Safety Analysis of Landing-Type Lifting Pole with Double-Level Arms under Wind Load Function

J. Qin
China Electric Power Research Institute
Beijing, China

H.S. Zhang
Harbin Institute of Technology
Harbin, China

J. Su
Shenyang Sanyo Building Machinery Co., Ltd
Shenyang, China

J.M. Zhang
China Electric Power Research Institute
Beijing, China

K.F. Huang
Peking University
Beijing, China

D. Ni
China Electric Power Research Institute
Beijing, China

***Abstract*—According to design requirements for landing-type lifting pole with double-level arms, the working conditions of landing-type lifting pole with double-level arms are proposed under different wind pressures and wind directions, and the component stresses of several important standard sections of pole body are calculated under different load factors. For standard sections whose main chord members cannot meet strength and safety requirements, this thesis considered adding hawser cables, thus obtaining the stress results meeting design requirements. Relevant calculation methods can be taken as reference for lifting pole design.**

Keywords-double-level arms; lifting pole; structural analysis; safety

I. INTRODUCTION

The landing-type lifting pole with double-level arms was developed from the construction tower crane[1]. The lifting pole is placed on the ground of iron tower center. For iron tower in transmission line which has the hollow structure and whose materials are distributed symmetrically about the pole body axle center during construction, the lifting pole is designed as the pattern with double arms[2], shown in Figure 1. Double hooks can lift objects in a balanced way within the ruled unbalanced moment difference. Besides the rated lifting capacity and rated lifting moment, the lifting pole still needs to control the lifting moment difference of double hooks automatically.

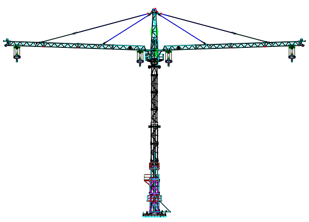

FIGURE Ⅰ.SP80 - LANDING-TYPE LIFTING POLE WITH DOUBLE-LEVEL ARMS.

The most unfavourable load combination is taken as designed working condition of lifting pole to check strength of components, thus ensuring safety. The height of lifting pole (maximum independent height) is taken as main calculated working condition based on the rated lifting capacity.

During the lifting operation process of iron tower, the wind load borne by lifting pole is changing with the rising of lifting part. The finite difference method (with each subsection of 10m) is adopted to work out the maximum wind loads on the lifting pole applied by lifting part and steel wire rope. With the changing of wind direction as well as the rotating and amplitude changing of lifting pole, the wind load also changes constantly, so the maximum wind load should be worked out from different angles.

II. WORKING CONDITION DESIGN OF POLE BODY

Composition of pole body: the pole body is 26.4m in height, and the lower 5 sections are common sections of 1.09m, while the upper 3 sections are pole body sections of 0.9m. The cross-section characteristics of pole body are shown in Table Ⅰ.

TABLE Ⅰ.THE CROSS-SECTION CHARACTERISTIC OF POLE BODY.

Main chord Cross-section	**Area(cm^2)**	**Inertia moment(cm^4)**	**Rotary radius(cm)**	**Slenderness ratio λ**	**φ**
□110×110×10, Q345B	37.425	569.36	3.9	38.46	0.9025

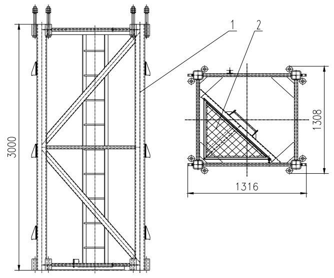

FIGURE Ⅱ.STANDARD SECTION OF POLE BODY.

The sizes of standard section of pole body are shown in TableⅡ.

TABLE Ⅱ.THE SIZES OF STANDARD SECTION.

Project	Length(mm)×Width(mm)× Height(mm)	Weight
standard sections without rest platform	1316×1308×3000	667.3
standard sections with rest platform	1316×1308×3000	682

There are 32 standard sections without rest platform when lifting pole is 150m (maximum working height). There is one standard section with rest platform each 3 standard sections without rest platform, and there are 16 standard sections with rest platform in 150m pole.

In this thesis, the wind loads under different wind pressures should be calculated firstly.

Working condition 1: wind pressure is 250Pa, blown from lateral.

Working condition 2: wind pressure is 250Pa, blown from rear.

Working condition 3: wind pressure is 1100Pa (abnormal), blown from lateral. Under this working condition, the lateral air blow is more dangerous than rear air blow, so it is only necessary to consider the lateral air blow.

The normal load factor is 1.0, static load factor is 1.25, and dynamic load factor is 1.1.

III. WIND LOAD CALCULATION OF POLE BODY

The ANSYS is adopted to calculate the overall load-bearing of SP80 under rated lifting capacity[3]. In the simplified model, the load above top of pole body is converted to the pole body top. The calculated load-bearing situations of various components of pole body in working conditions 1, 2 and 3 are as below:

Working Condition 1

(1) The calculation result of wind load/wind bending moment of pole top is shown in Table Ⅲ.

TABLE Ⅲ.CALCULATION RESULT OF WIND LOAD/WIND BENDING MOMENT OF POLE TOP.

Project	Wind load (kg)	Wind bending moment (kg.m)
Normal load	1352.85	4974.84
Static load factor 1.25	1477.85	5351.09
Dynamic load factor 1.1	1402.85	5125.34

(2)The load-bearing and stress of main chord in the lowest section (1.09m section) of pole body is shown in TableⅣ.

