Measuring Method of Crane Gauge and Its Improvement

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Abstract. According to the Chinese administrative normative documents "Regulations for the Supervision and Inspection of Lifting Machinery" which Promulgated in 2002, it gives a way to measure the gauge of cranes. This research analyzes the characteristics and shortcomings of this method. I compared the advantages of using a laser distance meter instead of a steel tape to measure the gauge. According to basic geometric theory, the height on any base side can be obtained by measuring the distance between three points to obtain the area. Use a laser distance meter and improving the measurement method, the accuracy of the track distance measurement has been improved.

Keywords: Crane · Track center · Inspection · Gauge · Measurement

1 Introduction

The purpose of the gauge measurement in crane inspection, is to evaluate whether the crane operation is in a safe and stable state. And it is also an important technical parameter for evaluating the quality of the rail construction during the installation process. The gauge measurement involved usually includes span, and trolley gauge. The measurement methods adopted in crane inspection are consistent. Among them: Span, refers to the horizontal distance between the center lines of the running rail of the bridge crane; Wheelbase, refers to the horizontal distance between the center line of the rail track of the jib crane or the center line of the running wheel tread of the crane; Trolley gauge, refers to distance between the centerlines of the trolley tracks [1].

The gauge is the basis for carrying cranes or hoisting trolleys. If the measured value of the gauge is larger or smaller than the standard value (design value), it will lead to rail gnawing. Rail gnawing is not good for crane operation, it may cause at least the following disadvantages or risks:

1) Since the gnawing of rails will significantly increase the friction between wheels and rails, it will reduce the service life of wheels and rails. The life cycles of wheels and rails will be greatly shortened.
2) Increase the operating resistance of the mechanism. If the power equipment of the driving mechanism runs longer than the normal load for a long time, it will increase the operating energy consumption and aggravates the loss of the driving components.

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3) Rail gnawing generates axial forces that can damage the steel structure in the area concerned.
4) Severe rail gnawing can lead to derailment and subsequent accidents.

2 The Method of Gauge Measurement in Chinese Administrative Normative Documents "REGulations for the Supervision and Inspection of Lifting Machinery"

In Chinese administrative normative documents "Regulations for the Supervision and Inspection of Lifting Machinery", it recommends that we use a steel tape and a spring balance or a dynamometer to measure the gauge. The specific operation method is: Hold the steel tape with a flat ruler, and pull the steel tape with a spring balance on the other side until the indicated tensile force reaches 150Nm. Place one end of the steel tape on the outer end face of one wheel, and the other end on the inner end face of the other wheel at the same height. Then, the length measured by the steel tape is the gauge measurement. The gauge is equal to this measurement plus the metering correction value for the steel tape [2]. Please see Table 1(partial citation) for metering correction values.

This method controls the lower deflection of the steel tape within a certain range, and the data measured by the steel tape under the same lower deflection is relatively accurate. This method has at least the following disadvantages:

1) The difference in toughness and strength of the flat ruler stuck on the steel tape will cause the flat ruler to deform to varying degrees, resulting in inconsistent measurement reference points at the beginning of the steel tape. Even if the same flat ruler is used, the measurement error caused by the deformation fluctuation cannot be eliminated.
2) Unless a mechanical device is used instead of manpower, it is difficult to stably maintain the steel tape with only manpower holding a spring balance and controlling the force value to 150N. The deformation of the steel tape caused by this unstable

Table 1. The steel tape correction value

Crane gauge m	Pull value N	Steel tape section size, mm			
		10×0.25	13×0.2	15×0.2	15×0.25
		Metering correction value, mm			
10.5;10	150	2.0	2.0	1.5	1.0
16.5;16;15.5		3.0	2.5	2.0	1.5
19.5;19;18.5		3.5	3.0	2.5	1.5
22.5;22;21.5		3.5	3.5	2.5	1
25.5;25;24.5		4	3.5	2.5	0.5
28.5;28;27.5		4	3.5	2.5	0
31.5;31;30.5		4	3.5	2	-0.5
34.5;34;33.5		4	3.5	1.5	-1.5

force is also inconsistent. That is: each time the lower deflection of the steel tape will fluctuate due to the fluctuation of the spring balance around 150N tension. This kind of fluctuation is difficult to eliminate in the case of only manual operation, which will inevitably lead to measurement errors.

