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TECHNICAL AND TECHNOLOGICAL FORMS OF TRANSPORTATION MEANS IN 21ST CENTURY EUROPE AS BASIS FOR INTEGRATION OF EUROPEAN COUNTRIES

ABSTRACT

The paper starts by dealing with the development tendencies of modern road vehicles and their characteristics. The emphasis is on the issues of reducing environmental pollution, conventional fuel consumption, and of reducing traffic injuries, at the same time increasing riding comfort, vehicles quality, easier and better vehicle maintenance, and lower cost of vehicles and their maintenance.

The second part deals with the railway vehicles and their characteristics which are to be developed in the future. Attention is paid to the possibilities of technical improvements regarding engine, propulsion technique, braking methods, case design and energy transmission.

Some conceptual solutions are given that should be implemented in the future, as well as solutions that have been recently implemented and represent useful technical improvements.

KEY WORDS

vehicle quality, vehicle safety, vehicle price, transportation price

1. INTRODUCTION

Man has always striven to transport himself, goods and other people from one place to another in the easiest, fastest and safest way possible. In order to fulfil this tendency, Man has invested during his evolution a lot of knowledge, efforts and skills in developing and producing various types and forms of transportation means. Therefore, if the development of transportation means is considered, from their first beginnings until today, we may then state that they are in fact a reflection of the state of the art of knowledge and technological possibilities of human civilisation at a certain level of its development.

Since modern civilisation is already at a high level of its scientific, technical and technological development, it is natural that not only modern transportation means, but also modern traffic as a whole, are technically and technologically highly developed. Their development includes practically all the scientific disciplines of modern society. Moreover, transport and the production of transportation means are practically the most important industry branches, since they employ the greatest number of people, and since using the whole of the human knowledge, they have the most efficient influence on the general production, and thus also on the standard and well-being of people. However, the usage of transportation means brings along a certain amount of harmful activities, which, most generally, can be divided into chemical, mechanical and sociological influences. Chemical influence includes environmental pollution, mechanical influences include vibrations and noise, and the sociological influences include traffic accidents and their consequences. The significance and importance of each of these influences on the quality of living, need not be specially emphasised and explained here, since these are well-known and proved facts.

2. ROAD VEHICLES

It is to be expected that the basis of joint activities of the European countries in the 21st century will be directed to further development of modern transportation means and traffic system in general regarding reduction of polluting the environment, reduction of conventional fuel consumption, increase in traffic safety, and increase in the riding comfort. It is also obvious that certain technically conflicting situations will occur here. Thus, e.g. the modern tendency in road vehicles development is directed to the design of vehicles of compact outer dimensions, simultaneously trying to provide maximum inner space for passengers and their baggage. Or, on the other hand, the increasingly strict requirements for increasing the active and passive vehicle safety, resulting in fitting the vehicle with a large number of safety elements. This, however, increases the mass of vehicles, and it has to be compensated somewhere else and in some other way. This, then, influences the issue of vehicle cost, which is contrary to the manufacturer's tendency to reduce it. Also, before, the vehicle development was preceded by precise definition of objectives and ways of realisation of the basic characteristics of the future vehicle, whereas the modern vehicle manufacturing process is characterised by sudden changes in vehicle make, short time available for their development, and sudden increase in the strictness of the requirements imposed by the society regarding environmental protection, traffic safety, fuel consumption and vehicle comfort. Besides, in order to fulfil these requirements, technically highly sophisticated solutions have to be found, that can be neither controlled nor managed by the previously used conventional automobile electricity and electronics. Of course, the vehicle buyers, in case of possible disturbance in the operation of such solutions, expect from the vehicle manufacturer reliable and safe systems that will enable a price-worthy, fast identification and removal of such disturbances. Therefore, technical possibilities for the realisation of the presented trends in the future common activities of the European countries are briefly considered further in the text.

2.1. Electricity and Electronics

In road vehicles, the field of electricity and electronics may be roughly divided into the following vehicle subsystems:

- Dashboard with instruments and switches;
- System for controlling the operation of the engine, brakes and transmission;
- System for heating, ventilation, air-conditioning, and closing of the vehicle;
- Computer system;
- System for the lights, windshield cleaning and signalling.

