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Rail pads in fastening system

September 2023

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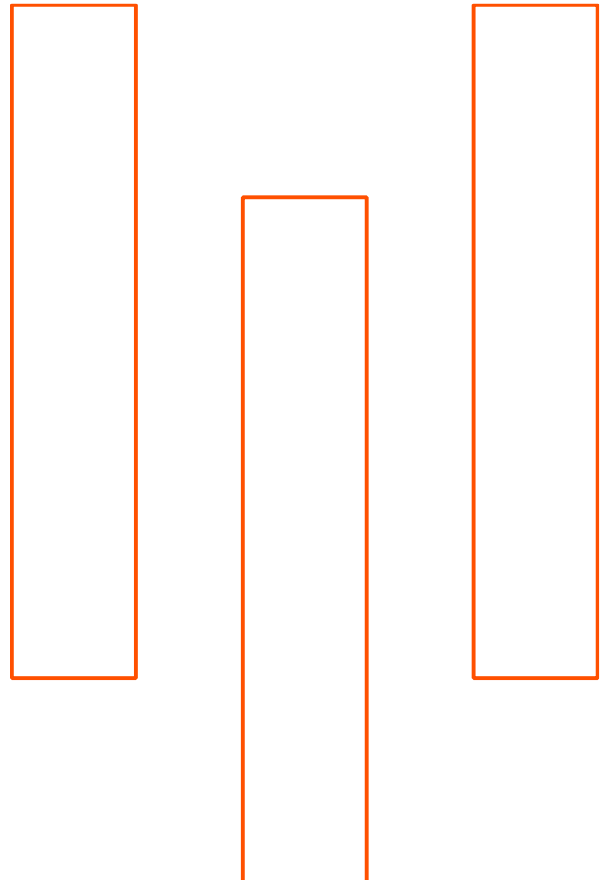
„Technology for a quieter Tomorrow“



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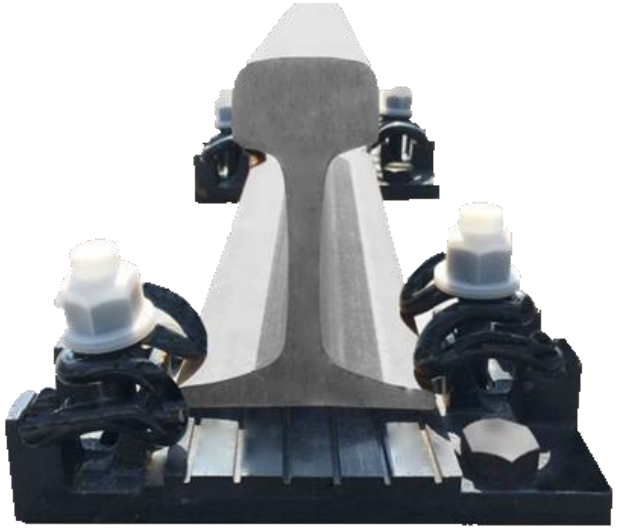
contents

1. A brief introduction to rail pads

1.1 The function of rail pads

- The rail pads, installed between the rail and the sleeper, is an important elastic component of the track fastening system. The rail pads can buffer the high-speed wheel-rail vibration and impact generated when trains pass by, significantly reduce the impact load transmitted from the rail to the track structure, protect the sleepers, and electrically insulate the signaling system of the track.
- Since the rail pads are exposed to the air for a long time, the pads should have good resistance to natural aging, cold resistance, and heat resistance. When installed in the subway, it should have good vibration mitigation and noise reduction properties.



