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Some Effects of Wind on Ship's Manoeuvrability

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ABSTRACT: All ships experience an air and wind resistance while under way of sea, and they may experience adverse effects on wind while manoeuvring in harbours and limited waterways. The wind resistance is proportional to relative wind speed squared, wind direction and the projected windage area of the ship. The paper describes the effect of wind pressure into the ship's superstructures and houses on ship manoeuvrability, in the range of the wind speed, for the ship which is with the large windage area. The above is one of the recommended information to be included in the ship's manoeuvring booklet, as per IMO Resolution A.601(15). In sea practice, the manoeuvring characteristics in wind, as wind forces and moments, course-keeping limitation, and drifting under wind influence are fare from these estimated. The results obtained during the several years of practice in ship's exploitation are included in this paper.

1 INTRODUCTION

Ship handling and manoeuvring is defined as the act of proper control of a ship while underway, especially in harbours, around docs and piers, or restricted waterways. All ships experience air and wind resistance while under way of sea, in harbours or in limited waterways. The environment surrounding a ship have a significant impact on ship resistance. When the ship navigates within harbour wharfs or approaching the berth, the wind is one of the biggest environmental factors effecting a ship. The wind resistance on a ship is a function of the ship's windage area, wind velocity, and direction relative to the ship's heading. In sea practice the pressure of wind on ship's superstructure is defined as the wind force per unit area. This force has units of tonnes and uses the simplified formula to multiply the wind pressure, expressed in tonnes per square meters, by the ship's windage area, expressed in square meters. When operating the traditional cargo ships, the windage area depends on ship's draught and distribution of cargo on deck. Specific types of ships, like car carriers, passenger ships, Ro-Ro/ passenger/train ships have a hull constructions getting thousands of square meters of the windage areas. The safety of port manoeuvrings of the above ships is associated with negative effects of wind pressure force on ship's hull and superstructure. The basic model of Ro-Ro/ Passenger ship superstructure for calculations and analysis of the wind influence when manoeuvring in harbour, is shown in Fig.1.

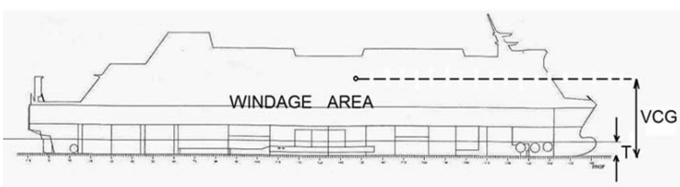

Figure 1. The basic model of ship's superstructure for calculation of wind pressure.

The above model of the ship's superstructure is created on the base of real Ro-Ro/ Passenger/ train ship with the following main particulars, shown in Table 1.

Table 1. Main particulars of presented ship.

Gross Capacity	32 000 RT
Maximum displacement	18 107 T
Deadweight	6 855 T
Length Overall	169.9 m
Breadth	28.0 m
High	42.3 m
Maximum draught	6.2 m

2 ANALYSE OF VERTICAL MOMENTS DUE TO WIND PRESSURE

The model of ship superstructure, described in this paper has a huge part of ship's hull above the water level. For maximum draught, just 6.20 meters of whole height of the ship's hull, is submerged of water. At the same time 36.1 meters of the whole ship's height is above the water level. This case presents a good example of wind influence on a ship superstructure during the manoeuvrings in restricted waters inside harbours.

The following tables contain the calculations of the windage areas and moments of wind pressure force on the ship for variable draughts of analysed model of a ship's superstructure.

Table 2. The results of wind pressure force for draught of 5.00 m.

MOMENT DUE TO WIND PRESSURE FORCE FOR Draught: 5.00 m					
Item	Area m²	Wind pressure N/m²	Wind force Tonnes	VCG m	Vertical moment Ton.m
Area no.1	1486.80	120.00	18.19	8.08	146.95
Area no.2	1533.30	120.00	18.76	18.15	340.42
Area no.3	148.80	120.00	1.82	28.20	51.33
Area no.4	286.50	120.00	3.50	26.06	91.33
Area no.5	50.50	120.00	0.62	26.60	16.43
Area no.6	194.50	120.00	2.38	3.10	7.38
Windage area	3700.40	120.00	45.27	14.44	653.84
DISPLACEMENT FOR DRAUGHT 5.00 m					13667.00 Tons

The single areas, as a basic elements of complete windage area of the analysed ship's superstructure are presented in Figure 2.