Each of these systems must, of course, function properly and safely, not only as a unit by itself, but in co-ordination with the operation of other vehicle systems. Thus, e.g. for safety reasons, the vehicle should not start to move before all the doors are closed. The conventional electro-mechanical systems in the vehicle cannot, however, support any more the extremely highly demanding conditions of control automation and safety of the individual and joint operation of the mentioned systems and their new sophisticated technical solutions. Therefore, new so-called FPS system - flexible programmed control system, will have to be developed, which, apart from using the up to now in practice tested and reliable systems for engine and brakes control, requires also the development of new hardware and software technology, as well as the related new reliable sensors on the vehicle for safe and precise collection of the necessary data.

2.2. Safety

Apart from the existing activities regarding improvement of deformation characteristics of the vehicle and strength of the passenger space, as well as design of the outer and inner surfaces using appropriate materials, the joint activities of the European countries will obviously have to be directed towards development of a new so-called ESP program (Electronic Stability Program), which consists of the following subprograms:

- ABS - Anti-lock Braking System;
- ABV - System for automatic regulation of the braking forces distribution;
- ASR - System for regulation of the driving wheel skidding (Antriebs Schlupf Regelung);
- GMR - System for avoiding vehicle swerving.

With buses and cargo vehicles, disc brake mechanisms will have to be used, which are more reliable in operation, react faster, are self-cleaning and adjustable, better cooled and easier to maintain compared to the conventional drum braking mechanisms.

Apart from this, the joint action of the European countries will have to be directed also towards the method of adjusting vehicle headlights. It is, namely, well known that about 30% of traffic accidents happen at night. Therefore, the electric equipment manufacturers paid great attention to the method of lighting the road by vehicle lights, reducing the possibility of blinding the driver in the vehicle moving in the opposite direction. Therefore, these manufacturers have produced highly efficient headlights, and have found the optimal angle of their position on the vehicle. However, the problem is that during the drive, the inclination of the car body changes due to its elasticity, depending on the change of vehicle load, as well as on the braking or acceleration. In order to compensate for the influence of the vehicle load on the angle of the headlights, the static manual adjustment of the headlights angle was used as standard equipment by the driver in the cabin using a hydraulic or a pneumatic transmission system. Practice has, however, shown that this method of adjusting is not optimal since it does not fulfil all the conditions of vehicle movement, and the drivers sometimes forget about it, which results in the visibility disturbances by the vehicles moving in the opposite direction at night. Therefore, there is a need in the future to use automatic electro-mechanical regulation of the headlights angle, giving advantage obviously to dynamic regulation compared to the so-called quasi-static, which realises this regulation only on the basis of the vehicle load change. The basis for this regulation consists of an electronic regulation device, which is, on the one hand, connected with the appropriate sensor on the front and on the back axle of the vehicle, and, on the other hand, with electric motors on the vehicle headlights.

2.3. Comfort

Regarding riding comfort, the attention will obviously be directed towards further simplification of vehicle driving conditions, as well as the reduction of mechanical vibrations and noise impact on the driver, since these cause tiredness and reduce the driver's concentration. With the previous standard use of hydraulic, and recently also electric and combined electro-hydraulic servo-mechanisms, there is a need to provide technically, beside the standard automatic transmission, also automatic shifting of the transmission stage in the multistage gear boxes mainly in use today. This may be achieved by using appropriate buttons on the steering wheel, near the driver's foot and the hand-brake handle, with specially designed and electronically controlled action devices on the clutch and gear box housings.

Practice has further shown that, during longer rides, the existing rigid seats cause increased strain and ache in the driver's back muscles, thus reducing the concentration. Therefore, it should be expected in the near future that the majority of makes and vehicle types will have installed the so-called active driver seats. These are, in fact, seats which have two hydraulic chambers fitted beneath the sitting surface, located next to each other, which are alternately filled with a mixture of water and glycol, thus alternately raising and lowering the edges of the driver's pelvis by about 1.5 cm. This rhythmically alternate scoliosis-like movement of the driver's backbone improves the supply of blood to the back muscles significantly reducing the strain. This rhythmic change of the liquid volume in the hydraulic chambers of the seat takes about half a minute, and then stops for about 10 s, followed by another repeated cycle. The driver can switch this seat operation on and off by a special switch near the seat.

High-frequency mechanical vibrations, accompanied, of course, by the noise in the vehicle will have to be dampened. Therefore, the current studies and research of new design solutions will have to be continued regarding transmission shaft joints, and various types of the so-called adaptive elements for joining the engine, its exhaust system, auxiliary aggregates, transmission and suspension with the vehicle body, and these elements can change their dynamic rigidity by means of electronically regulated piezo-electric or magnetostriction inserts. The same principle can be applied also to the change of the dynamic rigidity of the roof and the front wall of the passenger cabin, as the main noise carriers in that space caused by the vehicle structure. However, the noise intensity in the vehicle can be reduced also by the so-called electro-mechanically regulated interference, which means by mutual action and elimination of two opposing waves of the same frequency but opposing phase shifts, of which one comes from the noise origin and the other from another opposite located sound source. In this way, by locating additional electro-mechanically regulated sound sources at certain locations within the passenger cabin in the vehicle, the acoustic load on the driver and the passengers in the vehicle caused by the structure vibrations may be significantly reduced.

