

Dynamic Analysis of
**High-Speed
Railway Alignment**
Theory and Practice

SIRONG YI YING ZHU YOU DING XU YI XIE



西南交通大学出版社



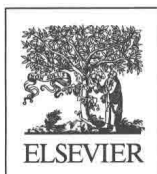
Dynamic Analysis of High-Speed Railway Alignment

Theory and Practice

Sirong Yi
Ying Zhu
Youding Xu
Yi Xie



西南交通大学出版社



ACADEMIC PRESS

An imprint of Elsevier

图书在版编目 (C I P) 数据

高速铁路空间线形动力学分析理论与方法 = Dynamic Analysis of High-Speed Railway Alignment: Theory and Practice: 英文 / 易思蓉等著. — 成都: 西南交通大学出版社, 2018.4

ISBN 978-7-5643-6135-8

I. ①高… II. ①易… III. ①高速铁路—轨道力学—动力学—研究—英文 IV. ①U213.2

中国版本图书馆 CIP 数据核字 (2018) 第 065265 号

高速铁路空间线形动力学分析理论与方法

易思蓉 朱颖 许佑顶 谢毅 著

出 版 人 阳 晓
责 任 编 辑 张文越
封 面 设 计 ELSEVIER

出 版 发 行 西南交通大学出版社
(四川省成都市二环路北一段 111 号
西南交通大学创新大厦 21 楼)
发 行 部 电 话 028-87600564 028-87600533
邮 政 编 码 610031
网 址 <http://www.xnjdcbs.com>

印 刷 四川森林印务有限责任公司
成 品 尺 寸 190 mm × 235 mm
印 张 20.25
字 数 656 千
版 次 2018 年 4 月第 1 版
印 次 2018 年 4 月第 1 次
书 号 ISBN 978-7-5643-6135-8
定 价 88.00 元



交大e出版
微信购书|数字资源



官方天猫店
上天猫 买正版

图书如有印装质量问题 本社负责退换
版权所有 盗版必究 举报电话: 028-87600562

Contents

CHAPTER 1	Introduction	1
1.1	Target Speed for High-Speed Railway.....	2
1.1.1	The Principle of Determining Target Speed for High-Speed Railway.....	2
1.1.2	The Influence Factor of Target Speed for High-Speed Railways.....	4
1.2	The Background and Overview of High-Speed Rail Curve Parameters.....	14
1.2.1	Background.....	14
1.2.2	Research Situation.....	17
1.3	Principle of Minimum Curve Radius Based on Optimal Dynamics Performance.....	21
CHAPTER 2	Models for Vehicle—Track Dynamic Simulation on Horizontal Curve Sections of High-Speed Railways	25
2.1	Alignment Models.....	26
2.1.1	The Line Space Coordinate System.....	26
2.1.2	Line Space Linear Model.....	27
2.2	Vehicle Models.....	28
2.2.1	Vehicle System Dynamics Model to Simplify Topology.....	28
2.2.2	The Equations of Vehicle Motion.....	29
2.3	Track Structure Models.....	39
2.3.1	Ballasted Track Structure Model and Dynamic Equations.....	40
2.3.2	The Structure Models and Dynamic Equations of the Slab Track.....	44
2.4	Wheel—Rail Three-Dimensional Dynamically Coupling Model.....	48
2.4.1	Geometric Parameters of the Wheel—Rail Spatial Contact.....	48
2.4.2	Contact Force.....	56