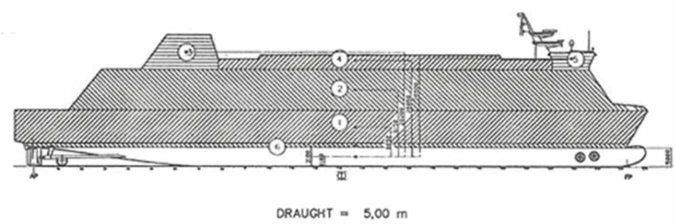

Figure 2. The elements of ship's windage area, as per calculations made in Tables 2 - 4.

In real conditions the whole windage area is going to be calculated as the sum of several geometrical areas of the ship superstructure, and, in many reasons also the cargo on deck. The above effect has been putted on view in presented Tables.

Area no.1 reflects volume of the main ship's hull, and does not depend on draught, keeping the value of 1486.80 square meters. Areas from No. 2 to No. 5 correspond the ship's superstructure as accommodations, and cargo decks (areas no. 2 and No. 4), navigation bridge (area No.5), and funnel (area No.3). The above areas have got still the same volumes of 1533.3 m², 286.5 m², 50.5 m², and 148.8 m², respectively. Only the area no. 6 changes its volume in function of the ship's draught - from 194.5 m² for draught 5.00 m to 0.00 m² for maximum ship's draught of 6.20 m.

Table 3. The results of wind pressure force for draught of 5.50 m.

MOMENT DUE TO WIND PRESSURE FORCE FOR Draught: 5.50 m					
Item	Area m²	Wind pressure N/m²	Wind force Tons	VCG m	Vertical moment Ton.m
Area no.1	1486.80	120.00	18.19	7.83	142.41
Area no.2	1533.30	120.00	18.76	17.90	335.73
Area no.3	148.80	120.00	1.82	27.95	50.87
Area no.4	286.50	120.00	3.50	25.81	90.45
Area no.5	50.50	120.00	0.62	26.35	16.28
Area no.6	112.60	120.00	1.38	3.10	4.27
Windage area	3618.50	120.00	44.27	14.46	640.01
DISPLACEMENT FOR DRAUGHT 5.50 m					15434.00 Tons

It should be noted, that in case of presented type of ships, like passenger ships, or Ro-Ro/passenger/train ships, the draught is acting on windage area in limited way. In case of presented model, the windage area varies from 3700.4 m² to 3505.9 m², causing very small difference of 2.38 tons in wind force pushing the ship.

The difference in windage areas: ΔA = 194.5 m² multiplied by wind pressure P = 120 N/m², and after that, divided by the gravitational acceleration of 9.81 m/s², is giving the value of wind force of 2.28 tons only.

The above is the proof, that in case of ships with a large windage areas, getting of several thousands of square meters, the increase in ship's draught does not transpose in reduction of wind force or vertical moment of wind pushing the ship.

When changing the draught, the different moments of the wind pressure force has to be appeared. The said effect is described in Table 2 for the ship's draught of 5.00 meters, in Table 3 for the ship's draught of 5.50 meters, and in Table 4 for the ship's maximum draught of 6.20 meters, respectively.

Table 4. The results of wind pressure force for draught of 6.20 m.

MOMENT DUE TO WIND PRESSURE FORCE FOR Draught: 6.20 m					
Item	Area m²	Wind pressure N/m²	Wind force Tons	VCG m	Vertical moment Ton.m
Area no.1	1486.80	120.00	18.19	7.48	136.04
Area no.2	1533.30	120.00	18.76	17.55	329.17
Area no.3	148.80	120.00	1.82	27.60	50.24
Area no.4	286.50	120.00	3.50	25.46	89.23
Area no.5	50.50	120.00	0.62	26.00	16.06
Windage area	3505.90	120.00	44.27	14.47	620.73
DISPLACEMENT FOR DRAUGHT 6.20 m					18107.00 Tons

3 SOME MANOEUVRING CHARACTERISTICS OF SHIP UNDER THE WIND PRESSURE FORCE

The manoeuvring particulars of presented superstructure model of Ro-Ro/passenger/train ship, shown in Fig.1, has been described in this paragraph. Discussion about some effects of wind on manoeuvring in harbour has been limited to the stage of the berth approaching. This type of ship has to be precisely directed into the individual bed, where the ship's ramp is boarding. When the force from the gust of wind is greater than the ship can immediately absorb, the berthing operation is dangerously disturbed.

When the wind blows against the side of the ship, the bow tends to turn slowly down the wind. The ship's hull have less lateral resistance under water in bow side than in stern. When the wind blown sideways, the bow and stern respond differently. The bow and stern thrusters are designated for pushing the ship against the wind.

The thrusters effects of presented ship's superstructure model are described in Table 5.