1. A brief introduction to rail pads

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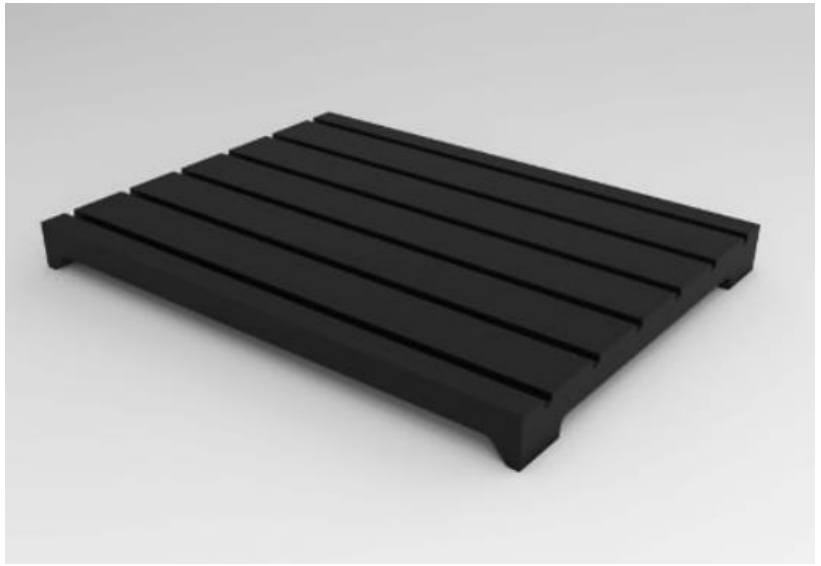
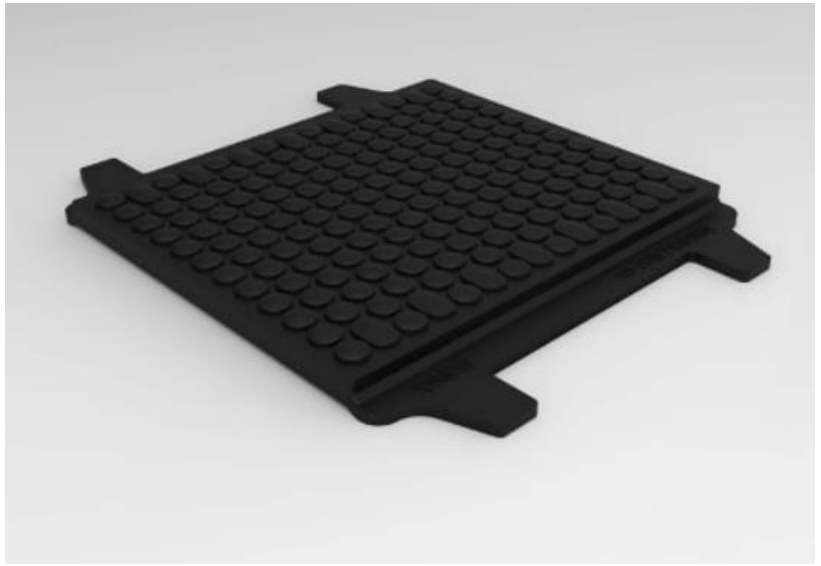
1.2 The classification of rail pads

- According to the structure type, it can be divided into groove type, boss type, groove and boss combination type.
- According to the raw materials, it can be divided into
  - Rubber: NR, SBR, CR, EPDM
  - Plastic: HDPE, EVA



groove type



boss type

1. A brief introduction to rail pads

1.3 The main technical requirements of rail pads

– Hardness, tensile strength, elongation at break, compression set, working resistance, Akron wear, aging properties (tensile strength, elongation at break), fatigue properties, static stiffness, etc.

Relevant specifications and standards in China and Thailand

Standard No	Standard Name	Country
TB/T 1495-2020	Type I fastening system	China
TB/T 3065-2020	Type Ⅱ fastening system	China
TB/T 3570-2021	Type III fastening system	China
TB/T 3395.1-2015	Fastening systems for high-speed railway Part 1: General requirement	China
TB/T 3395.2-2015	Fastening systems for high-speed railway Part 2: Type Ⅳ fastening system	China
TB/T 3395.3-2015	Fastening systems for high-speed railway Part 3: Type V fastening system	China
TB/T 3395.4-2015	Fastening systems for high-speed railway Part 4: WJ-7 fastening system	China
TB/T 3395.5-2015	Fastening systems for high-speed railway Part 5: WJ-8 fastening system	China
TIS 2667-2558	Rail rubber pad	Thailand

2. Different rubber materials for rail pads

2.1 Natural rubber

- An elastic hydrocarbon isoprene polymer, abbreviated as NR.
- The density at normal temperature is about 0.92g/cm^3. It has good low-temperature resistance and mechanical properties. It is less affected by temperature.
- Mainly used in tires, tapes, hoses, rubber shoes, wires and cables and most rubber products, it is the most widely used type of rubber.
- Thailand is the world's largest natural rubber producing country.

NR, STR

2. Different rubber materials for rail pads

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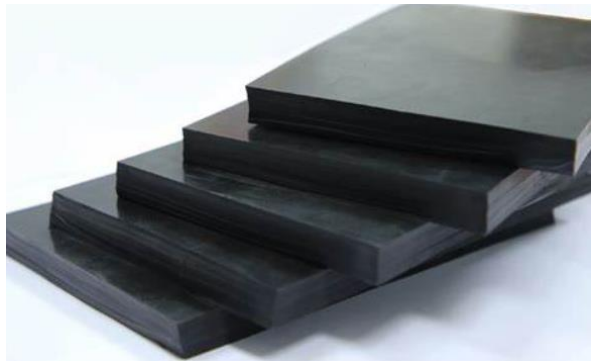
2.2 Styrene-butadiene rubber

- Synthetic rubber, made from the polymerization of styrene and butadiene , abbreviated as SBR.
- The density is about 0.94 g/cm^3. It has good wear resistance, natural aging resistance, water resistance and air tightness.
- Mainly used in tire industry, automobile parts, hoses, tapes, rubber shoes, wires and cables and other rubber products.
- The most widely produced general-purpose synthetic rubber can be used in place of natural rubber in most situations.



SBR

2. Different rubber materials for rail pads

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2.3 Chloroprene rubber

- Synthetic rubber, an elastomer produced by α-polymerization of chloroprene (i.e. 2-chloro-1,3-butadiene) as the main raw material, abbreviated as CR.
- The density is about 1.23~1.25g/cm^3, good physical and mechanical properties, oil resistance, heat resistance, flame resistance, sunlight resistance, ozone resistance, acid and alkali resistance, and chemical reagent resistance.
- Mainly used as wire and cable sheaths, hoses, oil-resistant rubber products, heat-resistant conveyor belts, building seals, bridge bearings, flame-retardant rubber products, etc.

