SHIP'S PIVOT POINT IN CURRENT AND SWELL

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Abstract

The target of this paper is to add few corrections to the pivot point theory in open sea, where is the position of pivot point (as being well established in rigid body mechanics and in ship’s manoeuvring theory). Main target of the work is to correct pivot point theory as it is presented in seafarers books, pivot point being one of very important element of safe manoeuvring of the vessel.

Keywords: Pivot Point in current and swell.

1. Introduction

Pivot point of the ship turning is defined in seafarers publications more or less accurately as follows. Pivot point is the point which trace the turning curve of a ship. It is located in the fore section of the ship, afterwards of the stem at 1/6-1/3 of ship’s length [3].

Although not intended, some publications may give the impression that the pivot point moves right aft with sternway. This is clearly not correct and can sometimes be misleading. It should also be stressed that other factors such as acceleration, shape of hull and speed may all affect the position of the pivot point [24].

The pivot point is defined also: that position aboard the vessel about which the ship rotates when turning. In conventional vessels, the pivot point was approximately one third (1/3) of the ship’s length, measured from forward, when moving ahead. Any forces acting on the hull, such as from wind or current, would cause the vessel to move about the hawse pipe position [14].

The phenomenon of pivot point existence in ship manoeuvring is well known to navigators, though there is unclearly statement regarding qualitatively and quantitatively its location on a ship during various modes of operation. The available literature on ship manoeuvring and handling does not cover all aspects of pivot point in a systematic way [7].

The pivot point (PP) is the point in diametrical plan of the vessel or in the prolongation of this plan, around which the vessel swings on the trajectory which she describes. This trajectory can be a circle arch with its own center of rotation on the traject (momentary center of rotation). From PP, fore and aft of the vessel can be seen swinging with the same angular speed, even if PP is out of ship’s shape.

PP (or tactical point of turning) is located in the point of intersection between ship’s diametrical plan and the perpendicular from momentary center of rotation. In PP, ship’s tangential speed on the trajectory is ship’s speed recorded on board.

PP is important for ships’ operators because it gives some indications regarding equilibrium of the forces acting on the vessel, by its indication regarding space swept during turning and by possibility to predict ship’s orientation.

If PP is not close to 1/2L, when space swept by the vessel is \( \pi L^2/4 \) and it is located fore or aft, necessary space for turning is 4 times larger (\( \pi L \)).

2. Movements of a vessel, Water Resistance and Pivot Point

The most important movements for ship’s handling are (fig.1):
1. Longitudinal, fore-aft, along axis X-X’;
2. Transversal, starboard-port, along axis Y-Y’;
3. Swinging to starboard or to port.
To find PP position we will simplify the factors which affect ship’s handling to the mechanical physics although the hydrodynamic effects have a considerable importance.

During straight foreward movement, water-resistance force is applied right on the stem, somewhere at mid draft, depending of bow shape (classic or bulbous). In the same time it is recorded high pressure in front and around the bow (fig. 2).

Same judgment works for straight astern movement simplifying and do not considering influence of the propeller and rudder. Shape of underwater hull is very important for high pressure repartition.

As soon as, during movement ahead or astern, due to one of controlled or uncontrolled horizontal forces acting on the vessel, ship starts to turn and she will expose to the water flow another section, larger than going straight along fore-aft axis X-X’, the pick of water-resistance and pressure will shift from axe X-X’ to the geometrical center of underwater hull section area perpendicular on the new direction of the movement. The maximum of the ship’s section which can be exposed to the water flow is her vertical longitudinal section for a lateral movement (drift; sway) on transversal axis Y-Y’.

The direction of the water-resistance (R), could be anywhere between longitudinal axis, X-X’ and transversal axis, Y-Y’.

Depending of the direction of the movement, the vessel’s speed, hull shape, trim and heel, the application point of the water-resistance force will be in different points along the vessel, changind continously during complex movement of the vessel.

To analyze the influence of horizontal forces applied on the vessel (steering force, propeller force, lateral thrusters, tugs or pushers, wind and currents) and reducing phenomenon to classical mechanics, we have to report these forces to the water-resistance force or high pressure in the area where it acts. This force will be present as long as vessel is floating and moving. The arm lever of these forces is distance between their supports and Water-Resistance Force.

