Technical and economical aspects of the Transrapid compared to traditional HSR systems

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Abstract

This synopses describes the technical and economical aspects of the Transrapid technology compared to the traditional HSR (High Speed Rail) systems. The approach of the outstanding Transrapid technology in terms of the main requirements like **flexibility**, **efficiency**, **high performance** and **safety** will be outlined in the following paper.

Introduction

The technical and economical aspects of the Transrapid will be compared to the traditional HSR-Systems. But for now a words about the current transportation situation and systems, which are worth to be mentioned.

Since the globalisation in the world is no more an empty phrase and the population is increasing continuously, it is no doubt, that the need for sophisticated transportation systems is rising world-wide. The demand for higher travelling comfort and travelling speed is always given. On the other hand higher passenger load capacity with a lower life cycle and maintenance costs are expected. And it goes without saying, that the demand for reliable safety systems, the availability and very high level of environmental friendliness has also to be fulfilled. Last but not least the investment costs must be low at an affordable level. Which system can satisfy all these demands? Modern HSR system, based on steel-wheel systems, like the Japanese Shinkansen, the French TGV and the German ICE are reaching remarkable results with every new generation. Their operation speed reaches speeds over 300 km/h at a very high level of comfort. But due to physical limits and economical reasons these systems are tending to leave the reasonable considerations about performance / costs ratio. They are coming up to a point, where higher speed with the conventional systems need too much efforts and where operation from the financial point of view is not reasonable anymore.

Why? The answer lies in the system itself. The contact of steel-wheel. For more than 30 years research and development of alternative systems, mainly magnetic levitated systems, have been done. The German solution, the Transrapid, has shown on a world-wide unique test facility in Emsland that the technology is mature and the system is ready for commercial application. Several test runs like 24h endurance tests, 450 km/h high speed tests, long period runs have been performed. Now these efforts are beginning to pay off. The advantages of the maglev system compared to the traditional rail system are becoming more and more aware and significant. The result is: The first commercial application of the maglev technology is currently in Shanghai, China under construction. The start of the first commercial operation is scheduled in January 2004, while the first VIP run will take place in January 2003.

The technology

Before the main requirements will be discussed here, a few words on the unique propulsion, support and guidance system technology of the Transrapid.

The propulsion system

The levitation high speed train is actuated by a synchronous longstator linear motor, which is used for propulsion and braking. The function of this non-contact propulsion and braking system can be derived from the functional principle of a rotating electric motor whose stator is cut open and stretched along both sides of the guideway. By supplying alternating current to a three-phase motor winding, an electromagnetic travelling field is generated which moves the vehicle, pulled along by its support magnets which act as the excitation components.

The speed can be continuously regulated from standstill to full operating speed by varying the frequency of the alternating current. Only the section of the "track motor" in which the vehicle is situated is supplied with power. This prevents a collision with other Transrapid trains. Since the primary propulsion part of the Transrapid is not in the vehicle but in the track, the Transrapid does not have to carry the entire engine power for the respective highest performance at all times. In sections with high boost requirements, as for example inclines, the power of the sub-track is increased. For the same reason, the performance of the Transrapid is neither influenced by its length nor the load it is carrying.

The support and guidance system

The non-contact support and guidance system of the Transrapid maglev system functions according to the principle of electromagnetic levitation. It uses the attractive forces between the individual, electronically controlled electromagnets in the vehicle and the ferromagnetic reaction rails which are installed on the underside of the guideway. The support magnets pull the vehicle up to the guideway from below, the guidance magnets keep it laterally on track. The support and guidance magnets are arranged on both sides along the entire length of the vehicle. A highly reliable, fully redundant electronic control system ensures that the vehicle hovers at an average distance of about 10 mm from it's guideway. The maximum distance between the top of the guideway and the underside of the vehicle is 150 mm.

Requirements

In the next part of the synopses a selection of four main requirements towards to Transrapid system will be discussed in order to show the technical and economical aspects of the Transrapid.

Flexibility

Two features of the Transrapid maglev system allows it to have extremely favorable route alignment parameters. These are the active guidance of the vehicle along the guideway and the propulsion system (motor) in the guideway. With these, gradients of 10% can be climbed and curves with tight radii and cants of up to 16° can be traveled without difficulty.

