A brief discussion on the method for measuring the adhesive amount on nylon cord fabric

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Abstract: The detection of the adhesive amount on nylon cord fabric is crucial for quality control of tires. The national standard method is a commonly used detection method. However, during the practical application of this method, the author found several issues, including strong solvent corrosion, long detection cycles, difficulty in observing dissolution phenomena, difficulty in cleaning filtration tools, and environmental pollution caused by the waste liquid generated during cleaning. This article will conduct an in-depth comparative discussion on these issues, aiming to provide readers with reference suggestions to further improve detection efficiency and quality, while reducing environmental pollution and promoting the development of nylon cord fabric adhesive amount detection technology towards a green, efficient, and precise direction.

Key words: nylon cord fabric; rubber coating amount; detection method

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The cord fabric used in tires is a skeleton fabric woven with high-strength strands as warp and single yarns of medium and low density as weft. It is named "cord fabric" because of its tightly arranged warp and loosely arranged weft, resembling a curtain. As the skeleton material for tire outer tubes, cord fabric is akin to the steel frame structure of a building, playing a crucial role in ensuring tire performance and quality. It is an essential raw material for tire production. Currently, tire cord fabrics mainly include nylon cord fabric, polyester cord fabric, aramid cord fabric, and steel cord fabric. Among them, nylon dipped cord fabric, as an ideal skeleton material for tires, possesses excellent properties such as high strength, strong wear resistance, good flexibility, fatigue resistance, good adhesion, and superior chemical stability. The level of dipping has a significant impact on the subsequent fatigue resistance, deformation resistance, and stability of tire products. Therefore, accurately testing the level of dipping can guide production control processes and ensure product quality.

1 Test method

Currently, the national standard testing methods for determining the amount of adhesive on nylon cord fabric mainly include GB/T 9102 and GB/T 9101 (GB/T 30310). The testing principle of these two methods is based on the fact that adhesive is insoluble in formic acid while nylon cord is soluble in formic acid. By separating the mass of adhesive and the mass of white cord, the amount of adhesive can be calculated.

When using the national standard method to detect the adhesive amount on nylon cord fabric, it was found that:

The solvent used in the experiment was formic acid. The acid mist generated during the suction filtration process and a small amount of formic acid reagent were prone to corrode the oil-sealed vacuum pump, leading to frequent malfunctions. Additionally, during maintenance, the high concentration of formic acid inside the pump could cause poisoning to maintenance personnel.

The testing cycle of this project is long.

The complete dissolution phenomenon of nylon fiber is not easy to observe, and the testing method does not specify the duration of stirring for sample dissolution.

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The G2 funnel used for filtration has a short service life, is difficult to clean, and the waste liquid generated during cleaning pollutes the environment.

Now, we will conduct a comparative discussion on the above four issues.

2 Comparison test and results

2.1 Discussion on the selection of suction filtration vacuum pumps

In the process of detecting the adhesive amount on nylon cord fabric, suction filtration equipment plays a crucial role. Oil-type vacuum pumps and circulating water-type vacuum pumps, as two common types of suction filtration equipment, exhibit significant differences in their performance characteristics. An in-depth analysis of these two types (see Table 1) helps us to scientifically and reasonably select the most suitable equipment.

As can be seen from Table 1, oil-sealed vacuum pumps exhibit significant advantages in terms of vacuum degree and pumping speed, but they are relatively vulnerable to corrosive gases. For example, when using formic acid reagent for the detection of adhesive content on nylon cord fabric, the acid mist generated by its volatilization can easily corrode the internal components of the oil-sealed vacuum pump, leading to frequent equipment malfunctions. Conversely, the greatest advantage of circulating water vacuum pumps lies in their excellent corrosion resistance, coupled with their simple structure and convenient operation and maintenance. However, the vacuum degree of circulating water vacuum pumps is lower than that of oil-sealed vacuum pumps, which may not meet the requirements in some detection scenarios where high vacuum degree is essential. Therefore, when selecting suction filtration equipment, it is necessary to comprehensively consider the specific requirements of the detection task.