TABLE Ⅳ. THE LOAD-BEARING AND STRESS.

Project	Normal load	Static load	Dynamic load
Bending moment (kg.m)	40000	50000	44000
Wind bending moment (pole body root) (kg.m)	40446.5	26460.15	41908
Wind bending moment (kg.m)	10501.11	6300.67	10501.11
Total wind bending moment (pole body root)(kg.m)	50947.61	32760.82	52409.11
Gross weight of upper tower crane (kg)	28479	30816.5	29414
Main chord load-bearing (kg)	48838.84	45667.8	51577.86
Main chord stress (MPa)	144.6	135.21	152.71

A. Working Condition 2

(1) The calculation result of wind load/wind bending moment of pole top is shown in TableⅤ.

TABLEⅤ.CALCULATION RESULT OF WIND LOAD/WIND BENDING MOMENT OF POLE TOP.

Project	Wind load (kg)	Wind bending moment (kg.m)
Normal load	884.05	3102.4
Static load factor 1.25	997.8	3444.31
Dynamic load factor 1.1	929.55	3239.15

(2) The load-bearing and stress of main chord in the lowest section of pole body is shown in Table Ⅵ

TABLEⅥ.THE LOAD-BEARING AND STRESS.

Project	The lowest section (0.9m section)			The sixth section calculated from the bottom (0.9m section)		
	Norm-al load	Static load	Dyn-amic load	Norm-al load	Static load	Dyn-amic load
Bending moment (kg.m)	40000	50000	44000	40000	50000	44000
Wind bending moment (pole body root) (kg.m)	26282	17764	27612	13021	8783	13668

Wind bending moment (kg.m)	14848	8909	14848	2259	1355	2259
Total wind bending moment(pole body root)(kg.m)	41130	26673	42460	15280	10139	15927
Total bending moment(pole body root)(kg.m)	81130	76673	68860	55280	60139	59927
Gross weight of upper tower crane (kg)	28479	30816	29414	24629	26966	25564
Main chord load-bearing (kg)	59759	57451	63450	49596	53998	53481
Main chord stress (MPa)	176	170	187	146	159	158

(3) The calculation result of bolt strength is shown in TableⅦ.

TABLE Ⅶ. THE BOLT STRENGTH.

M30 Class 10.9	Normal load	Static load	Dynamic load	Allowable value
Tension force borne by single bolt (kg)	22759.77	21021.48	24371.93	27021
Shear force borne by single bolt (kg)	737.74	611.53	772.47	3867

Summary: Under working conditions 1 and 2, the height of tower crane is 26.4m, and the pole body consists of lower 5 common sections of 1.09m and upper 3 standard sections of 0.9m, and pole body and bolt strength are all qualified.

B. Working Condition 3

(1) The load-bearing and stress of main chord of standard tower is shown in TableⅧ.

TABLEⅧ. CALCULATION OF MAIN CHORD LOAD-BEARING AND STRESS.

Project	The lowest section (1.09m section)	The third section calculated from the bottom (1.09m section)	The sixth section calculated from the bottom (0.9m section)
Bending moment of pole top (kg.m)	0	0	0
Wind bending moment of pole top (pole body root) (kg.m)	177964.62	142249.44	88676.67
Wind bending moment of pole body (kg.m)	65333.71	39186.93	12425.53
Total wind bending moment of pole body root (kg.m)	243298.32	181436.37	101102.2
Total bending moment of pole body root (kg.m)	243298.32	181436.37	101102.2
Gross weight of upper tower crane (kg)	19129	17589	15279
Main chord load-bearing (kg)	162639.02	122116.76	83265.14
Main chord stress (MPa)	481.52 (unqualified)	361.55 (unqualified)	246.52 (unqualified)

(2) The calculation of hawser cable is shown in TableⅨ. The angle between hawser cable and ground is 80°.

TABLEⅨ.THE THIRD SECTION (1.09M SECTION) FROM THE BOTTOM.

Bending moment of pole top (kg.m)	0	
Total wind bending moment of pole body root (kg.m)	181436	
Horizontal force of hawser cable (kg)	7000	4000
Bending moment generated by horizontal force of hawser cable (kg.m)	185150	105800
Vertical force of hawser cable (kg)	39690	22680
Total bending moment of pole body root (kg.m)	—	75636
Gross weight of upper tower crane (kg)	17589	17589
Main chord load-bearing (kg)	14319	59141
Main chord stress (MPa)	42.4	175

(3) The calculation result of bolt strength (M30 Class 10.9) is shown in Table Ⅹ.

TABLE Ⅹ.THE BOLT STRENGTH.

Bolt M30 Class 10.9	Theoretical value	Allowable value	Remark
Tension force borne by single bolt (kg)	19503.56	27021	Qualified
Shear force borne by single bolt (kg)	2734	8635.5	Qualified

Summary: Under working condition 3, the height of tower crane is 26.4m, and the main chord stress of pole body exceeds allowable value in case that there is no hawser cable, so it is necessary to reduce two 1.09m sections and then add hawser cable, with the horizontal force borne by hawser cable of 4t-7t. At this time, the main chord stress should be within the allowable scope.

In a word, the pole body structure meets stability requirements.

IV. CONCLUSION

Through analysing the wind load borne by pole body of landing-type lifting pole with double-level arms, this thesis proposed wind load conditions under different wind pressures and wind directions, and has judged the safety and stability of pole body and bolt strength according to calculated load-bearing situations of various components of pole body under working conditions 1, 2 and 3.

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