Experimental Data Analysis of Tire Cleat Test

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Abstract. Tire envelop and impact characteristics have a great influence on the ride comfort of the vehicle. In this paper, the test results of the envelop and impact characteristics which are about in-and-out plane are analyzed to study the fluctuations on the load and velocity of the tire in the time of cleat. When the tire passes through the cleat at a low speed, the envelop characteristics of the tire can be analyzed: when the cleat is transverse, the in-plane envelop characteristics are obtained and the rule of RF and TF on changing load is summarized; when the cleat is oblique, the in-and-out-plane envelop characteristics are obtained and the rule of LF on changing load is summarized. When the tire passes through the cleat at a high speed, the impact characteristics can be analyzed: when the cleat is transverse, the in-and-out-plane impact characteristics are obtained and rules of RF, TF and LF on changing load and velocity in the time and frequency domain are summarized. When the cleat is oblique, the in-and-out-plane impact characteristics are obtained and the rules of RF, TF and LF on changing load and velocity are summarized.

1. Text Equipment

1.1 Significance and Purpose of the experiment

Tires are components that support the body on various vehicles, buffer external impacts, make contact with the road and ensure the driving performance of the vehicle. They carry all the weight of the vehicle. With the gradual improvement of the level of the automotive industry[1], the requirements for the smoothness of the vehicle[2] are also increasing. The envelop and impact characteristics[3] of a tire are important to ride comfort and stability. Also, the test data is necessary to build a tire model[4] for other relative experiments.

In order to analyze envelop and impact characteristics of the tire better, it is necessary to rely on an equipment with higher accuracy[5] to conduct experiments.

Fig. 1 ZF tire high speed uniformity testing equipment

1.2 Test Equipment for Tire envelop and impact characteristic

Tire envelop and impact characteristics are tested by high speed uniformity equipment which is researched and developed by ZF in Germany. In order to conduct various tests on in-and-out plane envelop characteristics and impact characteristics, the cleat can be installed transversely (0 degree) or obliquely (45 degree).

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2. Tire Envelop Characteristics Test and Analysis

2.1 Test Conditions of the Tire Envelop Characteristics

Tire envelop characteristic mainly refers to the variation of radial force (RF), tangential force (LF) and lateral force (TF) on changing load when the tire passes through the cleat at a low speed[6].

The in-plane installation (0 degree) and out-plane installation (45 degree) are selected to conduct tests with a piece of cleat whose size is 15mm×15mm to obtain envelop characteristics. Other test conditions are as follows:

Test speed: 2km/h
Test pressure: 220kPa
Test load: 40% LI load; 80% LI load; 120% LI load (LI is load index that is a standard parameter of a tire.)
Tire specification: 225/55R17

2.2 Test Results of Tire in-plane envelop characteristic

When cleat is transverse, it only stimulates the in-plane characteristics of tire. Firstly, the results of the test for transverse cleat by analyzing are shown in Figure. 2 and Figure. 3.

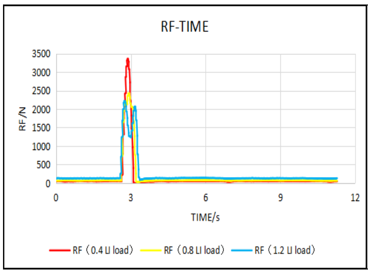

Fig. 2 Relative value of RF variation with load

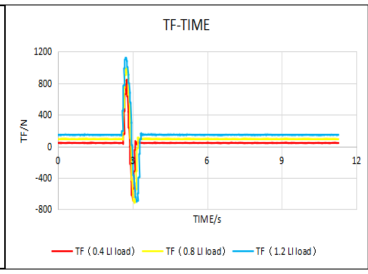

Fig. 3 Relative value of TF variation with load

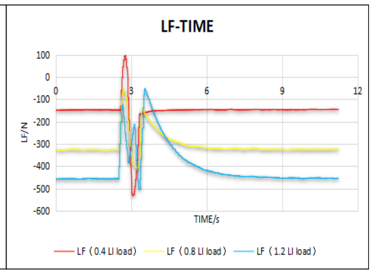

Fig. 4 Relative value of LF variation with load

It can be concluded from Figure. 2 that as the load increases, the RF maximum decreases and the RF curve has obvious depression. It can be seen that the tire envelop characteristics are more pronounced in the case of increasing load. Therefore, when the load increases, the RF decreases.

