The Optimization of Pivot Points of Crane Telescopic Jib Based on Genetic Algorithm

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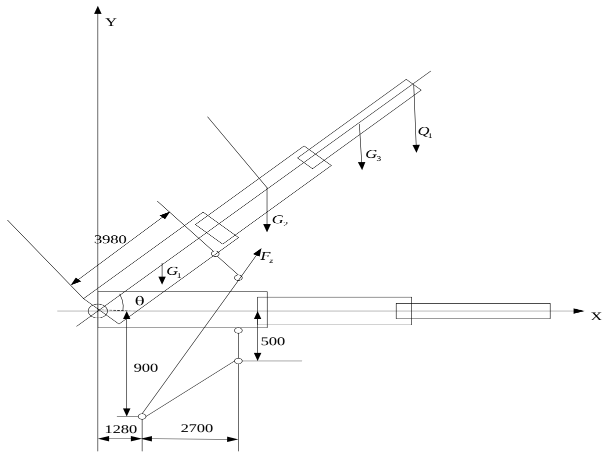
Abstract. Pointing at the system of pivot points of crane telescopic jib, the working condition of crane telescopic jib is selected. And based on this, setting the minimum force of luffing cylinder as optimization goal, the bounds of optimization variables, geometry size, motion constraints and cylinder constraints as constraints, Genetic Algorithm is used to finish the optimization. The force on the cylinder is optimized, and this can provide reference for the design of the pivot points of crane telescopic jib.

Keywords: Telescopic Jib, Pivot Points, Genetic Algorithm.

1. Introduction

The crane telescopic jib is a key part which can affect the overall performance, the locations of pivot points have a direct impact on the stress of the telescopic jib. According to the reflection from the customer service, the weld bead locations of the pivot points of cylinder usually crack after a period of usage. In order to avoid this situation, many crane manufacturers come up with the solution of welding stiffeners on the cylinder support base, but this will increase the weight of the cylinder support base, and the overall heavyweight costs increased. In addition, the locations of the pivot points have an effect on the thrust size and the stability of telescopic jib, therefore it's necessary to optimize the locations of the pivot points. The optimized points should satisfy the condition that the tress on the cylinder reaches its minimum under the premise to meet the lifting moment.

2. The Stress Analysis of the Pivot Points and the Selection of Working Condition



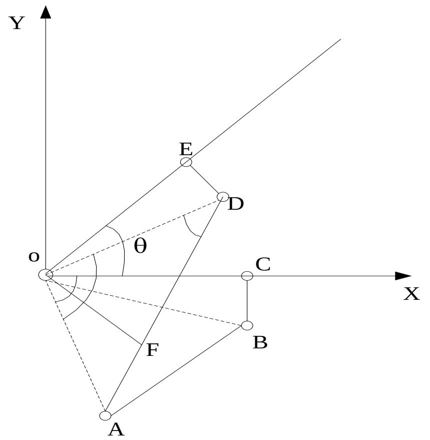


Fig. 1 The stress and size of the luffing mechanism Fig. 2 Luffing mechanism calculation diagram

As we all know that the stress on the luffing cylinder gets its maximum at the beginning moment with a certain weight. But for the different rated load under different conditions, we should figure out the condition when the stress on the cylinder reaches the maximum, and then make the optimization.

As is shown in picture 1, the initial data is that:

The distance from the support point of the luffing cylinder to the back pivot point of the telescopic jib: BC=DE=500mm, to the below pivot point is 2700mm, and to the vertical distance is 400mm. The distance from the back pivot point to the below one is 1280mm, and to the supporting point on the telescopic jib is 3980mm.

We can get that:

$$F_z = \frac{\varphi_1(G_1 l_1 + G_2 l_2 + G_3 l_3) + \varphi_2(Q_0 + G_0)L}{l_z}\cos\theta \quad (1)$$

Among this:

G_1, G_2, G_3 is the gravity of the first, second and third telescopic arm;

l_1, l_2, l_3 is the length of the centroid of the first, second and third telescopic arm

F_z is the thrust force of the cylinder

l_z is the arm of the cylinder's thrust force

The gravity of the luffing cylinder and some small components is ignored, and the mass of telescopic jib is assumed to be equally distributed, so we can get: W1 is 12142N, W2 is 8879N, W3 is 7242N. The length of the first telescopic arm is 9773mm, the second is 9738mm, and third is 9452mm.

Table 1 The Calculation of The First Telescopic Arm (10.2m)

Item	3	4	5	6	7	8
Rated load	20000	15100	12000	9500	7500	6100
Lifting angle	72.90	66.91	60.65	53.97	46.66	38.34
Luffing cylinder length	4567	4423	4267	4094	3899	3674
the thrust force	557926	532887	506058	463780	416487	381993

We can conclude from the computed data above that, when the length of the first telescopic arm is 10.2m, the amplitude is 3m, and the rated load weight is 20000kg, we can get the maximum of luffing cylinder's thrust force 557926N. So we can select this condition to make the optimization of the pivot points.

