Wind influence on container handling, equipment and stacking

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Over the course of hundreds of hours per year, ports experience the influence of wind on nautical and terminal operations. This influence is increased by the global trend of ever increasing vessel sizes and the movement of ports to deeper water near or even beyond the coastline. The influence of wind and possible solutions to this problem are discussed in this article.

Introduction

Wind is an uncontrollable source of disturbances, reducing efficiency of port operations and sometimes even causing downtime. Because of the increase in scale, the movement further towards sea and also stricter regulations, the impact of wind continues to increase.



Figure 1. The effect of wind increases due to larger wind surfaces of cranes and because of the extra wind speed at higher altitudes.

TABLE 1: BEAUFORT SCALE (MEAN WIND SPEED IS 10 MIN AVERAGE AT 10	M)
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Scale of Beaufort	Mean Wind speed [m/sec]	Description	
6	10,8 – 13,8	Strong breeze	Large waves begin to form; white foam crests, probably spray.
7	13,9 – 17,1	Near gale	Sea heaps up and white foam blown in streaks along the direction of the wind.
8	17,2 – 20,7	Gale	Moderately high waves, crests begin to break into spindrift.
9	20,8 – 24,4	Strong gale	High waves. Dense foam along the direction of the wind. Crests of waves begin to roll over. Spray may affect visibility.
10	24,5 – 28,4	Storm	Very high waves with long overhanging crests. The surface of the sea takes a white appearance. The tumbling of the sea becomes heavy and shock like. Visibility affected.
11	28,5 – 32,6	Violent storm	Exceptionally high waves. The sea is completely covered with long white patches of foam lying in the direction of the wind. Visibility affected.
12	32,7 – more	Hurricane	The air is filled with foam and spray. Sea completely white with driving spray. Visibility very seriously affected.

TABLE 2. REI	LATION BETW	EEN AVERA	AGE WIND S	SPEED OVER	VARIOUS P	ERIODS AN	D MEAN SPE	ED (SOURCE	EN 13001)
Gust factor									
Period	[s]	1	3	5	10	30	60	120	600
							(1 min)	(2 min)	(10 min)
V(t)/Vmean	[.]	1.6	1.5	1.5	1.4	1.3	1.2	1.1	1



Wind characteristics

Wind can be characterised by speed and direction. Unfortunately in the working environment of ports there is confusion about Beaufort scale (Table 1) and wind speed. The wind speed of the Beaufort scale is 'the average wind speed taken over the ten minutes preceding the time of observation at 10 m' (J. Weringa en P.J. Rijkoort Windklimaat van Nederland, KNMI) or mean wind. Sometimes however, a wind regime at Beaufort 6 is wrongly interpreted as gusts of wind with speeds varying between 10.8 and 13.8 m/s.

By definition of the European standard for Crane design (European standard EN13001 Cranes – general design) the gust wind is the average three-second wind. Table 2 shows the relation between the maximum wind speed and the measure time interval. The table shows that wind speed increases with decreasing interval time. The maximum gust wind at Beaufort 6 is therefore not 13.8 but $13.8 \times 1.5 = 20.7$ m/s!



Increase of wind velocity

To handle vessels with deep draught the international trend is to construct new ports closer to the sea, while older docks near city centres become less important or are even closed. The difference in wind speed between the coast and the open sea is indicated by the Royal Meteorological Institute of the Netherlands (KNMI) as: "under equal circumstances ... it is concluded that potential wind on sea is 12% stronger than on open terrain on shore only because of the difference in roughness. However, most experiments reveal a difference of 20% or more mainly because the shore terrain is not open but rugged."

This is also confirmed by our own research where we found that 30 km off-shore the mean wind speed is up to two m/s higher than on shore, while for wind gusts, the difference can be even four m/s. If we assume that moving five km towards sea (from Maasvlakte I to Maasvlakte II) increases mean wind speed with one m/s, the amount of hours with troubling winds and loss of productivity on a container terminal due to wind will double.