2.4. Fuel Consumption

Motor vehicle manufacturers in Europe plan to reduce the fuel consumption by the year 2008, by one third of the current amount. Such a drastic reduction in fuel consumption is possible only by joint efforts of the experts from all the European countries regarding certain design modifications on the engines and appropriate structural solutions on the vehicles themselves.

Certain reduction in the fuel consumption regarding engines can be achieved by using the already well known principle of direct and multistage injection, and by greater share of diesel propulsion in passenger cars. There are also possibilities of reducing fuel consumption by the so-called recirculation of energy, i.e. by returning heat energy from exhaust gases and the generated energy during engine braking again into the aggregate vehicle system, e.g. for additional charging of the electric battery, heating of the passenger cabin, etc. Certain saving in fuel consumption can be also achieved, beside the current aerodynamic design of vehicle body, by reducing the rolling friction of the pneumatics, where a reduction of the rolling coefficient from the current 0.0135 to as little as 0.009 is expected.

Greatest possibilities for fuel saving can be achieved by reducing the vehicle mass, which is predicted to be reduced by the year 2008, by 25%, and this will be achieved by replacing steel, the today's standard engineering material of high strength and rigidity, but of high specific weight as well, with lighter materials. The considered materials for this replacement include:

- *High strength steel* - The use of this material allows reduction in the car body sheet thickness, and thus the vehicle mass itself, at the same time maintaining the appropriate car body rigidity so as to insure the passive safety of the vehicle.

- *Welded panels* - The new technology of car body manufacture by means of the so-called welded panels also reduces the total vehicle mass. This technology uses laser welding to join variously profiled panels, cut from steel sheet of different thickness and quality, thus forming single components of the vehicle body.
- *Steel sandwich panels* - A reduction in vehicle mass by about 50% compared to the steel sheet of same thickness can be achieved by using the so-called steel sandwich plates consisting of two steel sheets only 0.12 or 0.14 mm thin, adhesive bonded together by polypropylene material.
- *Metal foams* - A very interesting novelty regarding the possibility of reducing vehicle mass is the use of metal foams, produced by special treatment of metal powders. These foams are used to fill the gaps within the contour of steel sheet of the pressed certain part of the vehicle, or, adhesive bonded to the outer thin steel or aluminium sheets, these foams are used to produce sandwich plates for certain parts of the vehicle body. These sandwich plates are by 4.5 times lighter than full aluminium sheet, i.e. by as much as 36 times lighter than full steel sheet of the same thickness. Moreover, such sandwich plates have good properties regarding noise and vibration dampening.
- *Aluminium* - The vehicle manufacturers have most experience with various aluminium alloys. Since aluminium alloys are about three times lighter than steel material, they are expected to be used increasingly for the manufacture of various cast and forged parts of the engine and vehicle.
- *Magnesium* - This material is even lighter than aluminium, but it has low strength which is then improved by various alloying procedures, so that this material is considered for manufacture of outer parts on the vehicle body, which are subjected to corrosion.
- *Artificial materials* - A significant application with the aim of reducing the vehicle mass is also provided by artificial materials which can be used in engines as well, e.g. for the manifold system cover, housing of the engine suction system, cooling system air guide, etc. whereas the applications in vehicle body are much wider, especially within the so-called hybrid structures, which means in combination of metals and artificial materials.

2.5. Ecology

The problem of reducing the pollution is one of the most important issues of the modern civilisation today. Special problem is the air pollution caused by road vehicles in the narrow and traffic congested centres of the big cities, due to poor air circulation, unfavourable operation regime of the vehicle engines, with frequent stopping, sudden acceleration and engine braking, short relations, frequent cold start-ups, relatively long operation of the insufficiently warmed up engine at one place, etc. True, over the recent few years, due to the increasingly strict legal and technical regulations, the situation regarding road vehicle harmful emissions, has been improving constantly by using various catalysts and by appropriate control of their proper operation.