CR

2. Different rubber materials for rail pads

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2.4 Ethylene Propylene Diene Monomer

- Synthetic rubber, a copolymer of ethylene, propylene and a small amount of dicyclopentadiene, abbreviated as EPDM.
- The density is about 0.86~0.90 g/cm^3, and it has excellent aging resistance, heat resistance, cold resistance, chemical resistance (except non-polar solvents) and electrical insulation properties.
- It is widely used in automobile parts, construction waterproof materials, wire and cable sheaths, heat-resistant hoses, tapes, automobile seals, etc.

EPDM

3. Comparison of relevant standards for rail pads

3.1 Relevant standards for rail pads

Standard No	Standard Name	Scope of application
TB/T 1495-2020	Type I fastening system	Mixed passenger and freight railway, ballast track, 50kg/m rail
TB/T 3065-2020	Type Ⅱ fastening system	Mixed passenger and freight railway, ballast track, 60/75kg/m rail
TB/T 3570-2021	Type III fastening system	Mixed passenger and freight railway, ballast track, 60kg/m rail
TB/T 3395.1-2015	Fastening systems for high-speed railway Part 1: General requirement	High-speed railway, ballast track or ballastless track
TB/T 3395.2-2015	Fastening systems for high-speed railway Part 2: Type Ⅳ fastening system	High-speed railway, ballast track
TB/T 3395.3-2015	Fastening systems for high-speed railway Part 3: Type V fastening system	High-speed railway, ballast track
TB/T 3395.4-2015	Fastening systems for high-speed railway Part 4: WJ-7 fastening system	High-speed railway, ballastless track
TB/T 3395.5-2015	Fastening systems for high-speed railway Part 5: WJ-8 fastening system	High-speed railway, ballastless track
TIS 2667-2558	Rail rubber pad	

- TB/T 1495, TB/T 3065 and TB/T 3570 are referred to as “Chinese mixed passenger and freight railway standard”; TB/T 3395 series is referred to as “Chinese high-speed railway standard”.
- Thailand: TIS 2667-2588 Rail rubber pad, hereinafter referred to as “Thai standard”.

3. Comparison of relevant standards for rail pads

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3.2 The technical requirements for rail pads in these standards

S.N.	Technical requirement	Unit	Thai standard	Chinese mixed passenger and freight railway standard	Chinese high-speed railway standard
1	Raw material	-	Natural rubber or synthetic rubber	Rubber or other materials not inferior in performance, recycled materials shall not be used	Natural or synthetic rubber, recycled rubber should not be used
2	Appearance	-	No blisters, cracks, pores and foreign objects	Smooth and flat, trim neat, no missing corner, no short shot, no sponges, no more than 3mm burrs	No short shot, no sponge, no more than 2mm burrs
3	Type and dimension	-	Meet the design requirements	There are specific size requirements and classification models	Meet the design requirements
4	Hardness	Shore A	65-80	≥ 65	≥ 65
5	Before aging Tensile Strength Elongation at break	 MPa %	 ≥ 12 ≥ 250	 ≥ 12.5 ≥ 250	 ≥ 12.5 ≥ 250
6	After aging Tensile strength (change rate%) Elongation at break (change rate%)	 MPa %	Type 1: 70℃, 168h, Type 2:100℃, 96h ≥ 10 (≤ 30) ≥ 180 (≤ 40)	100℃, 72h ≥ 10 (-) ≥ 150 (-)	70℃, 168h ≥ 10 (≤ 30) ≥ 180 (≤ 40)
7	Constant elongation stress	MPa	3-5 (100%)	≥ 9.5 (200%)	≥ 7 (200%)
8	Permanent deformation	%	Type 1: 70℃, 24h, Type 2:100℃, 24h ≤ 25 (tension), ≤ 30 (compress)	100℃, 24h ≤ 20 (compress)	100℃, 24h ≤ 25 (tension), ≤ 30 (compress)

3. Comparison of relevant standards for rail pads

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3.2 The technical requirements for rail pads in these standards

S.N.	Technical requirement	Unit	Thai standard	Chinese mixed passenger and freight railway standard	Chinese high-speed railway standard
9	Akron abrasion	cm^3/1.6km	Not required	≤ 0.6	Not required
10	Oil resistance	%	SAE 40 oil, 70℃, 24h Volume change, negotiated by both parties	46# oil, 23℃, 24h Mass change rate ≤ 20	46# oil, 23℃, 24h Mass change rate ≤ 20
11	Working resistance	Ω	≥ 1×10^8	≥ 1×10^6	≥ 1×10^8
12	Ozone resistance	-	25×10-8 (50×10^{-8}), 40℃, 72h, tension 20% No cracks	Not required	Not required
13	Static stiffness	kN/mm	Not required	Evaluation range 20-80kN Depending on model: 40-140	Evaluation range 20-70kN 60±10 (Ballast), 35±10 (Ballastless)
14	Dynamic stiffening ratio	-	Not required	≤ 2.0	≤ 2.0 (Ballast), ≤ 1.5 (Ballastless)
15	Fatigue performance	%	Not required	3 million times, 4Hz, Load: 20-130kN Change rate of static stiffness after fatigue test: ≤ 10-20	3 million times, 4Hz, Load: 20-80kN Change rate of static stiffness after fatigue test: ≤ 15 Permanent deformation after fatigue test: ≤ 10
16	Cold resistance	%	Not required	-35℃, 16h Low temperature static stiffness change rate: ≤ 20	-35℃, 16h Low temperature static stiffness change rate: ≤ 20