2.5	Track Irregularity Excitation Model.....	57
2.5.1	Geometrical Irregularity of the Track.....	58
2.5.2	The Model of Random Irregularity of the Track	60
2.6	Solution Method for the Vehicle—Track Coupling Model	63
2.6.1	Numerical Integration Method.....	63
2.6.2	Wheel—Rail Excitation Input Model.....	64
2.6.3	Data Storage Format.....	65
2.6.4	Flowchart of the System.....	67
2.6.5	Program Verification.....	68
CHAPTER 3	The Effect Law of the Curve Parameters of a High-Speed Railway on Vehicle—Line Dynamic Performance	73
3.1	The Calculation Parameters of the Curve and the Dynamic Performance Evaluation Index of the Vehicle—Line System	74
3.1.1	The Calculation Parameters and Calculation Conditions	74
3.1.2	Evaluation Index of the Dynamic Performance of the Vehicle System	76
3.2	The Influence Law of Curve Negotiation Speed on the Vehicle—Track System Dynamic Characteristics.....	81
3.2.1	The Simulation Calculation Results.....	81
3.2.2	The Influence Law of Curve Negotiation Speed on the Vehicle—Track System Dynamic Characteristics	84
3.3	The Influence Law of Curve Radius on the Vehicle—Track System Dynamic Characteristics	88
3.3.1	The Simulation Calculation Results.....	88
3.3.2	The Influence Law of Curve Radius on the Vehicle—Track System Dynamic Characteristics	92
3.4	The Influence Law of the Actual Elevation of the Curve on the Vehicle—Track System Dynamic Characteristics	95
3.4.1	The Simulation Calculation Results.....	95
3.4.2	The Influence Law of the Actual Elevation of Curve on the Vehicle—Track System Dynamic Characteristics	97

3.5	The Influence Law of the Unbalanced Superelevation on the Vehicle—Track System Dynamic Characteristics.....	98
3.5.1	The Analysis of the Influence of the Form of Unbalanced Superelevation on the Vehicle—Track Dynamic Characteristics.....	99
3.5.2	The Influence Law of Unbalanced Superelevation on the Vehicle—Track Dynamic Characteristics	105
CHAPTER 4	Dynamic Analysis of High-Speed Railway Curves: Theory and Practice.....	109
4.1	The Vehicle—Track Dynamic Characteristics and the Relationship Model of Curve Parameter on High-Speed Railway	109
4.1.1	The Law of the Influence of the Track Structure State on the Vehicle—Track Dynamic Characteristics	109
4.1.2	The Relationship Between the Deficient Superelevation and Lateral Acceleration of Vehicle Body.....	119
CHAPTER 5	The High-Speed Railway Comfort Degree: Experiment of Passenger in Curve.....	121
5.1	Theory and Method	121
5.1.1	Experiment Theory.....	121
5.1.2	Implementation Method for Test.....	122
5.2	Case Studies of Passenger Comfort Test on Curves.....	125
5.2.1	Guang-Shen Test.....	125
5.2.2	Suining—Chongqing Test.....	136
5.2.3	Research on Wuhan—Guangzhou Railway.....	146
5.2.4	Research on Beijing—Shanghai High-Speed Railway.....	149
CHAPTER 6	Calculation Method for Minimum Curve Radius of High-Speed Railways	153
6.1	Principle of Calculation of Minimum Curve Radius of High-Speed Railways.....	154
6.1.1	Calculation Formula of Traditional Theory	154
6.1.2	Modified Method of Traditional Theory Formula.....	156
6.1.3	Calculation Method for Minimum Curve Radius Based on the Best Vehicle—Line Dynamic Performance.....	159

6.2	Method to Determine Allowable Actual Superelevation of External Rails on a Curve	160
6.2.1	The Maximum Allowed Superelevation Determined by Safety Conditions.....	160
6.2.2	The Maximum Allowed Superelevation Determined by Comfort	161
6.2.3	Engineering Application Practice at Home and Abroad	161
6.2.4	Vehicle—Line Dynamic Simulation Analysis.....	162
6.2.5	Suggestions on Allowable Value of Superelevation	163
6.3	Determination Method of Deficient Superelevation	165
6.3.1	The Test of the Ride Comfort of Passengers	165
6.3.2	Vehicle—Track Dynamic Simulation Analysis	168
6.3.3	Foreign Engineering Practice.....	170
6.3.4	The Suggestions for Allowable Value of Deficient Superelevation	174
6.4	The Method for Determining the Allowable Value of the Surplus Superelevation	175
6.4.1	Passenger Ride Comfort Test.....	176
6.4.2	Related Research Results.....	177
6.4.3	The Surplus Superelevation's Impact on Rail Wear	177
6.4.4	Analysis of Vehicle—Track Dynamics Simulation	179
6.4.5	Suggestions for the Allowed Surplus Superelevation Value	179
6.5	Minimum Curve Radius Calculation Method for High-Speed Railway Based on Dynamic Analysis.....	180
6.5.1	High-Speed Railway Speed Matching Mode	180
6.5.2	Calculation and Analysis of the Minimum Curve Radius.....	182
6.5.3	Minimum Curve Radius of High-Speed Railways in Foreign Countries	185
6.5.4	Recommended Value of the Minimum Curve Radius.....	186
6.6	Calculation Method for Maximum Curve Radius of High-Speed Railways.....	186
6.6.1	Maximum Curve Radius Limited to Accuracy of Setting Out.....	186
6.6.2	The Maximum Curve Radius Adapted to the Accuracy of Track Geometric State Detection.....	190
6.6.3	Train—Line Dynamic Simulation Analysis.....	193

