Influence Analysis of Rated Capacity on Stress Level of Portal Slewing Crane Based on Data Mining

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Abstract. Portal slewing crane is used frequently and the working conditions is poor. Rated capacity is the main technical parameter of crane. In this paper, according to different rated capacities, high stress value measuring points are selected by means of statistical test data samples, and the relationship between the overall stress and the rated capacity as well as the distribution law of each position are determined. Furthermore, the stress distribution law of high stress value measuring points and the stress characteristics of each position on cranes with different rated capacities are excavated.

Keywords: Portal slewing crane; Rated capacity; High stress value measuring points; Stress characteristics.

1. Introduction
Portal slewing crane is used for cargo loading and unloading of ships and vehicles at ports. The most common type is combinatorial boom portal slewing crane (hereinafter referred to as portal crane), as shown in Fig.1. It has the characteristics of frequent use and large impact load [1]. Rated capacity is one of the most important technical parameters of portal crane, which refers to the maximum net weight that can be lifted by portal crane under normal working conditions [2]. Therefore, it has practical application value and safety guiding significance to carry out the research and analysis of rated capacity and overall stress distribution and stress characteristics of portal crane.

Fig. 1 Portal slewing crane
2. Rated Capacity and High Stress Value Measuring Points

According to the national standard GB/T 29560-2013 Portal Slewing Crane, the common rated capacity series values that can meet the requirements of hook/grab/magnet are 3.2T, 5T, 8T, 16T, 20T, 25T, 32T and 40T [3]. At present, the portal cranes at home and abroad are developing towards large-scale machinery. In addition to individual inland river wharfs, the types with rated capacities less than 20T can hardly be seen, while the portal cranes with rated capacities of 25T, 32T and 40T are widely used. Therefore, we select three categories with rated capacities of 25T, 32T and 40T respectively. In each category, fifty portal cranes from different ports and wharfs are selected as samples. Furthermore, we choose the same representative measuring points on each crane in each sample, which are respectively located in boom system, A-frame system and cylinder & portal. According to the relevant requirements [5] of transportation industry standard JT/T 1262-2019, the cranes are tested by static and dynamic load.

In static load test and dynamic load test results of each crane in each sample, the two measuring points with the largest stress value are defined as high stress value measuring points (hereinafter referred to as h-s-v measuring points). Furthermore, the distribution proportion of h-s-v measuring points of each type of portal cranes with different rated capacities in different positions is counted, and the results are shown in Fig.2.

![Fig. 2 Distribution proportion of h-s-v measuring points at various positions with different rated capacities](image)

As can be seen from the figure that no matter for the portal cranes with rated capacities of 25T, 32T and 40T, the distribution of h-s-v measuring points of each type with different rated capacities has quite dissimilarity, but the stress performance rules are roughly the same in its own static load test and dynamic load test. For the cranes with rated capacities of 25T and 40T, the distribution proportion of h-s-v measuring points is higher in A-frame system, while that is lower in boom system, which is especially obvious in static load test. For the cranes with rated capacity of 32T, the distribution proportion of h-s-v measuring points increases remarkably, even more than 50%, while that is low in A-frame system and cylinder & portal. On the whole, the changes of distribution proportion in different rated capacities are mainly concentrated in boom system and A-frame system, and changes in cylinder & portal are not very obvious.

Through calculation, the mathematical expectations and standard deviations of h-s-v measuring points of portal cranes with different rated capacities are shown in Table 1.

| Table 1. Stress characteristics of h-s-v measuring points with different rated capacities |
|----------------------------------------|------------------------|------------------------|------------------------|------------------------|------------------------|
| static load test                       | mathematical expectation (Q=25T) = 62.47MPa | mathematical expectation (Q=32T) = 70.06MPa | mathematical expectation(Q=40T) = 82.04MPa | σ₁(Q=25T) = 10.73MPa | σ₁(Q=32T) = 23.07MPa |
| dynamic load test                      | E₁ (Q=25T) = 69.60MPa                      | E₁ (Q=32T) = 79.98MPa                      | E₁ (Q=40T) = 91.40MPa                       | σ₂(Q=25T) = 14.17MPa | σ₂(Q=32T) = 25.28MPa |
|                                       | E₂ (Q=32T) = 79.98MPa                      | E₂ (Q=40T) = 91.40MPa                       | σ₃(Q=40T) = 26.12MPa                        |                       | 
It can be concluded from the data that in static load test and dynamic load test, with the increase of rated capacity, the mathematical expectations and standard deviations of h-s-v measuring points increase correspondingly. This shows that the average stress level and stress fluctuation also increase with the increase of rated capacity.

