Chapter 6
Super-Speed Rail (SSR)

In 1776, there would be no steam engine without Watt's fancy. In 1879, there would be no electric generator without Edison's unthinkable idea. In 1886, there would be no train without Carl Benz's cock and boll stories. In 1903, there would be no plane without the Wright brothers' impossible task. In 2013, there would be no SSR without Elon musk's naive dream.

Now human mainly use aircraft as the high-speed long-distance passenger transport and the operating speed of the passenger aircraft is about 1000 km/h. However, for long-distance travel of more than 5000 km, the time and economic cost of traveling by aircraft are staggering, and the aircraft also caused serious environmental pollution. Especially the continuous air disasters have made people aware of the shortcomings of the civil aviation system. By this time, a new type of vehicle with a minimum speed of 1000 km/h, energy consumption less than 1/10 of that of civil aviation passenger aircraft, less noise, few exhaust pollution and lower accident rate: a super-speed rail (vacuum pipeline MHSR train) is on the horizon. Figure 6.1 shows the architecture of SSR train.

The resistance of the HSR in the high-speed travel mainly comes from two aspects: air resistance and the wheel friction. The HSR train is suspended above the ground in the magnetic floating environment, and it can avoid the wheel friction. Hence, the power of HSR train is mainly used for overcoming strong air resistance. According to the aerodynamic theory, the air resistance is proportional to the square of velocity, so the input force is proportional to the cubic of velocity. To solve air resistance problem, some scholars thought of vacuum tubes. In vacuum, SSR can run at high speed without any resistances. Figure 6.2 shows the SSR pipeline.

The several ways of modern transportation such as ships, trains, planes, cars, etc. have brought the progress and prosperity to human. However, it also has brought the pollution, traffic jam and death. SSR, which Musk calls the "fifth transportation mode", is as fast as airplanes and cheaper than train. It can operate continuously under any weather conditions and discharge no carbon emissions. The SSR turns the city to the subway site. Then the geographical boundaries will disappear and a global village under the SSR environment will come.

Q. Hu and S. Qu, *A Brief History of High-Speed Rail*,
https://doi.org/10.1007/978-981-19-3635-7_6

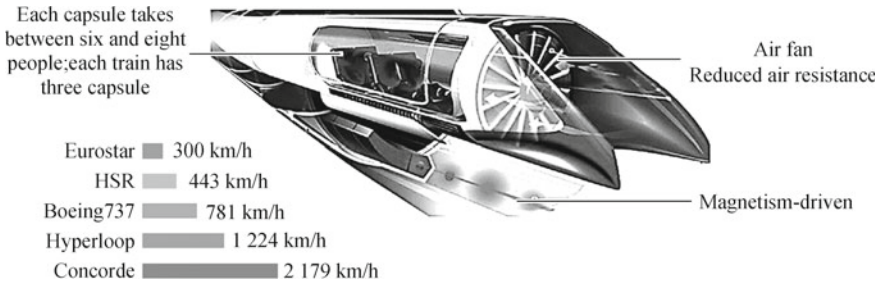

Fig. 6.1 The architecture of SSR train (picture from the network)

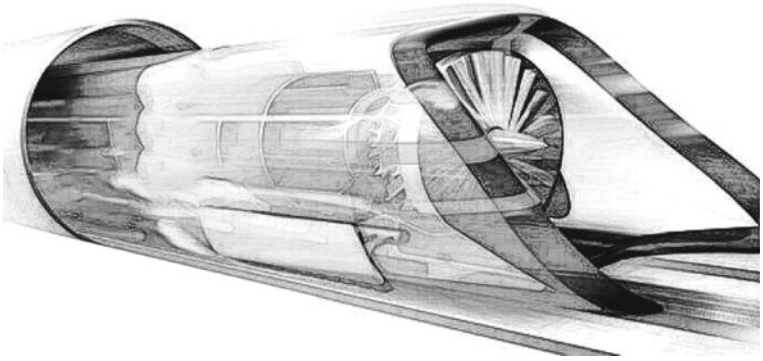

Fig. 6.2 The SSR pipeline (picture from network)

As the concept of "Super-Speed Rail" has not yet been popularized, most people are amazed at its theoretical speed, but they can't find reliable channels to understand its technical details. Meanwhile, there have been many voices of doubt in society because of a lack of scientific understanding of SSR. Therefore, based on the definition of SSR, this chapter analyzes the operation principle, basic structure and attribute characteristics of SSR, and identifies the main problems and explore the feasibility of SSR. Figure 6.3 shows the SSR station.

6.1 The Basic Principle of SSR

The SSR is a type of transportation vehicle which is designed based on the theory of ETT (Evacuated Tube Transportation). It has the feathers of super speed, high safety, low energy consumption, low noise, no vibration and no pollution, etc. It could be a new generation of transportation after cars, ships, trains and airplanes. In the future, under the premise of oil shortage, the ETT will be able to provide a popular ground super-speed vehicles to make up for the shortage of the aircraft. Therefore, the

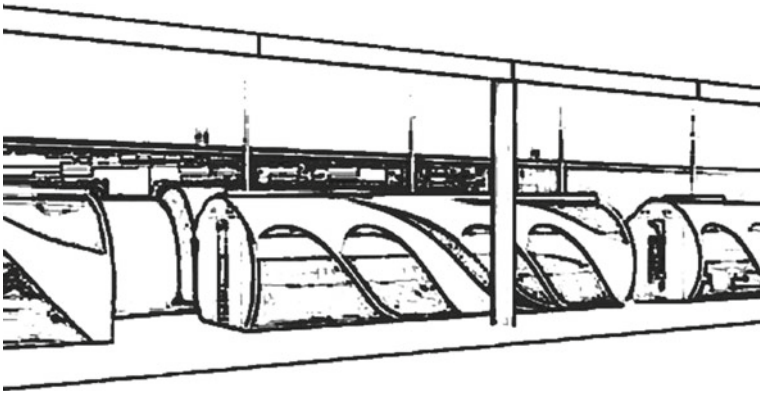

Fig. 6.3 The SSR station

significance of ETT technology is similar to that of the original steam engine which replaced horsepower and the ETT technology will bring epoch-making changes. Then civil aviation and rail transport will be replaced by large areas, then humankind will enter a cleaner, more efficient travel era. Figure 6.4 shows the imagine Figure of SSR.

(1) The principle of ETT technology. The principle of ETT technology is to build a closed pipeline on the ground or underground, and then turn it into a vacuum or partial vacuum by means of a vacuum pump. Driving in such an environment, driving resistance will be greatly reduced. In addition, the energy consumption and the aerodynamic noise can be greatly reduced, which is in line with environmental protection requirements. Vacuum tube magnetic interstellar train (VCMS) is a kind of train which has not been built yet, and it is the fastest transportation vehicle in the world. Figure 6.5 shows the frame diagram of SSR.