6.6.4	The Maximum Curve Radius of the High-Speed Test Lines in Foreign Countries	195
6.6.5	Recommended Value of the Maximum Curve Radius	196
	Appendix	196
CHAPTER 7	The Length of the Transition Curve.....	201
7.1	The Easement Curve Length Calculation Principle.....	203
7.1.1	Easement Curve Length Should Meet Ultrahigh Time-Varying Rate While Not Making Passengers Uncomfortable.....	203
7.1.2	Easement Curve Length of Deficient Time-Varying Superelevation Rate	204
7.1.3	Easement Curve Length Should Meet the Condition That Ultrahigh Slopes Cannot Cause Wheels to Derail (Vehicle Derailment Safety).....	204
7.1.4	Minimum Easement Curve Length Calculation.....	205
7.2	Transition Curve Ultrahigh Time-Varying Rate Allowable Value.....	205
7.2.1	The Largest Ultrahigh Time-Varying Rate Permitted by Comfort Test.....	205
7.2.2	Car-Line Dynamics Simulation Analysis	206
7.2.3	Domestic and International Related Research and Engineering Practice	208
7.2.4	Proposal Allowing the Value of Ultrahigh Time-Varying Rate	208
7.3	Maximum Deficient Superelevation Time-Varying Rate b Allowed Value	210
7.3.1	Experiment to Determine Comfort of Maximum Ultrahigh Time-Varying Rate	210
7.3.2	Car-Line Dynamics Simulation Analysis	211
7.3.3	Related Research and Engineering Practice at Home and Abroad	212
7.3.4	Suggestions About Ultrahigh Time-Varying Rate Value	214
7.4	Maximum Allowable Value of Ultrahigh Slope i_0	215
7.4.1	Traffic Safety Allowable Ultrahigh Slope	215
7.4.2	Ultrahigh Slopes as Determined by Passenger Comfort.....	216
7.4.3	Overseas Related Research and Engineering Practices.....	216

7.4.4	Research and Engineering Practice in China	217
7.4.5	Ultrahigh Slope Allowable Value Suggestion	217
7.5	Minimum Transition Curve Length Calculation	217
7.6	Three Parabolic Easement Curve Error Analysis and Correction Method	218
7.6.1	Error of the Approximate Formula of the Easement Curve	218
7.6.2	Modified Three Parabolic	222
CHAPTER 8	The Minimum Length of the Intermediate Straight Line and Circular Curve.....	225
8.1	Calculation Principles of the Minimum Length of the Intermediate Straight Line and Circular Curve.....	225
8.1.1	Ensuring the Line Maintenance Requirements.....	225
8.1.2	Vehicle Lateral Swing Does Not Affect the Smooth Running of the Train.....	226
8.1.3	The Vibration of Vehicle Does Not Affect the Comfort of Passengers	226
8.2	The Minimum Length of Intermediate Straight Line and Circular Curve at Home and Abroad.....	227
8.3	Vehicle Line Dynamics Simulation Analysis	230
8.4	The Recommended Values of Minimum Length of the Intermediate Straight Line and Intermediate Circular Curve	231
CHAPTER 9	The Radius of Vertical Curve	233
9.1	The Minimum Radius of Vertical Curve Required by Passenger Comfort Condition	233
9.1.1	Calculation Principles	233
9.1.2	The Values of Vertical Centrifugal Acceleration Limit.....	234
9.1.3	Vehicle Line Dynamics Simulation Analysis.....	235
9.1.4	The Radius of Vertical Curve of Passenger Comfort Requirement.....	237
9.2	The Minimum Radius of Vertical Curve of Running Safety Requirements	241
9.3	The Maintenance Conditions	243
9.4	The Standards of Minimum Radius of Vertical Curve.....	243
CHAPTER 10	The Maximum Gradient.....	245
10.1	The Maximum Calculated Gradient.....	246
10.1.1	Calculation Model of Maximum Gradient of Design Line.....	246