Table 1 Comparison of performance characteristics between oil-type vacuum pumps and circulating water-type vacuum pumps

	Oil-sealed rotary vane vacuum pump	Circulating water vacuum pump
Performance characteristics	1. It boasts an ultra-high ultimate vacuum degree, typically reaching 10-2 Pa or even higher. There is no vacuum gauge on the equipment, so it cannot display the vacuum degree during filtration;	1. The ultimate vacuum degree is usually between 2,000 and 4,000 Pa. There is a vacuum gauge on the equipment, which allows for continuous observation of the vacuum degree during filtration;
	2. The pumping rate remains relatively stable within different pressure ranges;	2. The pumping rate is generally high, but it will significantly decrease under higher vacuum conditions;
	3. The pump head is primarily made of metal components, which are not resistant to corrosion;	3. The pump head has few metal parts and is corrosion-resistant;
	4. The maintenance process is cumbersome. If not handled properly, oil contamination may affect performance or even damage the equipment. If used for suction filtration of corrosive reagents, the high concentration of corrosive gas in the pump during maintenance can easily cause poisoning and suffocation of maintenance personnel;	4. The maintenance of this system is simpler than that of an oil pump, requiring only regular replacement of circulating water and cleaning of impurities inside the water tank and pump body;
	5. The medium for vacuuming is vacuum pump oil, which needs to be replaced regularly. Dismantling the pump during replacement can easily cause poor sealing of the vacuum pump;	5. The vacuum medium is circulating water. If it is used for suction filtration of corrosive reagents, the corrosive gases entering the circulating water during the filtration process can be immediately discharged through the drain valve, preventing corrosion of the pump head;
	6. Single-head suction filtration;	6. With dual taps, filtration can be performed individually or in parallel;
	7. An additional gas scrubbing device can be installed to remove corrosive components such as acidic or alkaline substances from the gas entering the pipeline, thereby reducing corrosion to the pump.	7. An additional gas scrubbing device can be installed to remove corrosive components such as acidic or alkaline substances from the gas entering the pipeline, thereby reducing corrosion to the pump.

2.2 Discussion on sample length comparison

In the inspection of glue application amount on nylon cord fabric, the inspection efficiency directly affects the timeliness of production and product quality control. The selection of sample preparation length directly impacts the efficiency of inspection work. By analyzing the sample preparation time and sample dissolution time under different sample preparation lengths, identifying the sample preparation length that corresponds to the shortest time for both can help improve inspection efficiency.

2.2.1 Comparison of required durations for different sample preparation lengths

Five experimenters simultaneously cut the 1870dtex/2 and 1260dtex/1 cord fabric samples into small segments of 1~2 mm, 3mm, 5 mm, and 10 mm. Each 1870dtex/2 cord fabric sample weighed approximately 5 g, while each 1260dtex/1 cord fabric sample weighed approximately 6 g. The average sample preparation time of the five experimenters was recorded and compared. The results are shown in Figure 1.

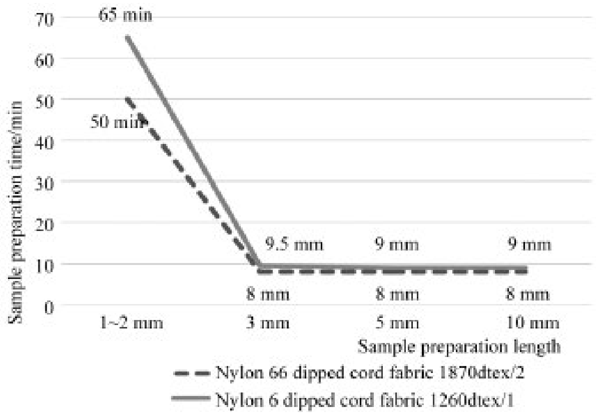

Figure 1 Comparison of required durations for different sample preparation lengths

2.2.2 Comparison of the required duration for dissolving and stirring samples with different sample lengths

After drying the samples prepared in 2.2.1 to constant weight, divide them into two portions. Each portion of 1870dtex/2 sample weighs approximately 2g, and each portion of 1260dtex/1 sample weighs approximately 2.5g. After adding the standard required formic acid, observe and record the average time when the nylon fibers of the cord fabric are completely dissolved (no white cord fabric, and the state of the stirred sample remains unchanged). The results are shown in Figure 2.

