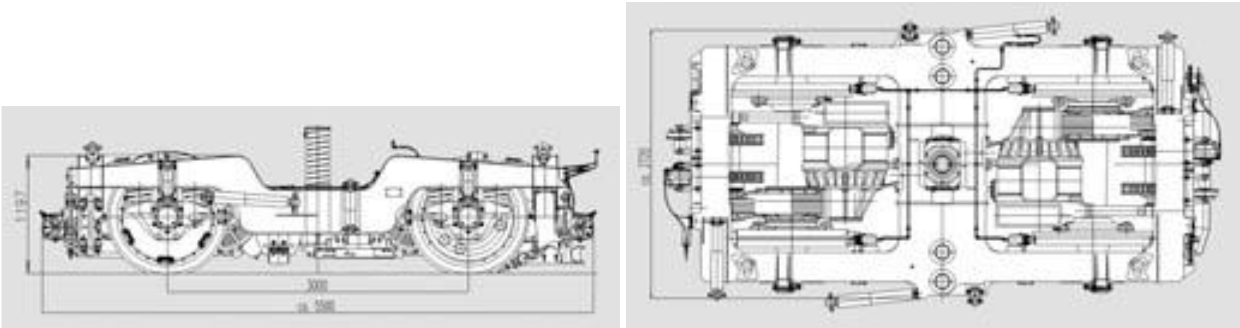


Fig. 3. Bogie SF1.

The frame of the bogie is a fastened structure, which comprises two side beams, a transverse beam and two end beams.

Three-point resilient axle-bearing distribution in the bogie frame is used to control the axes. This allows to achieve a passive radial position on the curves, which improves dynamic characteristic and diminishes wear characteristics. The breaking and tractive efforts are transferred through the lower draw gear to the wheelset. The coil of the central suspension is mounted at a set angle, which allows to avoid undesired load of the side beams and diminish the braking mass. The distance between the tractive effort transfer point and the surface of a rail is 420 mm.

The main characteristics of SF series locomotives are provided in Table 1.

Table 1. Technical characteristics of SF series bogies.

Technical characteristic	SF1	SF2	SF3	SF6
Max. speed, km/h	230	140	160	140
Axis load, t	21,5	22	22	21,5
Power per wheelset, W	1600	1600	750	1080
Highest staring tractive effort per wheelset, kN	75	75	62,5	70
Bogie base, mm	3 000	2 900	2 700	2000 or 2250
Track gauge, mm	1 435	1 435	1 435	1435
New or used wheel diameter, mm	1150 or 1070	1250 or 1170	1100 or 1020	1250 or 1170
Minimum curve radius, m	120	80	120 or 100	80
Weight including brakes, t	18	17	14	25,5
Brakes	disc or separate brake axle	disc	disc	disc

Analysis of data of Table 1 allows to evaluate each model of SF series bogie (S1, SF2, etc.) according to the desired criteria and comparing them among each other.

Siemens provided Lietuvos Geležinkeliai (LG) with six-axled freight diesel locomotive ER20CF. The length of LG’s main lines with 1520 mm track width is approximately 1 771.2 km, of which 122 km are electrified (25 kW, 50 Hz alternating current). Obviously, diesel rolling stock comprises the main part of the traction rolling stock in Lithuania (Мямлин 2014; Грузовой тепловоз … 2009; Дайлидка et al. 2012).

The main line freight diesel locomotive ER20CF of Siemens Transportation Systems (Figure 4a) is manufactured for 1520 mm tracks (operating temperature from –34 °C to +40 °C); structural speed 120 km/h; axis load 225 kN ±3 % (locomotive weight 135.7 t with 2/3 servicing); power output (diesel) 2 000 kW; maximum speed 160 km/h (power to wheels 1 600 kW) (Мямлин 2014; Грузовой тепловоз … 2009; Дайлидка et al. 2012).

The envisaged total weight of the train of diesel locomotive ER20CF is 6 000 t (operating according to two units scheme). Old type 2M62 locomotives used in Lithuania up until then are able to haul only 4 000 t trains (Мямлин 2014; Грузовой тепловоз … 2009; Дайлидка et al. 2012). Diesel locomotives ER20CF with electric gears can be used not only for transportation of freight trains, but also for manoeuvre works on all LG railways. They can also be used together with other diesel locomotives in a multiple traction regime (up to three locomotives).

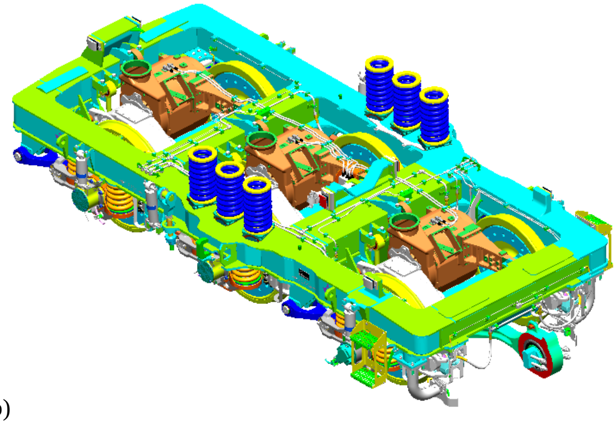
a)  b) 

Fig. 4. Diesel locomotive ER20CF: a) general view; b) bogie.

ER20CF diesel locomotives use non-pedestal bogie (Fig. 4b) – a separate two-level coil suspension, which uses Flexicoil springs to connect vibration baffle of the body, bogie and hydraulics. A rod is used to transfer tractive effort from the bogie to the frame. Electric traction engines are mounted on the bearing frames with two level reducer, leading hollow driving axle and supportive roller bearings.