10.1.2	The Maximum Calculated Gradient of the Tunnel Section	247
10.1.3	Calculation and Analysis of Maximum Calculated Gradient.....	253
10.1.4	Calculation and Analysis of Additional Air Resistance in Tunnel.....	258
10.1.5	The Maximum Calculated Grade Value of Passenger Dedicated Line	269
10.2	Influence of Engineering Economic Conditions on Maximum Gradient.....	270
10.2.1	The Impact on the Number of Projects.....	270
10.2.2	Impact on Operating Expenses.....	271
10.3	The Application of the Maximum Gradient at Home and Abroad	271
10.3.1	The Application of the Maximum Gradient Abroad	271
10.3.2	Application of Maximum Gradient in China.....	272
10.4	Principle of Maximum Gradient.....	274
CHAPTER 11	The Minimum Length of Grade Section.....	275
11.1	The Minimum Length of Grade Section Required for the Longitudinal Force Condition of the Coupler.....	275
11.2	The Minimum Length of Grade Section That Meets the Requirement of the Stable Operation of the Train	278
11.2.1	The Calculation Principle.....	278
11.2.2	The Simulation of Vehicle Vibration Decay Time	281
11.2.3	Domestic and International Research and Engineering Practice	281
11.2.4	The Minimum Length of Grade Section to Ensure That the Vehicle Vibration Does Not Overlap.....	282
11.3	The Length of Grade Section of the Passenger Trains Meets the Requirement When the Train Crosses Two Knick Points at Different Times.....	284
11.4	The Effect of the Minimum Length of Grade Section on the Economy of the Passenger-Dedicated Line	284
11.5	The Value of the Minimum Length of Grade Section.....	285

11.6	The Limitation of the Maximum Length of Grade Section	286
11.6.1	Foreign Research and Engineering Practice.....	286
11.6.2	The Simulation Analysis of the Length of Gradient Section.....	286
11.6.3	Requirements of the Maximum Length of Gradient Section of the Maximum Slope	287
CHAPTER 12	Overview of Design Method and Standard Proposed Values of Main Technical Parameters for Spatial Line Shape of High-Speed Railway	289
12.1	The Minimum Curve Radius Standard and Its Parameter Value	289
12.2	The Minimum Transition Curve Length Standard and Its Parameter Value	292
12.3	The Minimum Recommended Value of the Length of the Intermediate Straight Line and the Circular Curve	293
12.4	The Standard of the Minimum Vertical Curve Radius	293
12.5	The Design Principles for Maximum Design Slope.....	294
12.6	Design Principles of Minimum Length of Grade Section	295
	Bibliography.....	297
	Index.....	303