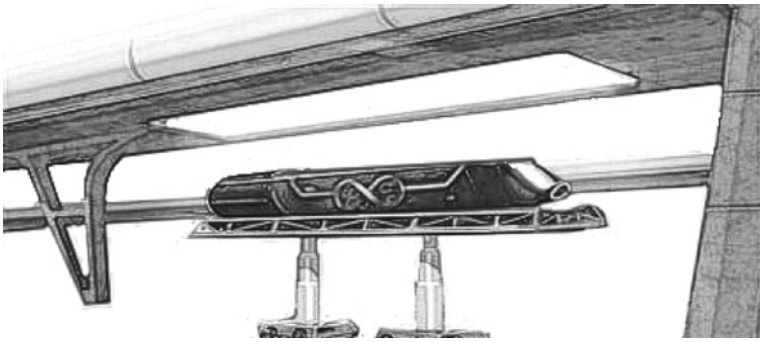

Fig. 6.4 The imagine figure of SSR

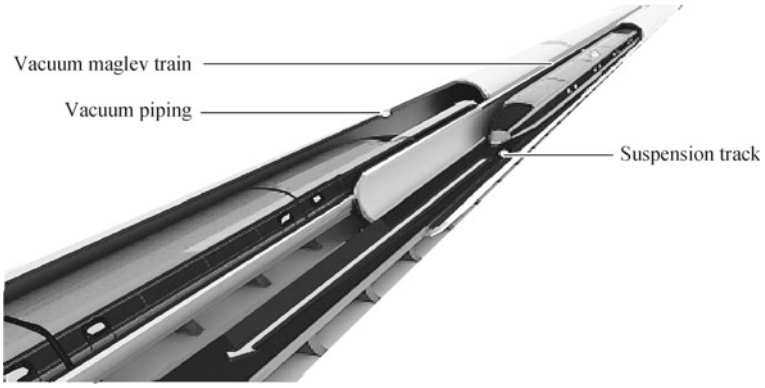

Fig. 6.5 The frame diagram of SSR (picture from network)

(2) The features of ETT technology. The vacuum magnetic train travels in a closed vacuum pipeline. The air resistance, friction resistance and weather have no effect on it. The cost of its passenger dedicated rail is lower than that of the traditional rail. The speed of the rail can reach 1000–20,000 km/h, which is several times higher than that of plane, while the energy consumption is many times lower than that of plane. SSR may become the fastest means of transportation in the twenty-first century.

① Low cost: The cost of ETT will be very cheap, only 1/4 of that of the freeway, 1/2 of that of the HSR.

② Strong high environmental protection: The energy supply of the vacuum pipeline transportation can be fully supplied by solar energy without environmental pollution. Figure 6.6 shows the station map of SSR.

Fig. 6.6 The station map of SSR

③ Super speed: The speed of the SSR can reach at least 1000 km/h. It is far greater than the 400 km/h "cordon" of the WHSR. So, its speed is much higher than any other form of transportation's.
④ Good energy-saving effect: The super high-speed rail can make its energy consumption far lower than aircraft, wheel rail, magnetic high-speed rail, car, and other means of transport by eliminating the effects of air resistance.
⑤ High safety: SSR travels in the vacuum pipeline without being affected by the external environment. When the pipeline breaks and air enters, it only affects the speed of operation, which can guarantee the absolute safety of passengers.
⑥ Low noise: When the SSR train is running in a vacuum duct, there is no air as a conductor, so the operation process will not produce high decibel noise.

6.2 The Development History of SSR

The best way to ensure comfort and energy efficiency at super high speed is to run the train in a near-vacuum environment, where the idea of a vacuum tube SSR train was born (it is also called Hyperloop in U.S.). The idea of SSR was first proposed by the chief executive of Tesla, Elon Musk, in 2013. In theory, when the train is suspended above the track, it can reach ultra-speed, and the top speed is designed to be 750 miles per hour (about sonic speed 1200 km/h). The speed of the SSR is thirty-four times faster than that of the bullet train, and it can reach twice the speed of the plane. At the same time, it will be able to replenish its own energy, and when solar panels are installed in the system, the energy received will exceed the energy consumed by the entire system. In addition, the system also has an energy storage facility and the train can travel for 1 week without the battery panel. As expected, the transport system consists of low-pressure steel tubes and aluminum capsule bodies that are internally protected by gas, with a maximum operating speed of more than 745 miles per hour. Figure 6.7 shows the design of SSR from Argo Design company. The SSR cabin is shaped like a capsule, as shown in Fig. 6.8.

(1) The train of Hyperloop. The Hyperloop train is expected to build fixed vacuum pipes on the ground that act like rail tracks, and to place "capsules" in the pipelines. According to the research team, the cabin is shaped like a space capsule. Its individual mass is 183 kg, lighter than a car. It is about 4.87 m long and can accommodate 4 to 6 passengers or 367 kg of cargo.
(2) The operation mode of Hyperloop. The "capsule" train floats in the vacuum pipeline and the cockpit is activated by an ejection device like firing a cannonball, non-stop to the destination. The maximum operating speed of the "capsule" train could reach 6500 km because of the vacuum environment and no friction. In this way, the travel from New York to Los Angeles only needs

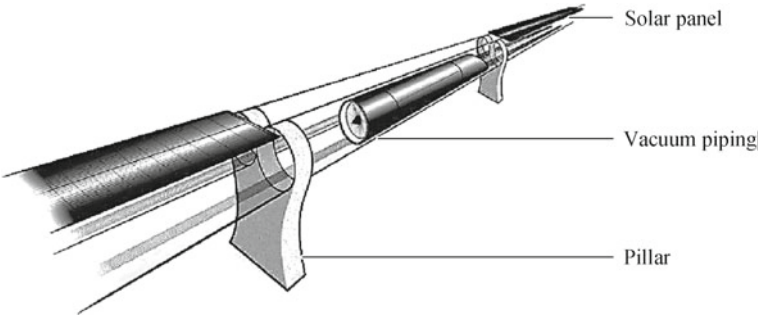

Fig. 6.7 The design of SSR from Argo Design company

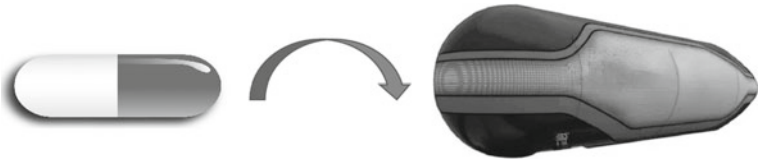

Fig. 6.8 The capsule cabin

5 min, the travel from New York to Beijing only needs 2 h, the global travel only needs 6 h.

6.3 The Architecture Design of SSR

The design concept of SSR has been put forward for many years, some people put forward the idea of transportation in vacuum pipeline decades ago, but it has not been realized because of the limitation of technical conditions. In recent years, the concept of SSR was put forward again. It is a manifestation of technological progress, a further promotion of vehicle requirements and represents the pursuit of "faster". The design concept of the train and line of SSR were put forward, which represented a further effort on the commercial operation of the SSR. Figure 6.9 shows the design drawing of SSR.