It can be seen from Figure. 3 that the maximum of TF gradually increases with the increasing load, but the amplitude is small. From the graph, it can also be seen that there are two maximum values respectively in positive and negative directions, and the absolute value of them are not much different.

2.3 Test Results of Tire out-plane envelop characteristic

When the cleat is installed obliquely for testing, it will simultaneously stimulate both the in-plane and out-of-plane characteristics of the tire, that is, the LF will also change largely during the test. Time domain curves of LF value with changing load are shown in Figure. 4.

It can be seen from Fig. 4 that when the load is small, the maximum values of both the positive and negative directions are large, and the negative maximum is higher than the positive one. As the load increases, the absolute value of the positive maximum gradually increases and the negative maximum gradually decreases. Meanwhile, the second extreme value in the positive direction appears. When the 120% LI load is reached, the secondary extreme value is higher than the first extreme point.

3. Tire Impact Characteristics Test and Analysis

3.1 Test Conditions of Tire Impact Characteristics

Tire impact characteristic mainly refers to the variation of radial force (RF), tangential force (LF) and lateral force (TF) in time domain and frequency domain when the tire passes through the cleat at a high speed.

The cleat whose size is 15mm×15mm is selected to conduct tests at three different speeds (30km/h, 60km/h, 90km/h) to obtain the in-plane and out-plane impact characteristics on changing load and velocity. Other test conditions are as follows:
Test pressure: 220kPa
Test load: 40% LI load; 80% LI load; 120% LI load
Tire specification: 225/55R17

3.2 Test Results in time domain of Tire impact characteristic

It can only stimulate the in-plane impact characteristics when the cleat is transverse. So only the RF and TF values are analyzed for transverse cleat. The maximum values of RF and TF is selected as the analysis target during the entire fluctuating process. It is shown in Table. 1.

Known from Table. 1, the RF maximum increases gradually with the increasing velocity and it decreases gradually with the increasing load, but the changing rate of the latter case becomes smaller and smaller. The TF maximum increases gradually with the increasing load. However, its maximum varies slightly with velocity. At 30km/h, TF maximum appears in the negative direction at a trough. At 60km/h and 90km/h, the TF maximum appears in the positive direction at a crest. Obviously, velocity has an effect on TF fluctuation. However, TF presents a trend of gradual decreasing with the increasing velocity as absolute values.

It can simultaneously stimulate the in-plane and out-plane characteristics when the cleat is oblique. For this, it needs to be analyzed for RF, TF and LF values. Same as the in-plane characteristics, the maximum of force in each direction is selected for analysis. It is shown in Table. 2.

Known from Table. 2, the RF maximum decreases with the increasing load and increases with the increasing velocity. Compared with the transverse impact characteristic, the RF maximum absolute value obliquely is less than the maximum when it is transverse. LF extreme value appears at a trough at 40% LI load, and it appears at a crest at 80% and 120% LI load. The absolute value of TF maximum increases gradually with the increasing load, and decreases with the increasing velocity. The TF maximum appears at a trough at the speed of 30km/h and 60km/h, and it appears at a crest at 90km/h.

3.3 Test Results in frequency domain of Tire impact characteristic

The frequency domain results of impact characteristics better reflect its vibration performance. For this purpose, the frequency domain characteristics are analyzed. In order to obtain frequency characteristics that are more in line with the performances of the tire, the low frequency characteristics are filtered out, and only the first-order extreme values higher than 20 Hz are analyzed. When the cleat is transverse, the corresponding extreme values and frequencies on different velocities and loads are shown in Table. 3.

Known from Table. 3, it can be seen that the RF first-order extreme frequencies do not fluctuate much in the frequency domain at the same velocity but at different loads. The extreme value decreases with the increasing load. The position of the TF first-order extreme frequency corresponds to the same frequency approximately and the extreme value increases with the increasing load. The RF first-order extreme frequencies do not fluctuate much in the frequency domain at the same loads but at different velocities. The extreme value increases with the increasing velocity. The position of the TF first-order extreme frequency does not correspond to the same frequency and the extreme value decreases with the increasing velocity.

When the cleat is oblique, the corresponding extreme frequencies on different velocities and loads are shown in Table. 4.

In the oblique cleat test results, the RF and TF frequency domain characteristics are almost the same as the transverse cleat results. However, the RF extreme frequencies at 30km/h are much different from 60km/h and 90km/h and the TF extreme frequencies at 90km/h are a little different from 30km/h and 60km/h. The LF extreme frequencies are different at different speeds. The extreme values decrease with the increasing load at the same velocity.

