The Analysis of a Wind Load on a Container Crane Using a Computation Fluid Dynamics

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Abstract

This study analyzed the fluid state around a container crane according to a wind direction when a wind load was applied to a container crane. The container crane for this research is a model of a 50-ton class used broadly in the current ports. The dimension of an external fluid field is 500m×200m.

This study considered the change of a wind velocity according to an altitude in a criterion of a wind velocity, 50m/s, applying a power series law. An incident angle applied to an interval of 30 degrees in 0° ~ 180° and this study carried out a computation fluid dynamics using a CFX 10.

In this study, we indicate the wind pressure and coefficient according to the height and section figure of each member. In addition, we suggest the wind load according to a wind direction.

Keywords: Container Crane, Computation Fluid Dynamics, Wind Load

1. Introduction

The container ships have been increase because the transition volume of a container has grown about 7% every year in proportion to economic globalization. As the competition of the shipping industry is strengthened since announcing the United States New Shipping Policy in 1984, the container ships have been larger to reduce a shipping expense a container. The 30~40 ships above 6,000TEU class are due to be launched until 2006 and the extra-large container ships of 12,000TEU class are expected to launch within 10years from now.

As the container ships are extra-larger, a marine transportation and berth are going to have an enormous influence. Therefore the volume to loading and unloading a container in one port is increased instead of decreasing the ports which the container ships anchor. The ports are namely divided into the Hub-port and Feeder Port according to touching the extra-large container ships and the role of each port is going to be mediated.(Yang et, 2002)

Hence each country is doing research about Port Loading Equipment for their domestic port to become a Hub-Port. The container crane of Port Loading Equipment is an equipment to load and unload a container from the ships. The larger is the container cranes, the lager the container ships and the container cranes must meet the requirements about operation system, automaton and swing.(Kim et, 2000)

The container crane operates in the condition to be no shielding facility. The container crane is self-gravity 850ton and its height comes close to the maximum 100m at mooring mode. Therefore, it may easily affect by a wind load. Especially, in the event of sudden attack by the typhoon “Maemi” totally 11 number of container crane was broken in the reason of heavy wind load. So, the function of a port is paralyzed.

Therefore this study analyzed the effect of the wind load of a container crane according to an incident angle from designing the fluid flow of wind to change the previous methods using the Finite Element Method. We will analyze the structural stability of a container crane to apply to the Fluid-Structure Connection Analysis.

2. Computation Fluid Dynamics

2.1 Wind load analysis

$$P = C_f \cdot C_A \cdot G_f \cdot q_Z \cdot A$$
$$q_Z = \frac{1}{2} \cdot \rho \cdot v_Z^2 \qquad (1)$$
$$V_Z = v_0 \cdot K_{Zr} \cdot K_{zt} \cdot I_w$$

P	:	Design wind load(kgf)
C_f	:	Wind load coefficient
G_f	:	Gust factor
C_A	:	Angle factor
q_z	:	Design velocity pressure(kgf/m2)
A	:	Area exposed the wind
V_z	:	Design wind velocity
V_0	:	Basic wind velocity
K_z	:	Wind velocity altitude distribution coefficient
K_{zt}	:	Wind extra coefficient
I_w	:	Importance coefficient

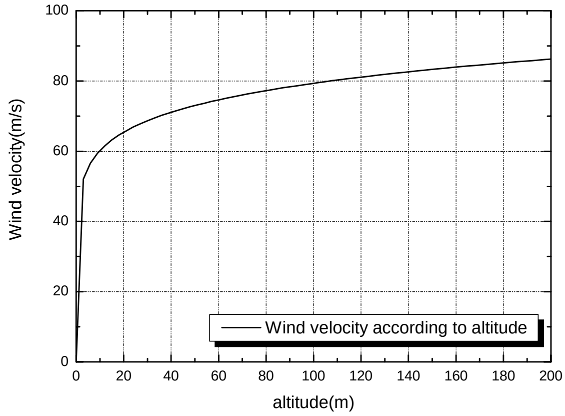

Figure. 1 Wind velocity according to an altitude

The Eq. (1) means the equation to calculate the wind load according to “Load Criteria of Building Structures”. This study indicates a wind pressure of a container crane.

ρ means an air density and v_z means a design wind velocity according to height in a wind pressure, q_z. The values of an air density, ρ is 0.125kgf·s^2/m^4.

2.2 Fluid field modeling

When the wind velocity, 75m/s is applied to a container crane, the wind flow according to height is designed in this study.