(1) Pressurization to solve operational problems. The cockpit is also called the Super-speed rail train (SSR train) or the Super train. Assuming that the departure interval of the SSR train is 2 min and the peak time can be as fast as 30 s. One SSR train needs at least 28 seats in order to meet the load of 840 people per hour during the peak hours. Now forty cockpits may be required during the peak hours, 6 of them are at the terminal for passengers to get on and off at the same time. The Super Train will have emergency brakes and engine-driven wheels, and once the massive decompression of SSR trains occurred, others trains will automatically slam on the brakes and the entire vacuum pipeline

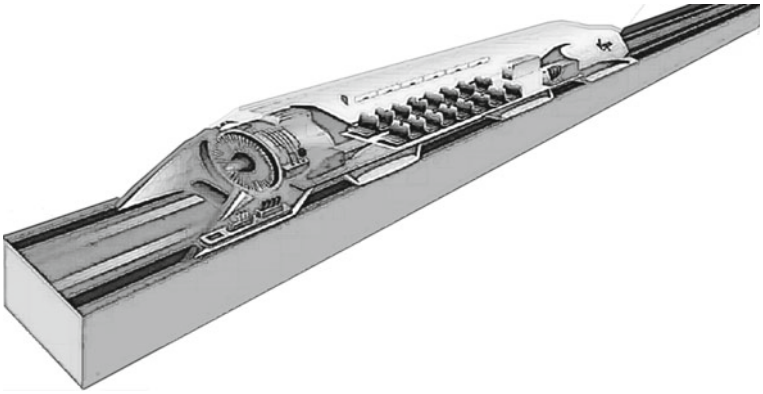

Fig. 6.9 The design drawing of SSR

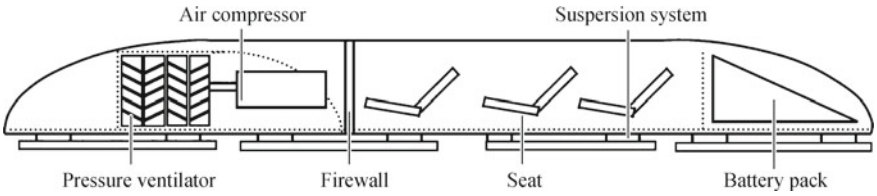

Fig. 6.10 The structure drawing of SSR train

will quickly start to supercharge. Then the super train uses the engine-driven wheels to run to safety. All the SSR trains will be equipped with a reserve of air to ensure the passengers safety under the worst conditions. Figure 6.10 shows the structure drawing of SSR train.

(2) Air cushion to solve suspension problem. At present, the method to solve the wheel friction is magnetic levitation. However, there are few commercial magnetic levitation lines in the world because of the high cost of magnetic levitation. The head of the vehicle is fitted with an engine and fan blades, a cockpit in the middle and a battery in the rear. By installing a compressed fan in the head of the train, the air is sucked in and discharged from the bottom of the train, forming a few millimeters of air cushion to make the train suspended. The forward power of the train is generated by the head compression fan. The front of the cockpit is equipped with an electric turbo compressor fan, which can send the high-pressure air in the front part into the skateboard and cabin. It can reduce the air resistance in front part of the entire vehicle, while the magnets and electromagnetic pulses in the skateboard can make the cockpit obtain the initial impetus. Figure 6.11 shows the operating diagram of the SSR.

(3) Pipe to solve air resistance problem. In order to achieve a good energy economy, the pipeline size is precise optimized to solve the air resistance problem by vacuum pumping. It is similar to an aircraft climbing to high-altitude flight to

Fig. 6.11 The operating diagram of the SSR (picture from internet)

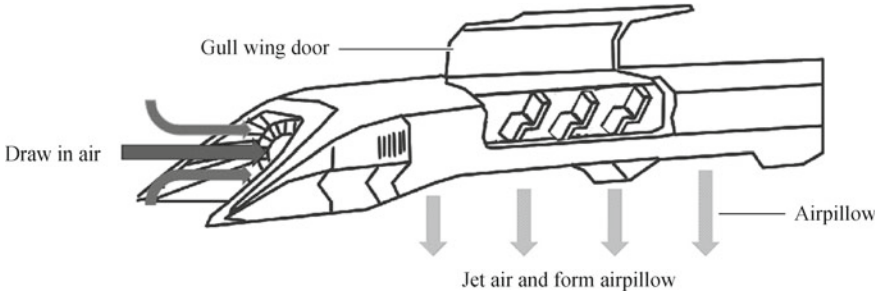

Fig. 6.12 The design principle diagram of the passenger compartment

reduce air resistance, but the cost of the vacuum is very high, and it is difficult to maintain a vacuum, because the air leakage may occur at any time. By pumping the pipe vacuum to about 10 QPA, reducing air density by reducing the air pressure in the pipeline to reduce friction consumption, the pressure is only 1/6 of that of the Martian atmosphere, which is equivalent to that of the air pressure when the plane flies at the height of 15,000 ft.

The passenger compartment is shown in Fig. 6.12, each streamlined seal cabin can accommodate 28 passengers, and one capsule can be issued in a few minutes. Two passengers are in a row, the luggage are concentrated in the front of the seal cabin or tail. As the system accelerates, passengers are subjected to less than 0.5 g (half the force of gravity).

6.3.1 The Design Concept of the SSR Train

The shape and interior of the SSR train will be similar to that of the traditional rail train, but the volume will be smaller than that of the traditional HSR trains, and even smaller than that of modern subway trains. For the vacuum pipelines operated by trains, experts are more inclined to the inner layer with steel pipe and the outer layer with reinforced concrete construction, which is mainly to reduce the amount of steel pipe and save costs. The vacuum pipeline is designed to have two doors at all the

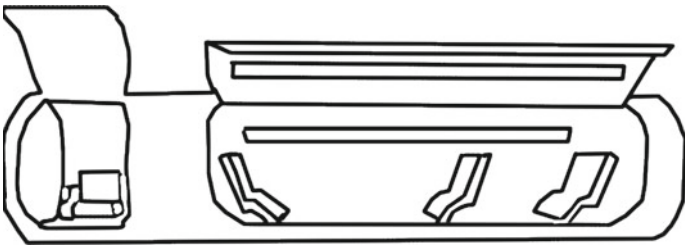

Fig. 6.13 The planning drawing of cabin of the SSR train

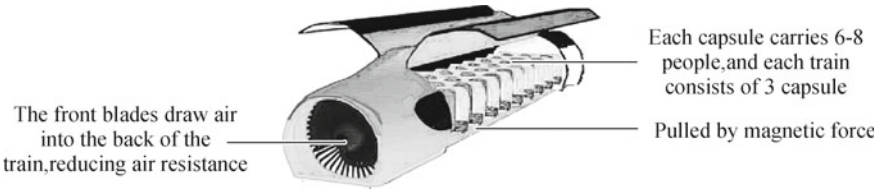

Fig. 6.14 The 3-dimensional form of the SSR cabin

entrance and exit. When the train is running, the staff firstly opens the outer door. The train will enter the inter layer of the pipeline which is between two doors from the station. When the outer door is closed, the vacuum pump starts to take away the air. At this time, the staff opens the inner door, the train will enter the vacuum pipeline and start to accelerate and run. And the order is reverse when the train is out of the pipeline, firstly the inner is door opened, secondly the train runs out, then the inner door is closed, finally the outer door is opened. The above process is similar to the operation mode of astronauts entering and leaving space in space (Fig. 6.13).

The vacuum MHSR train will be more stable than the plane when running. Although it is operated in a vacuum environment, the cabin is definitely not a vacuum environment. The fully sealed cabin will simulate the daily train environment and make passengers feel comfortable (Fig. 6.14).

6.3.2 The Design Concept of the Super Line

The super line is made up of pipelines. The super line requires a pumping station to be set up at the pipeline. A pumping station should be set up every 2 or 3 km in the vacuum pipeline, to extract air from the pipe. According to the design standards, the pressure in the pipeline should even reach 0.001 air pressure, that is, 1 thousandth of the atmospheric pressure, such pressure range is also the basic guarantee of the operation of trains at a high speed. The joint between the pipelines, must be sealed securely. In addition, there are many pumping stations along the pipeline, and the openings should be reserved for maintenance, inspection and emergency conditions.

These openings are airtight when the vacuum piping system was normally operated and it must ensure there is no leakage. A few leaks are unavoidable in the air lock part of the vehicle in and out of the main pipeline at each station along the line when the system runs continuously. But the seal must be reliable when closed to meet the corresponding sealing requirements. The pipeline is a vacuum state, in which the magnetic vehicle must be the atmosphere environment suitable for people, so the vehicle must have good sealing conditions.

