2022 Asia and Pacific Mathematical Contest in Modeling

Problem B

Optimal Design of High-speed Train

On April 12, 2022, China High Speed Railway Fuxing CR450 multiple units successfully achieved a single train speed of 435 km/h and a relative speed of 870 km/h on the open line, creating a world record for the speed of high-speed rail multiple units trains crossing open lines and tunnels. The new generation standard EMU "Fuxing" is a new generation of high-speed train independently researched and developed by China with full intellectual property rights. It integrates a large number of modern domestic high-tech, and achieves important breakthroughs in key technologies such as traction, braking, network, bogie, and axle. It is another major achievement of China's scientific and technological innovation. Figure 1 is a simplified model of the high-speed rail geometric structure.

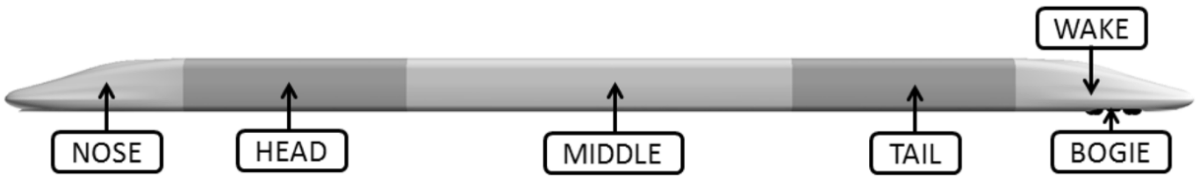

Figure 1. Simplified model of high-speed rail geometry.[1]

The head structure of China's high-speed railway is bullet head, and the duckbill structure is adopted by Japan's high-speed railway. Figure 2 shows the simplified models of four typical high-speed railway head structures including the types of TP1, TP2, TP3 and TP4. Among them, the design of high-speed rail head structure mainly considers air resistance and noise level.

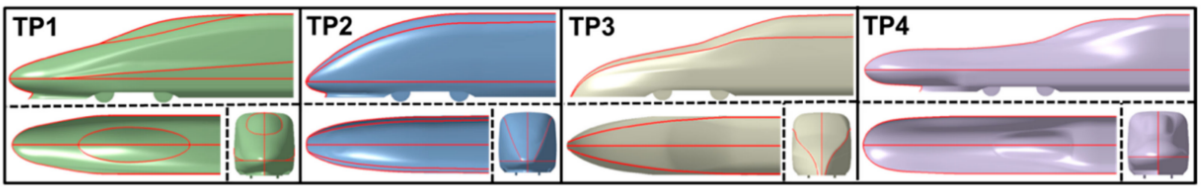

Figure 2. Simplified models of four typical high-speed rail head structures.[2]

The design process of bullet head of high-speed railway should not only take aerodynamics as the basic principle, but also conduct simulation and experiment repeatedly. To achieve the optimal scheme between the air flow, aerodynamic force, other relevant parameters around the car head and the car body can be optimized after thousands of calculations and experiments.

Figure 3 shows the different areas of the streamlined high-speed rail head structure.

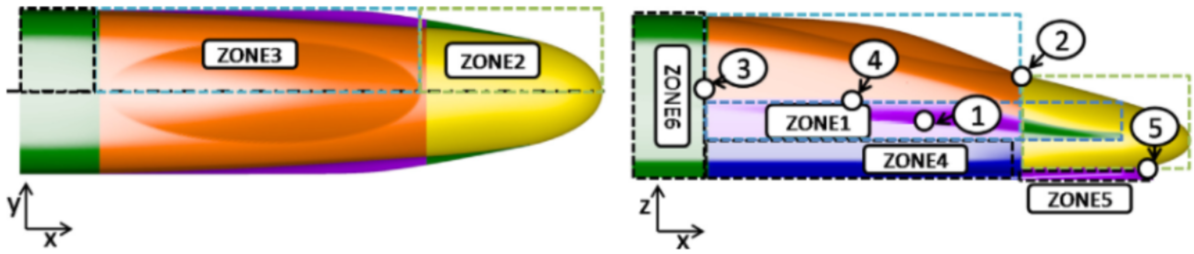

Figure 3. Different areas of streamlined high-speed rail head structure.[3]

Please collect relevant data, establish several mathematical models, and answer the following questions:

Question 1: Please establish a mathematical model for the air resistance of the high-speed railway, consider the relationship between the high-speed railway geometry and the force under the general condition and extreme weather (such as rain, snow and wind), simulate the distribution of air resistance for the conical type and the four typical high-speed railways as shown in Figure 2, and select the best high-speed railway shape with the smallest air resistance.

