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Main Vacuum Technical Issues of Evacuated Tube Transportation

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Abstract

In the future, Evacuated Tube Transportation (ETT) would be built and faster than jets. ETT tube with diameter 2~4m and length over 1000km will be the largest scale vacuum equipment on earth. This paper listed some main vacuum technical issues to be solved in ETT as follow. How to build ultra-large-scale vacuum chamber like ETT tube with low cost and high reliability? How to pump gas out off the ETT tube in short time? How to release heat or reduce temperature in the vacuum tube? Hot to avoid vacuum electricity discharge? How to manufacture vehicles with airproof shells and equip the life support system? How to detect leakage and find leakage position efficiently and fast as possible? Some relative solutions and suggestions are put up.

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Keywords: Evacuated tube transportation; Vacuum technology; Vacuum tube; Maglev; Vehicle

1. Introduction

Compared with the advanced Internet or IT technology, the nowadays situation of both traffic and logistics is clearly laggard. All countries are looking for new transport mode that will be faster, cleaner, safer and environmentally friendly. Although the speed of high-speed railway is 350km/h [1], the speed of Shanghai Maglev in operation in China is 430km/h [2], and Japan Yamanashi Maglev test line reached 581km/h [3], they aren't the ideal speed, and those vehicles run with extreme high aerodynamic noise and air drag. More and more clearly, it will be the correct orientation for trains to combine it with evacuated tube transportation (ETT), namely putting the maglev into the vacuum tube of ETT. Then the Maglev could run at a speed of 800~1000 km/h, and it's possible to run at a hypersonic speed, for example, 6000 km/h or even over 10000 km/h [4-6].

In order to operate maglev in vacuum tube, a series of vacuum technical issues need to be studied and solved. This paper lists and discusses some main vacuum technologies to be solved in ETT, and tries to present feasible solutions.

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2. Building ultra-large-scale vacuum chamber

Vacuum chamber in ETT will be a circular tube with inside diameter about 2-4m [7] and length 1000~15000 km. For such a large vacuum chamber, construction cost should be considered seriously. We have to select cost feasible construction materials and design right structure. In any case, at first we should consider how to construct such an ultra-large-scale vacuum chamber with low cost and high reliability.

Among a large number of materials types, steel and cement are cheap construction materials and they are right for building vacuum tube. With common steel and cement, three types of vacuum tube structure are suggested here.

2.1 Steel tube

The key merit of pure steel tube is that it is easy to keep airproof, and the cost is moderate. The current price of common steel in China market is about 6000 CNY for 1 ton. According to primary analysis, the feasible tube wall thickness w would be 8~20mm, and the feasible tube inside diameter d should be 2~ m. The diameter of up to 5m is included so as to compare the cost. Then the steel tube basic materials cost per kilometer are as shown in table 1.

Table 1 Steel tube materials cost (unit: million CNY/km)

w (mm) / d (m)	8	10	12	14	16	18	20
2	2.36	2.95	3.55	4.14	4.74	5.34	5.94
2.6	3.06	3.84	4.61	5.38	6.15	6.92	7.70
3	3.54	4.42	5.31	6.20	7.09	7.98	8.88
3.6	4.24	5.31	6.37	7.44	8.50	9.57	10.64
4	4.71	5.89	7.08	8.26	9.44	10.63	11.82
4.6	5.42	6.77	8.13	9.49	10.85	12.22	13.58
5	5.89	7.36	8.34	10.32	11.79	13.27	14.75

