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Research of The Design Life of Casting Crane Girder

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ABSTRACT: Casting crane widely used in iron and steel plant, which mainly used for lifting liquid metal. As frequent use, high full load rate, working environment dust, high temperature characteristics, it is especially pronounced safe life issues. The difference of service life and design life of casting crane is great. In order to study the design life of the main beam, The 13 S— N (stress— life) curves of the IIW (Institute of Welding International) standard are adopted to calculate the cycle times of the main beam. This study provides theoretical support and basis for the renewal of the casting crane and the discarding of the products.

Keywords: casting crane; main beam; design life; IIW standard; cycle times; S— N curves

I. INTRODUCTION

Casting cranes are mainly used for high-temperature liquid steel under the high temperature of the steel. Due to the frequent use, high load factor and complex working environment[1], the safety and service life has always been the focus of attention of enterprises and countries[2-4]. The life of traditional cranes is usually based on experience or related industry documents to predict, or based on a one-year maintenance records evaluation of machine performance life. In order to ensure the safe use of the casting crane, it is very important to study the fatigue life accurately.

1 Fatigue allowable stress model of main girder

The load of the main girder of the casting crane is asymmetrical cyclic stress. The cycle characteristics are $r = \frac{\sigma_{\min}}{\sigma_{\max}}$, $0 < r \le 1$.It is usually the main girder of the cycle characteristics of r which is between 0.24 to 0.32, in order to simplify the calculation, the average value of r=0.28 [5]. In the process of work, the number of stress cycles of the structural fatigue failure decreases with the increase of the stress amplitude, and the number of cycles here is the service life of the casting crane [6-7]. Generally, the tensile stress and compressive stress of the structure[8-9] are respectively:

tensile stress：

$$[\sigma_{rt}] = \frac{1.67[\sigma_{-1}]}{1-(1-\frac{\sigma_{-1}}{0.45\sigma_b})r} \tag{1}$$

compressive stress：

$$[\sigma_{rc}] = 1.2[\sigma_{rt}] \tag{2}$$

GB/T3811 specifies the allowable fatigue stress value $[\sigma_{-1}]$ of the Q235 and Q345 materials under different working conditions of the E, figure 1 is the allowable stress of the main girder of the casting crane at different working levels [10].

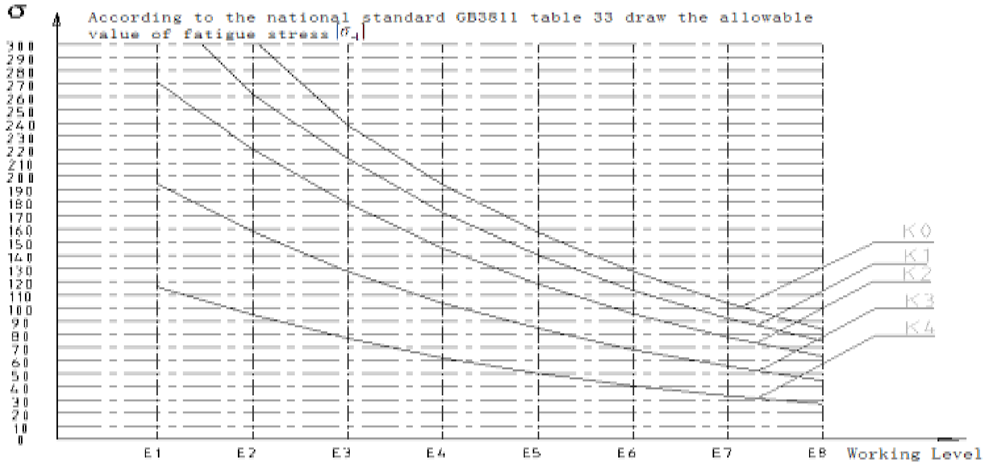

Fig.1.The basic allowable stress of the main girder of the casting crane under different working conditions

It can be seen from Fig. 1 that (1): the stress concentration level K of the weld directly affects the basic value of the allowable stress of the main girder, and the basic value of the allowable stress of the main girder can be improved by reducing the stress concentration level of the girders ;(2): the higher the structural level of the structural member, the lower the fatigue allowable stress.

