New Development in Transrapid Vehicle Technology

Luitpold Miller
Member of Managing Board
ThyssenKrupp Transrapid GmbH
Moosacher Str. 58
80809 Munich (Germany)
Phone: +49 89 35 46 91 01
Fax: +49 89 35 46 91 05
e-mail: miller@thyssen-transrapid.de

Dr.-Ing. Friedrich Löser
Senior Manager/ Head of System Engineering
ThyssenKrupp Transrapid GmbH
Moosacher Str. 58
80809 Munich (Germany)
Phone: +49 89 35 46 91 10
Fax: +49 89 35 46 91 12
e.mail:loeser@thyssen-transrapid.de

Keywords

Application, Electromagnetic Levitation System, Investions, Maintenance, Transrapid

Abstract

Due to the favourable characteristics application projects for shorter routes with operating speeds of 100 to 300 km/h gained momentum. These new fields of application require an adaptation of the vehicle technology. The solution is a family of vehicles, consisting of standardized modules. This paper includes a description of the system architecture as well as the concept of subsystems. The conclusion will concentrate on the various vehicle configurations for different field application.

1. Introduction

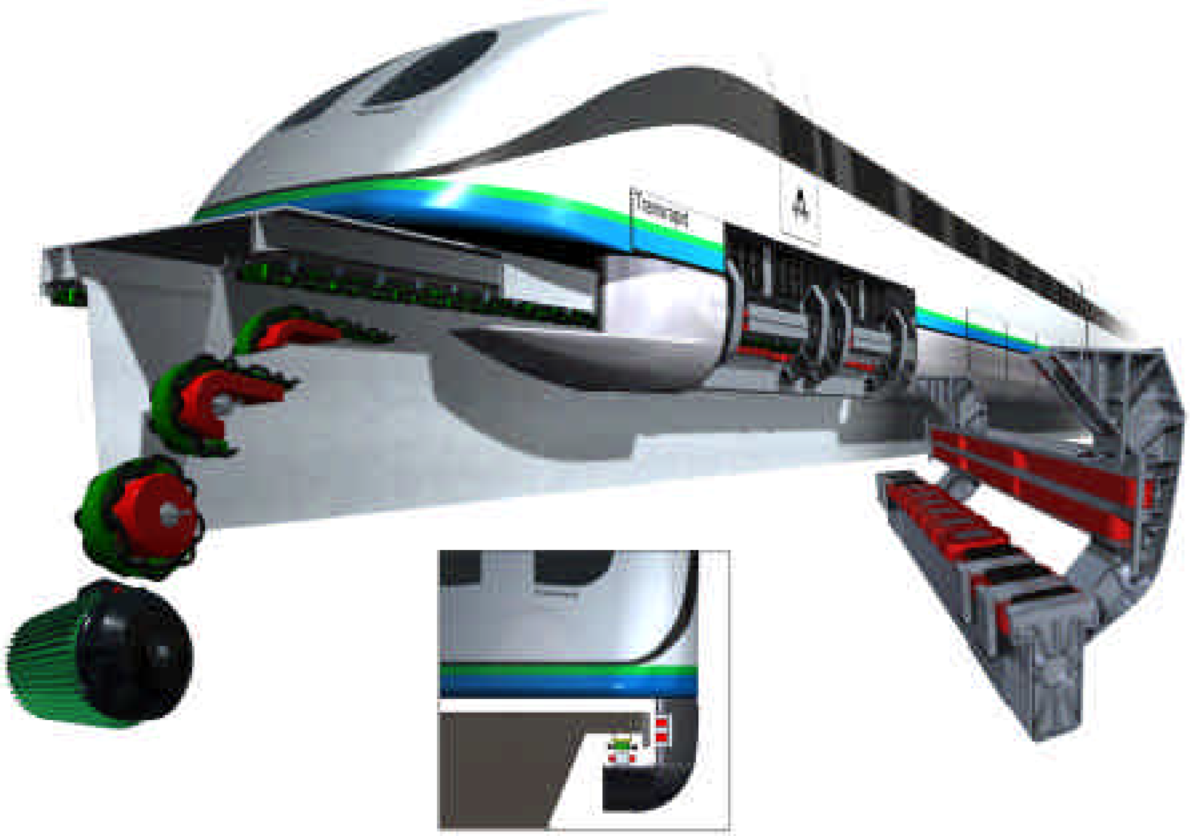

fig 1: Transrapid - Systemconcept

The Transrapid vehicles exclusively use

- direct, electromagnetic conversion of electrical energy into linear motion by means of synchronous linear motors and electronically-controlled electromagnets