The pipeline is composed of steel. Each 30 m of pipeline was propped by one holder. The structure is very strong with a certain seismic effect. Meanwhile, the surface of the pipeline is covered with solar panels to power the system. The power of the entire SSR train system is 21 MW and the surface-covered solar panel can provide 57 MW, which is fully enough. In order to avoid the discomfort caused by high-speed turning, the route choice is to try to maintain a straight line (Figs. 6.15 and 6.16).

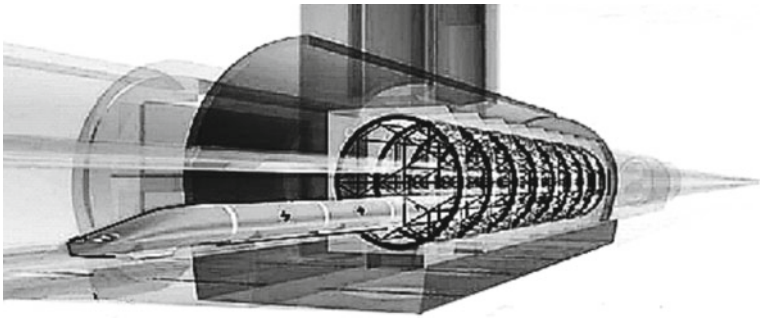

Fig. 6.15 The imagine figure of the SSR line

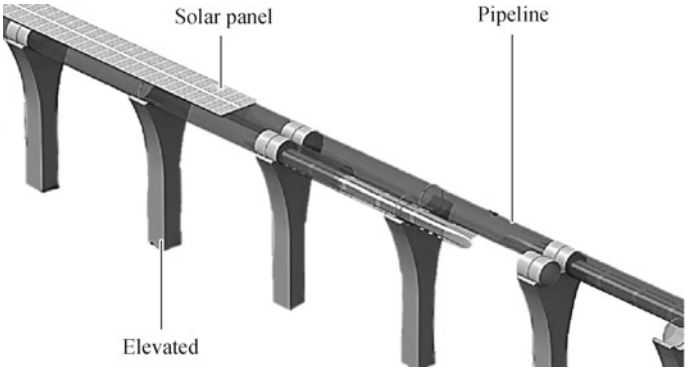

Fig. 6.16 The schematic diagram of the SSR pipeline

6.4 The Definition of SSR

Why is the SSR known as the "the fifth mode of vehicle" and what are the salient features of it that compared to other types of transportation? How is it different from other modes of transportation in operation? What is its specific definition? What is its basic characteristic?

6.4.1 The Basic Definition of SSR

The SSR is a kind of transportation, which is designed by the theory of "vacuum pipeline transportation". It connects a series of "vacuum pipelines" to form the whole transport line system, so that the passengers can arrive from A to B in a few minutes. As a means of transportation, the SSR save travel time and improve the delivery efficiency, it is convenient for passengers. Figure 6.17 shows the imagine Figure of the SSR train.

The SSR train is a kind of super train which runs in the vacuum pipeline, and it belongs to the Evacuated Tube Transport and travels in the airtight vacuum pipeline. SSR is unaffected by air resistance, friction and weather, especially unaffected by natural environment (such as gale, rainstorm, debris flow, low temperature, etc.). The super train can be regarded as an ideal mode of transportation because it can reach 1000–20,000 km/h, which is several times faster than aircraft. The advantages of SSR are no need for on-board power, high security, low energy consumption, static suspension, low noise, not easy to tinnitus, light body, and high-frequency departure; The disadvantage of SSR is the greatly increase in the cost of rail.

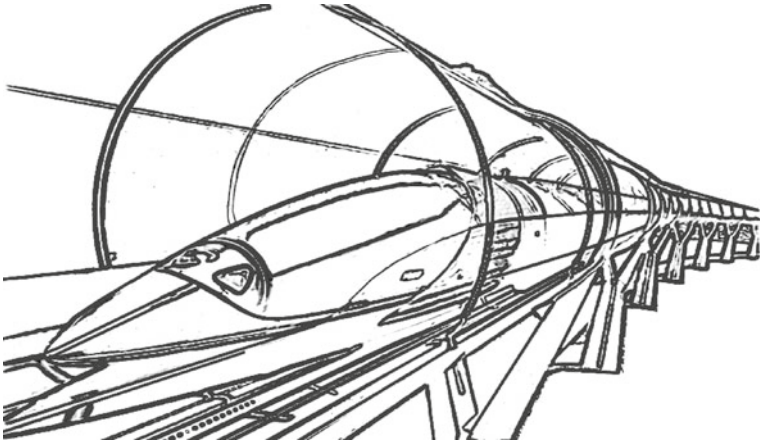

Fig. 6.17 The imagine figure of the SSR train

The Relationship Between Velocity and Air Resistance

Operating in a dense surface atmosphere, high-speed vehicles inevitably suffer friction (including contact friction and air friction, mainly air friction) resistance. The maximum speed of the surface vehicle is about 500 km/h, while the theoretical maximum velocity in the piping transport system can reach above 20,000 km/h. The resistance mainly comes from the air when the HSR exceeds the speed of 300 km/h, and the resistances can be up to 90% when the HSR exceeds the speed of 400 km/h, 99% when it is up to 500 km/h. The speed of HSR cannot exceed the speed of airplane, mainly because the surface air resistance encountered by the train is much greater than the air resistance encountered by the plane. Therefore, the speed of vehicles is related to air resistance, the greater the air resistance is, the smaller the speed of transport is.

(1) The resistance relationship of the surface. When the vehicle is running on the ground, it faces 1 bar pressure. The speed of the rail train is the king of the surface compared with the cars, ships and ordinary trains. According to the latest research, the highest running speed on the ground HSR (wheel-rail) in normal operation is 400 km/h, and the highest running speed of the ground HSR (magnetic-rail) in normal operation is 500 km/h. Therefore, on the surface, no matter which means of transport, the fastest running speed cannot exceed 500 km/h due to air resistance, the best operating speed at different distances is shown in Table 6.1.

(2) The resistance relationship in air. Because the air density at different altitude is different, the air resistance at different altitude is different, and this air resistance is also associated with atmospheric pressure. Therefore, the speed of transport at different atmospheric pressure is different. According to the current research results, the optimal velocity at different atmospheric pressure is shown in Table 6.2.

Through the analysis of air resistance on the ground surface and in the air, we drew the following conclusion: for the thinner the air and the smaller the air resistance, the greater the speed of transportation. Therefore, if a pipeline is constructed and the air in it is discharged, the interior of the pipeline becomes vacuum, so that the

Table 6.1 The optimal velocity value at different distances

Number	Distance/km	The running speed/(km/h)	The traffic tools
1.	<200	200	Motor train
2.	200–400	400	WHSR train
3.	400–600	500	MHSR train
4.	600–1500	1200	SSR train
5.	1500–10,000	2000	
6.	15,000–20,000	6500	
7.	>10,000	20,000	

Table 6.2 The optimal velocity value at different atmospheric pressure

Number	Height/m	Atmosphere/Pa	Flight speed/(km/h)	The running speed of The SSR/(km/h)
1.	<1000	1	400–500	<500
2.	1000–4000	0.8–1	500–600	500–1200
3.	4000–10,000	0.5–0.8	600–8000	
4.	10,000–20,000	0.2–0.5	800–1000	1200–2000
5.	12,000–15,000	0.05–0.2	1000–2000	
6.	15,000–20,000	0–0.05	2000–10,000	2000–20,000
7.	>20,000	0	>10,000	>20,000

vehicle running in the pipeline will not be subject to air resistance, and its speed can reach more than 6500 km/h; Even if there is a little air in the pipeline, as long as it is at a pressure of less than 0.1 atmospheres, the vehicle can also reach an speed of 1000–2000 km/h.