Table 1. The value of in-plane impact characteristics of tire in time domain

Testing Velocity and Item	40% LI load [N]	80% LI load [N]	120% LI load [N]
30km/h, Max TF	-3201	-4417	-5221
60km/h, Max TF	2589	3503	4285
90km/h, Max TF	1728	2578	3713
30km/h, Max RF	3586	3199	3057
60km/h, Max RF	5321	4356	4277
90km/h, Max RF	5998	5111	4653

Table 2. The value of out-plane impact characteristics of tire in time domain

Testing Velocity and Item	40% LI load [N]	80% LI load [N]	120% LI load [N]
30km/h, extreme TF	-1381	-1715	-1798
60km/h, extreme TF	-1204	-1765	-2389
90km/h, extreme TF	1101	1372	1800
30km/h, extreme RF	2604	2091	1912
60km/h, extreme RF	3232	2598	2400
90km/h, extreme RF	4411	3799	3375
30km/h, extreme LF	-701	500	632
60km/h, extreme LF	-985	889	871
90km/h, extreme LF	-733	605	469

Table 3 The value of in-plane impact characteristics of tire in frequency domain

Testing Velocity	Items	40% LI load	80% LI load	120% LI load
30km/h	TF extreme value [N]	220.28	509.74	791.03
	Extreme Frequency [Hz]	29.43	29.78	29.24
60km/h	TF extreme value [N]	64.82	122.30	271.71
	Extreme Frequency [Hz]	29.63	29.70	30.01
90km/h	TF extreme value [N]	65.13	90.94	107.63
	Extreme Frequency [Hz]	91.89	97.75	97.74
30km/h	RF extreme value [N]	52.84	71.14	108.94
	Extreme Frequency [Hz]	78.41	65.21	49.63
60km/h	RF extreme value [N]	251.62	95.41	111.12
	Extreme Frequency [Hz]	78.49	75.98	78.39
90km/h	RF extreme value [N]	335.40	306.41	233.40
	Extreme Frequency [Hz]	78.60	76.41	73.77

Table 4 The value of out-plane impact characteristics of tire in frequency domain

Testing Velocity	Items	40% LI load	80% LI load	120% LI load
30km/h	TF extreme value [N]	125.41	218.82	283.60
	Extreme Frequency [Hz]	30.63	30.76	30.41
60km/h	TF extreme value [N]	69.82	142.30	256.49
	Extreme Frequency [Hz]	31.21	31.46	31.35
90km/h	TF extreme value [N]	38.20	57.60	111.84
	Extreme Frequency [Hz]	33.10	34.30	32.43
30km/h	RF extreme value [N]	24.21	39.40	42.54
	Extreme Frequency [Hz]	41.84	40.30	31.21
60km/h	RF extreme value [N]	26.48	19.74	22.52
	Extreme Frequency [Hz]	78.30	78.30	63.21
90km/h	RF extreme value [N]	169.30	147.80	113.40
	Extreme Frequency [Hz]	78.40	76.56	76.72
30km/h	LF extreme value [N]	36.84	29.84	41.05
	Extreme Frequency [Hz]	24.30	24.30	18.93
60km/h	LF extreme value [N]	102.37	64.59	33.52
	Extreme Frequency [Hz]	53.12	53.12	39.63
90km/h	LF extreme value [N]	55.46	43.63	42.44
	Extreme Frequency [Hz]	51.12	51.43	51.85

4. Conclusion

In this paper, the in-plane and out-plane envelop characteristics of a tire at a low speed and impact characteristics at a high speed are all analyzed by testing. Conclusions are as follows:

(1)By testing with transverse and oblique cleat, the results of envelop characteristics on changing loads can be obtained in the time domain at a low speed. It reflects more obvious envelop performance in the RF curve. There are two maximum values in different directions during the fluctuation of TF. There are two extreme values of LF about out-plane envelop characteristic.

(2)It introduces and summarizes the rules of RF, TF and LF on changing loads and velocities in the time and frequency domain respectively by testing. The cleat is also installed transversely and obliquely. By analyzing experimental data, the in-plane and out-plane impact characteristics can be obtained.

(3)In this paper, it is about envelop and impact characteristics of both in-plane and out-plane of the tire. By tire cleat test, it can be seen that the basic rules of RF, TF and LF with different loads in the time domain about envelop characteristic and RF, TF and LF with different loads and velocities both in the time and frequency domain about impact characteristic are summarized. Accordingly, more experiments and studies may be carried on in the future and it is possible that we can obtain more relative and accurate rules and performances about the tire characteristics.

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