	Maglev Transrapid	High Speed Rail
	10%	4%

Tab. 1 – Grade Climbing Ability

Speed	Maglev Transrapid	High Speed Rail
0 km/h	350 m	150 m
200 km/h	705 m	1,400 m
300 km/h	1,590 m	3,200 m
400 km/h	2,825 m	
500 km/h	4,415 m	

Tab. 2 – Curve Radii

Speed	Maglev Transrapid		High Speed Rail	
	Crest	Sag	Crest	Sag
min.	600 m	600 m		
200 km/h	2,575 m	5,145 m	14,000 m	16,000 m
300 km/h	11,575 m	5,790 m		
400 km/h	20,575 m	10,290 m		
500 km/h	32,150 m	16,070 m		

Tab. 3 - Vertical Radii

These favorable parameters also allow the guideway to be flexibly adapted to the landscape without massive earthworks and it is often possible to collocate it with existing traffic routes, thus saving precious land and cost.
Furthermore the required land consumption for the guideway infrastructure is significantly low, compared with other transportation systems.

	Maglev Transrapid		High Speed Rail
	Elevated	At-grade	At-grade
	2 m²/m	12 m²/m	14 m²/m

Tab. 4 – Land Consumption (Double Track)

Efficiency

The guideway load of the Transrapid is distributed evenly on the whole length of the vehicle, whereas the entire load of the traditional steel-wheel systems causing high stress on a few cm^2 on the track. This fact leads to an enormous difference in the mechanical strain of the track.

	Maglev Transrapid	High Speed Rail
	0.7 kg/cm²	5,000 - 8,000 kg/cm²

Tab. 5 – Mechanical Strain

This difference obviously influences the maintenance and operation costs.

	Maglev Transrapid	High Speed Rail
Vehicle	0.38 Pf/Skm	0.93 Pf/Skm
Guideway	0.72 Pf/Skm	2.53 Pf/Skm
System	1.10 Pf/Skm	3.46 Pf/Skm

Tab. 6 – Maintenance Costs [Pfennigs per Seat-km]

One part of the working expenses is a direct result of the energy consumption. Even in this field the Transrapid is able to convince with very attractive values.

Speed	Maglev Transrapid*	High Speed Rail
200 km/h	30 Wh/Skm	36 Wh/Skm
250 km/h	36 Wh/Skm	46 Wh/Skm
300 km/h	44 Wh/Skm	58 Wh/Skm
400 km/h	63 Wh/Skm	

Tab. 7 – Energieconsumption per seat-km

These positive values can be substantially referred on the following properties of system:

- use of modern power electronics
- lack of electromechanical energy conversion using friction-based elements for and on-board power supply
- high efficiency of the synchronous longstator motor with the excitation by the vehicle support magnets
- low mass of approx. 0.5 t per seat
- low running resistance of approx. 0.2 kN per seat at 400 km/h (250 mph)

High performance

Regarding the abilities of the Transrapid it can be surely said, that this train sets new marks. Due to its outstanding performances concerning operating speed and acceleration abilities the Transrapid is a real alternative for current public transportation at midrange and longrange distances.

Speed	Maglev Transrapid		High Speed Rail	
	Time	Distance	Time	Distance
0 - 100 km/h	31 s	424 m		
0 - 200 km/h	61 s	1,700 m	140 s	4,400 m
0 - 300 km/h	97 s	4,200 m	370 s	20,900 m
0 - 400 km/h	148 s	9,100 m		
0 - 500 km/h	256 s	22,700 m		

Tab. 8 – Acceleration

As a result of the high travelling speed and the low maintenance expenses the Transrapid can reach very high operation performances (km/year). Therefore a smaller vehicle stock compared to traditional steel-wheel systems is necessary in order to reach a certain operation performance (km/year).

Maglev Transrapid	High Speed Rail
1,200,000 km	500,000 - 600,000 km

Tab. 9 – Operation Performance (km/year)

Safety

Several features and precaution properties are responsible for the fact, that despite the high speed of over 500 km/h the Transrapid is one of the safest means of transportation in the world.

Due to its construction, the Transrapid cannot derail, because it wraps around its guideway. Since grade crossings are not allowed, nothing can get in its way. As mentioned before, collisions between Transrapid vehicles are not possible, because only the section of the "track motor" in which the vehicle is situated is supplied with power. The vehicle and the travelling field of the guideway motor move synchronously, i.e. with the same speed and in the same direction. The Transrapid is absolutely weatherproof and masters wind and adverse weather easily. Regarding the aspect of fire protection the Transrapid meets the highest requirements of the relevant standards. No fuels or combustible materials are on board. All used materials within the vehicles are PVC-free, highly inflammable, poor conductors of heat, burn-through-proof and heat-proof. Fire proof doors can be optionally used in order to separate vehicle sections. Furthermore there are automatic guideway inspections and train protections to increase the safety of the entire Transrapid system.

References

[1] Transrapid International: High-Tech For "Flying on the Ground"; Berlin, Germany 06/01

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[3] Siemens AG Transportation Systems: Advance your Thinking. Experience the future – Transrapid; Erlangen, Germany 2001