Increase of wind pressure

The increase in world sea trade causes an increase in port equipment and vessel size. For example, the 9500 TEU container vessel commissioned in 2005 is almost ten times the capacity of the first generation container vessels of 1962. This also affects the size of the cranes. The effect of wind increases due to larger wind surfaces of cranes and vessels, but the effect is also



augmented because of the extra wind speed at higher altitudes. Besides the affects on vessels and cranes, high investments in quay strength are also needed, in order to support the high corner pressures of a 110 m high stowed crane, which is exposed to storm winds (Figure 1).

Strict regulations

Over the years society has become stricter in terms of accepted pollution and hazard level. An example of this increased attention is the stricter interpretation of wind pressure due to wind gusts in the new European crane design standard EN13001. Wind pressure on cranes is now explicitly dependent on wind gusts, while previously in National Standards (Din 15019 teil 1 Krane, Standsicherheit; NEN 2018 Hijskranen) only the wind categories 'light, normal, and heavy' were defined. Furthermore, terrain roughness factors account for higher coastal winds, while wind loads no longer depend on countries, but rather on a wind map where Europe is divided into wind regions (A to F) based on measured data (Figure 2).







Effects of wind

Port procedures

In general, international standards and port or terminal authorities both assume that ports are operational up to 6-8 Beaufort. At terminals in the port of Rotterdam, operations are suspended at Beaufort 8 or when gust wind speed exceeds 25 m/s. From figure 3, it can be deduced that a gust wind speed of 25 m/s signifies a mean wind speed of 25/1.5=17 m/s, which means that port operations in practice stop at the end of Beaufort 7.

Vessel mooring

For ship-shore loading and unloading, the movements of the vessel due to wind load need to be limited. We researched the dynamic response of a moored Ultra Large Container Vessel (ULCV) which carries 12.500 TEU on a typical wind spectrum at Beaufort scales 6 and 7. We found out that the maximum movements of the cell guides are acceptable for positioning containers in the cell guides, but the maximum calculated force of 150 kN in the mooring lines requires special lines and wharf bollards. For wind at Beaufort 8 or higher, storm bollards for these vessel types are highly recommended.

Crane operation

Beside vessel movement, wind also causes problems with crane operations. Wind causes undesirable movements (mainly sway and skew) of the container in the crane (Figure 4a and b). The crane driver can correct disturbances in sway, but an effective way to control skew does not yet exist. Heavy sway is generated by head on winds, but the crane driver can correct these movements. Skew is mainly generated by diagonal winds. If diagonal winds can be avoided, production loss due to uncontrollable skew can be reduced.

The vulnerability of the container in the crane to both skew and sway depend on the type of trolley. Because a (semi) rope trolley has a V-shape cable configuration the stiffness of the configuration in sway direction is higher than with machine trolley with vertical inner ropes. A computer simulation of the movements of the container exposed to wind for both trolley types show a 40% decrease in sway for the (semi) rope trolley (Figure 5a and b).

Terminal equipment

Because of the relative high frame height (1.1 m) and the

unlashed container load, the MTS-trailer is used to calculate the maximum wind for safe (container) transport on the terminal. Side wind reduces total trailer stability and can cause tilt of the (empty) container. The container/trailer combination stability while turning is sufficient during low gust winds, but at high speed and with gust winds above 22 m/s, an empty container can tilt from the trailer frame. It is therefore recommended to drive at lower speeds during high winds (Figure 6).

Another vulnerable container transportation vehicle to wind is the straddle carrier. Because of the high position of the container during transport, these vehicles have limited maximum speed. The stability of a straddle carrier loaded with a 45 ft empty container, as well as a straddle carrier with a maximum loaded (30 tonnes) 45ft container, decreases during higher gust winds. As with MTStrailers it is recommended to lower driving speed during high gust winds (Figure 7).

