Adjusting of polar crane running gear at the corporate customer site

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Abstract. The article discusses the issues of adjustment of polar cranes at the customer site. It shows that the defining characteristics when adjusting the movement of the crane around the circumference are the geometric parameters of the running gear. It is noted that the repair-fit geometry of the bridge and the running gear of the crane corresponds to its non-stressed state. The non-stressed state of the crane characterizes the condition under which the deformations in its structural elements are absent or minimal. This crane position is achieved by installing it on the track in the middle between the two limiting states that are predetermined. It is emphasized that defects are eliminated exclusively in the running gear of the crane in the process of adjustment. Errors made in the process of manufacturing and installation are compensated during the crane adjustment. It is noted it refers to all errors made in the manufacture of structural elements as well as those made directly during their installation, and non-standard gaps in the moving parts of the crane determining their backlash.

1. Introduction

The history of using polar cranes as one of the main types of equipment began with the implementation of the project of nuclear power plants with a WWER-1000 reactor. This lifting structure is installed in the reactor compartment of nuclear power plant units, it is designed at the stage of installation of equipment for main lifting and transport operations in a pressure vessel. Transportation of covers with fresh fuel to the reactor compartment and removal of spent fuel from it occurs at the operational stage, during the current planned preventive work, and also accompanies mechanical installation work on equipment replacement in the restricted access area. In subsequent projects of NPP-2006 and WWER-TOI NPPs the use of cranes of a similar type for solving the same tasks continues.

At the construction stage of the customer’s facility the running gear and the crane bridge are mounted on a rail track during the erection of the shell when its dome part is missing. Then installation of the crane portal on the bridge of load-lifting carts, and electrical equipment is installed. After that the adjustment of the crane is performed. As a rule, the adjustment of the crane is performed at the stage when the dome of the shell is closed and concreting is performed. Adjustment of the crane running gear is performed on the basis of the following theory [1-9].
2. Basic theory

In general the actual geometric characteristics of the crane in a static state can be described by the equation

\[ F_{ki} = f^k_i(x_i, y_i, z_i)T_i, \]

or

\[ F_{ki} = f^k_0(x_0, y_0, z_0) + f^k_m(\Delta x, \Delta y, \Delta z)_m + f^k_{deff}(\delta x_i, \delta y_i, \delta z_i)_{deff}, \]

where \( f^k_0(x_0, y_0, z_0) \) – design geometric characteristics of the crane;

\( f^k_m(\Delta x, \Delta y, \Delta z)_m \) – geometric errors in the position of the crane elements made during its manufacture and installation;

\( f^k_{deff}(\delta x_i, \delta y_i, \delta z_i)_{deff} \) – current deformation geometric characteristics of the crane.

When a crane moves in one direction or another there is a change in the relative position of its parts which determines the change in stress in its elements. The movement of the crane in one direction is associated with an increase in stresses in the running gear from the minimum to the maximum values, which in extreme conditions form an effort directed towards the discharge, exceeding the friction force of the wheel on the rail, and then the wheel slips along the rail unloading running gear. If the crane continues to move in the same direction, the wheel will soon slip again along the rail. This state of the crane will be called the limit. In case of change in the direction of crane movement there will be a gradual unloading of the running gear at first. Then the crane will go through the conditionally zero position of parasitic stresses and the stresses will begin to increase with continued movement, only their sign will be opposite to the stresses formed during the initial movement. As a result, wheel slip conditions along the rail will also be formed in this direction of movement. Thus, a second conditionally opposite limit state of the crane will be formed. It means that, in general terms, the actual geometric characteristics of the crane are a variable function depending on the size of the path traveled:

\[ F_{ki} = f^k_0(x_0, y_0, z_0) + f^k_m(\Delta x, \Delta y, \Delta z)_m + \int_{L_0}^{L_i} f^k_{deff}(\delta x_i, \delta y_i, \delta z_i)_{deff} \cdot dx \cdot dy. \]

where \( L_0, L_i \) – boundaries of the crane use.