However, further improvements in this field are to be expected in the future as well, since the joint research program of the Union of the European Car Industry and Mineral Oils, and the Committee on Integration in Europe, within the European program on Emission, Fuels and Engine Technology will undertake studies about further possibilities of reducing harmful emissions caused by vehicles. It may also be expected in the future that the Committees for Environmental Protection of certain European governments will undertake appropriate research in this sense, depending on their proper specific ecological problems. The volume of harmful components emitted by traffic is not related exclusively to direct emission from vehicles due to incomplete fuel combustion in the engine, and the fuel evaporation from the vehicle tank, as well as in turning off the warm engine, but it is also indirectly related to the production of electricity, as well as to production and distribution of fuels and lubricants. Therefore, further improvement of the current condition of polluting the environment caused by motor vehicles, offers many possibilities, such as:

- *Measures for reducing conventional fuel consumption* - The already mentioned measures for reducing conventional fuel consumption will most certainly result in the reduction of emitted amount of harmful components caused by vehicles.
- *Greater use of Diesel engines* - Diesel engines have a better utilisation of fuel than Otto engines, which means also lower consumption of conventional fuels, and significantly lower emission of harmful components. Therefore, greater use of Diesel engines for propulsion of passenger vehicles can substantially improve the today's ecological situation, since the already existing, and even more the future designs of catalysts, can reduce the emitted amounts of carbon monoxide, hydrocarbon, oxide, nitrogen and soot particles, to very small amounts.
- *Electric propulsion* - Strict ecological legislation in California initiated at the beginning of the 90s greater use of electro-cars as the so-called ZEV (Zero Emission Vehicles). Today, there are about 5,000-10,000 such vehicles in the world. Electro-cars are quiet in operation and do not pollute the atmosphere directly, except indirectly through

generating the primary electricity in electric power plants. Therefore, greater use of electrical propulsion in urban traffic would significantly improve the ecological situation in big cities. It is therefore to be expected that the European vehicle manufacturers will activate the old and start developing new programs in order to design completely new cars with electric propulsion so as to eliminate the existing drawbacks of such cars, which are the relatively small radius of movement and relatively poor performances. The situation may be improved in this sense by using the so-called fuel cells. In these cells, the energy, chemically contained in the fuel, is directly converted into electricity which can be used to propel the car. Research shows that proton guided cells, the so-called PEMFC (Proton Exchange Membrane Fuel Cell) could be considered for use in road vehicles. They have lower operating temperatures (20-120 °C), very flexible service behaviour, great amount of stored energy, they do not suffer from overload, and do not have the liquid aggressive electrolyte. Fuel cells are therefore, the carrier of the propulsion electric power of much greater capacity than the electric batteries. As source energy in the fuel cells, hydrogen, methanol or natural gas may be used. If hydrogen is used, then the product of the process is pure water. However, if methanol is used, then it has to be first mixed with water, and by means of a reformer, at a temperature of 200-350 °C, and using a heterogeneous catalyst made of copper, zinc and aluminium, the mixture is then separated into hydrogen, necessary for the operation of the fuel cell, and synthesised gas of carbon monoxide and carbon dioxide. Carbon monoxide from this synthesised gas is then also converted into carbon dioxide in a catalytic converter. Since fuel, as source of energy, in the fuel cells does not oxidise with open flame, the amounts of the thus generated carbon monoxide, hydrocarbon and nitrogen oxide are very small. Significant are obviously only greater amounts of the generated carbon dioxide. It should be noted that e.g. the German company Daimler-Benz produced already in 1997 three prototypes of such passenger vehicles with a movement radius of 400 km without refuelling, and maximum speed of up to 120 km/h. The company plans to develop mass production of such propulsion for passenger vehicles by the year 2004, as alternative for conventional propulsion of Otto engine.

- *Alternative fuels* - Recently, more intensive thought regarding reduction of harmful emissions caused by vehicles, has been given to the possible replacement of conventional fuels by appropriate alternative fuels, without any special modifications on the conventional Otto and Diesel engines. The study of the existing resources has shown that the following fuels might be considered as alternative in Europe:

- *Liquefied gas* - This gas started to be used at the beginning of this century as fuel for internal combustion engines in North America. Today it is used as propulsion fuel in about 4 million passenger and light cargo vehicles, mainly in Japan, Italy, Australia, New Zealand, USA and the Netherlands. Although the use of liquefied gas in passenger vehicles has a tendency to slightly lower harmful emissions than the petrol propulsion, still the research has shown that in non-stationary movement of vehicles in traffic and with the existing systems for preparing the combustion mixture, there is a slightly increased emission of harmful particles. However, technical improvements of these systems might certainly achieve a much greater purity of the engine emissions, by about 50% in carbon monoxide, and by about 60% in hydrocarbon and nitrogen oxide, compared to the use of conventional fuels. The research on using liquefied gas in buses with regulated three-way catalysts has shown, compared to the propulsion by conventional Diesel fuel, significant reduction of nitrogen oxide content and practically elimination of soot and sulphur dioxide in engine exhaust gases.
- *Rape-seed oil methyl-ester* - Rape-seed oil, as biological fuel, might be considered first of all for use in Diesel engines, but not in their original form, since, due to much higher value of the viscosity coefficient compared to the conventional Diesel fuel, the nozzles would get clogged, and there would be more soot within the combustion chamber of the engine cylinders, which would mean poorer combustion, resulting in more difficult starting of the engine, as well as substantial increase in the amount of carbon monoxide and hydrocarbon in the exhaust gas emissions. However, by esterification of this oil into methyl ester, a fuel is obtained whose characteristics are very similar to conventional Diesel fuel, with a somewhat lower carbon monoxide and hydrocarbon emission, and their content can probably be eliminated by improved technology for filtering exhaust gas emissions.
- *Natural gas* - There are about 1 million vehicles in the world today using this fuel. Mainly in Russia, Italy, Argentina, New Zealand and USA. This gas can be stored in the vehicle as gas or liquefied. Studies have shown that by using this gas, the exhaust emissions on such vehicles contain over 90% less amounts of higher hydrocarbons compared to the composition of exhaust gases of today's Otto and Diesel engines, as well as a significantly lower amount of soot particles in Diesel

engines, and the carbon monoxide and nitrogen oxide emissions have been reduced to less than one quarter compared to the use of conventional fuels. The main drawback in using natural gas is in the increased emission of methane, which, with its volume share of about 81-98% represents in fact the main component of natural gas. Therefore, vehicles using natural gas, have to be fitted with special and methane-oriented catalysts in order to filter the exhaust gas emissions, since the conventional catalysts do not give satisfactory results in these cases.

– *Hydrogen* - Germany has been experimenting for many years with liquefied hydrogen as fuel for Otto engines. The analysis of the exhaust gases emitted from Otto engines using this kind of fuel, has shown that carbon monoxide and hydrocarbon are present in traces and that as result of engine lubricant combustion, and vapour and nitrogen oxides are found, whose amounts can be easily reduced to below the emission levels of today's Otto engines by means of catalysts.

3. RAILWAY VEHICLES

Railway is, by its character, oriented both to domestic and to the international traffic in transporting passengers and cargo. In order to make it an additional integration factor of the European countries, and having in mind the whole complexity of the railway system, a lot has to be done on improvement and unification of all the segments of this system. One of the major segments of this system are the railway vehicles. This section will deal with the characteristics of the modern railway vehicles and tendencies of further development.

The basic requirements set on the modern railway vehicles are safety, reliability, high efficiency and uniformity. Railway vehicles, as a subsystem in railway traffic, can be designed in a range from simple cars to complex locomotives and high speed trains. The general approach in solving the very complex requirements is the modular construction and application of sophisticated electronics. So, e.g. electronics provides high-quality and efficient control and regulation of devices and auxiliary plants on vehicles, diagnostics of the technical condition of all the systems on the train, presentation of the condition to the technical personnel on the train and remote transmission to workshops. Application of electronics using optical fibre cables enables e.g. simultaneous activation of electro-pneumatic brakes on the whole train of significant length. Modern solutions of tilting trains with active systems, as well as active composition are possible only by using modern electronics.

Advantages of modern technology on vehicles are obvious and efficient only if the transportation provided is reliable and price-acceptable. In passenger transport, the increasing requirements for communication and travel information need to be met. In cargo transportation, reliable cargo identification, objective definition and traceability at any moment of monitoring is necessary. The devices in the vehicles and along the tracks in the form of a network have the complex task of integrally solving the set requirements.

Since many railway tracks are becoming the limiting factor in the trains throughput capacity, it is necessary to increase the throughput capacity of the vehicles themselves. Therefore, greater average driving speed is necessary, and this can be achieved by greater accelerations and decelerations if the maximum speed is limited. This can be achieved by lighter vehicle construction and more efficient braking systems. Light vehicle construction represents a great challenge for the manufacturers, and this is solved by taking in consideration the experience from the aircraft industry, and road vehicles design. Light construction is especially important in suburban transport vehicles which have greater frequency of starting and stopping in their exploitation.