The Main Problems in the Design of SSR

In the dense atmosphere of the ground surface, the transportation of vehicles is affected by contact friction and air friction, while the main limitation of transportation is air friction, i.e. air resistance. How to improve speed of a train? The only way is to reduce friction and reduce drag. On the one hand, for contact friction, the SSR essentially use magnets to provide the thrust, relying on compressed air to provide lift, so the SSR will not have the friction resistance between wheels and rails. On the other hand, for air friction, the SSR aims to achieve the target speed, so the driving track must maintain low pressure to reduce the resistance between the SSR train and air.

(1) Design principle-air resistance problem. The SSR pipeline can be built into a closed pipe. The air inside the pipe can be ruled out and the pipe becomes a vacuum or a partial vacuum during operation. In this way, the SSR runs in a closed pipe without air resistance, the resistance of the SSR will be greatly reduced, while the energy consumption, the aerodynamic noise and the vibration of SSR train are greatly reduced as well. Figure 6.18 shows the pipeline starting point of SSR.

(2) Design principle-contact friction problem. The friction resistance of the SSR comes from air friction and contact friction. In addition to eliminating the resistance from air friction, another highlight of the SSR is suspension technology. The problem which suspension technology wants to solve is the contact friction resistance. The suspension technology uses magnetic levitation technology to

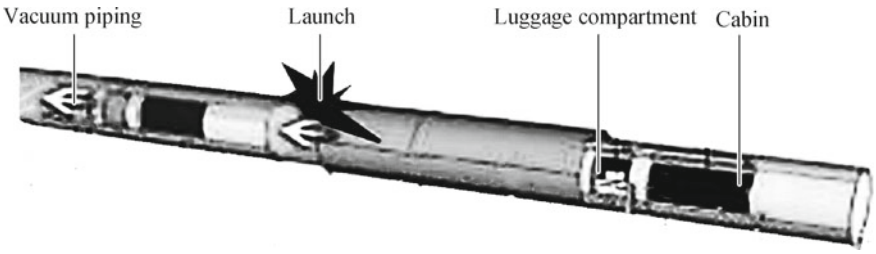

Fig. 6.18 The pipeline starting point of SSR

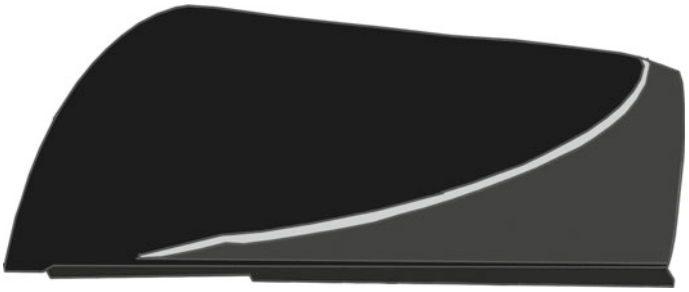

Fig. 6.19 The pipeline diagram of SSR

make delivery vehicles operate in the vacuum pipeline without contact and friction, to achieve point-to-point transport, so there is no contact friction problem. Figure 6.19 shows the pipeline diagram of SSR.

(3) Design principle-power drive problem. The SSR can be designed with self-power supply. According to U.S. expert Elon Musk, laying solar panels on the top of the pipeline can generate enough power to maintain its normal operation. When the SSR system is fitted with solar panels, the energy obtained can bear the power consumption of the entire system. Additional energy storage facilities in the SSR system can store excess energy for emergency use in the SSR system (Fig. 6.20).

Therefore, based on the above three principles, the construction of SSR is theoretically simple. Firstly, the air is pumped out of the closed environment to form a vacuum environment; Secondly, the friction is eliminated so that the delivery vehicle can be suspended in the pipeline and move at a high speed with less energy. Finally, under the impetus of solar energy, the SSR can operate fast in the vacuum pipe line.

The Basic Definition of the SHSR

The SSR system is a pipeline that is insulated from the outside air, which is pumped into a vacuum, where a MHSR train and other vehicles run (Based on Elon Musk

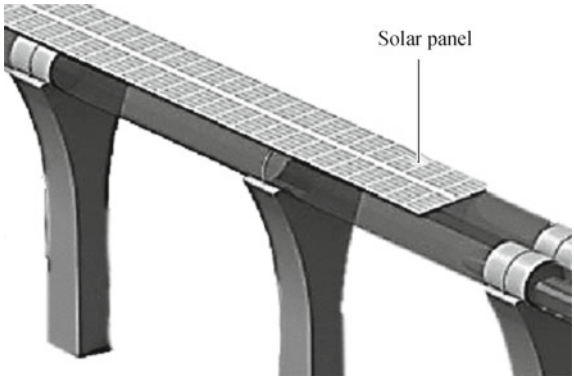

Fig. 6.20 The schematic diagram of solar panel of SSR (picture from network)

of the United States, the schematic diagram of the SSR is shown in Fig. 6.21). The means of delivery (i.e. the Super train) is in an almost frictionless environment, using a floating cabin to deliver passengers at 1200 km/h in a low-pressure tube. The characteristics and types of SSR are shown in Table 6.3.

(1) SSR train. The SSR is a new means of transportation built by the concept of "vacuum piping". The vehicle is a new generation of transportation after automobiles, ships, trains and airplanes, with the characteristics of ultra-speed, high safety, low energy consumption, no noise and zero pollution. Because of the vacuum operation in the pipeline and the use of magnetic levitation

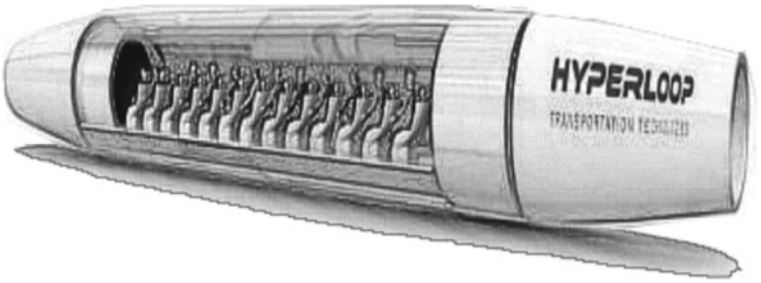

Fig. 6.21 Imagine figure of SSR train (Hyperloop) by Elon Musk (picture from network)

Table 6.3 Characteristics and types of SSR

Number	The specific characteristics	Type
1.	Transport in the pipeline	Pipeline
2.	Magnetic technology used	Rail
3.	The transport capacity is equivalent to the capacity of bus	Road
4.	Running at the same speed as the flight speed	Air
5.	Floating in the air	Water

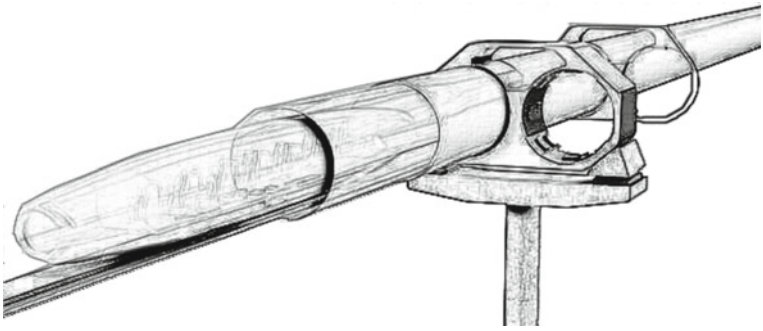

Fig. 6.22 The imagine figure of SSR pipeline (picture from network)

technology, this book suggests that the vehicle should be called vacuum rook or SSR train.