Table 5. Ship's thrusters effect

THRUSTER	kW [HP]	Time delay for full thrust [sec]	Turning rate at zero speed [deg/min]	Time delay for reverse full thrust [sec]	Not effective above speed [kt]
STERN	1600 [2176]	7	37	14	8.0
BOW	4800 [6528]	7	65	14	8.0
BOW & STERN	6400 [8704]	7	81	14	8.0

(documentation of Ro-Ro/passenger/train ship)

To compare the manoeuvring characteristics of presented Ro-Ro/passenger/train ship, the following data, shown in Table 6, should be taken into consideration.

Table 6. Forces acting on ship's hull.

Draught [m]	Wind force for pressure 120 N/m² [Tons]	Bow thrusters towing power [Tons]
5.00	45.27	84.84
5.50	44.27	84.84
6.20	42.89	84.84

Figure 3 shows the relationship between the wind pressure on the ship's hull and superstructure and the wind force pushing the side of the ship. The diagram from Figure 3 can also be used for determination of safe range of static wind effect against the bow thrusters of the ship.

For described superstructure model of Ro-Ro/passenger/train ship, the safe range of the wind effect under manoeuvrings is determined as 19 m/s or 8° B, when bow thrusters has to be used, only.

In real conditions of port manoeuvrings, not only static but lateral force caused by a sudden gust of wind is exerted on the ship (dynamical). The dynamical wind effects has to be important factor interrupting ship's manoeuvring when approaching the berth.

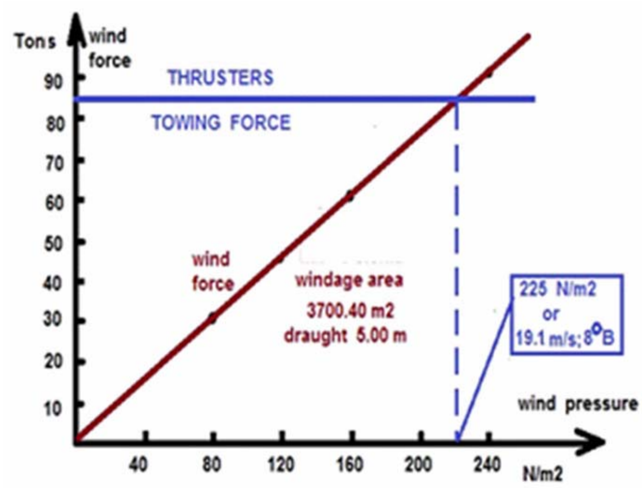

Figure 3. The relationship between wind pressure and ship's bow thrusters towing power.

Several publications (Azad A.K.,Alam M.M., 2010; Civitan L.,2003; Namkyun I., Van-Luong T.,) has presented the results of the dynamic wind effects researches, named as the gust effects.

Azad A.K. & Alam M.M. (2010) suggest, that the estimation of the wind gust based on hourly mean wind speed values has been initially suggested to be processed as follows:

$$V_G = K_G \times V_{mean} \quad (1)$$

where:
V_G – the gust speed [m/s],
V_{mean} – the hourly mean wind speed [m/s],
K_G – gust factor,

$$K_G = 1 + 2.28/ [\ln(z/n)] \quad (2)$$

where:
z - height above sea level [m],

n - the roughness length (2 -9) which depends on terrain characteristics.

As per formulas (1) and (2) the gust speed, for the mean wind speed of 19 m/s, will be equal :

$$1.7 \times 19 \text{ m/s} = 32.3 \text{ m/s} \quad (3)$$

Having an experience in exploitation of the above ship, there is clear that this type of ships is able to make a safe manoeuvrings even in case of the wind gust of 32.3 m/s.

When the wind is blowing with speed 32.3 m/s, the pushing force is equal 106 Tons, as it is presented in Table 7.

Taking into account the effect of combined work of bow and stern thrusters of the ship, there is a thrusters force of 113.12 Tons, directed against the gust.

Table 7. Forces from the gust of wind and combined work of Bow & Stern thrusters.

Draught [m]	Burst of force of high speed wind [Tons]	Combined bow & stern towing power [Tons]
5.50	106	113.12

4 CONCLUSIONS

During the port manoeuvrings not only bow or stern thrusters are being used, but also the main engines, powering the pitch propellers, and rudder blades.

This wide subject has not been discussed in presented paper.

It is important conclusion that not only analysed thrusters, but also the propulsion and steering machinery are being used to drive the presented ship's superstructure model against a wind pressure. There was stated that the successful ship operations in restricted waters could be made not only when strong winds are blowing with the speed greater than 10 m/s, but also during the short bursts of high speed wind, called gusts, or strong winds of intermediate duration, termed squalls.

In second paragraph it was also proved, that in case of ships with large windage areas, getting of several thousands of square meters, the increase in ship's draught does not transpose in reduction of wind force or vertical moment of wind pushing the ship.

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