2 The relationship between the allowable fatigue stress of main girder and the number of cycles

The International Welding Association IIW standard is the main method of fatigue life assessment [11]. IIW standard is a complete scientific system, which provides a large number of steel and aluminum materials welded joints S - N curve data [12-13]. From the point of view of supporting anti-fatigue design, the contribution of these data is beyond the reach of other ARR standards (the North American Railway Association standard), the EN standard (European standard), the BS standard (British steel structural fatigue design and evaluation criteria). These data represent the fatigue strength of welded joints of nearly one hundred steel structures, and the fatigue strength of the welded joints of different classes is shown in figure 2.

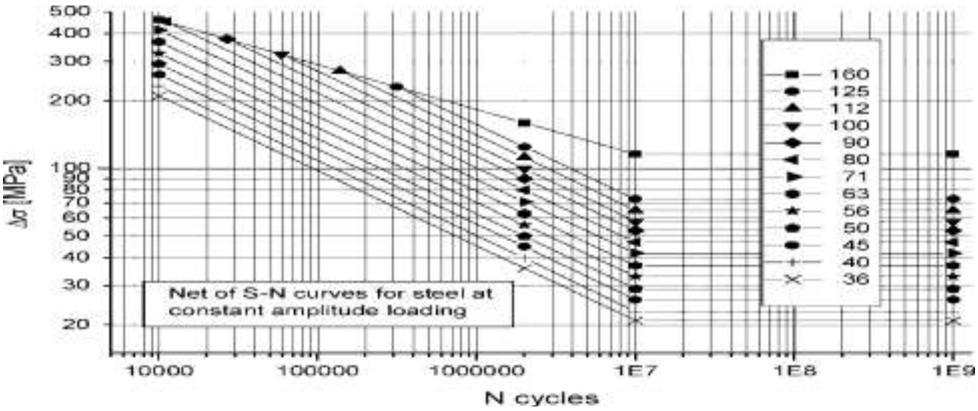

Fig.2 Different types of welded joints fatigue strength S-N curve

According to the deflection beam of the casting crane, the structure of the welding seam is different in different sections and different parts, as shown in Figure 3, and it will also correspond to different fatigue strength curves about Fig2.

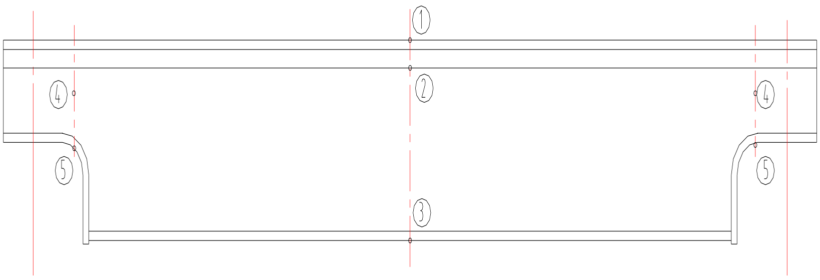

Fig.3 Fatigue risk point of main girder

point①——K1 stress concentration level——125 fatigue curve
point②——K1 stress concentration level——125 fatigue curve
point③——K2 stress concentration level——100 fatigue curve
point④——K0 stress concentration level——160 fatigue curve
point⑤——K3 stress concentration level——80 fatigue curve

According to Fig.1, the basic values of the fatigue allowable stress defined by the structural members at the E7 and E8 working stages are listed in Table 1

Table 1 Allowable fatigue stress values of welded components determined by GB/T3811

Component level	Tensile and compressive fatigue allowable basic stresses $[\sigma_{-1}]$ (N/mm2)			
	K0	K1	K2	K3
E7	103.5	92	77.6	55.4
E8	84	75	63	45