Eq. (2) means the design wind velocity according to height in observance of “Load Criteria of Building Structures”.

$$V_d = 1.925 \times (\tfrac{z}{500})^{0.12} \times 50 \qquad (2)$$

Figure 1.means the distribution of a wind velocity according to height to apply to Eq. (2). The wind velocity distribution is 45.6m/s in 1m and 86.2m/s in the maximum altitude, 200m

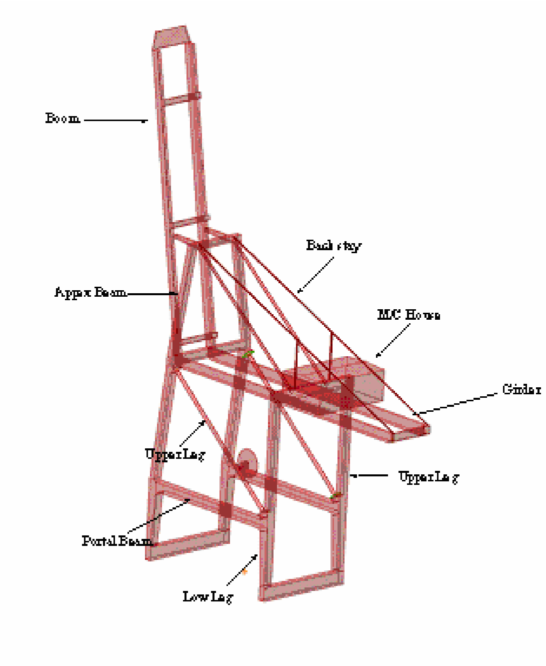

Figure 3. Structure drawing of a container crane

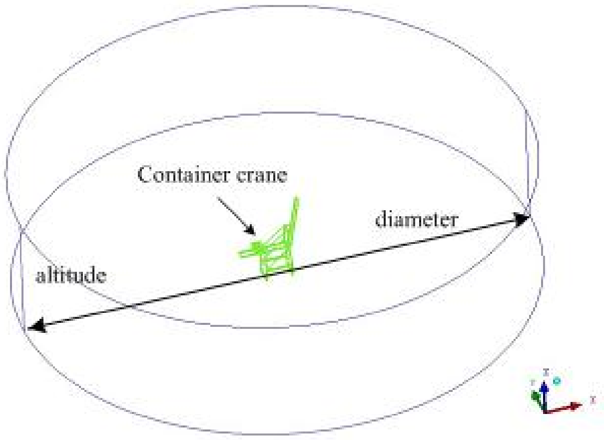

Figure 2. Fluid state around the container crane

The exponent of a right term, 1/α, applies 0.12 in the case of a port.

Figure 2. represents a container crane and fluid field. The shape of a fluid field applied the diameter of a cylinder, 500m, and height, 200m.

The fluid field went large to remove an influence by layers and a cylinder shape eliminated the repetition of meshing works in every angle which applies to this study. The results go more correct because of creating the same element number and the dense meshing size of about 2.6millions in surface of a container crane in every incident angle.

Figure 3. represents the container crane model to apply to this study.

A lift capacity is 50-ton, a total self-gravity 890ton, an out reach 51m, a rail span(distance between the land side and water side) 30.5m, the height from a land to a boom 40m and the height of a boom end 100m at the mooring mode. The water side(X-direction) area exposed to a wind is equal to 863m^2 and the land side(Y-direction) 997m^2. (Han Jin Heavy industry, 2000)

Figure 4. shows the direction of wind load in this study and Θ means an wind direction changed from 0-degree to 180-degree.

The incident angle is represented by the vector of a cylindrical coordinate system.

