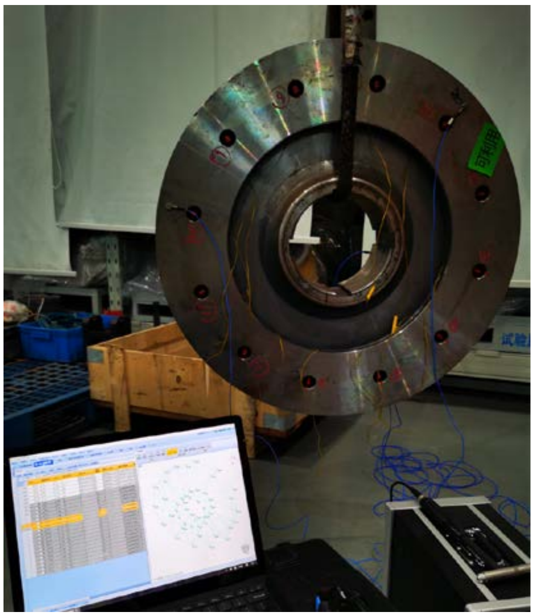
Modal testing can verify the accuracy of simulation results and determine the structural characteristics of an actual product. The following test designates a train brake disc as the test object. The modal parameters and mode shape of the train are studied and analyzed. The test piece is shown in the following figure.

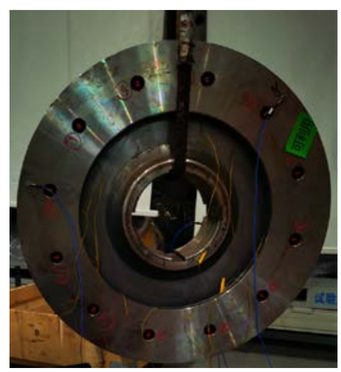


Modal measurement systems include sensors, acquisition devices, auxiliary tools, and the corresponding analysis software. The acquisition equipment used in the test was the Crystal Instruments Spider-80Xi. The Spider-80Xi is a classic modular acquisition device featuring 8 input channels which can expand to a system of up to 512 channels. Each channel has a sampling rate of up to 256 kHz. Patented dual 24-bit ADC technology provides high accuracy and high dynamic range. Data collection for a variety of modal test methods is available. Real-time analysis ensures a smooth acquisition and analysis process for the modal test.

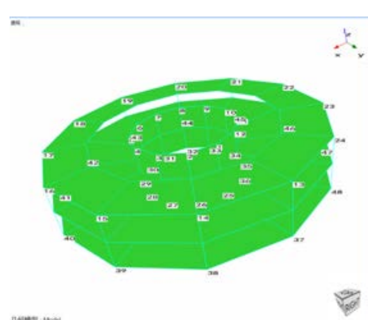
The PCB 086C03 modal impact hammer was used to excite the structure. This hammer has a sensitivity of 2.25mv/N and is suitable for exciting medium or large machinery components.

The acceleration sensor used for acquisition is a PCB piezoelectric single-axis sensor (model 333B30) with a sensitivity of 100 mv/g. The sensor cable uses a 15 m long dedicated shielded wire.

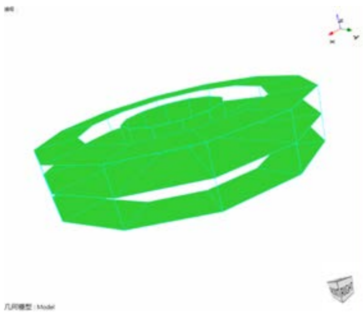
The brake disc was lifted by a service hook and held in a natural suspended state.



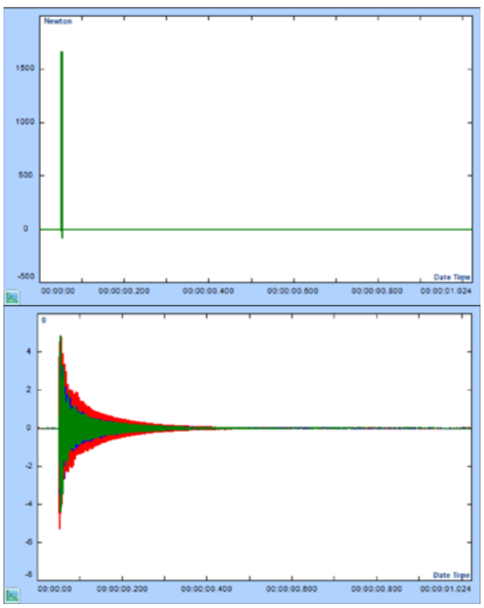
There was a total of 48 measurement points, 24 before and after each, distributed on the outside of the disc and the internal test.