3) The steel tape correction values given in Table 1 limit the cross-sectional dimensions of the steel tape. Steel tapes of other cross-sectional sizes cannot be used for gauge measurement unless the steel tape used for the field measurement is of the four cross-sectional sizes listed in Table 1.
4) Limits the range of crane gauges that can be measured. When the gauge is greater than 34.5m, there is no quoted correction value. For cranes with large gauge such as shipbuilding gantry cranes, this method cannot be used to measure.
5) If the steel tape is not perpendicular to the rail to be measured during the gauge measurement, it will cause a measurement error that is positively related to the cosine of the offset angle. At this time, the measured size is larger than the actual value, as shown in Table 2.

However, the relevant Chinese standards have the following provisions.

In “Gantry crane for general purpose” (GB/T 14406–2011) [3]: when the trolley gauge is not greater than 16m, the gauge tolerance should not exceed ± 2 mm at the end of the rail, [1, 5] in the middle of the rail (rail length not greater than 19.5 m) or [1, 7] (rail length greater than 19.5 m).

In “bridge crane for general purpose” (GB/T 14405–2011) [4]: For the trolley rail: when the trolley gauge S is not greater than 2 m, the gauge tolerance shall not exceed ± 2 mm; when the trolley gauge S is greater than 2m, the gauge tolerance shall not exceed ± [2 + 0.1(S-2)] mm; for crane operation Rail, when the rail S is less than 10m, the gauge tolerance does not exceed ± 2.5 mm, and when the rail S is greater than 10m, the rail tolerance does not exceed ± [2.5 + 0.1(S-10)] mm.

In “Portal slewing crane” (GB/T 29560–2013) [5]: At any point on the trolley rail, the allowable tolerance of the gauge K between the center line of the crane rail in the port and the shipyard is as follows: For K is not greater than 16 m, the tolerance is not greater than ± 5 mm, and if K is greater than 16 m, the tolerance is ± [5 + 0.25(K-16)] mm, the limit is ± 15 mm.

It can be seen that under the measurement offset angle given in Table 2, when the measurement offset angle is only offset to 5°, the measurement of the crane with a design gauge of 20 m has even deviated from 76 mm, which has greatly exceeded the standard value. Because the deviation is too large, the measurement data can no longer be used as

Table 2. Theoretical values under different offset angles and different design gauges

Gauge mm	Offset angle				
	1°	2°	3°	4°	5°
5000	5001	5003	5007	5012	5019
10000	10002	10006	10014	10024	10038
20000	20003	20012	20027	20049	20076

the basis for judging the inspection items. Even if the offset angle of the steel tape in the actual measurement is only 1°, in the case of a gauge of 20 m, there is still a deviation of 3 mm, which has formed a large measurement uncertainty. In practice, there are many cranes with a span of more than 100 m, in which case the deviation value will only be larger.

3 Improvement of Gauge Measurement Method

The Chinese government's normative document "Lifting Machinery Supervision and Inspection Regulations" was promulgated in 2002. It is a guiding document for all inspection agencies nationwide to carry out crane inspections. The geometric measurement methods and instruments that can be taken under the conditions at that time are limited, so the choice of steel tape to measure the size is in line with the national conditions at that time. With the remarkable improvement of China's economic level, the level of industry and technology is not the same as it was 20 years ago. To improve the inspection quality of crane gauge in terms of measurement accuracy and accuracy, it is necessary to choose more advanced measuring instruments or methods to replace the steel tape measure. Thanks to the development of electronic technology and instrument technology, today's laser rangefinder can achieve convenient measurement, high precision, and low cost. Therefore, when measuring various sizes of cranes, a steel tape measure is not used when a laser rangefinder can be used.

3.1 Laser Rangefinders Measure Track Distance Directly

A steel tape measure is a roll of steel with an accurate scale. It is necessary to straighten the "steel coil" when measuring, but in fact, the straightened steel coil must be deflected due to gravity, causing errors in the measurement. The laser rangefinder is an optical instrument, and the laser does not produce bending changes in the same medium, and will not produce errors due to the bending of the measurement path.

However, like measuring with a steel tape measure, when using a laser rangefinder to measure directly, it cannot be guaranteed that the measurement path is perpendicular to the track, and an offset angle will inevitably occur. It can be seen in Fig. 1. In practice, the measurement path has an offset angle α. The rail gauge L is equal to the value of the laser rangefinder multiplied by cosα. The measured value is larger than the actual value.