Although railway transportation is very favourable, the requirements to reduce energy consumption are still increasing. This is contributed by the lower mass of vehicles, better aerodynamic designs reducing the air drag, especially in high speed trains, and greater efficiency of traction vehicles regarding propelling energy. So, e.g. older electric traction vehicles had efficiency of converting electric power into mechanical work of about 78%, whereas today this value amounts to 90%. Traction engines on modern vehicles are commonly three-phase asynchronous engines, much lighter and of smaller dimensions per power unit, and enable reaching even the highest driving speeds of up to 350 km/h. Such high speeds require also very efficient, reliable and safe brakes. In order to increase efficiency, electro-dynamic brakes with power feedback into the contact line are regularly used. Thus, depending on the type of the train, about $6 \div 30$ % of power used in the train acceleration phase [9], can be returned into the contact line.

In the relation between the wheels and the tracks, solutions are being sought to reduce the forces acting as load on the tracks. Good results are obtained by using bogies with turning axles which, during negotiating a curve, are radial in relation to the curve centre, thus allowing for higher driving speed. In passenger traffic, trains with tilting cases contribute to the increase in speed on winding tracks.

In increasing the driving speed, the noise problem arises, which tends to be reduced by improving the carriage and the aerodynamics of the trains.

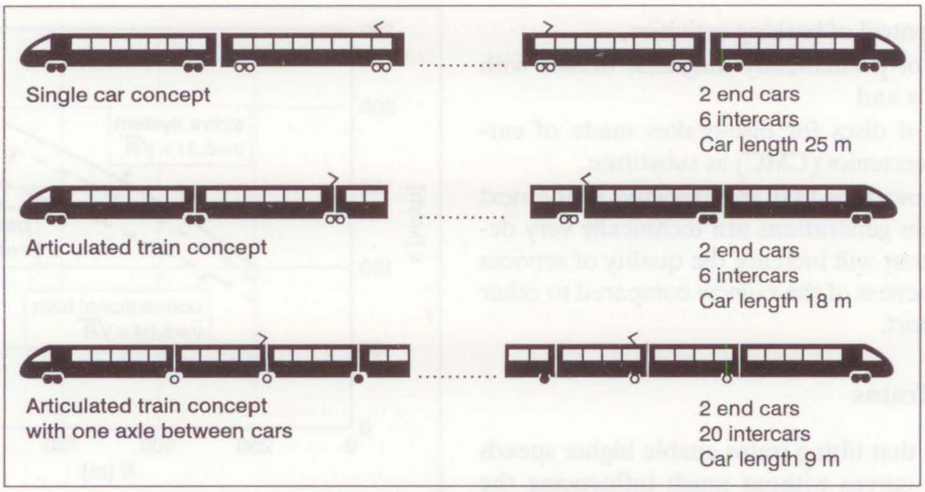

Figure 1 - Some possibilities of modern concepts of high-speed trains

All the improvements which contribute to the solving of certain problems have to be satisfactory also regarding the price. Quality solutions increase the life time and reduce the requirements in maintenance, which results in an acceptable price (LCC - life cycle cost).

3.1. High Speed Trains

Modern high speed trains have to fulfil the European TSI (Technical specification for Interoperability) and be equipped with ETCS (European Train Control System) in order to travel freely in international traffic.

For high speed trains, the engine, propelling system, brakes, car case structure and power transmission are of special importance.

There are several conceptual design possibilities for the high-speed trains in the future, each having its own technical and economic characteristics (Figure 1). The plans for all the concepts include trains with driving cars, which provide best results regarding acceleration and comfort. Trains, as a closed unit with appropriately designed end driving cars, offer the least air drag, which is especially significant for high-speed trains. The number of in-between cars in a train depends on the concept and the necessary capacity.

The single cars concept implies longer cars (about 25m) and fewer cars for a train of a certain length, i.e. of a certain capacity. The concept of an articulated train includes bogies for joining the cars or at the end of one car. In this case, cars are somewhat shorter (about 18m) so that for the same length as in a train with single cars, a greater number of cars is necessary. The main advantage of this solution are fewer bogies, which reduces the mass of the train. Further reduction of the train mass is achieved by the concept of articulated train with one axle which replaces the bogie, and is located at the position of joining two cars or at the end of one car. Cars are even shorter (about 9m), but they may be somewhat wider since shorter cars stay closer to the centre of the line in negotiating a curve. For the train length of 200m, apart from two end driving cars, 20 in-between cars are needed. This requires that a certain number of driving shafts are installed along the whole length of the train, i.e. over 50% of all the shafts in the train should be driving shafts.