3. Analysis result

3.1 Wind load analysis according to an wind direction

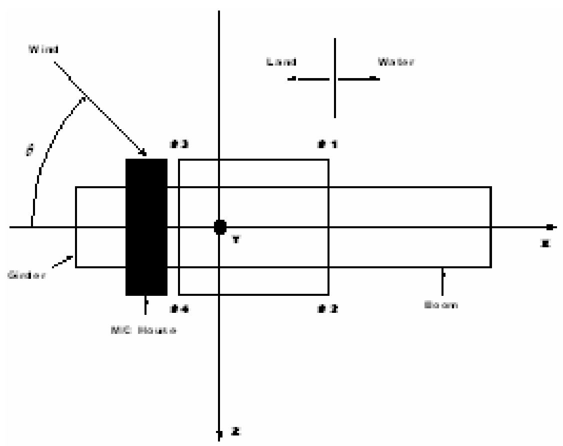

Figure 4. Definition of an incidence angle of a wind load

Table 1. Wind load of each part according to an incident angle

Units : N

	Low Leg	Upper Leg	Upper Dia.	Low Dia.	M/C	Portal Beam	Appex Beam	Girder	Boom	total
0°	92,976	225,389	23,102	2,788	246,802	19,247	331,937	293,419	267,913	2,215,400
30°	137,649	341,340	29,485	31,918	272,047	43,199	385,479	142,362	321,173	3,110,781
60°	158,300	317,766	61,870	59,254	248,783	112,675	259,560	326,622	457,650	3,316,419
90°	119,726	442,459	78,710	72,420	210,729	140,389	126,437	419,622	479,053	2,430,003
120°	159,307	307,305	61,615	58,672	254,245	116,607	260,982	309,848	457,620	3,257,883
150°	162,046	354,819	37,141	32,708	208,385	45,432	395,951	121,774	263,882	3,137,257
180°	96,010	240,318	14,727	6,090	104,053	803	414,715	5,026	75,044	2,322,532

Table. 1 represents the wind load of a container crane and main parts. The wind load applying to container crane is not the same value but change according to a wind direction.

The value of a maximum wind load is 3,300kN in 60-degree. The wind load of X, Y-directional front, 0 and 90 degrees, is smaller about 1,000kN.

The Leg part divides a Low Leg and an Upper Leg into a Portal Beam and the wind load of an Upper Leg doubles one of a Low Leg because the area of an Upper Leg exposed to wind and the wind velocity are larger.

The Portal Beam, Boom and Girder applies to the largest wind load in the front of an incident angle, 90-degree. The wind load of Boom and Girder in 90-degree is larger tha -0degree. The difference is 200kN. The Portal Beam is difference of 120kN because the area exposed to wind is fairly smaller than Boom and Girder.

The value of 180-degree is far smaller than 0-degree because of the influence of a shielding effect and the sectional shape.

Fig. 4 represents the wind load of X and Y-direction according to a wind direction. The X-directional wind load is 2,200kN in 0-degree but the maximum wind load is 2,500kN in 30-degree. The maximum wind load of Y-direction is 60-degree and the value is 2,900kN. The value of 90-degree is smaller 500kN.

3.2 Shielding effect

The shielding effect means that in spite of the same shape, the wind load of a back part is lower than one of a front part because the same two parts is parallel. The parts that the wind load applied largely to are a Portal Beam, Girder and Boom.

Table 2. means the wind load in the face according to a shielding effect in 90-degree. The wind load difference between a front and back part is approximately 50kN in the Portal Beam

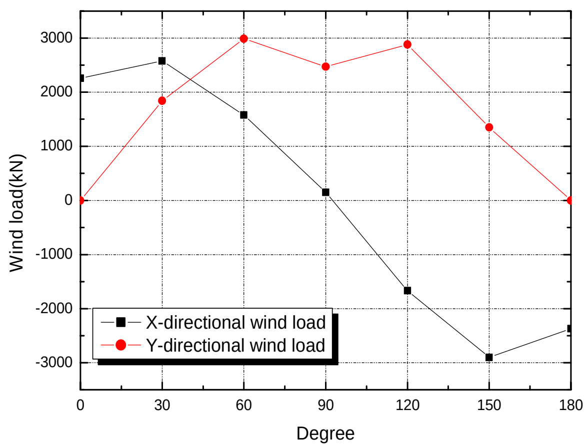

Figure 5. Wind load according to an incident angle

Table 2 The wind loads of each part by shield effect

	Portal Beam	Girder	Boom
Front	140kN	420kN	386kN
Back	92kN	41kN	110kN

and one of the Girder and Boom is each 400kN and 270kN.

The maximum shielding effect occurs in a Girder because the are a distance between two parts and the area exposed to a wind are relatively small.

Fig. 6 represents the the distribution of the wind pressure in a shielding face and the vector of a fluid flow in the Girder where the shielding effect occurs.

3.3. Comparison with the result of a wind force experience

The comparison of two results is given in the Fig. 2 and 3. The wind load of a X-direction is similar to the results of a wind force experience, but in the case of Y-direction, the nearer an incident angle is in the 90-degree, the larger a error is. The maximum error is 45% and occurs at 90-degree.

4. Conclusion

The model to apply to this study is the 50-ton class container crane used currently broadly in the ports.