The unloaded position or the position in which parasitic stresses in crane designs are minimal is in the middle of a segment of the path as it moves from one limiting state to the conventional opposite one. In this case, we note the general rule that the repair-fit geometry of the bridge and a running gear of the crane corresponds to its unstressed state.

3. Method of determining the unloaded condition of the crane

As noted above, the methodology for assessing the technical condition of crane equipment is based on the rule that the repair-fit geometry of the bridge and a running gear of the crane corresponds to its unstressed state, every other one is private and it characterizes its private (original) condition. That is, the non-stressed state of the crane characterizes the condition when there are no (or minimal) deformations in its structural elements.

\[ f^k_{deff}(\delta x_i, \delta y_i, \delta z_i)_{deff} = 0. \]

Then the actual repair-fit geometry of the crane, in general, will be determined by the formula

\[ F_{ki0} = f^k_0(x_0, y_0, z_0) + f^k_m(\Delta x, \Delta y, \Delta z)_m. \]

Errors made in the process of manufacturing and installation of the crane, determine the defects of its movement and can be identified, compensated or removed in the process of adjustment. It should be taken into consideration that in the process of adjustment the defects in the movement of the crane can be corrected exclusively by its running gear.
The proposed method for determining the non-stressed state of the crane, which consists in determining the limit deformation states of the crane (I and II) on the track. These limiting states correspond to the condition, which can be described in general formulas

\[ f_{deph}^k(\delta x_n, \delta y_n, \delta z_n)_{deph} = + T'_{max}, \]

\[ f_{deph}^k(\delta x_m, \delta y_m, \delta z_m)_{deph} = - T''_{min}. \]  

In this case the signs of deformations are taken conditionally. Fixing these positions the interval (on the crane path) where the main changes occur the geometry of the crane is determined. Then the crane is moved to the center of this segment, i.e. in the position of conditionally "zero" (unstressed) state (III), see figure. A study of crane geometry is carried out in this position. The above sequence of actions is repeated \( n \) times for reliable control of the geometry of the crane.

\[ F_k(1) = f_0^k(x_0, y_0, z_0) + f_m^k(\Delta x, \Delta y, \Delta z)_{m} + f_{deph}^k(\delta x_1, \delta y_1, \delta z_1)_{deph} \]

\[ F_k(z) = f_0^k(x_0, y_0, z_0) + f_m^k(\Delta x, \Delta y, \Delta z)_{m} + f_{deph}^k(\delta x_2, \delta y_2, \delta z_2)_{deph} \]

\[ F_k(p-1) = f_0^k(x_0, y_0, z_0) + f_m^k(\Delta x, \Delta y, \Delta z)_{m} + f_{deph}^k(\delta x_{p-1}, \delta y_{p-1}, \delta z_{p-1})_{deph} \]

\[ F_k(p) = f_0^k(x_0, y_0, z_0) + f_m^k(\Delta x, \Delta y, \Delta z)_{m} + f_{deph}^k(\delta x_p, \delta y_p, \delta z_p)_{deph} \]

An average value is taken as the final results characterizing the unstressed state of the crane

\[ \frac{\sum_{i=1}^{p} F_{ki}}{p} = f_0^k(x_0, y_0, z_0) + f_m^k(\Delta x, \Delta y, \Delta z)_{m} + \frac{\sum_{i=1}^{p} f_{deph}^{k(i)}(\delta x(i), \delta y(i), \delta z(i))_{deph}}{p} . \]  

In this case, the value of the third term in the right-hand side of equation (8) tends to zero as, in the general case, the quantities \( \delta x_i, \delta y_i, \delta z_i \) are random. Therefore, the parameters of repair-fit geometry are determined by analyzing the expression

\[ \overline{F_k} = \frac{\sum_{i=1}^{p} F_{ki}}{p} . \]  

The characteristics of straightening are determined from the difference

\[ \Delta F_k = \overline{F_k} - F_{k0} , \]  

where \( \Delta F_k \) – wheel alignment values;

\( \overline{F_k} \) – values of parameters of the actual geometrical position of the traveling wheels;

\( F_{k0} \) – values of the parameters of the design geometric position of the traveling wheels.