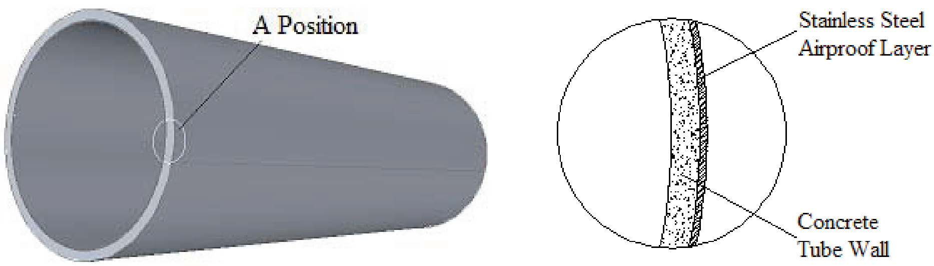
If the tube diameter 2m, 3m, 4m and 5m is respectively fit to the tube wall thickness 14mm, 16mm, 18mm and 20mm, then the materials volume and materials weight can be calculaed as shown in table 2.

Table 2 Steel tube materials volume and weight

Tube diameter (m)	2	3	4	5
Wall thickness (mm)	14	16	18	20
Materials volume (m^3/km)	88.53	151.52	227.09	315.25
Materials weight (t/km)	690.6	1181.9	1771.4	2459.0

2.2 Concrete composite structure tube with stainless steel airproof layer

For further reducing materials cost and increasing intensity of vacuum tube, a composite structure tube can be accepted [8]. Like shown in Fig. 1, a composite structure tube consists of inside concrete tube and outside stainless steel thin airproof layer. In this case, the outside stainless steel layer thickness would be 1~2 mm. Although the total thickness of the tube wall would be increased, the total materials cost would be reduced because the price of concrete is much less than the price of steel. In addition, the compressive strength that is significant for vacuum tube would be increased.



a. 3D sketch of ETT tube b. Enlarged view of A position in Fig. 2(a)

Fig. 1. Concrete composite structure ETT tube with stainless steel airproof layer

3. Pumping gas out off the ETT tube

How to efficiently evacuate gas out off the ETT tube in short time is another key issue for ETT system. For the ultra-large-scale vacuum chamber, the allowable time to pump gas from it will be quite short, for example, to pump gas from trunk tube in a few hours and pump gas from the airlock in some minutes. Therefore, it is necessary to install vacuum pumps each 1 or 2 kilometer, and the pumping speed of vacuum pumps or pump groups should be large enough. According to the primary estimation, the availability speed for 1 kilometer ETT tube should be more than $10m^3$ per second.

Along to the ETT line, airproof isolation gates should be set every 5~10 km as shown in Fig. 2. One of functions of the isolation gates is to facilitate pumping gas from the tube. Before pumping gas, all isolation gates are closed, and pumping gas from each sect of vacuum tubes. When the atmospheric pressure in each sect reaches prescriptive value, stop all vacuum pumps and open all isolation gates. Then the maglev can run through in it.

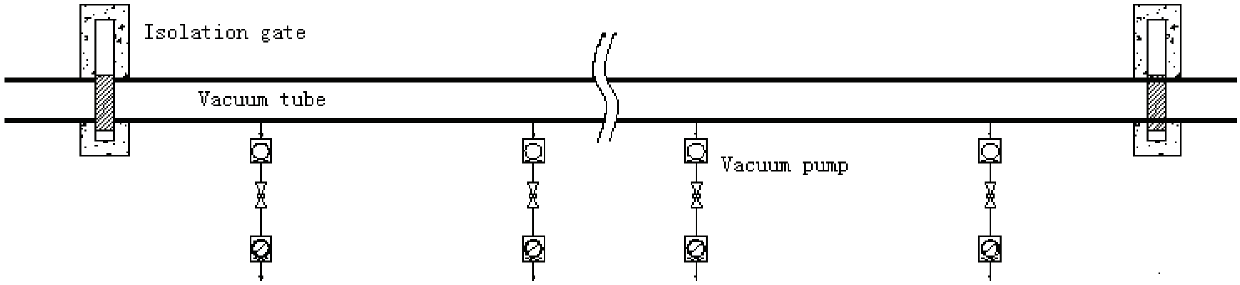


Fig. 2. Setting of gas isolation gates and pumps along with vacuum tube

Among current vacuum pumps, roots pumps are right for evacuating gas from ETT tube. The characteristics of roots pumps are high pumping speed, simple structure and low price. The maximum pumping speed of roots vacuum pumps is more than 12000L/S.