(2) Vacuum piping. The SSR is different from the traditional rail, and it is a vacuum suspension friction-free flight system, which is a new high-speed transportation system. The SSR system consists of transportation pipelines, manned compartments, vacuum equipment, suspension components, ejection and braking systems and so on. On the one hand, the SSR train is suspended inside the pipeline, and the speed can reach more than 1000 km/h; On the other hand, magnetic technology is used to float super trains in vacuum-treated pipelines, and then ejection devices are used to launch super trains along the pipelines to destinations uninterruptedly (Fig. 6.22).

6.4.2 The Propulsion System of SSR

The SSR runs in the tunnel, is not affected by the weather, and its propulsion system is placed in the pipeline without human error. Therefore, the design of the SSR is safer than the general mode of transportation. If a serious accident occurs during the operation of the SSR, passengers in the enclosed cabin are likely to be oxygen-deficient. To guard against this potential hazard, the SSR provides oxygen masks.

(1) The propulsion system of SSR: it is mainly by air compression. The SSR train includes three processes throughout the course of the journey: acceleration running at a high steady speed slowing down to the stop. And the basic requirements of the SSR propulsion system are as follows: during the start-up phase, the train can accelerate the cockpit from 0 to 480 km/h at a relatively low speed, which requires a large starting acceleration; In the linear acceleration region, the train can accelerate from 400 to 1220 km/h with an acceleration of 1 g (9.8 m/s^2); The fan of SSR train's head is sufficient to provide the force to maintain 1200 km/h. As for the acceleration and deceleration process, the force is completed by a linear motor on the wall of the pipeline, which accelerates

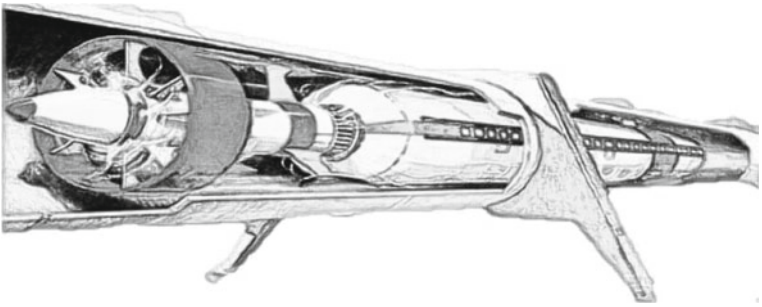

Fig. 6.23 The propulsion system of SSR

the train when it starts off and slows down when it arrives. Figure 6.23 shows the propulsion system of SSR.

(2) Energy supply pattern of SSR: solar energy is the most suitable power source for SSR. The batteries in the car are mainly used to make their own air cushions. In tunnels, an external linear motor is installed to replenish the train's power every 110 km. The pipes are covered with solar panels, which converts solar energy into electricity to make the system self-sufficient and even surplus. The power of the entire SSR train system is 21 MW, and the surface-covered solar panel can provide 57 MW of electricity, which is sufficient.

6.4.3 The Technical Characteristics of SSR

Vacuum MHSR trains are considered to be the fastest means of transportation in the world. In fact, the SSR train is a vacuum MHSR train. In addition to the superiority of the speed, the vacuum piping system also has the characteristics of fast, punctuality, large volume of traffic, comfort, safety, all-weather operation, energy saving, environmental protection and so on.

The Safety of SSR

(1) No matter which kind of transportation, safety is the first. Therefore, safety and reliability are the primary factor of passengers' travel considerations. The SSR connects many cities with huge, near-vacuum pipelines, forming a SSR network to facilitate quick travel. What about the safety of the SSR?

(2) Objective safe level. Objectively speaking, the natural environment has a large impact on various modes of transportation, but it has no effect on the SSR because it operates in a fully enclosed system, as shown in Table 6.4.

Table 6.4 Comparison of safety about SSR with other transportation modes

Type	Earthquake	Wind	Temperature	Thunder and lighting	Rainstorm	Debris flow
SSR	Smallest	Smallest	Smallest	Smallest	Smallest	Smallest
Plane	Small	Small	Smallest	Largest	Small	Small
Train	Largest	Large	Large	Large	Largest	Largest
car	Large	Largest	Largest	Small	Large	Large

Table 6.5 Subjective safety of SSR

1.	With speed limits, the cabin is fully contained in the pipeline and is not easily derailed
2.	Have advanced control and guarantee system, it is not easy to appear man-made accident
3.	There is a safety compartment along the vacuum pipeline, which can be escaped from the safe cabin in case of malfunction

(3) Subjective safe level. Subjectively, most of the traffic accidents are related to people, while the SSR is mainly intelligent control, less human-made effect. The subjective performance of super high speed railway is shown in Table 6.5.

In short, SSR is the safest mode of transportation, both subjectively and objectively, compared to the vehicles such as cars, airplanes, ships and WHSR.

The Comfort of SSR

Comfort is another key reason for people to choose the SSR to travel. It has been suggested that SSR is faster than airplane and cannot be tolerated by humans, but in fact they can be tolerated according to the scientific analysis of the human body. Scientific analysis shows that the human body can withstand. The reasons are as follows:

(1) The adaptability of the human body compared with the automobile. The limit that the human body usually withstands is the acceleration around 50 m/s^2 while the hundred kilometers accelerate of a car is about 10 s. If you can easily speed up to 1000 km/h in 1 to 2 min, it is not a problem for the human body to withstand the speed of SSR.

(2) The adaptability of the human body compared with the aircraft. The acceleration of the SSR reaches the acceleration of the aircraft, and the acceleration of the aircraft is generally 0.5–0.6 g, equivalent to the acceleration at 5 m/s^2. In fact, the acceleration of the people's 100-m sprint is much greater than this. Therefore, this acceleration is entirely within the acceptable range of human beings. The train will not always be in accelerating motion after accelerating to a certain value, and it will enter a uniform motion state. At that time, passengers do not have any sense of speed, just as smooth as the astronauts flying in the

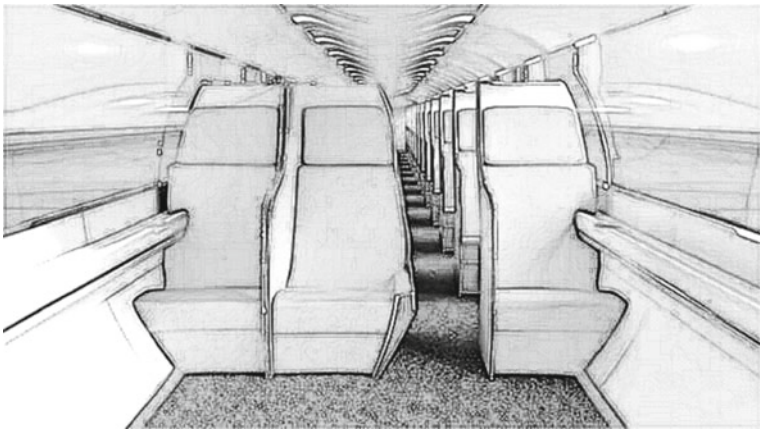

Fig. 6.24 The seat diagram of SSR

air. So even the acceleration of the SSR train is too fast, people still can bear it. Figure 6.24 shows the seat diagram of SSR.