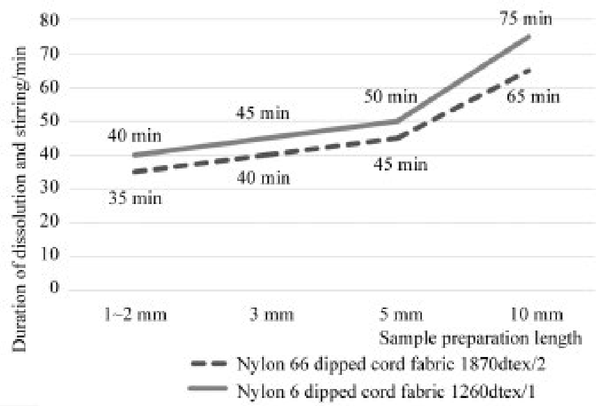

Figure 2 Comparison of dissolution duration for different sample preparation lengths

2.2.3 Comparative analysis

Analyze the optimal sample preparation length based on the time ratio between sample preparation and sample dissolution. The results are shown in Figure 3.

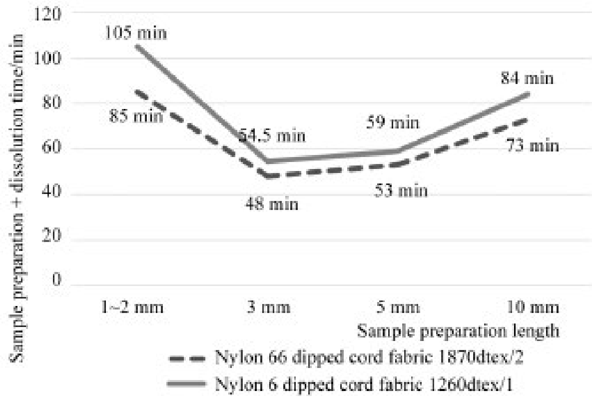

Figure 3 Comparison of sample processing (sample preparation + dissolution) duration

As can be seen from Figures 1, 2, and 3, the longer the sample preparation length, the shorter the time required to complete the preparation. An increase in sample length leads to an increase in the duration of sample dissolution. When the sample preparation length is set at 3 mm, the entire sample processing process (including both sample preparation and dissolution) takes the least amount of time.

2.3 Discussion on the judgment criteria for complete dissolution of nylon fibers and the duration of dissolution stirring

Cut the sample into approximately 3 mm long pieces, and compare the test results of samples with different stirring durations for dissolution (each sample is tested in three parallel groups, and the final result is the average). When observing the dissolution state of the sample, record the corresponding duration when there is no longer any white cord in the sample and the state of the sample does not change even after further stirring. This is the shortest time for the sample to fully dissolve. Perform statistical analysis on the test data at this time point and other data with different stirring durations. Based on the comparison results, explore the impact of stirring duration on the results, determine the time and phenomenon of complete dissolution of the sample, and ensure the accuracy and reliability of the test results. The results are shown in Tables 2 and 3.

By analyzing the results presented in Tables 2 and 3 using statistical and error analysis methods, it was concluded that when the nylon fibers of the dipped cord fabric were

Table 2 Comparison of test results for nylon 66 dipped cord fabric 1870dtex/2 with different dissolution and stirring durations

Sample length / mm	Dissolution and stirring duration/min			Test result / %		
	Dissolve	Stir	Total	Sample 1	Sample 2	Sample 3
3	15	30	45	4.8	5.2	5.6
	15	50	65	4.7	5.1	5.5
	15	70	85	4.6	5.2	5.6
	15	90	105	4.7	5.2	5.6
	15	110	125	4.8	5.1	5.5
Result comparison and analysis	Average			4.72	5.16	5.56
	Standard deviation S			0.08	0.05	0.05
	|Z| value			1	0.8	0.8
	Absolute deviation			0.08	0.04	0.04
	Relative deviation δ			1.69	0.78	0.72

Table 3 Comparison of test results of nylon 6 dipped cord fabric 1260dtex/1 with different dissolution and stirring durations