3. Comparison of relevant standards for rail pads

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3.3 Differences in technical requirements

- 1) **For the technical requirements of No. 1-8**, Thai standard is basically similar to Chinese mixed passenger and freight railway standard and Chinese high-speed railway standard; The requirement of Thai standard for constant elongation stress is 100% constant elongation value, which is lower than the requirement value of 200% constant elongation stress of Chinese mixed passenger and freight railway standard and Chinese high-speed railway standard.
- 2) **For wear resistance**, Thai standard and Chinese high-speed railway standard have no requirements, and Chinese mixed passenger and freight railway standard take a certain Akron wear value as the required value; As the elastic element under the rail, the impact of wear on the normal function of the rubber rail pad needs to be considered under the condition that the train passes for a long time.
- 3) **For oil resistance**, Thai standard does not make specific requirements, and it is recommended that both parties negotiate to evaluate it based on the volume change; The oil resistance requirements of Chinese mixed passenger and freight railway standard and Chinese high-speed railway standard are consistent, and the evaluation is based on the mass change rate.

3. Comparison of relevant standards for rail pads

3.3 Differences in technical requirements

- 4) **For insulation performance**, Thai standard and Chinese high-speed railway standard require working resistance ≥ 1×10^{8} Ω, which is stricter than the requirement (≥ 1×10^{6} Ω) of Chinese mixed passenger and freight railway standard.
- 5) **For ozone resistance**, Thai standard has made corresponding requirements, but there are no requirements in Chinese mixed passenger and freight railway standard and Chinese high-speed railway standard; Considering Thailand is located in the tropical region and the intensity of sunlight ultraviolet is high, it is reasonable to require ozone resistance of rubber rail pad.
- 6) **For the requirements of static stiffness and dynamic stiffening ratio**, Thai standard has no relevant requirements, but Annex C of the standard specifies the test contents of static stiffness and dynamic stiffness; As an elastic element under the rail, the rubber rail pad has a certain cushioning effect on the wheel-rail impact force and rail vibration, and it is necessary to require its stiffness.

3. Comparison of relevant standards for rail pads

3.3 Differences in technical requirements

- 7) **For fatigue performance**, there are no relevant requirements in Thai standard. The change rate of static stiffness after fatigue test is evaluated in Chinese mixed passenger and freight railway standard and Chinese high-speed railway standard; As an elastic element under the rail, the appearance, size, shape, and mechanical elasticity of the rubber rail pad will deteriorate to some extent under the condition of long time train passing. To ensure the long-term elastic damping function of the rubber rail pad, it is necessary to require its fatigue performance.
- 8) **For cold resistance**, there is no relevant requirement in Thai standard; Considering Thailand is located in the tropical region and the possiblity of extremely cold environmental conditions is small, it is acceptable not to require cold resistance.

4. Non-uniform stiffness rail pads

4.1 Engineering background

- Traditional fastening system design generally considers straight lines and adds the load increased in curves. The difference in load and stiffness is not considered when applying curve segments.
- Based on standardized design, construction, and post-maintenance requirements, only one fastener model is used in the same location. Unified model requirements can prevent installation errors during construction and provide convenience during maintenance and repair.
- Traditional fastening system design mainly considers the ability to maintain track geometry under static conditions. For the dynamic conditions of train operation, the stiffness balance of fasteners is not paid much attention to.

The goal is to solve the uneven dynamic stiffness of internal rail and external rail of curve segments and curves with different radius.

Starting from the development of rubber rail pads with non-linear stiffness characteristics (different load gradients, different dynamic stiffness).

