Random Vibration Response Analysis and Material Optimization of EMU Equipment Bracket

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Abstract. Based on the carbon fiber laminates and Aluminum Alloy two materials EMU equipment bracket which is the main bearing structure modal comparative analysis based on ABAQUS. The paper can conclude that there is little difference between the inherent frequency of two material structure. And carbon fiber laminate material is Aluminum Alloy scaffold for weight loss of about 43%. In addition, the paper do random vibration analysis of carbon fiber laminate materials equipment bracketcombined with the track spectrum. We can conclude the stress distribution of the root mean square value. The feasible way for the application of carbon fiber laminate materials and equipment bracket exploration.

Guidelines

The equipment cabin is installed for the protection of the car equipment and improve the structure must train aerodynamic performances in high-speed train body bottom.Mainly comprises a bottom plate, apron, end plate and bracket.As the main components of equipment cabin cabin equipment support, many scholars have done a lot of research on the equipment Aluminum Alloy material class[1]-[4].

But the application of carbon fiber laminate materials are few in the structure of the main bearing of locomotive and vehicle. In addition, with the high-speed train speed continues to improve, effect of track irregularity caused by random vibration of equipment bracket produced more and more.Due to the advantages of specific stiffness, high specific modulus and corrosion resistance, the carbon fiber composite materials has been widely in the aerospace field,butIt is still mainly used in non-bearing structure in the field of railway transportation.

This paper makes a comparative analysis on the carbon fiber laminates and Aluminum Alloy materials equipment bracket by ABAQUS finite element software, a feasible way for the application of carbon fiber laminates in high-speed train exploration.

The Finite Element Model And Modal Theory

The equipment is mainly composed of a handle bracket, a slide rail and beam. It is thin plate structure.The author use Part module in ABAQUS to get the geometric cleaning equipment cabin bracket shell model. It can be shown in Figure 1.

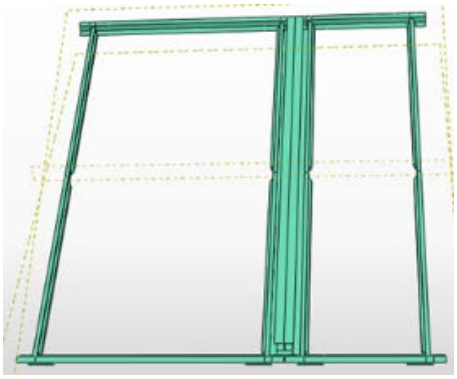


Figure 1 cabin geometry model of equipment

Material Attributes. Carbon fiber laminate and Aluminum Alloy material properties are shown in Table 1, Table 2 for each part of the stacking sequence, Slide part layer is shown in Figure 2.

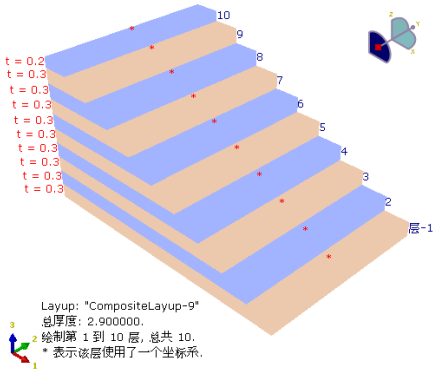


Figure 2 part layer of slide

Comparison of modal analysis results . Set frequency extraction step analysis in the ABAQUS. The paper extract Aluminum Alloy material and carbon fiber laminate materials equipment bracket 20 natural frequency (see Table 3) and natural modes (see Figure 3). In view of the limited space, this article only take a few order natural frequency images were compared and analyzed. In contrast to its natural frequency can be obtained: There is little difference in the first ten order natural frequency between Aluminum Alloy material and carbon fiber laminates material in equipment bracket. And the natural frequency is relatively low, which is about 10~15Hz.