Three performances of SSR comfort are as follows: ① Each passenger compartment of the SSR train is pressurized, the SSR train is fitted with oxygen masks and an emergency braking system to avoid the possibility of physical discomfort; ② The SSR train is ejected at the starting point. It will rely on the magnetic force to run all the way and will not encounter turbulence like an airplane on the way; ③ When the SSR train is launched, the passengers will feel the acceleration, and once the super train is full ahead, the passenger won't feel anymore. As a result, the passenger experience is comfortable on the SSR, and the SSR will be more comfortable and quieter than the WHSR and the aircraft. Especially from the technical level, the SSR comfort also includes vibration, temperature, noise, air, light and other factors. A comparison of the comfort of various vehicles is shown in Table 6.6.

The Economics of SSR

The economics is one of the main factors to be considered in building SSR. According to Musk's design philosophy, the SSR is a very economical way of transportation for any two big cities with distances not exceeding 1500 km. For example, the cost of building a SSR between Beijing and Shanghai is 6 billion Yuan. The SSR is dispatched every 3 min. Each SSR train carries 30 people, and the operating cost per trip is about 200 Yuan. Therefore, the one-way fare can be set at 200 Yuan per sheet, which is very cheap and acceptable to passengers. The comparison of the cost and operating cost of the SSR and other transportation modes is shown in Table 6.7.

(1) The economic analysis based on the cost of construction. The operation route of the SSR is the pipeline. The pipeline is supported away from the ground by

Table 6.6 Comparison of the comfort of various vehicles

The traffic tools		SSR	Traditional rail	WHSR	Cars	Aircraft
In-car stability	Longitudinal stability (°)	1.5	3	2	3	3.2
	Horizontal stability (°)	0.2	2.2	2	2.5	2.6
	Vertical stability (°)	1	2.5	2	2.8	5
In-car noise (db)		50	70	65	76	80
In-car temperature		Automatic temperature control	Higher than normal temperature	Automatic temperature control	Higher than normal temperature	Self-adjust the normal temperature
In-car air		Inferior to outdoor	The same as outdoor	Inferior to outdoor	The same as outdoor	Inferior to outdoor
In-car light		Automatic light control	The same as outdoor	Inferior to outdoor	The same as outdoor	Automatic light control
The smaller the stability value, the more stable the car environment, the more comfortable, the international stability of the value of the threshold is 2						

Table 6.7 Comparison of the cost and operating cost of SSR and other transportation modes (regard the cost of SSR as 1)

Mode of transport	Cost	Operating cost	Comments
SSR	1	1	The cost of SSR is 1
Freeway	4	NA	
WHSR	10	2	

the elevated pillar. It reduces the occupation of land resources. The vacuum pipelines between two cities are built on the ground like HSR. Wherever there is a road, there can be two pipelines for two directions. And the vacuum pipeline may be "attached" to the already built high-speed bridge, thus saving the route resources and infrastructure cost. Therefore, the construction cost of SSR is lower than that of other transportation.

(2) The economic analysis based on operating cost. The use of solar power in the SSR train greatly reduced the cost of transportation. The SSR train can use its own technology to carry out multiple energy storage. After the SSR system accelerates the SSR train to a certain speed, the SSR train can rely on inertia to operate in a vacuum pipeline without any additional energy. The existing kinetic energy of the SSR train can be recovered and reused by the motor when the passengers are about to arrive and the train needs to slow down, so that the transportation cost of the SSR train is only 1/10 of the transportation cost of the WHSR train. As a result, the operating cost of the SSR is lower than that of the WHSR (Table 6.8).

Table 6.8 The cost of SSR

Type	Cost (Yuan)/100 million	The specific cost (Yuan)/100 million			Cost per kilometer (Yuan)/100 million
		Elevated cost	Land	Pipeline	
Passenger SSR	360	153	60	39	About 0.1
Passenger and cargo dual-use SSR	450				

Table 6.9 The convenience of SSR

Number	Convenience	Reason
1.	No waiting time	No need to reserve the seat and the short departure interval
2.	Everyone is equal	No grade difference of the seat
3.	Saving time	The station is located in the center of the city without transfer
4.	Choose the travel time by yourself (optional trip time)	Run automatically without fear of delay
5.	Free choice	Select running speed according to line length

The Convenience of SSR

Convenience is one of the choice conditions for SSR travel. If the SSR network can be built around the world, it will take hours to travel around the world to achieve the goal of global day trips (morning go and evening back, global work). According to Musk's design concept, the convenience of SSR is shown in Table 6.9.

The Energy Saving and Environmental Protection of SSR

In addition to the superiority of speed, the vacuum piping system of the SSR is more energy efficient and environmentally friendly, especially in low-carbon emission, energy saving and environmental protection. On the one hand, as a transportation vehicle, SSR not only has zero carbon emissions, but also no dust, fumes and other exhaust pollutants. On the other hand, vacuum pipeline transportation is a transportation method without air and friction, and it is quieter than the WHSR and the aircraft.

(1) Analysis of the technical characteristics based on energy consumption. Due to the reduction of contact friction and air friction, the vacuum pipeline transportation consumes less energy than any traditional transportation. The transportation capacity per kilowatt-hour of the SSR is 50 times of that of the WHSR. The SSR system will be powered by solar energy. It can replenish its own energy,

Table 6.10 Comparison for energy consumption of various vehicles (kg/person)

Vehicle	Traditional rail	WHSR	SSR	Car	Aircraft
Per person equal mileage energy consumption	1	0.5	0.1	6	4

Table 6.11 Comparison of various vehicle environmental protection

Vehicle	Traditional rail	WHSR	SSR	Car	Aircraft
CO_2 emissions per person per kilometer/[mg/(km·person)]	1	0.5	0.2	10	4
Noise per person per kilometer/[db/(km·person)]	0.1	0.05	0.01	1	1

and the system has a facility to store energy. It can travel for a week without using a panel. According to the analysis of existing research results, the energy consumption comparison of various vehicles is shown in Table 6.10.

(2) Analysis of the technical characteristics based on Environmental Protection. The SSR is more than twice as fast as the aircraft, but it consumes less than 1/10 of the energy of the civilian airliner. The noise, exhaust pollution and accident rate of the SSR are close to zero. In particular, the pipelines of SSR are built underground or on the ground, there is basically no pollution to the environment. According to the analysis of existing research results, the environmental protection comparison of various modes of transportation is shown in Table 6.11.

6.4.4 The Existing Problems of SSR

Once the SSR system succeeds, it will completely subvert the human's perception of traffic. But the higher the speed is, the greater the risk is, and if an accident happens, the vacuum pipeline will bring an unthinkable disaster to passengers. At present, from a technical point of view, a variety of key technologies used in the SSR system (including low-voltage pipelines, compressors, solar energy and other technologies) are mature and feasible, but from the application level, there are many other problems to be solved (Fig. 6.25).

(1) From the view of theoretical point, the SSR system is completely feasible. In the theory, pipeline transportation is currently the most efficient and energy efficient transportation method. Vacuum MHSR train is the fastest vehicle in the world, which has been verified theoretically. Therefore, from the theoretical point of view, the construction of SSR system is entirely feasible. The specific reasons are shown in Table 6.12.