3. The Implementation of the Optimization

3.1. The Confirmation of Optimization Variables.

We can set up the coordinate with the back pivot point of telescopic jib as the origin, horizontal direction as the X-axis, vertical direction as the Y-axis. There are 5 parameters in the pivot points system:

$$X = (x_a, y_a, x_b) \quad (2)$$

That is $X = (x_1, x_2, x_3)$

3.2. The Confirmation of the Objective Function.

When we make the optimization for the pivot points, the objective function can be defined that:According to the functions above we can calculate the length that:

$$OB = OD = \sqrt{x_3^{\,2} + 2500}\,(mm) \quad (3)$$

$$OA = \sqrt{x_1^{\,2} + x_2^{\,2}}\,(mm) \quad (4)$$

$$AB = \sqrt{(x_1 - x_3)^2 + (x_2 + 500)^2}\,(mm) \quad (5)$$

$$AD = \sqrt{OA^2 + OD^2 - 2\times OA\times OD\times\cos(72.9^\circ + \arccos(\frac{OA^2 + OB^2 - AB^2}{2\times OA\times OB}))} \quad (6)$$

$$F_z = \frac{734236885\times AD}{OA\times OD\times\sin(72.9^\circ + \arccos(\frac{OA^2 + OB^2 - AB^2}{2\times OA\times OB}))} \quad (7)$$

3.3. The Confirmation of the Constraints.

3.3.1 The Bounds of Optimization Variables

According to the implement requests, the optimization variables should have bounds that:

$$x_{i\min} \le x_i \le x_{i\max} \, (i=1,2,3) \tag{8}$$

3.3.2 The Geometry Size Constraints

In the triangle OAB and OAD, we can conclude that:

$$OA+OB-AB>0\,;OA+AB-OB>0\,;OB+AB-OA>0 \tag{9}$$

$$OA+OD-AD>0\,;OA+AD-OD>0\,;OD+AD-OA>0 \tag{10}$$

3.3.3 The Motion Constraints

In order to make sure the stability of the luffing cylinder, the motion constraints should be given. When the telescopic jib is moving, the ratio of the maximum and minimum of the luffing cylinder's length is defined contraction ratio. According to the cylinder design specifications we know that the contraction ratio range from 1.6 to 1.7, so the constraint can be given that:

$$1.6 \le \lambda = \frac{l_{y\max}}{l_{y\min}} \le 1.7 \tag{11}$$

In this paper, the lifting angle reaches its maximum 74.4°when the length of the cylinder reaches its maximum, and it is on the minimum position when the telescopic jib is horizontal, so we get that:

$$1.6 \le \frac{\sqrt{OA^2+OD^2-2\times OA\times OD\times\cos(74.74^\circ+\arccos(\frac{OA^2+OB^2-AB^2}{2\times OA\times OB}))}}{2730} \le 1.7 \tag{12}$$

3.3.4 The Size of Cylinder Constraints

According to the cylinder design specifications, there should be cylinder head at the two end of the cylinder, so the length of the cylinder should be bigger than the sum of the stroke and the size of the cylinder heads:

$$\Delta l_y + (T_1+T_2) - l_{y\min} > 0 \tag{13}$$

$$\sqrt{OA^2+OD^2-2\times OA\times OD\times\cos(74.74^\circ+\arccos(\frac{OA^2+OB^2-AB^2}{2\times OA\times OB}))} + (T_1+T_2) - 2l_{y\min} > 0 \tag{14}$$

4. The Analysis of the Optimization Result

The information about the location of the pivot points and the stress on the cylinder are shown in the picture as follows:

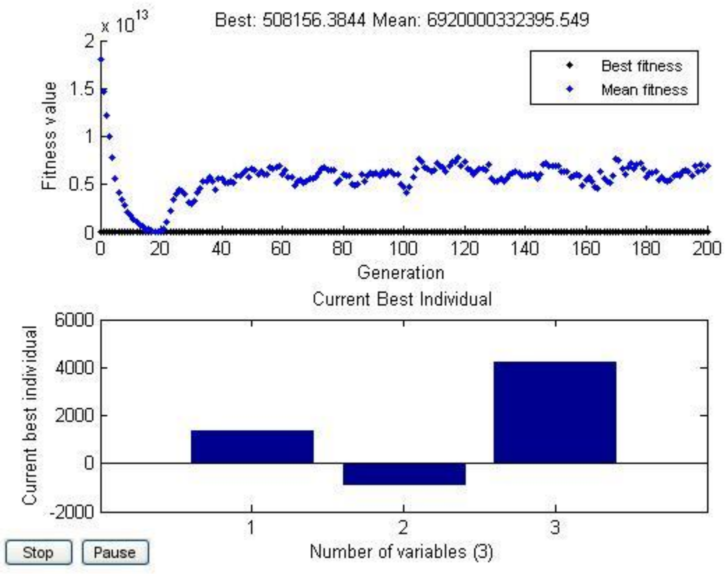


Fig. 3 optimization results of Genetic algorithm

Table 2 The Optimization Results

Item	x_1(mm)	x_2(mm)	x_3(mm)	The thrust force(N)
Before optimization	1280	-900	3980	557926
Optimized	1485.5	-713	4208	508156

According to the result of the optimization, the stress on the cylinder declines 8.92%, and the stress declines under every condition, so the optimization goal is optimized.

5. Conclusion

The condition that the stress of luffing cylinder reaches its maximum is confirmed with theoretical arithmetic, and the optimization is made with Genetic Algorithm. The result of the optimization shows that: the stress on the luffing cylinder is improved, and this is instructive in designing work of the telescopic jib.

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