- direct, electromagnetic conversion of kinetic energy of the vehicles into electrical energy for the onboard power supply.

The vision of applying electronically-controlled electromagnets and linear motors in track-bound transport systems was first described in 1934 by Hermann Kemper in his patent “Levitation train with vehicles without wheels guided along iron tracks using magnetic fields”. His vision was to achieve high travelling speeds at minimum wear and a relatively low energy consumption as well as a high ride comfort by means of a non-contact relation between vehicle and guideway.

But only the innovations in aerospace and communication technology regarding the areas of

- microelectronics

- lightweight constructions using compound materials

- control and monitoring of complex technical systems by means of self-operating, computer aided online-diagnosis and control units

allowed to convert this vision into a safe, reliable and economic transport system: the Transrapid Magnetic Levitation Trains.

The vehicles were designed for passengers and priority cargo transport at travelling speeds up to 500 km/h. Propulsion and braking, levitation, guidance and power supply are performed in a non-contact way.

High reliability and safety are achieved by the

- modular structure,

- mainly autonomous and feedback-free function of the components,

- self-operating failure detection and diagnosis also during operation,

- functional redundancy and self-operating system reaction in order to ensure safety and mission fulfilment in the case of device failure,

- fully automatic operation and

- ease of handling and good maintainability based on computer-aided operating instructions and maintenance procedures

Other features of the non-contact transport technology are:

- high ride comfort (“flying at zero level”)

- low running resistance and noise emission

- favourable features of guideway dynamics with very little loads on of the guideway resulting in minimal maintenance costs

The technical description can be summarized as follows:

- The **trains** consist of two end sections and 0 to 8 middle sections. Any combination of passenger and cargo sections may be used to form a train

- The **non-contact levitation and guidance function** is supplied by modular levitation chassis consisting of controlled and safely monitored electromagnets (fail-safe power electronics!) placed on the train over the entire length of vehicle

- The **power** is supplied by autonomous, safe-life on-board power supply units in redundant configuration, fed by linear generators and backed up with NiCd-batteries

- **Non-contact propulsion and braking functions** are provided by a synchronous long stator linear motor, being exited by the levitation magnets of the vehicle and having its stators and motor coils in the guideway. The transformation of the traction power is performed in stationary subunits. They are placed in a distance of 5 to 40 km on the relevant guideway section, depending on the type of guideway, the average travelling speed and the headway of the trains

- The **safe retardation of the vehicle** is achieved by means of safe-life eddy current brakes in the vehicle (which are only activated if the synchronous long stator linear motor is not available)

- A computer-aided operation control system **controls the vehicles and the guideway and ensures the safe and automatic operation.**

- The **guideways** are available either in elevated or at-grade constructions with a variable span beam length between 3 m to 31 m. Bendable switches and transfer tables provide the track changing for the vehicles.

  The operation of the guideway causes neither shifts of adjustments nor wear and tear of the functional elements (reaction rails) resulting in minimal maintenance cost.

The **influence of magnetic fields on the health** is discussed all over the world. Extensive tests performed on the TVE by several German and American institutes have proven that the electrical, magnetic and electromagnetic fields of the Transrapid vehicles

- in the cabin are less than the natural magnetic field of the earth,

- have no influence on pace-makers

- produce no interferences with telecommunication devices and

- generally are significantly below the limits of relevant rules and norms

In order to achieve **highest safety standards** the Transrapid system was subjected to detailed and extensive safety analysis and assessment in all phases of development and testing. Accident risks derived from experience with other systems were taken into account. A set of measures was derived from the analysis of