3. Stress Distribution Law and Stress Performance Characteristics of Rated Capacity 25T Cranes

Select the sample with rated capacity of 25T, and count the frequency of h-s-v measuring points in different stress intervals, as shown in Fig.3, and the stress performance characteristics in this sample are shown in Table 2.

![Fig. 3 Frequency distribution accumulation of h-s-v measuring points on 25T cranes](image)

As can be seen from the figure, the cranes with rated capacity of 25T are divided into six stress intervals. In static load test, the h-s-v measuring points are more concentrated in the range of 40~80MPa. However, in dynamic load test, the h-s-v measuring points are distributed in each stress interval of 40~100MPa, and the most concentrated in the interval of 60~70MPa.

|                         | mathematical expectation (static load test) | mathematical expectation (dynamic load test) | standard deviation (static load test) | standard deviation (dynamic load test) |
|-------------------------|---------------------------------------------|---------------------------------------------|---------------------------------------|----------------------------------------|
| boom system             | $E_b$ (sta) = 59.41MPa                      | $E_b$ (dyn) = 63.83MPa                      | $\sigma_b$ (sta) = 10.24MPa           | $\sigma_b$ (dyn) = 15.25MPa            |
| A-frame system          | $E_A$ (sta) = 63.68MPa                      | $E_A$ (dyn) = 73.08MPa                      | $\sigma_A$ (sta) = 11.34MPa           | $\sigma_A$ (dyn) = 14.05MPa            |
| cylinder & portal       | $E_c$ (sta) = 60.27MPa                      | $E_c$ (dyn) = 67.45MPa                      | $\sigma_c$ (sta) = 10.15MPa           | $\sigma_c$ (dyn) = 9.77MPa             |

According to the comparison of data in the table, no matter in static or dynamic load test, the mathematical expectations of h-s-v measuring points are the highest in A-frame system, followed by cylinder & portal, and the lowest in boom system. The standard deviations of h-s-v measuring points at each position have little difference in static load test, while the standard deviations in boom system and A-frame system are larger, and in cylinder & portal are smaller in dynamic load test. To sum up, the stress level of A-frame system is high and the stress fluctuation is large, while the stress level of cylinder & portal is low and the stress fluctuation is small, and the boom system is the middle level.
4. Stress Distribution Law and Stress Performance Characteristics of Rated Capacity 32T Cranes

Select the sample with rated capacity of 32T, and count the frequency of h-s-v measuring points in different stress intervals, as shown in Fig.4, and the stress performance characteristics in this sample are shown in Table 3.

![Frequency distribution accumulation of h-s-v measuring points on 32T cranes](image)

As can be seen from the figure, the cranes with rated capacity of 32T are divided into seven stress intervals. In static load test, the h-s-v measuring points are distributed in the range of 40~90Mpa, especially in the range of 60~90Mpa. However, in dynamic load test, all the h-s-v measuring points are distributed in the range of more than 50Mpa, and the most concentrated in the range of 60~100Mpa.

|                         | mathematical expectation (static load test) | mathematical expectation (dynamic load test) | standard deviation (static load test) | standard deviation (dynamic load test) |
|-------------------------|--------------------------------------------|---------------------------------------------|--------------------------------------|---------------------------------------|
| boom system             | $E_b (sta) = 65.43$MPa                    | $E_b (dyn) = 80.43$MPa                     | $\sigma_b (sta) = 9.41$MPa           | $\sigma_b (dyn) = 15.61$MPa           |
| A-frame system          | $E_A (sta) = 84.08$MPa                    | $E_A (dyn) = 95.87$MPa                     | $\sigma_A (sta) = 12.58$MPa          | $\sigma_A (dyn) = 13.09$MPa           |
| cylinder & portal       | $E_c (sta) = 57.76$MPa                    | $E_c (dyn) = 68.57$MPa                     | $\sigma_c (sta) = 11.15$MPa          | $\sigma_c (dyn) = 12.07$MPa           |