The difference of the track width of the bogie structure, particularly of a wheelset, has been evaluated in the scientific works (Мямлин 2014; Грузовой тепловоз … 2009; Дайлидка et al. 2012). The axis is designed in such a way as to allow formation of 1435 mm and 1520 mm width track wheelsets without changes in the bogie.

Evaluation of the analysed structures of the diesel locomotives and their bogies shows that manufacturers pay special attention to the dynamic characteristics of traction rolling stock, seeking to ensure the required traction and power characteristics. The low level of emitted noise, low level of toxic compounds of emitted gas, high level of passive safety, simple technical maintenance and repair are ensured, and technological processes of manufacturing of equipment components and mounting are improved.

Every time a diesel locomotive is adapted to a new railway system (examples of system characteristics: track width, train weight, speed, curves), different types of bogies must be selected. This can be achieved based on the data provided in Table 1 through application of a particular multi-criteria evaluation method.

3. Multi-criteria comparison of parameters of diesel locomotive bogies

The simplest multi-criteria comparison method is the sum of ratings. Using this method for evaluation, each of the four analysed bogie types correspondingly attributed ratings one to four according to each analysed parameter. For example, according to speed: Table 1 demonstrates that the highest speed can be developed by bogie SF1 (230 km/h). It is attributed the first rating. Write 1 in Table 2 under SF1. The second rating is attributed to SF3 bogie by entering 2 under it. Bogies SF2 and SF6 are correspondingly attributed the third and the fourth ratings in relation to speed, enter 3.5 under them. This way the ratings are entered in relation to every analysed parameter. At the bottom of the table the ratings are summed up, and priority 1 to 4 is attributed to every bogie model (priority 1 is attributed to the bogie with the lowest total sum, 4 – with the highest total sum).

According to date provided in Table 2, the first priority is attributed to bogie SF1, the last to SF3.

This multi-criteria comparison method is simple and can be quickly implemented. However, this method has a shortcoming. By attributing the rating of a bogie model according to every characteristic (in this case from 1 to 4), quantitative difference of the characteristic is not assessed (for example, whether the analysed characteristic of different bogies differs by 1 per cent or by 10 times). Seeking to eliminate the drawback of this method, we enter the portion of the sum of all characteristic values (for all bogie models) comprising the analysed characteristic of that bogie model, when filling out the table:

$$X_{ij} = \frac{\sum_{i=1}^{n} x_{ij}}{x_{ij}}, \quad (1)$$

where: X_{ij} – j average of the total sum of value of the characteristic, when i is from 1 to n; x_{ij} – value of the characteristic (j – variety of characteristics, i – variety of bogie models).

Table 2. Comparison of parameters of diesel locomotive bogies by the sum of ratings method.

Technical characteristics	SF1	SF2	SF3	SF6
Maximum speed, km/h	1	3.5	2	3.5
Axis load, t	1	3.5	3.5	2
Power per wheelset, W	1.5	1.5	3	2
Highest staring tractive effort per wheelset, kN	1.5	1.5	3	2
Minimum curve radius, m	2	1	3	1
Weight including brakes, t	3	2	1	4
Total	10	13	15.5	14.5
Priority	1	2	4	3

Table 3 should be filled out the following way:

Table 3. Comparison of parameters of diesel locomotive bogies by evaluating the average of the values

Technical characteristics	SF1	SF2	SF3	SF6	Characteristic indication symbol[†]
Maximum speed, km/h	0.343	0.209	0.239	0.209	+
Axis load, t	0.247	0.253	0.253	0.247	–
Power per wheelset, W	0.318	0.318	0.149	0.215	+
Highest staring tractive effort per wheelset, kN	0.265	0.265	0.221	0.248	+
Minimum curve radius, m	0.308	0.205	0.282	0.205	+
Weight including brakes, t	0.242	0.228	0.188	0.342	–
Total	**0.75**	**0.52**	**0.45**	**0.29**	
Priority	**1**	**2**	**3**	**4**	

The sum of values according to Table 3 is marked by symbol + or – in the columns. The priority of the bogie models are determined according to the obtained amounts: the highest amount – priority 1, the lowest – 4. Comparison of Tables 2 and 3 (distribution of the priorities of the bogie models) demonstrates that there is only one difference – in Table 2 priority 3 is attributed to SF6 model, and priority 4 to SF3 model, while in Table 3 priority 3 attributed to SF3 and priority 4 to SF6. In this case it can be considered that both methods produced similar results, however it is obvious that with the change on nomenclature of the analysed objects (in this case the bogies), the achieved results could differ. Therefore, when choosing a diesel locomotive bogie, one cannot rely only on the simplest multi-criteria optimisation method – the sum of ratings method.

[†] Symbol "+" denotes that a higher value of the characteristic is better, "–" – worse.

4. Conclusions

1. Technical parameters of the bogies are some of central factors for selecting a bogie, while the model of a bogie can be selected by applying the multi-criteria optimisation models.
2. Having analysed the parameters of the 4 bogie models offered by Siemens through application of several multi-criteria optimisation methods, it was observed that the in the analysed case the first priority does not depend on the chosen optimisation method, however the third and the fourth priorities differ. It is obvious that with the change of nomenclature of the analysed bogies, the achieved results could differ.
3. When choosing a diesel locomotive bogie, one cannot rely only on the simplest multi-criteria optimisation method – the sum of ratings method.

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