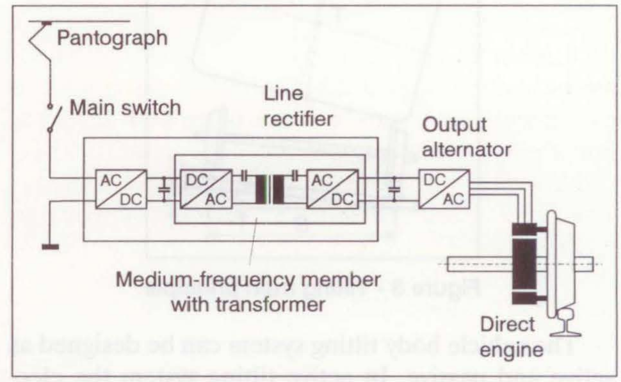

Figure 2 - Modern driving concept

Driving technology is developing towards the application of modular IGBT static liquid cooled converters, and traction engines directly joined to the wheelset axle or to the wheel, which operates on the principle of the transversal magnetic flow. This substantially reduces the weight of the driving unit per power unit. The idea flowchart of such a solution is presented in Figure 2 [10]

Great share in the mass of electric vehicles for alternate current, belongs to the transformer, which can be replaced in the modern solution by the equipment which is known under the working name "medium frequency trafo". The mass of the total equipment in the driving circuit may thus be reduced by as much as 50%.

The development of brakes should move in three segments:

- electronic control of braking activities,
- application of permanently magnetic brakes with eddy currents and
- application of discs for disc-brakes made of carbon-matrix-ceramics (CMC) as substitute.

All the innovations that are expected in the next high speed train generations are technically very demanding, but they will increase the quality of services and competitiveness of the railway compared to other types of transport.

3.1. Tilting Trains

It is known that tilting trains enable higher speeds in negotiating curves without much influencing the passengers' comfort. This implies that with the outer rail superelevation (h), i.e. inclination (α), formed by the tracks, the vehicle body is additionally tilted by the angle β (Figure 3).

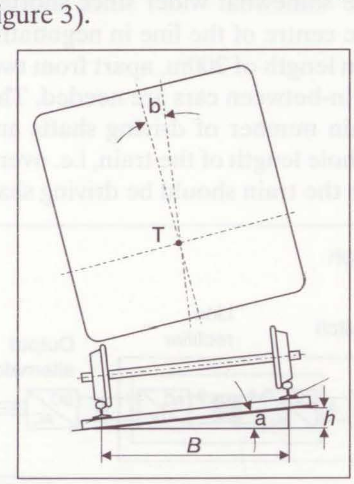

Figure 3 - Tilting train principle

The vehicle body tilting system can be designed as active and passive. In active tilting system the electro-mechanical instead of hydro-mechanical tilting device is used. In the active system the vehicle body is additionally tilted up to $\beta = 8°$, and in the passive system up to $\beta = 3 \div 5°$. In order to reach greater speeds in negotiating the curves, the superelevation of the outer rail needs to be increased from the usual $h = 150$ mm, to the so-called super-superelevation of $h = 200$ mm [11]. The increase of the maximum speed in negotiating a curve compared to the conventional train design depends on the curve radius and the type of the tilting system, and can amount to 25% (Figure 4). The diagram presents also the relations for calculating the appropriate maximum speeds.

The role of the tilting trains is, in the first place, to increase the average driving speed on tracks with many curves without greater investments into the tracks modification. They are not competitive with high-speed trains, because these are planned for traffic on the newly constructed tracks, requiring extremely high investment funds. Therefore, the tilting trains are expected to find increasing application in the future. They can use both electric or diesel propulsion which makes them suitable for any type of railway lines.

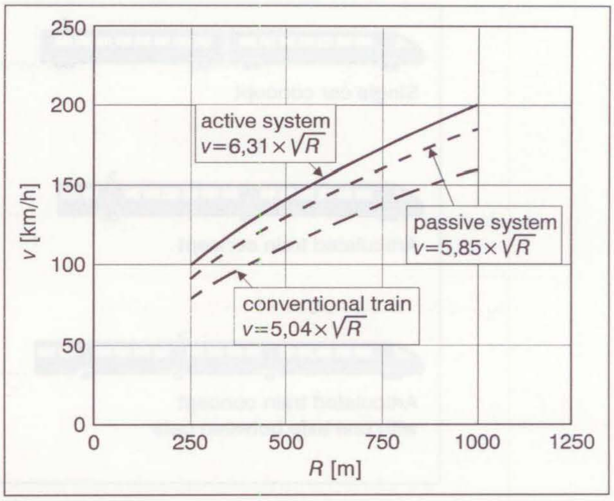

Figure 4 - Dependence of curve negotiating speed on the curve radius for a tilting and a conventional train