Attention should be paid to the fact that the limiting states (I and II), estimated by the specific numerical characteristics of the crane, are close (usually equal) values depending on the crane mass, wheel friction coefficient on the rail, wheel shape and rail head, and area of wheel and rail contact, etc.
They are achieved by moving straight and back in the general case with a different order of increasing stresses in the structural elements of the crane. Changes in stresses in the elements of the crane as a function of the distance traveled depends, moreover, on the design of the crane elements.

Here it is necessary to consider the symmetric and asymmetrical design solutions of the crane and, as a result, the symmetric and asymmetrical buildup of stresses in the crane elements relatively to the “zero” state, when parasitic stresses are completely absent in the crane structural elements.

The symmetry control of the crane deformations during its movement is the equality of the arithmetic mean values of geometric parameters determined by the characteristics obtained from the crane installed in fixed diametrically opposite limit positions (+\(T_{\text{max}}\), \(-T_{\text{max}}\)) and the geometric parameters of the crane installed at the center of this interval \(F_{kL/2}\).

\[
\frac{F_{-T_{\text{max}}} + F_{+T_{\text{max}}}}{2} \cong F_{kL/2}
\]

Definition of limit states and the study of symmetry of changes in crane deformations is possible to carry out by our proposed method:

Method of side leveling. A vertically oriented reference plane (for example, the collimation plane of the tacheometer) is formed in the zone of the main balancers sequentially on each side of the crane. The device is oriented along the transverse axis of the crane, and the crane is rolled, sequentially, in two mutually opposite directions. When moving the crane, the rails mounted horizontally and perpendicularly to the direction of movement are observed on the main balancers. When registering a complete attenuation of changes in counts, the movement of the crane is stopped. Having performed the counting on the scale of the slats which characterizes the limiting state of the crane balancer (leaving the trajectory of its design movement), they begin to move in the opposite direction before registering the opposite critical state. The position of the crane is fixed on the track at its limiting states (+\(T_{\text{max}}\), \(-T_{\text{max}}\)) at the places of registration of maximum readings on rails located on balancers.

![Figure 1. The movement trajectory of the wheel contact patch on the track during non-standard crane operation.](image)

4. Monitoring of the crane geometric parameters and the definition of the straightening of its traveling wheels

Fixing the position of the limit states +\(T_{\text{max}}\) and \(-T_{\text{max}}\) on the rail, the crane is move to the location of the “unstressed” state. If the design of the undercarriage is symmetrical, the “zero (non-stressed)” state of the crane will be in the center of the segment, between the +\(T_{\text{max}}\) and \(-T_{\text{max}}\) positions, its ultimate states. Then a complete study of the geometry of the crane is performed. At the same time the relative position of the main and end beams, the main balancers, the small balancers and the traveling wheels relative to the longitudinal and transverse axes of the crane, which intersection point is its optimum center, is controlled. After that, successively, the crane is moved to the zones of its limiting states, and a full
study of its geometry is carried out at each statement of the crane. When processing the results of the crane survey, the symmetry of the deformation process of the crane metal structures is evaluated (11). Then the geometric parameters of the repair-fit geometry are determined (9) and the size of the alignment of the travel wheels (10).

After that recommendations are developed for restoring the regulatory characteristics of the crane running gear based on the parameters $\Delta F_{k}$.

In conclusion, it should be noted that the customer’s enterprise may adjust the crane, up to the regulatory requirements of its movement, only having boxed mounting of the traveling wheels in balancers. Such work can be performed only at the factory for cranes with non-axle installation of the travel wheels in small balancers as the repair of the running gear is made by replacing small balancers with geometric defects.

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