4. Non-uniform stiffness rail pads

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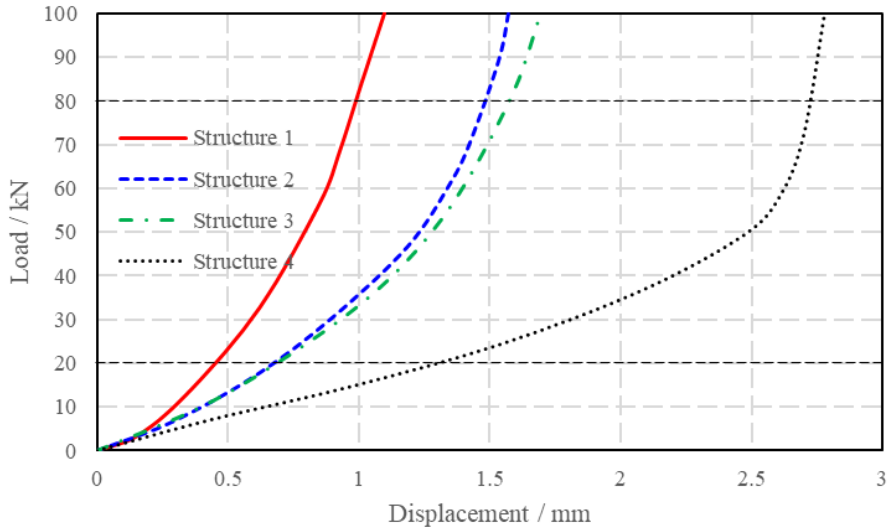
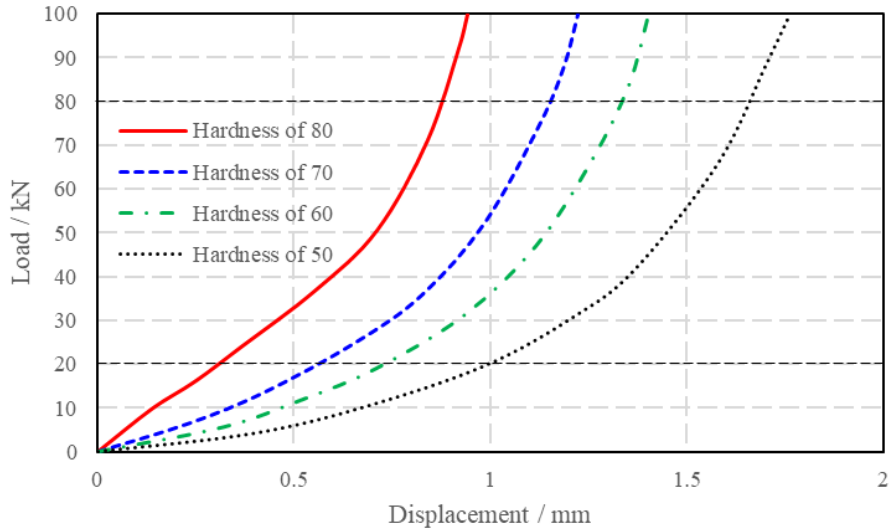
4.2 Factors affecting the stiffness of the rail pads

- Structure 1 has a groove number of 11 and double-sided grooves; Structure 2 has a groove number of 17 and double-sided grooves; Structure 3 has a groove number of 17 and double-sided grooves; Structure 4 has a boss number of 77 and a single-sided boss. The load-bearing areas of Structure 4, Structure 3, Structure 2, and Structure 1 increase in sequence, and the static stiffness of the rubber pad corresponding to the 20~80kN range increases in sequence.
- As the hardness of the rubber material increases, the static stiffness of the rubber pad increases sequentially in the range of 20~80kN.





4. Non-uniform stiffness rail pads

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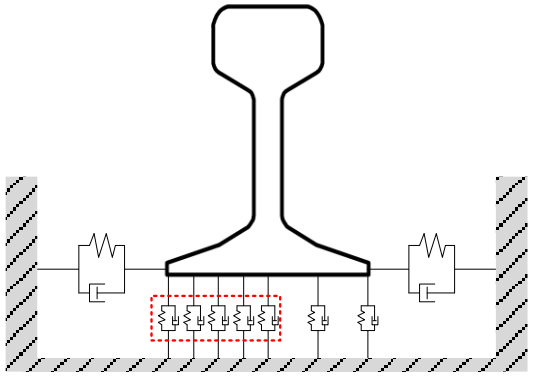
4.3 Non-uniform stiffness design of the rail pads

Large partitions design in longitudinal of the railway line and small partitions design in left and right for rubber rail pads.

- Firstly, the stiffness of the rail pad is designed according to different curve radii along the longitudinal direction of the railway line;
- Then, the stiffness of the rail pad is designed according to the internal rail and external rail in each section (rail cant);
- Finally, the stiffness of the left and right sides of the same rail pad is designed by partition.



Theoretical design model of stiffness partitioning on the left and right sides of the rail pad

Structural design model of stiffness partitioning on the left and right sides of the rail pad

4. Non-uniform stiffness rail pads

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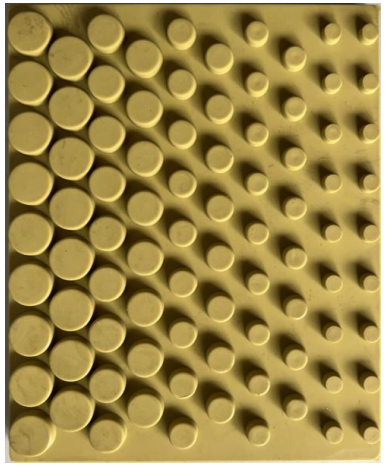
4.3 Non-uniform stiffness design of the rail pads

– Material and structural design ideas: adjust material hardness, adjust the size, distribution and number of grooves (bosses).



- Color: orange
- Structure: Boss
- non-uniform arrangement

- Color: red
- Structure: Groove +Boss
- non-uniform arrangement

– The structure and stiffness of the rubber pad are adjusted using a multi-dimensional and reasonable partitioning method.