The action of a force or resultant of few forces acting on a stopped vessel can generate all three movements. For our purpose, the rotation and the sideways movement are considered. The rotation movement has a center of rotation which it is used to be call Pivot Point (PP).

The ship’s PP is the place from where fore and aft extremities of the vessel are turning with the same angular speed. This does not mean that PP is inside of ship’s shape in all situations.

Beside of PP, vessel’s trajectory has its own center of curvature call Momentary Center of Rotation (i.e. center of turning circle). In fact all forces acting upon a vessel have, more or less, momentary effects in ship’s dynamic movement.

3. Water Resistance and Pivot Point of a vessel stopped

Considering a stopped ship, without movement through the water and rudder mid ship’s, we can find a point situated about at its mid length, from where if a tug will push with a force F (fig. 3), fore and aft extremities of the ship are moving with same speeds \( V_1 = V_2 \). The force \( F \) is applied on the same support as water-resistance force \( R \). Its center of application is Center of Water Resistance (CLR). Arm lever of \( F \) and \( R \) is zero.
Figure 3. Lateral movement of a vessel

The ship will be translated from axis 1 to 2 (parallel axis). In this case there is not rotation, nor PP, or it is situated at infinity.

Figure 4. PP of a stopped rotational vessel

Considering 2 forces equals, parallels and of different sens, $F_1$ and $F_2$ acting at the extremities of a vessel (fig.4) with the condition $F_1d_1 = F_2d_2$, $d_{1,2}$ measured from the vertical plan of CLR, the vessel will have a pure rotational movement (ROT) and its PP will be in the vertical plan of CLR around mid ship. Vessel is on even keel and no heel.

If one force is applied close to CLR but more to one side of the considered ship, let to say aft in respect with CLR (Fig.5), the arm lever of forces $F$ and $R$ will be “d” and the ship will record a side movement and a rotation ($V_1 > V_2$). The longitudinal axis of 2 consecutive positions will be intersected in PP. If the ship would be anchored, PP would be where the anchor was dropped or where the cable will leave the bottom. In this case PP is outside of ship’s shap.

Figure 5. Pivot point of a stopped vessel
If the tug will push with force F closer to aft (Fig.6), the arm lever of \( F \) and \( R \), \( d_i > d \) (from fig.5) and rotation of the ship will be faster \( (V_1 >> V_2) \) and PP will be located inside of ship’s shape closer to application point of \( R \) in ship fore part.

If the force \( F \) acting upon the vessel is situated extremly aft, let to say force is applied on the rudder (fig.7), \( d_i > d_j > d \); position of PP will be more closer to \( R \). The same phenomena is if force \( F \) is applied fore, bow thruster or tug (fig.8). PP will be situated aft; it can be even on the stern or in aft area(fig.8). During ship’s manoeuvring all these forces are in dinamically relation. The position and magnitude of the water resistance and therefor of PP is continously change.
4. Water Resistance and Pivot Point of a moving vessel

If the ship will start to move ahead keeping her rudder mid ship’s (fig.10,1’), due to lateral resistance $R_L$ (drifting movement with speed $V_1=V_2$ and longitudinal resistance $R_I$ (fore ward movement given by propulsion arrangements), it appears a resultant water resistance force $R_T$ high, which has its application point fore ward. The result is a shift of PP fore ward in the direction of the movement. Arm levers of $F_1$ and $F_2$ reported to $R_T$ are changing and $d_2 > d_1$. In consequence $V_2 >> V_1$, it means the vessel will turn more quickly. Even with a kick ahead, this increasing of rotation speed can be seen. This phenomenon is valid for astern movement if the tug or bow thruster acts fore ward.

Due to short distance between $R_L$ application point and PP, in practice, ship handlers use to consider PP as reference point for $R_L$ application point. In reality application point of $R_L$ depend of underwater shape of the vessel.

PP is the result of composing water resistance of the vessel moving through the water and resultant of all other forces acting upon the vessel.