4. Release heat or reduce temperature in the vacuum tube

In ETT tube, there are some heat resources to lead temperature rise:

(1) Electrical devices operation such as linear motor which drives the maglev.

(2) There is also small little of gas in the tube because it will be rough vacuum inside it. Therefore, aerodynamics heating would be produced when maglev runs at a high speed in the vacuum tube.

(3) The maglev vehicles will release heat.

(4) Sun radiation thermal through the tube wall when the ETT tube is put on the ground.

Because there is not air convection in ETT tube and vacuum circumstance act as heat isolation medium, heat in ETT tube would pile up and temperature would rise continuously. Thus we should find methods to release heat and reduce temperature in it.

At first, we should select tube wall structure and materials which facilitate releasing heat. In this sense, steel tube is better than concrete tube, and common steel is better than stainless steel because the thermal conductivity of stainless steel is much less than common steel. At the same time, wall thickness should be thin as soon as possible.

Secondly, the ETT tube should be put under ground as soon as possible because it's constant temperature environment under ground and no sun radiation.

The third, a metal pipe with recycle cold water is effective for reducing temperature in ETT tube. The detailed methods are discussed in the paper "Analysis of cooling schemes of linear motor in evacuated tube" [9].

The fourth, an ETT system with the driving system outside the tube is effective for reducing heat in the tube. The detailed scheme is shown in Chinese patent [10].

5. Avoid vacuum electricity discharge

Electricity is apt to break through vacuum environment more easily. Vacuum discharge characteristic are not generally considered for some electrical equipments of maglev in open space, but it must be considered in vacuum tube. In order to avoiding vacuum discharge in ETT tube, some suggestions are given as following.

(1) Prohibit installing nude wire in ETT tube, namely the wire must be insulated.

(2) Don’t keep wire of linear motor in nude situation. For some wire or electrode which has to be nude in linear motor, a safe distance from other nude wire or electrode should be kept.

(3) Don’t keep wire on maglev in nude situation. For some wire or electrode which has to be nude on maglev, a safe distance from other nude wire or electrode on maglev self or in vacuum tube should be warranted.

6. Make vehicles with airproof shells and life support system

ETT vehicles will run in vacuum environment, 1 atm in vehicle while 0.1~0.001 atm outside vehicle (but in vacuum tube), as shown in Fig. 3. Therefore the vehicles should be designed according to following two principles:

(1) ETT vehicle shells must be airproof and strong enough to endure pressure inside vehicles.

(2) Oxygen must be provided and an aircondition must be installed inside vehicles.

(3) A life support system in the ETT vehicle is needed.

Anyway, it’s necessary to make vehicles with airproof shells and life support system. Although we can use existing spacecraft technology to make ETT vehicles, it is a key issue to be studied at all.

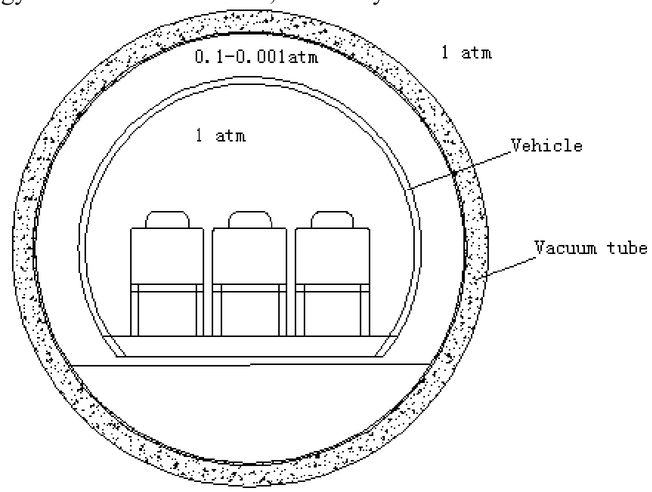


Fig. 3. Sketch of the vehicle with inside pressure 1 atm and the vacuum tube with inside pressure 0.1~0.001atm