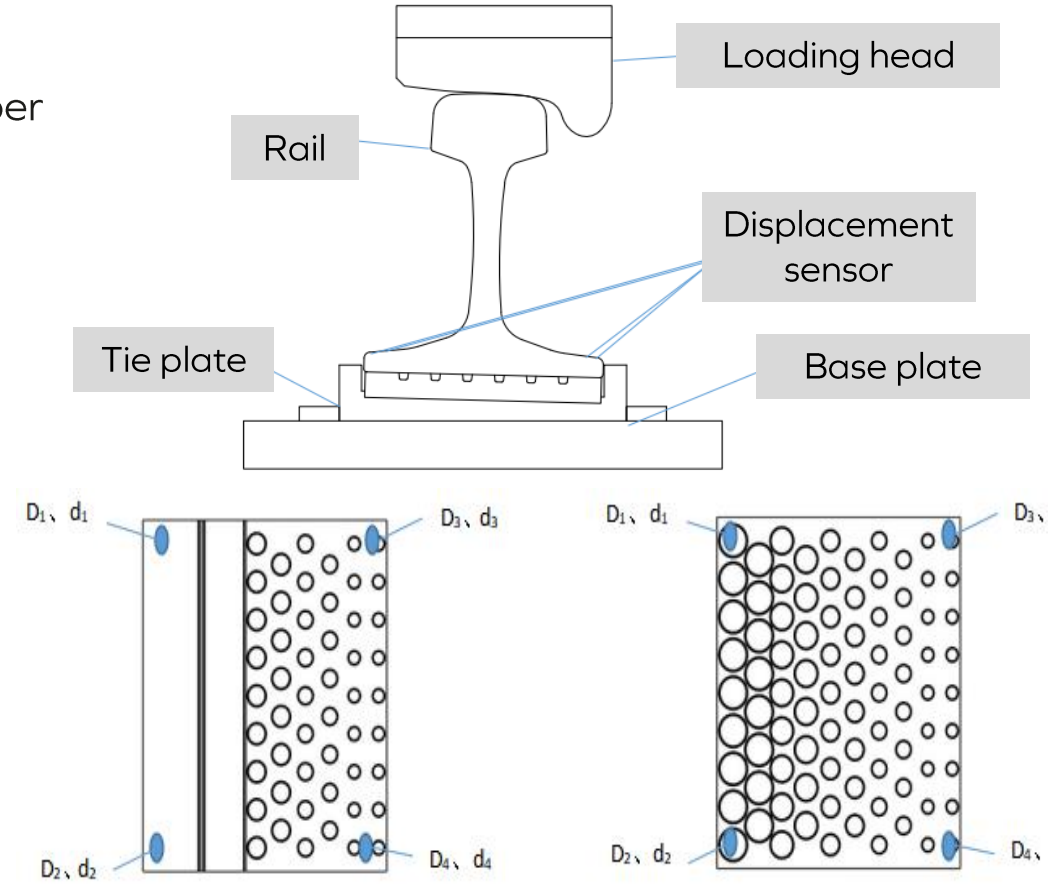
– Improve the rail-wheel contact surface, reduce rail wear and reduce line maintenance. ← Function Goal

– Reduce the stiffness unevenness of trains passing through curved sections to ensure smooth train operation.

4. Non-uniform stiffness rail pads

4.4 Test verification of the rail pad with non-uniform stiffness

- Install on the testing machine from bottom to top: base plate, sandpaper (sand side up), rubber rail pad to be tested, sandpaper (sand side down), rail, loading head.
- Set the displacement sensor to zero, then load it to 80kN at a speed of 1kN/s, and then reduce the load to 0.5kN at a speed of 1kN/s. Stay for 1 minute after unloading, cycle loading and unloading 3 times. Record the deformations d_1, d_2, d_3, d_4, D_1, D_2, D_3, D_4 of the four measuring points on the rubber pad at F_1 (20kN) and F_2 (70kN) at the third cycle.
- According to the test results, the static stiffness meets the design requirements, and the structure of rubber rail pad also plays a corresponding deflection role, achieving the function of adjusting the wheel-rail contact.



5. Fastening load monitoring system

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5.1 Overview

- **Research and development ideas**: Multiple force sensors are built into the fastening system structure to collect the actual load data of the fastening system when the train passes, providing a basis for the design optimization of the fastening system structure and its components, and laying the foundation for monitoring the service status of the wheel-rail system.
- **Advantages**: ① Obtain fastening system load data directly without conversion. The load measurement accuracy is high. ②The distributed design of multiple sensors can obtain the plane distribution of the load on fastening system. ③The equipment is simple and lightweight, and the installation and testing process is convenient. ④ Equipped with special software, the test data has been standardized and the statistics and analysis of load data can be quickly performed.