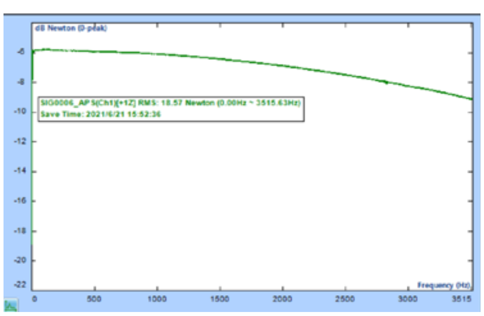
The train disc is simplified as a solid shape and modeled as a sandwich with front and rear discs as rings and the center of the middle disc protruding forward and backward.



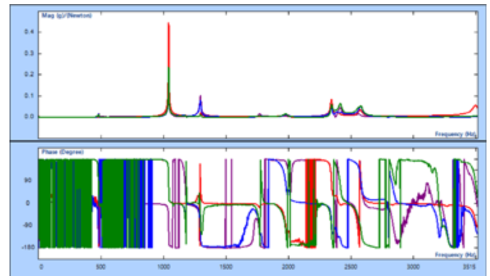
The FFT configuration settings had a frequency range of 3.5 kHz, the number of spectral lines was 3600, no window was implemented, and three linear averages. Care was taken to ensure the integrity of the excitation signal and the response signal.



The force spectrum was acceptably attenuated over the measurement range with the selection of metal hammer heads plus mass blocks,



The roving excitation method was implemented for this modal test. The measured FRFs were displayed within the analysis range and the results of different sets of measurement points had the same trend and peak point. The parameters and methods were valid.



Due to the wide range of analysis frequencies, the force hammer excitation effect is still different in the low frequency and high frequency regions. At the same time, in order to facilitate the analysis and reduce the amount of calculation during parameter extraction, the analysis range is divided into 50~1500 Hz for the low frequency region and 1500 Hz~3000 Hz for the high frequency region.

50 to 1500 Hz Frequency Band

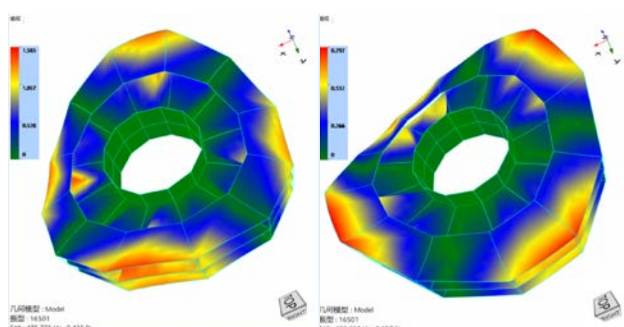
The following seven modes are extracted:

模态振型数据

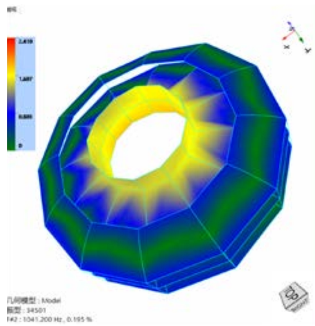
振型序号	频率(Hz)	阻尼比 (%)
F#1	476.336	0.744
F#2	480.848	0.057
F#3	1041.175	0.186
F#4	1070.168	0.453
F#5	1170.304	0.453
F#6	1284.011	0.461
F#7	1293.781	0.225

Comprehensive sets of data analysis:

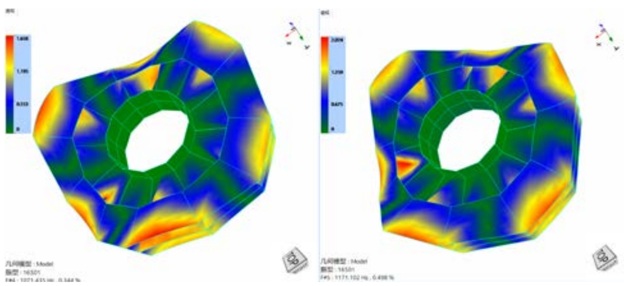
1. 475 Hz and 480 Hz should represent the heavy root mode of the train brake disc with the same mode shape characteristics and an angle difference of about 60°.



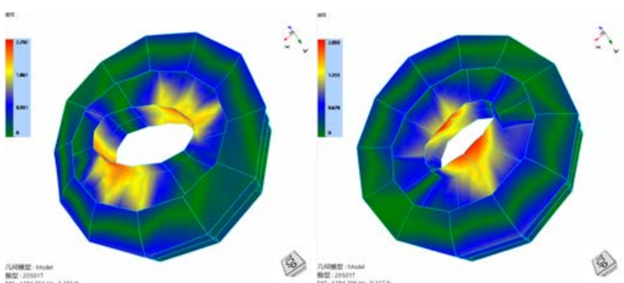
2. All sets of data show a mode of 1041 Hz.