Table 1 material properties of carbon fiber layer plate and Aluminum Alloy

Material		E（Gpa）		G（Gpa）				
		E1	E2	G12	G13	G23		
CFRP Laminate	A1	71.33	22.41	12.64	12.64	12.64	0.18	1750
	A2	67.5	67.5	15.78	15.78	15.78	0.11	
	B1	67.53	24.84	8.48	8.48	8.48	0.3	
	B2	64.62	64.62	10.79	10.79	10.79	0.1	
Al Alloys		69					0.33	2700

Table 2 equipment parts bracket stacking sequence

	Overlay material and order
Handle	[/45/-45/45/-45/45/-45/45/-45/45/]
Slide	[/45/-45/45/-45/45/-45/45/-45/45/]
Diaphragm	[0/45/0//45/45///45/45//0/45/0]
The lower edge of the Beam edge	[0/45//45///45//45/0/0/45/0//45/45///45/45//0/45/0]

It can be seen in Figure 3, the low order natural frequency of two materials mainly in slide bending deformation.In the thirteenth order natural frequency begins as beam bending deformation.Comparison of two kinds of vibration type material view: There are roughly the

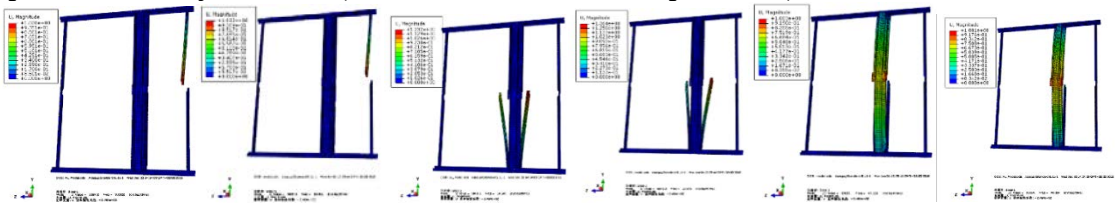
samevibration type between Aluminum Alloy material and carbon fiber laminate materials in equipment bracket.Equipment bracket carbon fiber laminates material compared to Aluminum Alloy material whose stiffness is almost unchanged.But the total quality comparison of two kinds of materials equipment cabin bracket:Aluminum Alloy material equipment bracket total mass 30.2Kg.Carbon fiber laminate material equipment bracket as the total mass of 21.1Kg.They compared weight loss 43%.Through the analysis and comparison of two kinds of ABAQUS equipment bracket material, can be obtained:Carbon fiber laminates in EMU main bearing application structure is feasible.

Table 3 different materials and equipment bracket natural frequency

	Natural Frequency (Hz)									
Order	1	2	3	4	5	6	7	8	9	10
CFRP	10.821	10.826	11.039	11.073	12.873	13.479	14.984	15.173	15.187	15.391
Al.Alloys	9.0938	9.1764	9.2841	9.4424	14.649	15.535	16.505	16.613	16.618	16.710
Order	11	12	13	14	15	16	17	18	19	20
CFRP	16.564	17.922	47.131	58.334	69.350	71.250	71.836	73.777	74.391	76.288
Al.Alloys	18.270	18.752	49.084	62.897	84.051	84.064	84.183	85.128	87.791	89.224

Random Vibration

Track irregularity power spectrum density function. Because the rail surface wear, laying the track initial error and so on many factors, it is easy to cause the track irregularity. It is mainly divided into high and low level, and the track irregularity. The irregularity is random function about the mileage. Track irregularity is the main external excitation of wheel rail system. It will cause random vibration. Study on random vibration of train is mainly based on track irregularity power spectrum density function (referred to as the "track spectrum")[5].



Al Alloys CFRP Al Alloys CFRP Al Alloys CFRP

(a) The first order nature mode (b) The fifth order nature mode (b) The fifth order nature mode

Figure 3 The nature mode of different material equipment cabin bracket

The train track spectrum used in random vibration analysis can be divided into United States ' six track spectrum, the German spectrum as well as the domestic track spectrum summarized byChinese Academy of Railway Science.

United States ' six track spectrum:

(2-1)

(2-2)

(2-3)

In functions: ,the units are ([).Respectively, low level, and the track gauge irregularity of track spectrum fitting function.is the spatial frequency of the track irregularity().is roughness constant. and are cut-off frequency. Kis reduction factor,often take 0.25.

The German spectrum:

(2-4)

(2-5)

(2-6)

In functions: is cut-off frequency. b is constant, value is 0.75.