In this paper, the metal structure of the casting crane is Q235, its tensile strength is $\sigma_b = 370N/mm^2$.It can be seen from Fig. 3 that the stress point of fatigue of the main girder is mainly tensile stress and compressive stress. Due to space constraints, this paper selects ① and ③ two points for fatigue life analysis.
Based on the allowable stress values of welded components in table 1, $r = 0.28$,take these data into the formula (1), as shown in formula (3), so it can be obtained E7, E8 working level corresponding to the point ③ allowable fatigue stress; take these data into the formula (2), as shown in formula (4), so it can be obtained E7, E8 working level corresponding to the point ① allowable fatigue stress. The results are shown in Table 2.

$$[\sigma_{rt}] = \frac{1.67[\sigma_{-1}]}{1-(1-\frac{\sigma_{-1}}{0.45\times 370})\times 0.28} \quad (3)$$

$$[\sigma_{rc}] = 1.2[\sigma_{rt}] \quad (4)$$

According to the IIW standard, the fatigue curve of 160 corresponding to K0, the fatigue curve of 125 corresponding to K1, the fatigue curve of 100 corresponding to K2, the fatigue curve of 80 corresponding to K3, and the corresponding number of cycles according to the working level E7 and E8 in Fig. 2.The detailed fatigue life results are shown in Table 3.

Table 2 $r = 0.28$, $\sigma_b = 370N/mm^2$ corresponding to $[\sigma_{rt}]$ and $[\sigma_{rc}]$

Component level	Tensile fatigue allowable stress $[\sigma_{rt}]$ (N/mm2)			
	K0	K1	K2	K3
E7	193.3	175.6	152.4	113.8
E8	162.9	148.0	127.4	94.4
Component level	Compressive fatigue allowable stress $[\sigma_{rc}]$ (N/mm2)			
	K0	K1	K2	K3
E7	232.0	210.7	182.9	136.6
E8	195.5	177.6	152.9	113.3

Table 3 $r = 0.28$, $\sigma_b = 370N/mm^2$ corresponding to fatigue life

Component level	Tensile stress fatigue life (stress cycle number)			
	K0	K1	K2	K3
E7	7.0×10^5	7.0×10^5	6.3×10^5	7.0×10^5
E8	1.2×10^6	1.2×10^6	1.0×10^6	1.2×10^6
Component level	Compressive stress fatigue life (number of stress cycles)			
	K0	K1	K2	K3

E7	1.2×10^5	3.0×10^5	1.3×10^5	5.3×10^5
E8	7.2×10^5	7.2×10^5	6.3×10^5	7.0×10^5

As can be seen from Table 3, at the E7,E8 working level, the point ③ is the tensile stress cycle, the corresponding K2 stress concentration of the number of cycles is 6.3×10^5 and 1.0×10^6; but K2 stress state cycle times are $5.0 \times 10^5 \sim 1.0 \times 10^6$ and $1.0 \times 10^6 \sim 2.0 \times 10^6$ under GB / T3811 for the work level E7, E8; At the E7, E8 working level, the point ①of the compression stress cycle, the corresponding K1 stress concentration cycle of the number of cycles are 3.0×10^5 and 7.2×10^5, K1 stress compression cycle times are $2.5 \times 10^5 \sim 5.0 \times 10^5$ and $5.0 \times 10^5 \sim 1.0 \times 10^6$ under GB / T3811 for the work level E7, E8. Thus, the main girder cycle calculated by IIW standard calculation method meets the requirements of GB / T3811, which is equivalent to the IIW standard to verify the number of cycles specified by GB/T3811.

II. CONCLUSION

By consulting the GB/T3811 and IIW standard stress life curve, the calculated results can meet the requirements of the stress cycle number of the main girder specified by GB/T3811. Through the S-N curve to find the number of cycles with a certain degree of accuracy, rather than the provisions of a certain range of national standard range, not only can the design staff be provided by some references, but also the number of cycles provides a relatively accurate theoretical basis for the casting crane product replacement and retirement. Later, we can try to use the limit stress state method and crack propagation theory to further study the design life, the results can be compared with the results of this study, mutual verification.

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