According to the comparison of data in the table, no matter in static or dynamic load test, the mathematical expectations of h-s-v measuring points are the highest in A-frame system, followed by boom system, and the lowest in cylinder & portal, and those in A-frame system are obviously higher than the other two. The standard deviations of h-s-v measuring points at each structure have little difference. In conclusion, the stress level of A-frame system is relatively high, and the stress fluctuation of the three is relatively close.

5. Stress Distribution Law and Stress Performance Characteristics of Rated Capacity 40T Cranes

Select the sample with rated capacity of 40T, and count the frequency of h-s-v measuring points in different stress ranges, as shown in Fig.5, and the stress performance characteristics in this sample are shown in Table 4.
As can be seen from the figure, the cranes with rated capacity of 40T are divided into eight stress intervals. In static load test, the h-s-v measuring points are more concentrated in the range of 60~100Mpa, especially in the stress interval of 80~90Mpa. However, in dynamic load test, all the h-s-v measuring points are distributed in the range of more than 60Mpa, and the most concentrated in the stress interval of 90~100Mpa.

Table 4. Stress characteristics of h-s-v measuring points at various positions on 40T cranes

|              | mathematical expectation (static load test) | mathematical expectation (dynamic load test) | standard deviation (static load test) | standard deviation (dynamic load test) |
|--------------|-------------------------------------------|---------------------------------------------|--------------------------------------|---------------------------------------|
| boom system  | \( E_b^{(sta)} \) = 81.06MPa              | \( E_b^{(dyn)} \) = 93.61MPa               | \( \sigma_b^{(sta)} \) = 40.29MPa    | \( \sigma_b^{(dyn)} \) = 41.05MPa    |
| A-frame system | \( E_A^{(sta)} \) = 80.23MPa            | \( E_A^{(dyn)} \) = 90.20MPa               | \( \sigma_A^{(sta)} \) = 17.33MPa    | \( \sigma_A^{(dyn)} \) = 17.63MPa    |
| cylinder & portal | \( E_c^{(sta)} \) = 85.08MPa        | \( E_c^{(dyn)} \) = 92.07MPa               | \( \sigma_c^{(sta)} \) = 24.22MPa    | \( \sigma_c^{(dyn)} \) = 25.54MPa    |

From the comparison of data in the table, whether in static or dynamic load test, the mathematical expectations of h-s-v measuring points are all high in boom system, A-frame system and cylinder & portal, but there is no significant difference among them. However, the standard deviations in boom system are the largest, followed by cylinder & portal, and the minimum in A-frame system. Compared with other sample groups, the overall standard deviations of the three are relatively large. Above all, the stress level of A-frame system is high and the stress fluctuation is large, while the stress levels of each structure are all high, and the stress fluctuation of boom system is the largest.

6. Conclusion

The overall stress level and stress fluctuation of portal cranes increase with the increase of rated capacity, and the number of stress distribution intervals also gradually increase with the increase of rated capacity. With the increase of rated capacity, the distribution proportion of h-s-v measuring points on boom system shows a trend of first increasing and then decreasing. In the longitudinal comparison of each group of samples, when the rated capacity reaches 40T, the stress level and the stress fluctuation of boom system both have a sudden increase, so special attention should be paid to this point in the production.
With the increase of rated capacity, the distribution proportion of h-s-v measuring points on A-frame system shows a trend of first decreasing and then increasing. In the longitudinal comparison of each group of samples, when the rated capacity exceeds 32T, the stress level and the stress fluctuation of A-frame system reach a relatively stable statue, and no longer have an obvious increasing trend.

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