Introduction

CHAPTER OUTLINE

1.1 Target Speed for High-Speed Railway	2
1.1.1 The Principle of Determining Target Speed for High-Speed Railway	2
1.1.1.1 <i>Comply With the Requirements of Macroeconomic Development...</i>	3
1.1.1.2 <i>Comply With China's National Conditions</i>	3
1.1.1.3 <i>To Market Demand, Taking into Account Long-Term Development.....</i>	4
1.1.1.4 <i>Pay Attention to Economic Investment Projects</i>	4
1.1.1.5 <i>Consider Regional Differences</i>	4
1.1.2 The Influence Factor of Target Speed for High-Speed Railways.....	4
1.1.2.1 <i>The Economy Speed of High-Speed Railway</i>	5
1.1.2.2 <i>The Suitable Speed Range of Technical Characteristics of High-Speed Rail System</i>	6
1.1.2.3 <i>The Effect of the Target Speed Value on the Use of High-Speed Railway</i>	7
1.1.2.4 <i>The Effect of the Target Speed Value on Passenger Fares</i>	9
1.1.2.5 <i>The Impact of Target Speed Value on the Utility Value of Transportation of High-Speed Railway.....</i>	10
1.1.2.6 <i>The Impact of the Target Speed Value on the Travel Speed</i>	12
1.1.2.7 <i>The Design Speed and Experience of the High-Speed Railway Around the World</i>	13
1.1.2.8 <i>Summary of Research and Application in China.....</i>	13
1.1.2.9 <i>Research Steps of the Target Speed Value.....</i>	14
1.2 The Background and Overview of High-Speed Rail Curve Parameters.....	14
1.2.1 Background	14
1.2.2 Research Situation	17
1.3 Principle of Minimum Curve Radius Based on Optimal Dynamics Performance	21

High-speed railway technology mainly reflects the traction power, vehicle, route and track structure, communication signal, organization of train operation, operation management, etc., in the progress of science and technology. Improving high-speed railway technology is the most effective way of greatly improving the railway capacity of passenger transport and service level.

1.1 TARGET SPEED FOR HIGH-SPEED RAILWAY

Target speed for high-speed railway is the basis of layout and design for high-speed railway location, vehicles, research and manufacture of other equipment, market requirement prediction, economic benefit, and social benefit evaluation. Target speed for high-speed railway is the most basic parameter of developing high-speed railway systems.

1.1.1 THE PRINCIPLE OF DETERMINING TARGET SPEED FOR HIGH-SPEED RAILWAY

The driving speed of high-speed railway is the symbol of railway modernization. It is not only the basis of railway location design criteria and selection of equipment types but also the basis of vehicle selection and manufacturing. In addition, traveling speed is very closely related to the target speed, which is the basis of high-speed railway market analysis and economic evaluation.

The relationship of infrastructure top speed, mobile devices top speed, and commercial operation speed is as follows:

infrastructure top speed > mobile devices top speed > commercial operation speed

Commercial operation speed is the basis of researching target speed. To determine the commercial operation speed we need to consider the development of the social and economic situation, analyze market requirement for high-speed railway traveling speed, base the technical features of high-speed railway, and determine the top speed of train operation.

Mobile devices top speed should retain some leeway on the basis of commercial operation speed to adapt to changes in the market demand for commercial operation speed requirements. Mobile devices top speed should be able to meet the target commercial operation during the life of the speed of the mobile device requirements.

Infrastructure is high-speed train running carrier. It requires huge investment and has long service life. Once the infrastructure is completed, reconstruction is difficult. There should be long-term study of social development and forecasting of mobile devices top speed of long-term requirement to ensure that infrastructure can adapt to long-term social and economic development.

In general, with the higher target speed for high-speed railway, infrastructure construction costs are more expensive. At the same time, the development cycle of vehicles and related equipment are longer and manufacturing costs also are increased. To deal with the relationship among the three target speeds is the major technical and economic issue in high-speed transportation system planning. On the one hand, if the speed that is reserved from infrastructure design speed to the actual train speed is smaller, it will save initial investments in the construction of railway lines. However, if railway lines need further acceleration, infrastructure renovation project amount will be great and the speed increase will be not obvious. On the other hand, if the reserved speed is very large, it will require higher capital investment at

low economic level stage. Meanwhile, it will increase the difficulty of financing projects and bring a heavy financial burden on the beginning of the operation.

In Japan, infrastructure design speed reserved room is small. Conventional railway uses lower technical standards, and the track structure is narrow-gauge railway. So now into the 20th century, the railway infrastructure cannot meet the market demand and technology development in terms of traffic speed. In particular, when high-speed railway needs develop, the government has to build a new gauge system called the standard gauge system. As a result, the situation of one country with two systems makes operation and management inconvenient. In the development of high-speed railway, Tōkaidō Shinkansen infrastructure target speed also used a lower civil engineering design standard so that there is no difference between infrastructure design speed and rolling stock's top speed. So with the upgrading of the train and the improvement of operating speed, the infrastructure cannot adapt gradually. Some problems have constrained further improvement in operational speed, such as mud pumping, tunnel aerodynamic influence, and noise.