Question 2: Please analyze the influence of the radian of the high-speed rail head's curve on the air resistance, establish an optimization model of the high-speed rail's shape, design the best high-speed rail's shape, making the high-speed rail suffer the least air resistance, and draw a sketch of the optimized high-speed rail's shape.

Question 3: Please establish a mathematical model for the noise generated by high-speed rail, analyze the intensity of the noise generated by the conical type and the four typical high-speed rail as shown in Figure 2, simulate the distribution of their respective noise, and select the best high-speed rail shape which generates the least noise.

Question 4: Please combine the results of the previous three questions to establish a comprehensive optimization model of the high-speed rail shape and design the best high-speed rail shape, while improving the speed of high-speed trains and reducing noise. Draw a sketch of the high-speed rail's shape and give the corresponding structural parameters.

Your PDF solution of no more than 25 total pages should include:

- One-page Summary Sheet.
- Table of Contents.
- Your complete solution.

Note: The APMCM Contest has a 25-page limit. All aspects of your submission count toward the 25-page limit (Summary Sheet, Table of Contents, your complete solution). However, the pages of Reference List and Appendices are not limited.

Attachment:

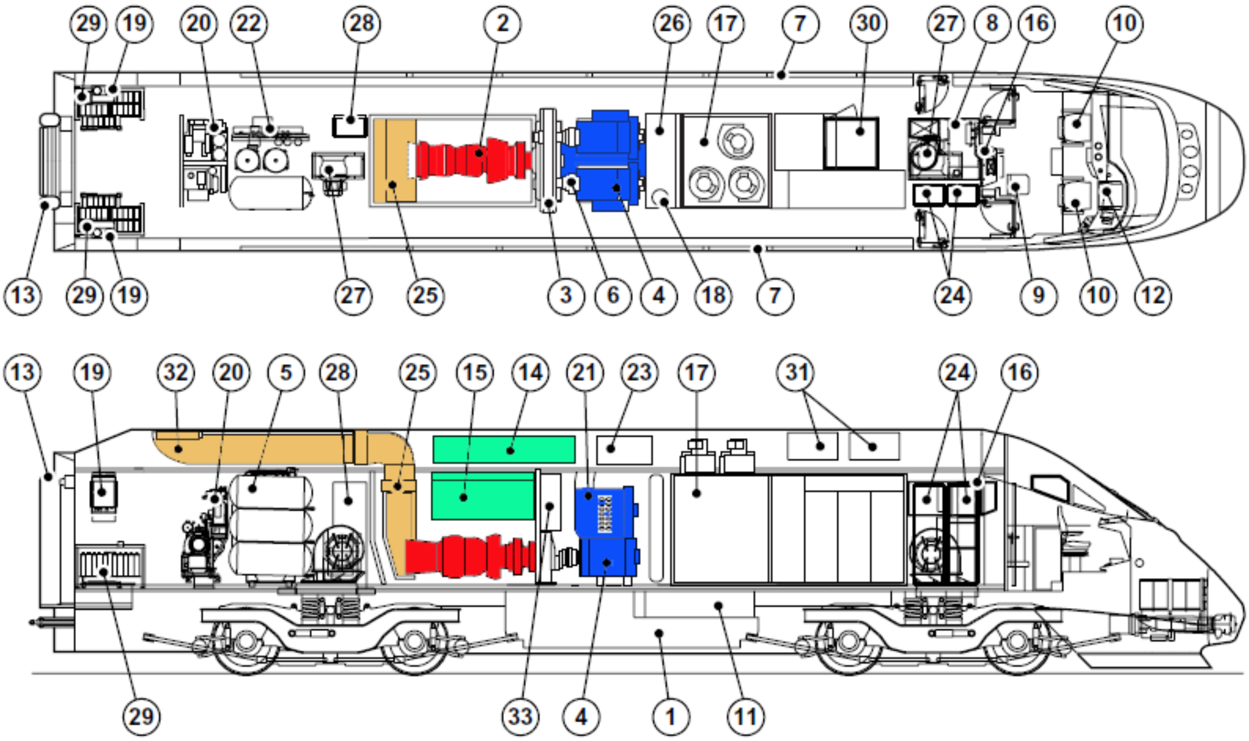

Figure 4. Schematic diagram of different regional structures of general high-speed railway.

References:

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