We obtained the domestic track spectrum unified formula in reference to the United States and Germany high-speed spectrum:

(2-7)

In functions: is the unified track spectrum fitting function.is the spatial frequency.a,b,c,d,e,k are spectral characteristic parameters[6]-[7].

According to comparative analysis about United States ' six track spectrum, the German spectrum as well as the domestic track spectrum,the paper use domestic track spectrum to make random vibration response analysis.Because the domestic track spectrum fitting formula is given in the spatial frequencies,analysis of power spectrum density are needed in time and frequency under random vibration using ABAQUS, the spatial frequency and time frequency conversion.In the spatial frequency and time frequency, spectrum should have the same bandwidth mean square value. That is:

(2-8)

According to ,

(2-9)

In functions: The value of reference about a, b, c, d, e, k according to [7].， is the train speed. in the paper.Substitution (2-8) type to track spectrum density function:

(2-10)

(2-11)

Figure 4 and figure 5 areand track spectrum curve.

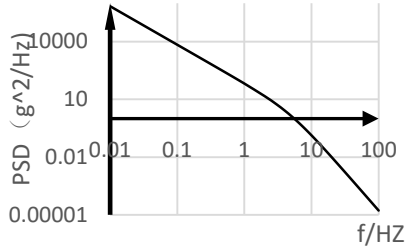


Fig4 Track height irregularity spectrum

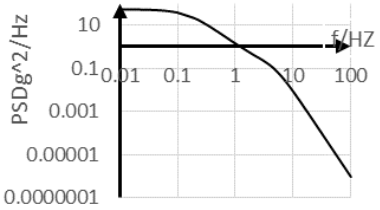
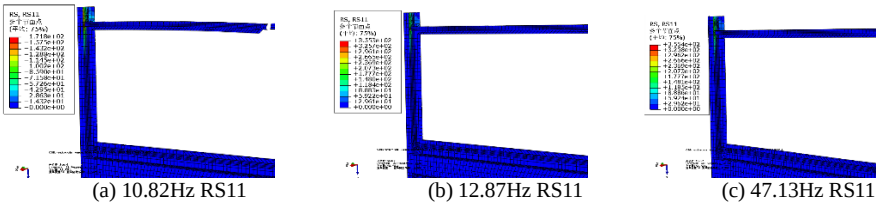


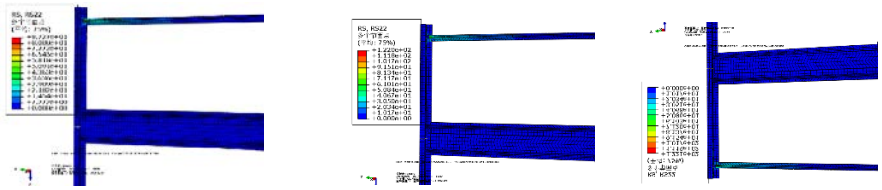
Fig5 Track level regularity spectrum

Analysis of random vibration simulation . Applying the random vibration load on the carbon fiber laminate material equipment bracket. The type (2-9) and (2-10) were used as the support equipment cabin vertical and lateral random vibration loads are applied by the random vibration response of carbon fiber equipment bracket. Referring to fig6 and fig 7, RS11 and RS22 direction stress mean square about several typical frequency in equipment cabin. It can be seen from the figure, according to the random vibration load and the inherent characteristics of materials, carbon fiber device bracket stress RMS contact position on the rail and the handle of the relatively large, but the overall stress RMS value is not large. RMS to greater stress compared with RS11 direction is vertical[8].



(a) 10.82Hz RS11 (b) 12.87Hz RS11 (c) 47.13Hz RS11

Fig6 The RS11 direction stress RMS



(a) 10.82Hz RS22 (b) 12.87Hz RS22 (c) 47.13Hz RS22

Fig7 The RS22 direction stress RMS

Conclusion

The paper sum up the natural frequency of support equipment cabin in two kinds of material and stiffness are roughly the same, but the device bracket carbon fiber laminates material compared Aluminum Alloy material weight 43%.The paper obtain track irregularity of track spectrum fitting formula according to combination of domestic statistical analysis. So,random vibration analysis of equipment bracket of carbon fiber laminate material could be done.Draw in track spectrum random excitation, equipment cabin bracket stress RMS value is larger on the slide rail and a handle at the joint, and vertical influence is larger.

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