Although the Europe's railway is the oldest, which was mostly built in the middle of the 19th century, the technical standard of its infrastructure left large gaps. Railway adapted to the development of social economy and technology in the long period so that it still plays an important role. For example, Germany's existing railways, whose design speed is 160 km/h; civil engineering; and other infrastructure facilities are still in use. With the development of the social economy and the tilting train technology maturity, line can achieved 200 km/h or higher driving speed, even with high-speed trains. Today, in the whole of Europe, although the high-speed passenger-dedicated lines are less than 3000 km, lines with high-speed trains are more than 10,000 km. It makes high-speed rail still outshine and achieve good economic results in the railway industry facing a downturn as a whole.

For these reasons, when planning our high-speed rail system the relationship among infrastructure design speed, mobile device design speed, and commercial operation speed must be handled. Generally, it should follow the following principles.

1.1.1.1 Comply With the Requirements of Macroeconomic Development

High-speed railway as a mode of transportation has its specific technical, economic, and social characteristics. It is large-scale construction, having an important influence on national transportation system structure, economic layout, energy, and environmental conditions. Thus high-speed railway target speed should help to improve the transportation system structure to meet the long-term national development plans and to comply with the country's political, economic, energy, and environmental policies.

1.1.1.2 Comply With China's National Conditions

The situation of China should be considered as the fundamental starting point to develop target speed. With economic development, the concept of time value is enhanced, incomes continue to improve, and the quality requirements for

transportation services are also rising. Improving railway speed has become the objective requirement of people's travel, but it is limited to the level of economic development and the domestic technology. So it should take into account the technical and economic feasibility of high-speed railway construction project. Besides, the introduction of foreign equipment should consider the amount of the state's finances, the domestic development of equipment and processing levels of related industries in China.

1.1.1.3 To Market Demand, Taking into Account Long-Term Development

Market requirement is the basis of high-speed railway for its survival. It should study deeply the speed requirements of the railway transport market to maximize gain market share; studying potential demand for high-speed railway transport can lead to maximizing the number of additional passengers to ensure economic efficiency.

Because of the huge investments of high-speed railway and infrastructure with long life, related people should thoroughly analyze the long-term changes of transport demand and develop a reasonable mobile devices top speed and infrastructure top speed to meet medium- and long-term needs of the transport market.

1.1.1.4 Pay Attention to Economic Investment Projects

Target speed has a significant impact on the economic benefits of high-speed railway investment projects. First, we should study the relationship among the target speed and the project investment and transportation costs. Moreover, we need to analyze high-speed train fares. Second, we should study the influence of target speed on travel time and fares. Third, by market analysis, we should study the impact of passenger fares and travel speed on passenger needs to find the maximum profit point.

1.1.1.5 Consider Regional Differences

Our country has vast land, many kinds of natural conditions, and widely different levels of economic development. Under different natural conditions, the target speed has different influences on project investment and operating costs. Similarly, under different levels of economic development, passengers have different ideas on the quality of service requirements and fares of transport. Therefore countries with different natural conditions and levels of economic development have different commercial operation speed, so as to have a different target speed.

1.1.2 THE INFLUENCE FACTOR OF TARGET SPEED FOR HIGH-SPEED RAILWAYS

The study of target speed focuses on meeting the maximum requirements of transportation market. First, it is necessary to study the best commercial operating speed in each case, and then you should predict the development of the law of the best commercial operating speed. After this, you should determine the speed target value

of the mobile device at short and long terms. According to the speed target value at short and long terms, the speed target value of base facility should be determined.

To study the optimum commercial operation speed, the following main researches should be done:

- the commercial operation speed of high-speed railway from the velocity structure of transportation system;
- the suitable speed range of the technical characteristics of high-speed railway system;
- effects of different travel distances on the optimal operating speed;
- effects of different levels of economic development on the optimum operating speed;
- effects of different terrain conditions on the optimal operating speed.