5. Fastening load monitoring system

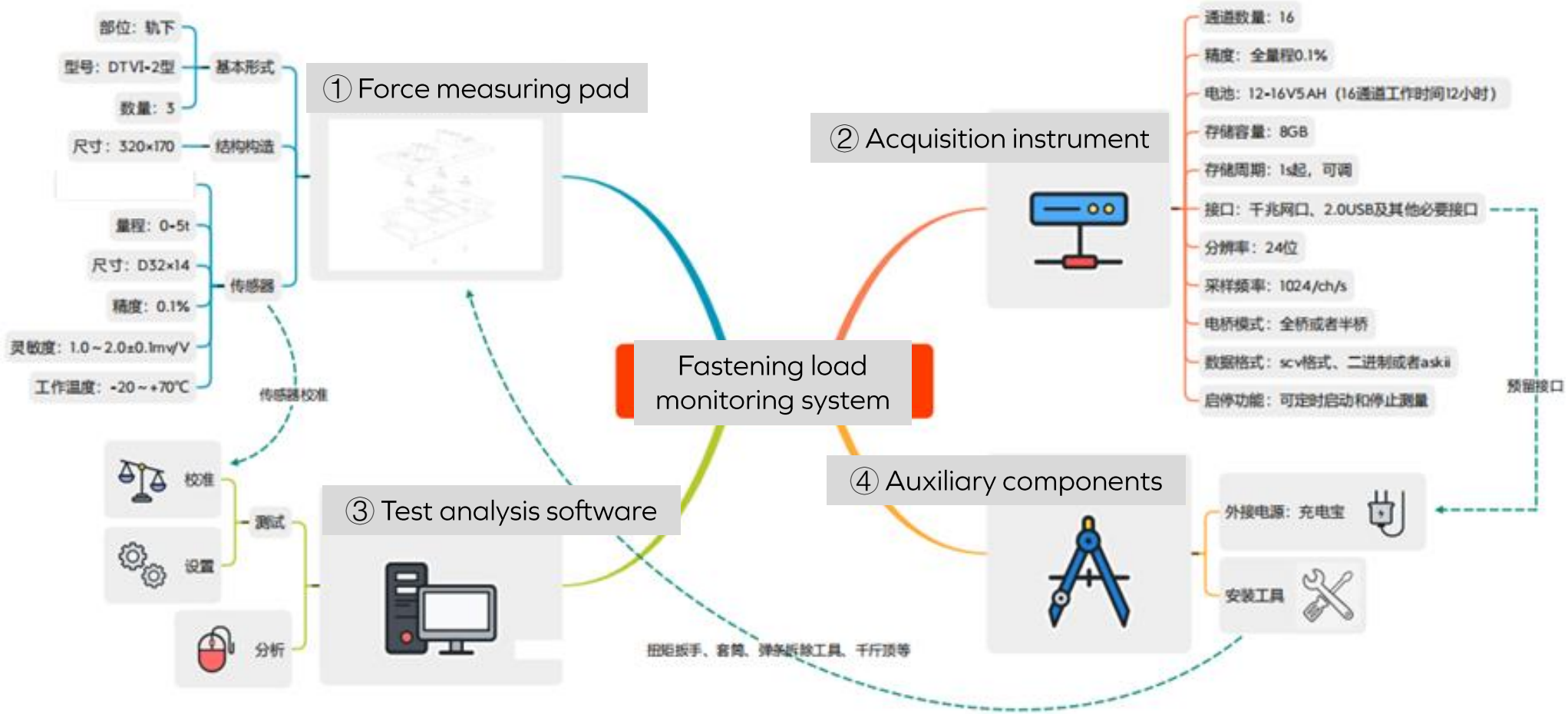
5.1 Overview

- R&D process:
  1. The first phase, in 2021, technical research and design conception will be completed;
  2. The second phase, in 2022, the sensor selection, design and manufacturing of the force measuring pad, prototype development of the acquisition instrument and software were completed, and preliminary experimental verification was conducted, which is version 1.0;
  3. The third phase, in 2023, the force measuring pad was optimized, the acquisition instrument and supporting software were upgraded, forming version 2.0, and a system functional verification test was conducted.

5. Fastening load monitoring system

5.2 System composition

– **Divided into four subsystems**: ① force measuring pad (including sensors), ② acquisition instrument, ③ test analysis software, ④ auxiliary components.



5. Fastening load monitoring system

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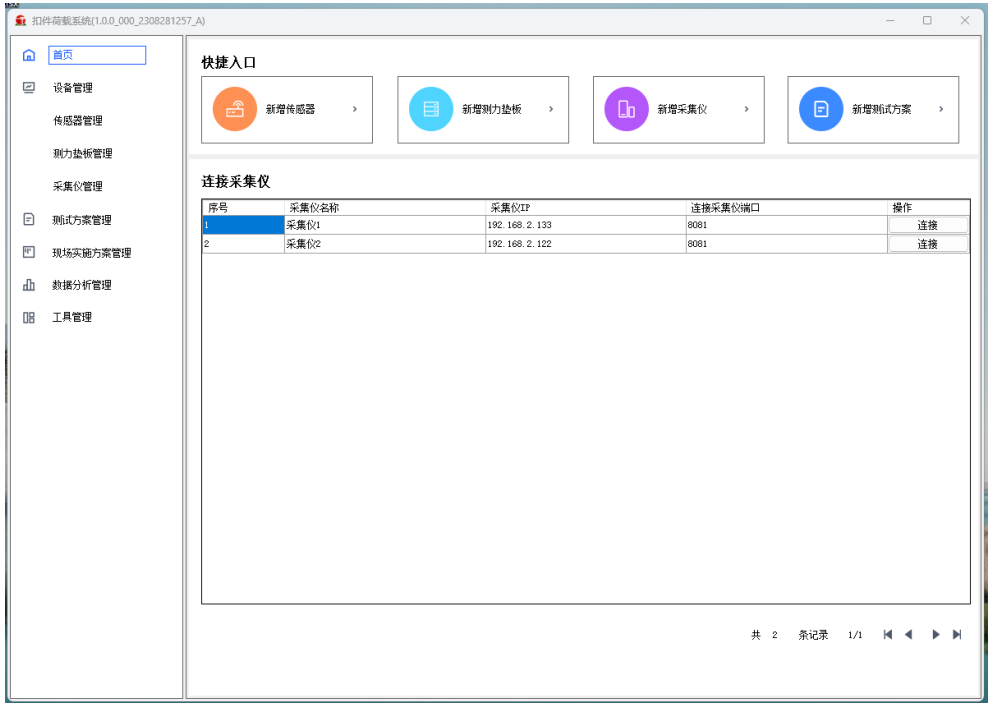
5.2 System composition