Sample length (mm)	Dissolution and stirring duration/min			Test result / %		
	Dissolve	Stir	Total	Sample 1	Sample 2	Sample 3
3	15	35	50	4.8	5.4	3.9
	15	55	70	4.8	5.3	3.8
	15	75	90	4.7	5.4	3.9
	15	95	110	4.8	5.2	3.8
	15	115	130	4.7	5.3	3.8
Result comparison and analysis	Average			4.76	5.32	3.84
	Standard deviation S			0.05	0.08	0.05
	|Z| value			0.8	1.0	1.2
	Absolute deviation			0.04	0.08	0.06
	Relative deviation δ			0.84	1.50	1.56

completely dissolved (without any white cord threads) and the state of the stirred sample remained unchanged, further stirring and dissolving for an additional 1.5 hours would not result in any changes to the test results.

2.4 Discussion on the selection of filtering tools

By comparing the test results obtained using medium-speed quantitative filter paper and G2 sand-core funnel as filtration tools, respectively, and averaging the results from three parallel tests for each sample, we explored the impact of different filtration tools on the test outcomes. This provides a valuable reference for selecting filtration tools in practical applications. The results are presented in Tables 4 and 5.

Table 4 Comparison of test results for nylon 66 dipped cord fabric 1870dtex/2 using different filtering tools

Sample length / mm	Dissolution and stirring duration/min	Filter tool	Test result / %		
			Sample1	Sample2	Sample3
3	45	G2 sand core funnel + filter paper	5.8	5.3	5.4
		Sand core filtration device + medium-speed quantitative filter paper	5.8	5.2	5.4
Result comparison and analysis		Average value / %	5.80	5.25	5.40
		Standard deviation S	0.03	0.07	0.02
		|Z| value	0	1.4	0
		Absolute difference value / %	0	0.1	0
		Relative deviation δ/%	0	0.95	0

The statistical analysis and error analysis of the comparison results in Table 4 and Table 5 indicate that there is no significant difference between the test results obtained using medium-speed quantitative filter paper as the filtering tool and using a G2 sand-core funnel as the filtering tool. Therefore, using medium-speed quantitative filter paper for the detection of glue adhesion on nylon cord fabric will not significantly affect the test results.

3 Conclusion

Through experimental statistics and analysis, we can draw the following conclusions:

Table 5 Comparison of test results for nylon 6 dipped cord fabric 1260dtex/1 using different filtering tools Sample length

Sample length / mm	Dissolution and stirring duration/min	Filter tool	Test result / %		
			Sample1	Sample2	Sample3
3	50	G2 sand core funnel	5.2	4.3	5.6
		Sand core filtration device + medium-speed quantitative filter paper	5.3	4.2	5.6
Result comparison and analysis		Average value / %	5.25	4.25	5.60
		Standard deviation S	0.06	0.07	0.03
		|Z| value	1.7	1.4	0
		Absolute difference /%	0.1	0.1	0
		Relative deviation δ/%	0.95	1.18	0

(1) Overall, the circulating water vacuum pump is more suitable as a suction filtration device for detecting the adhesive amount on nylon cord fabric due to its simple structure, excellent resistance to formic acid corrosion, real-time measurable vacuum degree, convenient maintenance operation, medium circulation and anti-corrosion design, flexible suction filtration mode, and the additional installation of a gas washing device to further enhance its protective properties.

(2) When the sample preparation length is 3 mm, the detection cycle can be reduced, enhancing detection efficiency and meeting the practical needs of efficient detection.

(3) Medium-speed quantitative filter paper can serve as a filtering tool for detecting the amount of adhesive on nylon cord fabric. The use of this filter paper can effectively reduce the discharge of waste liquid generated during the cleaning of funnels, aligning with the current development concept of green environmental protection.

(4) The criterion for determining complete dissolution of nylon fibers in the sample is as follows: there is no white cord, and the state of the sample remains unchanged after continuous stirring. This criterion is highly operable and accurate, providing a clear and unambiguous basis for judgment in testing work.

(5) When the nylon fibers in the sample reach a state of complete dissolution, continue stirring for an additional 1.5 hours. The test results will not change due to an increase in stirring duration.