- What can happen? and

- What must not happen?

and the expected safety level was calculated. For each measure the assessment criteria is the degree of reduction of the forecasted risk. Each measure that contributes to a significant reduction of risk is realised. The following principle-based features need to be mentioned:

- Save track guidance due to the vehicle being "wrapped" around the guideway
- Insensitivity to side winds due to the active guidance by electromagnets
- No technical fire risk due to the complete monitoring and safety circuits on all active units of the vehicle
- Highest electromagnetic compatibility (completely maintains its function even when hit by lightening)
- Protection of passengers during boarding and disembarking of trains in station by automated gateways
- Automatic guideway inspection system integrated in the vehicle
- Set of protective measures and barriers in order to avoid destructions of the vehicles and the guideway structure.

2. Characteristics of the Transrapid Levitation System

- Constant distribution of vehicle loads on the stators and guidance tracks with approx. 2,5 kg/cm^2
- Low dynamic stress of levitation chassis and guideways. The stress is approximately 10 % of the static loads in the entire speed range up to 500 km/h which is a result of the non-contact levitation technology
- Possible slope of 10% due to friction-independent propulsion and braking function (A higher slope is principally feasible, but would result normally in an uneconomically high power consumption of the propulsion system)
- Active guidance with highest dynamic stability even in the case of extremely strong side wind
- Up to 12 degrees of super elevation of the guideway in curves as a rule, up to 16 degrees in special cases, allow high speed in curves and favourable track layout (capability to adjust to existing infrastructures and given topographic structures)

2.1 Energy consumption

Low energy consumption is due to the guideway motor. There are no weight restrictions in the design of the electric units for the supply of the linear motor (stationary, not assembled in the vehicle). The efficiency of the linear propulsion stands as a result of the cost/effect analysis – which means investment versus energy consumption - and of the low specific vehicle weight (propulsion in the guideway!)

Due to the principle-based advantages the Transrapid needs less energy than a railway system over the entire range of speed. The specific energy consumption of the Transrapid is:

- at 200 km/h approx. 29 Wh per km per seat
- at 330 km/h approx. 45 Wh per km per seat
- at 430 km/h approx. 63 Wh per km per seat

For modern railway systems the following energy consumption values were calculated:

- at 200 km/h approx. 32 Wh per km per seat
- at 330 km/h approx. 59 Wh per km per seat

The values based on the measurements verify that the specific energy consumption of the Transrapid is approx. 10% less at 200 km/h, approx. 15% less at 250 km/h, approx. 20% less at 300 km/h and approx. 25% less at 330 km/h. That means that both in the regional traffic systems (maximal speed 100 to 300 km/h) and in the super speed traffic systems (maximal speed 400 to 500 km/h) the Transrapid systems offers a highly efficient operation.

2.2 Noise Emission

Also the passing-by noise levels reflect the principle-based advantages because there are no aerial power lines and current pickup devices, as well as no mechanical contact noise of the wheels which increases significantly when the form is changed due to tear and wear (surface quality of wheels and railway).

From a distance of 25 m the Transrapid is at low speeds between 50 to 100 km/h approx. 5 dB less noisy and at speeds above 200 km/h approx. 10 dB less noisy than modern railway systems (10 dB are considered a doubling of noise).

2.3 Economy

Investigations comparing the planning and construction costs of a new railway track with the detailed planning costs for the Transrapid project between Berlin and Hamburg show, that in flat areas the infrastructure costs for the Transrapid and for a railway system are approximately the same (see fig. 2). In areas with hills and mountains significant advantages with the Transrapid system can be expected (higher possible slope, smaller curve radii at equal speed due to higher lateral stability and, as a result of that, applicability of curve elevation of 12 degrees compared to 6 degrees in a railway system). Maintenance costs for the infrastructure are crucial. With a Transrapid system these costs occur nearly independently from speed and train frequency and are around 0,3 % p. a. of the capital investment (see fig. 3). With a railway system including the limitations in operations during maintenance up to 3 % p. a. of the investment have to be taken into account for maintenance calculating the life cycle costs.