3. The mode shape of 1071 Hz and 1171 Hz.



4. The modes at 1284 Hz and 1294 Hz have the same mode shape with an angle difference of about 60°, which can be considered as a heavy root mode.



1500~3000 Hz Frequency Band

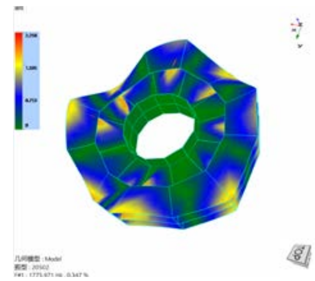
The following seven modes are extracted:

模态振型数据

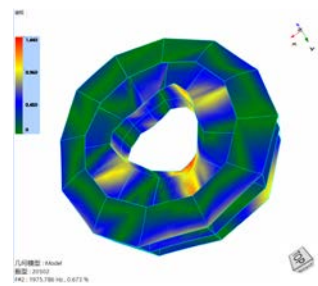
	振型序号	频率(Hz)	阻尼比 (%)
▶	F#1	1763.402	0.532
	F#2	2005.632	0.434
	F#3	2342.725	0.279
	F#4	2380.04	0.726
	F#5	2403.842	0.503
	F#6	2561.885	0.457
	F#7	2808.598	0.685

Comprehensive sets of data analysis:

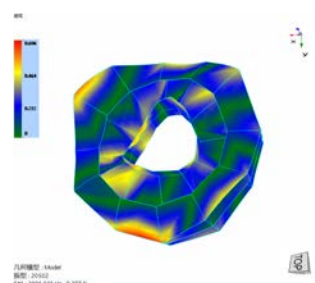
1. The mode shape at 1775 Hz.



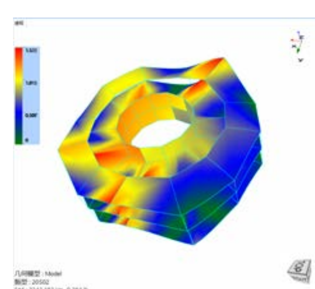
2. The mode shape at 1975 Hz frequency is mainly the bending deformation at the center of the inner disc.



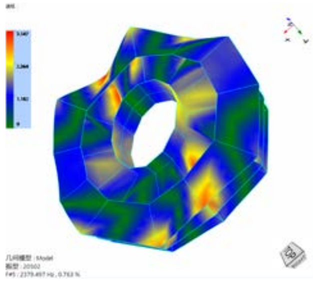
3. The 2006 Hz mode shape is shown below.



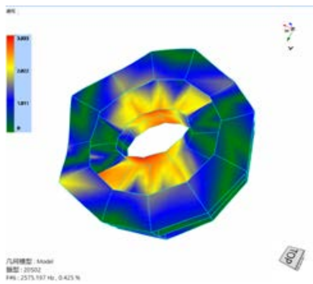
4. The mode shape at 2342 Hz is shown in the figure below.



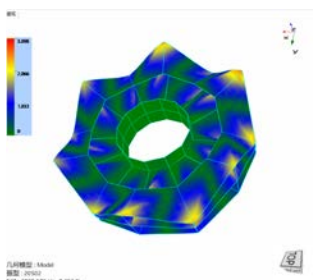
5. The mode shape of 2379 Hz is shown in the figure. The mode at 2403 Hz is 90° different from the previous frequency mode, and the two should be heavy root modes.



6. The 2575 Hz mode is as follows.



7. 2808 Hz frequency mode shape is shown below.



The fourteen modes are as follows:

Order	Frequency	Comment
1.	475 Hz	Heavy root
2.	480 Hz	
3.	1041 Hz	
4.	1071 Hz	
5.	1171 Hz	
6.	1284 Hz	Heavy root
7.	1294 Hz	
8.	1775 Hz	
9.	1975 Hz	
10.	2006 Hz	
11.	2342Hz	
12.	2379 Hz	
13.	2575 Hz	
14.	2808 Hz	

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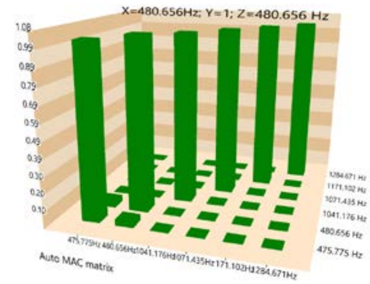
1. From the perspective of identification, the test meets the requirements, and the modes are well identified in the desired frequency ranges



2. The quality of the force spectrum and frequency response signal in the acquisition process is better. However, from the perspective of coherence, such as switching to a larger force hammer, it should be possible to obtain a better signal and the frequency response in the high frequency region of 1700 Hz~2600 Hz can be partially improved. There may be some degree of quality misalignment in both the brake discs and the lifting, which can also affect the results.