7. Detect leakage and find leakage position efficiently and fast

Gas leakage will damage vacuum environment in ETT tube and increase cost to maintain vacuum. There are three resources which lead gas leakage. (1) crack on tube wall; (2) seal bug at linkage positions such as emergency exits, pump outlets and joint points between tube sects; (3) airlock at stations.

For this ultra-large-scale vacuum chamber, helium mass spectrometer leak detection may be not applicable. However, daily measuring and leakage detecting will be important works and they are more difficult than do in small vacuum device. Some feasible methods to detect leakage and find leakage position efficiently and fast are suggested as following.

(1) Isolation gates must be set along to the vacuum tube line, one isolation gate every 5~10km. Smaller distance between two adjacent isolation gates, for example, one every 2km, is more benefit to detect gas leakage, but increasing construction cost and maglev running hazard. After operation ends, close all isolation gates and check all segments of the whole line, including detection of gas leakage of each sect.

(2) After closing isolation gates, by observing the vacuum gauge, we can find the segment which leak gas apparently. As for in same one sect, we should install vacuum gauge densely, for example, one vacuum gauge every 20~100m. By observe display of all vacuum gauges in one sect, we may find the rough position where gas leakage is happening.

(3) Ultrasonic detecting is also applicable for ETT tube.

8. Conclusions

This paper discussed some key vacuum technology issues to be solved in ETT, and some relative solutions have been suggested. In fact, more vacuum technology issues need to be discussed and more optimizing solution would be put up. This paper is looking forward to more vacuum experts focus on vacuum technologies of ETT and believes ETT will be one of the most important vacuum application areas.

9. Acknowledgement

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References

[1] http://www.china-mor.gov.cn/, Ministry of Railway, People's Republic of China, July 2011.
[2] http://www.transrapid.de/, Transrapid, Germany, Dec. 2010.
[3] http://www.rtri.or.jp/, Railway Technical Research Institute, Tokyo Japan, March 2010.
[4] Zhang Yaoping, Li Yanyan. Role and Position of ETT in the Future Comprehensive Transportation System. 2007 International Conference of Transportation Engineering, Chengdu, China, July 10, 2007, pp. 2796-2803
[5] Yaoping ZHANG. Vehicle Scheme of Evacuated Tube Transportation in the Future Logistics System. Singapore: ICILT, Feb. 26-28, 2010, pp. 190-192.
[6] Yaoping ZHANG, Daryl OSTER. Primary Analysis on Tube Section Size of Evacuated Tube Transportation. Beijing: ICRE 2010, Aug. 21-23, 2010, pp. 67-72.
[7] Yaoping ZHANG, Benlin LIU, Yong ZHAO. Some Possible Station Layouts of Evacuated Tube Transportation and Their Characteristics. Chengdu: Journal of Modern Transportation, 3rd, Sep. 30, 2011, pp. 181-185.
[8] Yaoping ZHANG, Shenshan LI, Benlin LIU. et al. Steel-concrete composite structure tube fitting to Evacuated Tube Transportation. Chinese patent, No. 201020540727.6, Nov. 26, 2011.
[9] Yingfeng YAO, Yaoping ZANG, Zhaoyang YU. Analysis of cooling schemes of linear motor in evacuated tube. Vacuum, Vol. 44, No.5, Sep. 2007, pp. 66-68(Chinese).
[10] Yaoping ZHANG, Shenshan LI, Tieqi DING, et al. A maglev vacuum tube transportation system with a thin wall and driving device outside the tube. Chinese papent, No. 201010192101.5, June 6, 2010.