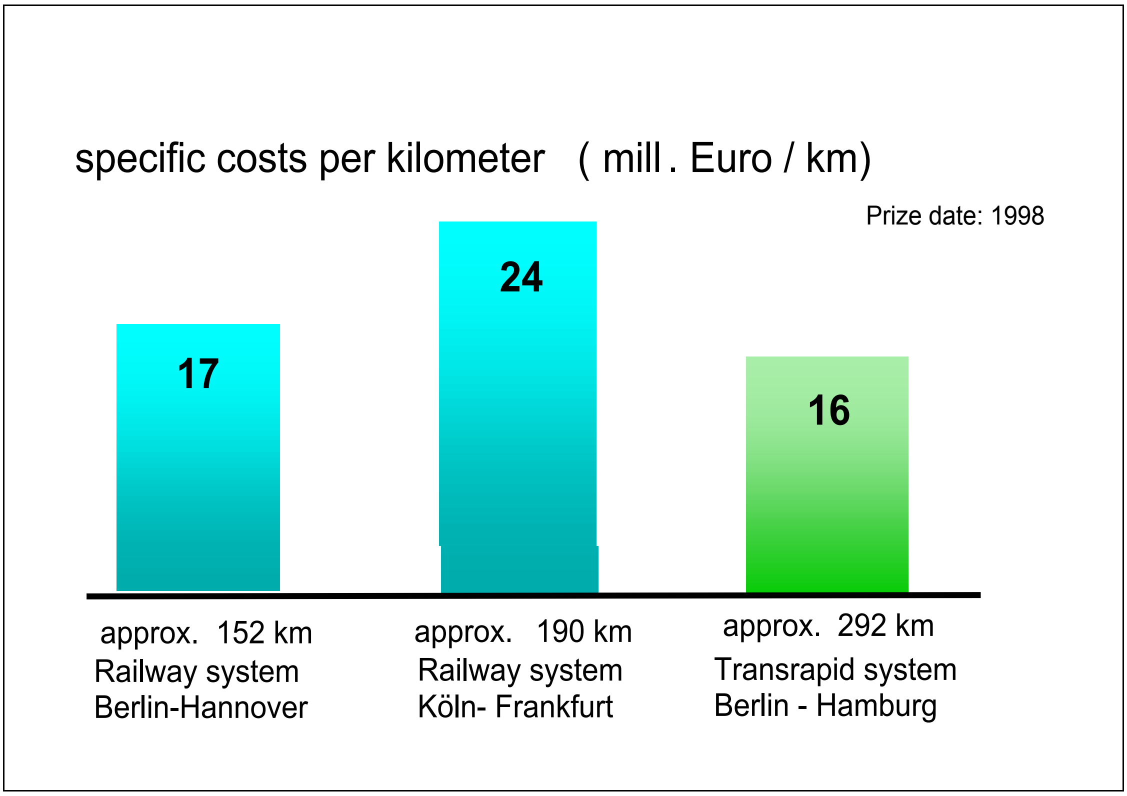

fig 2: guideway – investment Railway system and Transrapid system

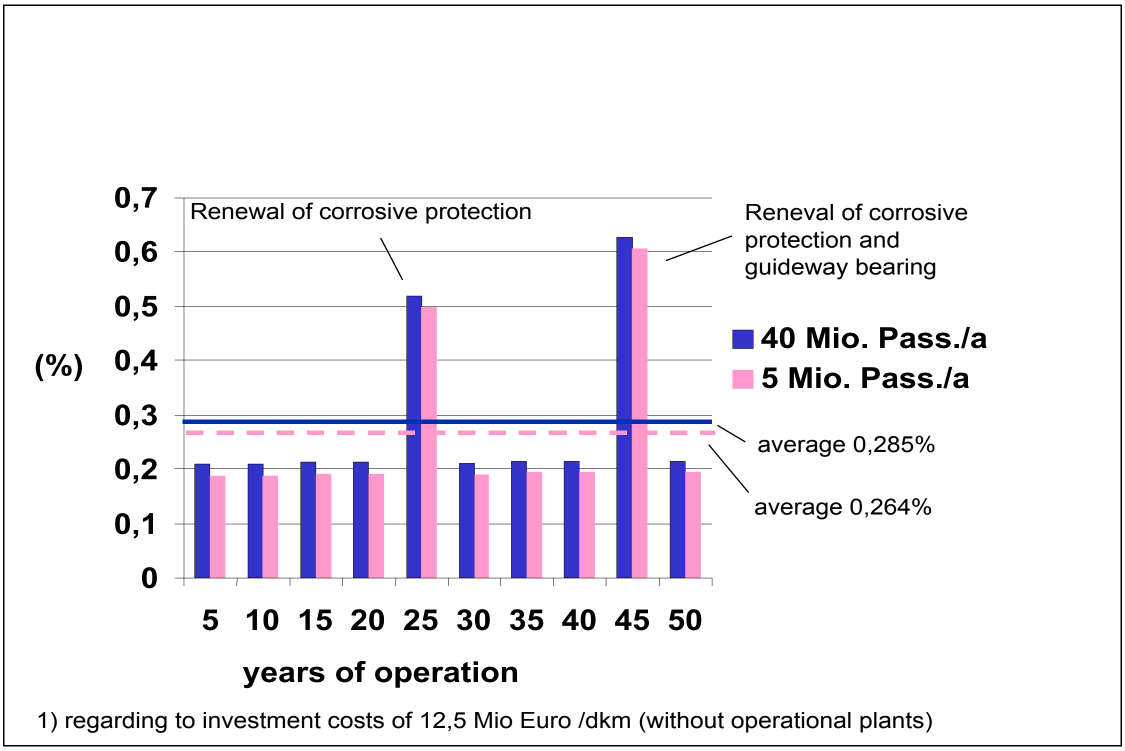

fig 3: Transrapid - guideway specific maintenance costs 1)

3. Description of vehicle configurations

Table 1 shows the main parameters of Transrapid vehicles for long and short distance application. The data demonstrate that in addition to the favourable features described in the chapters 1 and 2 the ability to serve as an advantageous mean for operation in the field of regional transportation too.

Table 1: Typical data for long and short distance application

Criterion (Typical figures)	Long Distance	Short Distance
range of line length	100 – 1000 km	20 - 100
average distance of stops	30 – 100 km	5 – 10 km
max. speed	500 km/h	150 – 300 km/h
average travelling speed	300 – 400 km/h	100 – 200 km/h
typ acceleration of propulsion	1 m/s^2	1,5 m/s^2
headway	15 – 30 min	2,5 – 10 min
seat arrangement	only seating passengers, compartments separated from entrance area by compartment doors	seating and standing passengers, no compartment doors
seating strategy	seat reservation integrated in ticketing	no reservation
entrance doors width	0,9 m	1,4 to 1,8 m

Transport capacity	Long Distance		Short Distance	
	End Section	Middle Section	End Section	Middle Section
Nominal payload Maximal payload (incl. interior equipment)	10,5 t 15,5 t	14,0 t 19,0 t	14,5 t 18,5 t	18 t 23 t
Permitted total weight	62,0 t	64,5 t	67,5 t	70 t
Max. total weight in case of extraordinary events	67,0 t	69,5 t	72,5 t	75 t
Nominal number of passengers	92	126	145	180
Transport floorspace	70 m²	77 m²	62 m²	77 m²
Passengers per m_ of floorspace (average seated + standing)	1,3	1,6	2,3	2,3

4. Fields of Application and Outlook

In the 90s the aim of Transrapid development was to close the travelling speed gap between modern track-bound railway vehicles and air traffic systems. But based on the present system data, the Transrapid technology provides also in regional applications clearly favourable values regarding environmental behaviour and availability, as well as better economy due to lower operating and life cycle costs. The application lines in Washington, Pittsburgh, Munich and in the Ruhr area are therefore primarily not to be considered as reference lines, but as attractive and economical alternatives in the track-bound regional traffic. It can be expected that in long terms - especially due to the continuing, extremely fast innovation in the fields of microelectronics, electrical engineering and low-weight constructions - the Transrapid technology will be applied worldwide.