Empty container stacking

For storage, empty containers at the terminal area are stacked up to 10 high. The risk of a single container sliding, or the tilting of a whole row of containers, is calculated with wind pressure according to the Dutch TGB standard (Nen 6720). Depending on the stacking height, the risk of the total row tilting increases. In respect to a container sliding, a friction coefficient of 0.1 is taken (the lowest steel-steel contact friction). The sliding and tilting risk is calculated for several different container types, but for safety reasons, the wind speed at which the first container type starts to slide or tilt is plotted. The calculations clearly show that tilting and sliding can occur at low wind speeds near or around 10 m/s (Figure 8). Lashing down stacked empty containers and reshuffling empty containers in normal stack to lower positions is therefore necessary at Beaufort 5 or even at lower wind regimes!

Reduction of wind influence

Reduction of wind

The wind regime on a wind sensible terminal location can be lowered by raising the 'climatological' roughness. The terminal should be planned in the shadow of other industrial installations or buildings, and quay and cranes should be properly oriented to reduce the influence of the dominant wind direction. As an alternative, one can also use a lashed empty container stack as a roughness increasing obstacle.



Wind on vessels

To avoid the breakage of mooring lines or wharf bollards at Beaufort 8 or higher, severe storms bollards must be installed on the wharf.

Container ship-to-shore cranes

The effect of severe wind on ship-to-shore operations can be limited by using a rope trolley instead of a machine trolley. Another way of reducing wind influence on the load and unloading process is to change the crane cycle under stormy conditions. With 'rectangular hoisting,' combined horizontal and vertical movements are avoided, which reduce sway and skew significantly, but the loading and unloading process becomes slower. Another possibility is a new crane concept, the Carrier Crane, where a container is hoisted from the ship by a trolley, transported over the main crane beam with a carrier and again, on land, unloaded with a trolley. This division of the crane cycle significantly increases crane performance because the cycle time of each process is a lot shorter than that of an original total load or unload cycle (Figure 9).

Terminal equipment

If terminal operations have to continue at Beaufort 8, terminal movements have to be performed by equipment other than straddle carriers. In order to use MTS-trailers or similar transportation equipment at stormy conditions, containers need to be fixed on the frame.

Conclusion

Wind causes production loss, and heavy winds even cause downtime at the terminal. Port expansions move in the direction of the sea, and in this perspective, more wind and additional wind problems for terminals can be expected. Therefore, wind influences should receive proper attention as a design aspect for new terminals and port expansion programmes.

Wind speed can be reduced by using obstacles which increase the climatological roughness of the area. If no installation or natural barrier is available, an empty container stack can be used as an obstacle.

The effects of wind can also be reduced by proper orientation of the quay to the dominant wind direction, and use of a rope trolley combined with the 'rectangular hoisting' procedure for ship-to-shore movements. Use of new crane types, such as the Carrier Crane, can improve production as well as reduce vulnerability to wind.

Empty containers are sensitive to wind, and lashing of container stacks and reshuffling of empty containers in normal stacks is necessary even at Beaufort 5. During stormy conditions, it is advised to lock containers to the transporting vehicle frame and to avoid the use of straddle carriers.

ABOUT THE AUTHOR AND THE COMPANY

Wouter van den Bos graduated in 1998 from Delft University in Mechanical Engineering (MSc). He is employed at the section Transport Technology and Logistic at the same university. He has carried out various research programmes with a focus on transport, cranes and load influences on mechanical designs.

The field of 'Transport Engineering and Logistics' at **Delft University** encompasses the controlled handling and transportation of unit loads and bulk materials. The research and teaching involve the use of basic

principles and applied engineering to design industrial systems and equipment for the handling and transport of unit loads and bulk materials. In addition to the equipment itself, aspects such as energy consumption, the exchange of information and automation are given due consideration. The functions to be fulfilled by the equipment are defined on the basis of an inventory of requirements. The research activities are carried out in close cooperation with the Netherlands Research School for Transport, Infrastructure and Logistics, (TRAIL), and with industrial partners, especially those located in the Rotterdam area of the Netherlands.

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