(2) From the view of application point, the construction of SSR system is very difficult, and it will not be completed in a short time. At present, the realization of

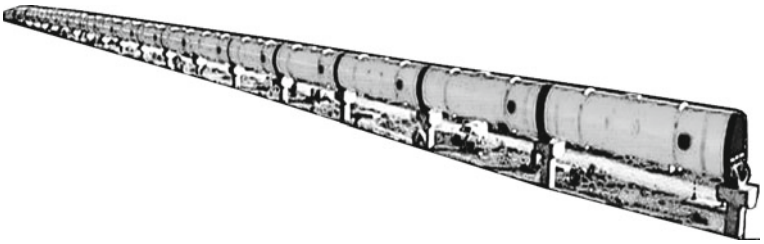

Fig. 6.25 The real figure of SSR pipeline in experiment

Table 6.12 The reason that the SSR work

Number	Feature	Reason
1.	Can realize high-speed operation	Not affected by friction and air resistance, the maximum speed can reach 20,000 km/h theoretically
2.	High safety of the system	SSR trains in fully enclosed environments are completely unaffected by weather changes
3.	Reasonable energy supply	Self-powered design, laying the solar panel above the pipeline can generate enough electricity

vacuum transportation over 1000 km is restricted, especially in technology, cost and management. Therefore, the construction of SSR system is not feasible. The reasons are shown in Table 6.13.

In short, SSR has many advantages, perhaps in the future can lead to a revolution in the field of transport and promote the great progress of human society. However, many problems in terms of technology and cost require scholars to constantly study and discuss. The development of the super HSR must be gradual, otherwise human

Table 6.13 The reason that the SSR does not work

Number	Reason	The specific performance
1.	Long distance vacuum pipe is difficult to construct	The pressure difference inside and outside the vacuum pipe is great, and the existing technical means are difficult to meet the requirement
2.	Magnetic technology is not perfect	At present, magnetic technology is not mature in practical application
3.	The problem of voltage stability	The problem of "vacuum breakdown" is easily produced in the vacuum environment, and has not been solved
4.	The problem of system managing	Transnational transport, coordinated management of different countries is difficult to solve

will pay a heavy price. Only when the traditional rail is gradually transformed into WHSR will it be able to stimulate the pace of SSR. At that time, it is possible to achieve the balance of "speed and safety" and global integration under the SSR environment and realize the global day tour that people go out in the morning and return in the evening.

6.5 Development Vision of SSR

It is a long way to realize the ultra-speed research. When the train runs, the pressure inside the pipe is 10 times lower than that outside, and the train can use more power to drive the vehicle speed forward. In 1992, researchers deduced from high-speed spin experiments that the experimental speed of HTS (high temperature superconducting) Maglev was up to 3600 km/h, but this is just theoretically, there is a long way to go.

On August 30, 2017, China Aerospace Science and Industry Corporation (CASIC) announced the launch of the "High-speed flight (HSF) train" research and demonstration. It is proposed to develop a new generation of vehicles through commercialization and marketization, combining the supersonic flight technology with the rail transit technology. Utilizing the superconducting magnetic levitation technology and the vacuum piping, researchers are committed to achieving the supersonic "near-earth flight", whose theoretical maximum speed can be achieved 4000 km/h. The HSF train is a transportation system which reduces the air resistance by using low vacuum environment and supersonic shape. It reduces the frictional resistance through magnetic levitation, and realize supersonic running. Compared with the traditional WHSR train, the speed of the HSF train is increased 10 times; Compared with the existing civil aircraft, the speed has been increased 5 times and the maximum speed can be achieved 4000 km/h. It is a great step forward for the ultimate pursuit of vehicle speed. The advent of a new era is often accompanied by a great change in transportation mode, and the CASIC HSF train project will open a new era! Fig. 6.26 shows the concept Figure of the HSR train.

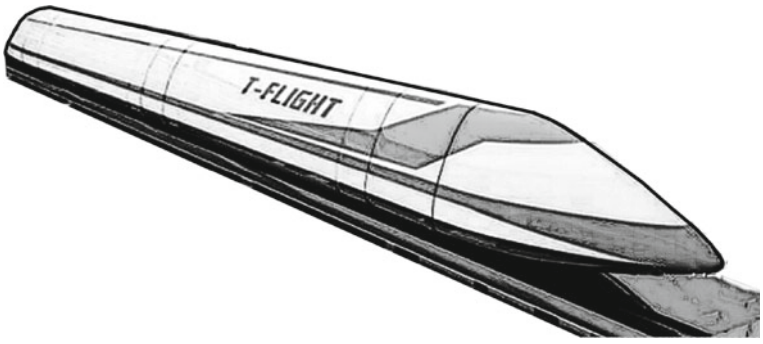

Fig. 6.26 The concept figure of the HSR train

(1) Bright future. Vacuum tube MHSR is the most natural and direct scientific inference result based on all known traffic modes. The friction resistance between the train and the track is eliminated, and the friction resistance between the train and the atmosphere is eliminated. The ideal combination of MHSR and vacuum pipeline concept is the choice of future traffic, and the real call of the global village era. Now the era of the internet has enabled information to travel on earth at the speed of light, so that anyone in every corner can instantly know the knowledge he needs. However, the physical transmission is still limited to the time and space background. The concept of magnetic levitation in vacuum pipeline emerges as the times require, its superiority is also obvious, such as high speed, convenience, high efficiency, energy saving, clean, environmental protection, and safety. It will realize the space travel on the earth and bring the human travel to a new stage.

(2) Complicated ways. There are still many insurmountable obstacles in the actual operation of MHSR train, let alone the vacuum transportation based on suspension technology. There are many specific problems in the practice of vacuum pipeline transportation, and how to solve these problems has never been proposed. For example, the voltage in the vacuum environment is prone to "vacuum breakdown" phenomenon, resulting in a self-sustaining discharge and the damage to the electrodes caused by the transport system paralysis. How to ensure voltage stability in a vacuum environment? In addition, the pipeline is a vacuum state, and the maglev vehicle running in it must be suitable for the human ride in the atmosphere. So how to ensure that the internal and external environment to meet the standards is also a difficult point. At present, no one can determine how much the feasibility of the vacuum pipeline transport, because all the description of the scheme is not detailed enough and short of practical necessary arguments, it is difficult to distinguish its technical rationality and engineering feasibility. As a new concept transportation system, which was put forward in 2013, SSR has been paid much attention since emergence. This concept has evolved over several years leading to several mature ideas. These ideas are the foundation of the SSR study in the future.

Vision is always ahead of reality and determines reality. The development of fast, convenient, efficient energy-saving, clean, environmental, safe, economic and practical transportation system is the goal, let us bravely to promote the future! Super-speed rail set sail!

6.6 Summary

"The concept is feasible, the theory is defective". Under the promotion of WHSR, the rapid formation of national metropolitan areas greatly narrows the distance between urban and rural and accelerates the integration of urban and rural areas. But in the future, with the promotion of the SSR, the world economic circle will also be rapidly

formed. The HSR will greatly shorten the distance between countries and promote the rapid development of countries, forming a global village under the HSR environment. However, the rail is a high cost, high investment infrastructure projects, and the SSR is a high-risk facility, directly related to a country's livelihood. In the theory, it is possible to achieve higher speeds in the vacuum environment, but the maximum speed is related to not only the vacuum, but also the technology of suspension guidance system, traction system, rail system and operation control system. Therefore, the super high-speed rail also needs further theoretical research.

"The ideal is feasible, the technology is not pefect." The speed enhancement, which shortens the time and space and narrows the distance, has reconstructed the world space–time layout and realized the global integration. However, the SSR provides people the imagination space to continue to improve the travel speed, and it is hard to achieve engineering applications; there are many problems to be solved, human need to continue to study, so the myth will become reality.