1.1.2.1 The Economy Speed of High-Speed Railway

The economy speed is the most profitable speed of high-speed railway. At the beginning of building high-speed railway, European countries have studied the economy speed. Studies have shown that increasing speed can save travel time. However, with the increase in maximum speed, the improvement of building standards, and more advanced technology and equipment, railway investment is bound to increase. At the same time, requirements of maintenance quality for trains line and vehicles will be improved. Also, because of the large amount of energy consumed for air resistance, operating costs and transportation costs will be increased.

It is generally agreed that the purpose of increasing train speed is that the competition capacity with other modes of transportation and railway revenue are increased by reducing the travel time. Of course, competition with other modes of transportation does not simply depend on the speed, but at least it can be said that in the competition those who have longer travel time will be at a distinct disadvantage.

According to the view of Dr. Brighton in Switzerland, under the condition of average speed of 600 km/h (wait, replacement, and other required formalities need 90 min) for aircraft and 80 km/h for car, with 30 min for railway waiting and transfer time, when at close range (300 km or less), if the average speed of railway cannot reach 100 km/h, it cannot compete with the car. When in the middle distance (500–600 km), if the average speed of railway cannot reach 250 km/h or more, it cannot compete with the aircraft.

Before and after the 1970s, western European countries had studied their own economic speed according to their specific circumstances. The economic speed is 230 km/h in Britain, 280–300 km/h in France, and 270 km/h in Germany. However, according to the result of the International Union of Railways, economic speed is 300–350 km/h. Economic speed can be a guidance for the maximum speed. In general, the maximum speed is slightly higher than the economic speed.

In May 1985, Economic Commission for Europe established a definition for railway running speed. It defined a maximum operating speed of 300 km/h for high-speed

passenger special line, 250 km/h for mixed passenger and freight transport, and 160–200 km/h for existing railway reconstruction.

Practice in China has proved that 300–350 km/h speed should be economical and reasonable for long high-speed railway.

1.1.2.2 The Suitable Speed Range of Technical Characteristics of High-Speed Rail System

1.1.2.2.1 The Limit Speed of Adhesion Railway

With the interaction between wheel and track, normal railway will produce traction force. The maximum speed achieved in the normal railway is called the limit speed of adhesion railway. When the speed increases, the traction force gradually decreases and the running resistance gradually increases. When the traction force is equal to the running resistance, the speed cannot increase any more. This speed is called the limit speed.

According to earlier studies in Germany and France, the limit speed is considered as about 350 km/h.

In February 1981, in France, the TGV16 EMU reached a speed of 380 km/h and set a record.

In 1988, in Germany, the ICE reached a speed of 406 km/h and set a new record.

In 1986, France set a new speed record of 482.4 km/h again.

In May 2000, in France, the TGV325 reached a speed of 515.3 km/h and set the current world record. The French believed that the test speed was potential and could be increased. However, it was difficult to reach 500 km/h business speed, especially with the problems of line maintenance.

These facts show that, under the present conditions, on choosing economical and reasonable target speed values, the limit speed of adhesion railway will not be a limiting condition.

1.1.2.2.2 The Speed Determined by Traction Characteristics

Since the air resistance that the train suffers is proportional to the square of speed, when the speed of high-speed railway increases to 500 km/h, the air resistance that the train suffers is three times as big as that when the speed is 300 km/h. Relevant study shows that the dynamic performance of air resistance at this time is close to uneconomic state. Under high speed running, it should be taken into consideration when the train runs on thin air environment, namely, aspirator pressure tunnel or using aircraft flying at low altitude air density of the atmosphere. According to the traction characteristics of high-speed railway in China, for eight marshalling CRH3 EMU, when the maximum speed reaches 350 km/h on a flat ramp, its running resistance and traction reach balanced state (Fig. 1.1).

The running speed is also connected to the train mass. For example, when the train mass is 800 t, the top speed is stipulated as 250 km/h and the needed total power is 9600 kW. If you use the high-speed EMU whose single shaft power is 1100 kW, it will need nine movable shafts. If you use the EMU whose single shaft power is 1200 kW, it will need eight movable shafts. Also, if the power does not