The previous method applied to a load in each node with a finite element method used to analyze the structural stability of a 50-ton class container crane. But, the previous method couldn't apply correctly to the turbulence properties of wind. This study

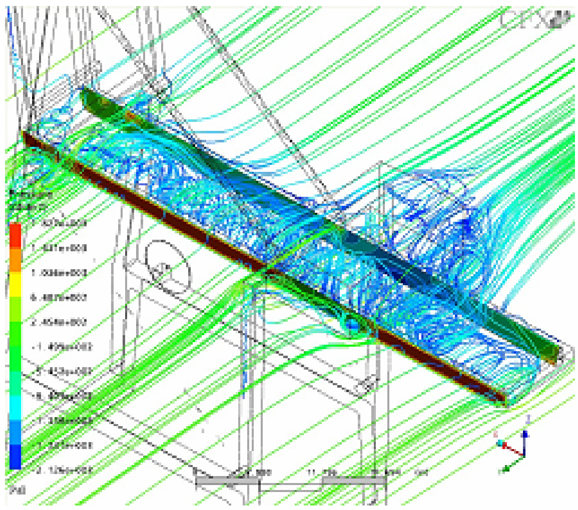

Figure 6. Fluid shape and wind pressure at the girder

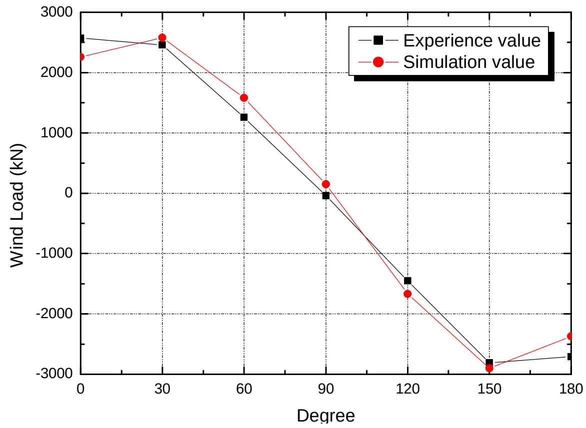

Figure 7. X-directional wind load according to an incident angle

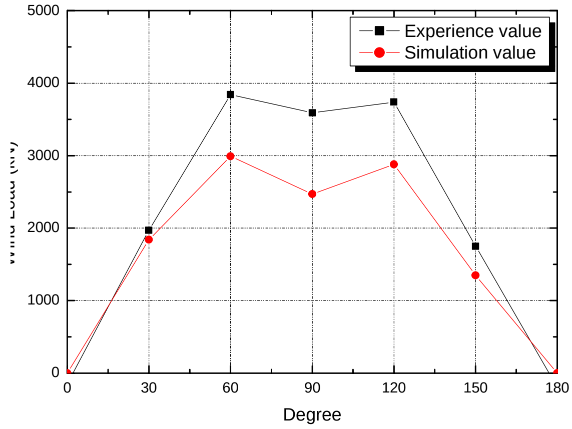

Figure 8. Y-directional wind load according to an incident angle

made up for a weak point to apply to the computation fluid dynamics.

As the results of this study, the maximum wind load apply to not the front of X and Y-direction but inclined direction. The maximum shielding effects occur at the Girder and the minimum 50kN in the Portal Beam.

In the case of comparing the results of the experience and simulation, the results are similar in the X-direction near 0° and 180° but the closer the incident angle comes to Y-direction, the larger the gap comes. The maximum difference is 45% in the 90-degree. We are due to reduce the error to analyze the difference of the fluid field.

We will apply to the structural stability analysis of a container crane to integrate a fluid-structure connection analysis with the wind load of this study and compare the results of this study with ones using the finite element method.

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Reference

Here are the samples of references.

1. P. J. Tailor, "GPS Ambiguity Fixing Concepts," *Chapter 3 of GPS for Positioning,* 2nd Edition, Springer, 1999, pp. 311-328..
2. Kim, K. H., Lee, Y. J., Lee, J. W. and Lee, K. S., "A Design and Characteristic Analysis of High Efficiency Gantry Crane," J. of KINPR, Vol. 14, No. 4, pp. 395-406, 2000.
3. Ministry of construction & Transportation of Korean Government (2000) : Load Criteria of Building Structure.
4. Han Jin Heavy Industry & construction Co. Ltd, "Structural &Mechanical Caculation for 50-ton Container Crane for Busan Port," 2000.
5. Lee, S. W., Shim, J. J., Han, D. S., Park, J. S., Han, G. J., Lee, K. S. and Kim, T. H, "The Effect of Wind Load on the Stability of a Container Crane" Journal of KSPE, Vol. 22, No. 2, pp.148-155