- **Divided into four subsystems**: ① force measuring pad (including sensors), ② acquisition instrument, ③ test analysis software, ④ auxiliary components.

① Force measuring pad

② Acquisition instrument



③ Test analysis software - Main interface

Sensors

④ Auxiliary components

5. Fastening load monitoring system

5.2 System composition

– **Divided into four subsystems**: ① force measuring pad (including sensors), ② acquisition instrument, ③ test analysis software, ④ auxiliary components.

③ Test analysis software - Test plan configuration

③ Test analysis software - Scheduled task configuration

5. Fastening load monitoring system

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5.3 Test verification

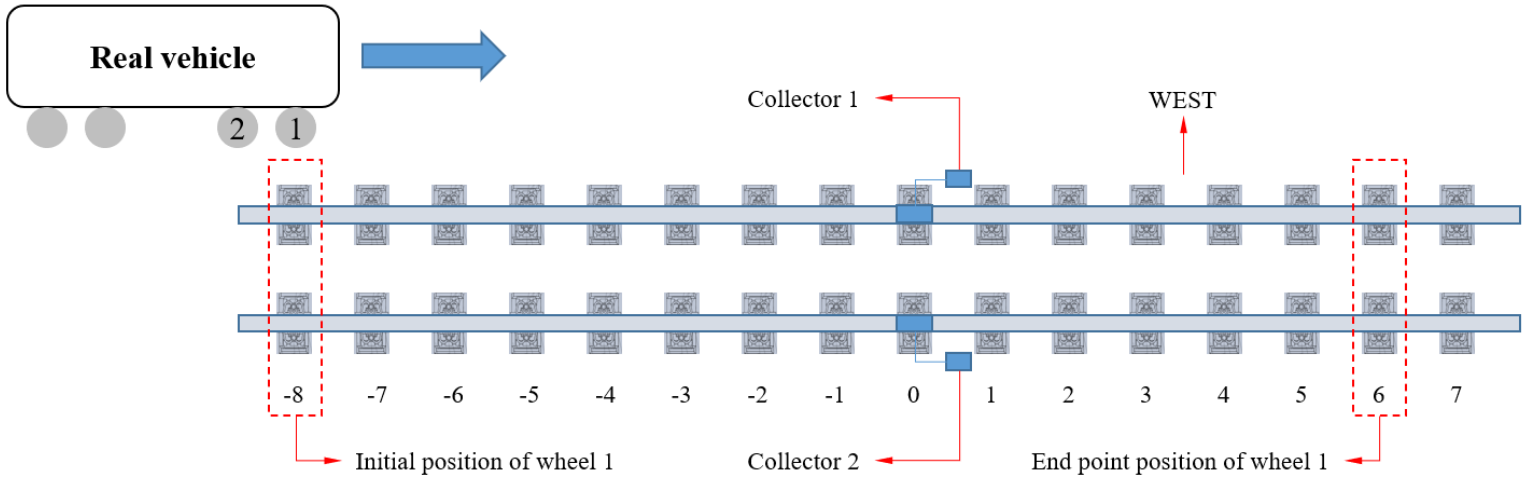
Static test

Dynamic test

Test by single axle

5. Fastening load monitoring system

5.3 Test verification



Test by real vehicle

- Through static test, dynamic test and test by real vehicle, Load monitoring fastening system version 2.0:
- 1. In general, the structural scheme, components and assembly performance are good and have achieved the expected results.
- 2. The overall accuracy of this system is approximately 95%.

6. Summary

- It shows that the rail pad is an important elastic component in the fastening system.
- The rubber materials commonly used in the manufacture of rail pads are introduced.
- The relevant standard differences in technical requirements for rail pads were compared, and reference suggestions were put forward.
- The optimization of the stiffness design of the rail pads through structural and material improvements of the rail pads is discussed, and an rail pad with gradient stiffness is showed.
- The fastening load monitoring system is introduced to provide support and foundation for the refined design of the rail pads.

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Welcome to visit Tiantie for communication and cooperation!

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