3.2. Railway vehicle bogies with swivel wheelsets

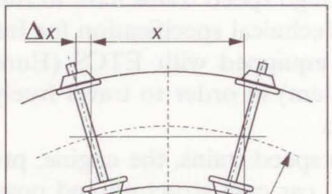

Figure 5 - Radial positioning of the wheelsets

Radial positioning of the wheelsets while the vehicle is negotiating a curve results in lower friction and wear of the wheels and the tracks, reduction of guiding forces which in turn reduces the load of the permanent way, and generally makes it easier for the vehicle to pass through a curve.

Radial positioning of the wheelsets requires necessary swivel freedom in the bogie which depends on the curve radius, wheel base and the track gauge (Figure 5). So, e.g. on a railway line with a normal track gauge, for a two-axles bogie with a wheel base of $x = 2.5$m to negotiate a curve of radius $R = 250$ m, each axle needs to swivel at an angle of $\psi = 2.865$, i.e. the outer wheel axis needs to shift by $\Delta x = 3.6$ mm.

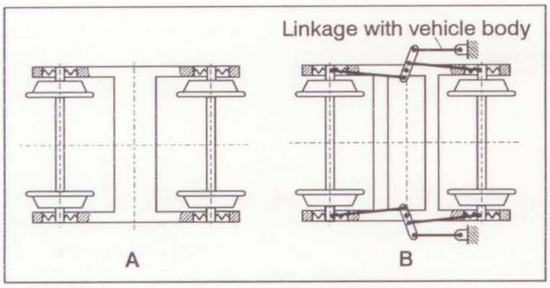

Figure 6 - Some possibilities of turning of the wheelsets in the bogie

Some of the possible design solutions for the bogies with swivel wheelsets are schematically presented in Figure 6 [12]. Elastically guided wheelsets (Fig. 6-A) represent the simplest bogie design where the wheelsets are elastically connected longitudinally in relation to the bogie frame. This allows independent swivelling of the wheelsets in negotiating a curve, based on the tapered design of the wheel flange. There is no mechanical connection between the wheelsets. The advantage of this design lies in its simplicity, and the drawbacks include unsuitability for curves of smaller radius and the limited maximum speed along straight railway lines.

Wheelsets controlled by the vehicle body (Fig. 6-B). This is a solution when the relative swivelling of the bogie in relation to the vehicle body, in negotiating a curve, is used for swivelling of wheelsets into the radial position by means of a special mechanism. The device represents a more complex design, but it allows for suitable swivelling in all curves, as well as the necessary characteristics for straight riding at higher speeds.

4. CONCLUSION

The tendencies in the development of transportation means are oriented towards design and manufacture of vehicles of highest possible quality, lowest possible cost, lowest possible fuel consumption, lowest possible environmental pollution, easiest and least expensive maintenance, highest possible riding comfort and highest possible traffic safety. For further improvement of the quality of living on Earth, which means the increasingly strict legislation regarding environmental protection and traffic safety, there is a need for higher activation of the overall human knowledge and intelligence, and this means also more intensive joint activities of all the European countries, in order to achieve all those needs that are of general interest for the modern human society.

In the future, railway will represent an increasingly important aspect of passenger and goods transportation due to its advantages, such as: great safety, low energy consumption, and less harmful impact on the environment compared to other aspects of transportation. In passenger traffic, the quality of services will get further improved, and the shortening of travel time will play a particularly important role. Therefore, new high-speed tracks are being built in the world, and suitable high-speed trains are being designed, that reach the maximum speeds of up to 350 km/h. On the existing railway lines, with relatively small reconstruction, the average travelling speeds can be increased by the use of tilting trains. They allow the increase of the maximum speed in curves of up to 25% without exceeding the allowed uncompensated lateral acceleration of passengers.

In order to increase the competitiveness of the railway in relation to other aspects of transportation regarding railway vehicles, improvements will be carried out primarily in engines, propulsion technique, braking methods, vehicle body design, and in energy transmission. This has to be accompanied by a sufficiently high level of safety, minimum vehicle weight and minimum fuel consumption. This is helped by new engineering materials, new technical solutions and technically adopted new electronic components necessary for the improvement of driving technique.

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