Therefore, compared with measuring with a steel tape measure, using a laser distance meter to measure the crane gauge has the following advantages:

1) In the process of measuring with a steel tape measure, the ruler is deformed and cannot be avoided. The deformation will inevitably affect the measurement accuracy. The principle of the laser rangefinder is different, so the measurement accuracy of the laser rangefinder is higher than that of the steel tape measure.
2) The steel tape measure has a limited range, generally up to 50m, which cannot measure the gauge of a larger size, while the laser rangefinder can easily achieve a range of hundreds of meters.

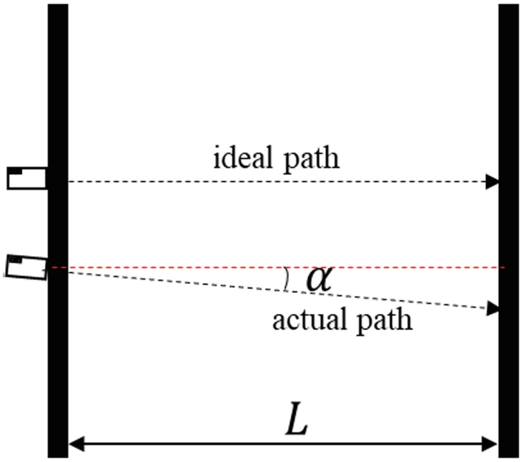

Fig. 1. Laser rangefinder measures rail gauge angle deviation

3) According to the method of "Regulations for the Supervision and Inspection of Lifting Machinery", the steel tape measure is used for measurement. The operation is complicated and requires the cooperation of many people, while the operation of the laser range finder is very convenient.

3.2 Measuring the Rail Gauge Based on the Three-Point Slant Distance Method Using a Laser Distance Meter

Direct measurement with a laser rangefinder cannot guarantee that the laser emission angle of the laser rangefinder is perpendicular to the track. However, the length of the side between three points on the track can be measured and the area can be obtained by Heron's formula. After obtaining the area of the triangle, divide the area by the length of the base between two points on the same track to obtain the height on the base, which is the gauge of the track.

Arrange three measurement marks on the centerline of the rail or at the same relative position, as shown in Fig. 2. Place the gimbal at any suitable position outside the track,

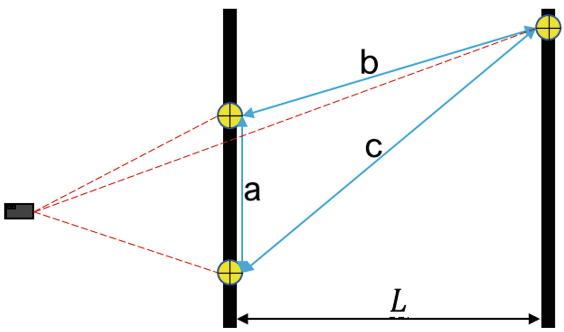

Fig. 2. Schematic diagram of laser rangefinder measurement based on three-points method

install the laser range finder on the gimbal, and select the point-to-point slant distance measurement mode. Measure the sloping distances between the three yellow marked points in Fig. 2, respectively, to obtain the lengths a, b, and c of the three sides of the triangle formed by the three points. According to Heron's formula:

$$S = \sqrt{p(p-a)(p-b)(p-c)} \tag{1}$$

where p is the half-perimeter. It is convenient and quick to find the area of a triangle composed of three points. Using the area of the triangle, the height on the base a of the triangle can be obtained as 2S/a, which is the measured rail gauge. Compared with the direct measurement with the laser rangefinder, this method has the following advantages:

1) Since this value is calculated by measuring the lengths of the three sides of the triangle. If the accuracy of the instrument is reliable during the measurement process and the three marking points are selected accurately, the measurement value of the gauge is accurate and reliable.
2) The position of the measuring instrument is flexible and can be placed in any suitable position.
3) Arranging multiple points and combining multiple triangles to obtain the degaussing distance can further improve the measurement accuracy.

4 Epilogue

In the process of test and inspection of cranes, the gauge is measured in an appropriate way, and the measurement uncertainty is controlled within the range as small as possible, so that reliable data can be obtained. According to these data, the actual status of the crane can be accurately grasped, and reliable data support can be provided for evaluating the safety status of the crane. If conditions permit, the method of measuring the crane rail gauge based on the three-point slant distance method using a laser distance meter is reliable, with good data repeatability, and the measurement process is simple and convenient.

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