It is important not to overlook the fact that we are considering only the ship’s headway or sternway through the water, not over the ground. If the vessel is stationary with respect to the shore, but is stemming and turning in the current, the PP will be forward, since the vessel has headway with respect to the water. Likewise, if she is tied to the dock, with a current from astern, the pivot point will be aft at the moment the lines are cast off and ship will start to turn.

It is clear that efficiency of bow thruster is lower during fore ward movement (fig. 11) and higher during aft ward movement (fig. 12).

Changing of arm lever of ship’s thrusters is very well known by ship handlers which use it to increase efficiency of these controllable forces. If bow thruster is weak it is enough a kick astern to increase its arm lever and consequently its efficiency.

Obviously PP will exist only when the vessel is in turning movement and to predict its position is not easy in all cases. For a stabilised turning on calm sea without current, PP is situated fore or aft, function of sens of movement in fore or aft area as it is presented in the most of publications, at 1/5-1/3L from fore or aft.
Figure 11. Low efficiency of bow thruster

Figure 12. High efficiency of bow thruster
Figure 13. Elements for Pivot Point definition
   a. Movements and speeds in 3D of freedom
   b. PP absissa

The position of PP (fig. 13) depend of the ratio of lateral movement ($v$) and rotational movement ($r$). In other words, PP is defined as a point at distance $X_{pp}$, measured from the center of gravity of the ship that satisfies the relationship [7]:

$$v + X_{pp} \cdot r = 0 \quad (1)$$

Where:
- $v$ - is sway speed at the center of gravity of the ship;
- $r$ - is the yaw rate (known on ships as ROT – rate of turn).

It follows, from Eq.(1) that:

$$X_{pp} = -\frac{v}{r} \quad (2)$$

Eq.(2) is ill defined when the yaw rate is zero, which corresponds to a straight line motion. When the vessel moves on a straight line ahead or astern or she is in a pure sway motion, it is reasonable to consider PP at infinity [7]. In other words saying, when the vessel moves along axe $X-X'$ or she drifts along axe $Y-Y'$, there are not a PP and it is unfair to declare that PP is fore or aft function of direction of ship’s movement, as it is used in present.

Fig.14.a shows the measured sway speed, $v$, and 14.b the yaw rate, $r$, for a Very Large Crude Oil Carrier at 35 degrees rudder turning maneuver[4]. PP computed with Eq.(2) is shown in Fig. 14.c. It is observed that during 35 degrees turning maneuver, the PP moves from midship to about 1/5 ship length aft from the bow.In full-bodied ships, pivot point is closer to the bow, in slender ships farther from the bow.
Once ship starts to rotate under action of a force $F$ (Fig. 10), important masses of water move under and along her hull. Due to their inertia and ship’s inertia, water movement will continue when action of $F$ ceases and ship will continue to rotate.

To estimate effect of $F$ it has to calculate its moment. Again, in practice ship handlers use to calculate this taking arm lever, $d$, between estimated PP and position of the tug or thruster. Explanation is clear although it is not correct. PP can be appreciated by sight but R application point can not.

5. Water Resistance, Pivot Point and particular effects

5.1 Coming into wind

An interesting effect against usual behavior of changing $R$ application point is coming into wind.

To be more evident, we will consider a vessel with accommodation aft and a right hand propeller, rudder mid ship’s, being in position along axis a-a’ and just start moving astern (Fig. 15). The wind blows from starboard quarter.

Expectation, due to propeller transversal thrust and wind is movement $M1$, a turning and eventually drifting to port. Due to shifting of $R$ application point aft, between wind force $W$ and $R$ appear a couple which will bring ship’s stern in movement $M2$ on axis b-b’ into the wind, up to a certain angle when $d$ will become zero.

Opposite effect can be obtained if it will try to turn the vessel using the thruster situated at same level as $R$, in our case stern thruster. Its arm lever will be almost zero and the effect will be the drift of entire vessel only. In this case no PP.
5.2 “Donkey-like” effect

One of the most spectacular effects of application of an external force upon a vessel and getting an opposite result (donkey-like) is the movement of the vessel when a tug is acting on the support of water resistance force against it (fig.16).

In fig.16 it were represented only the speed vectors of the vessel and the tug. If the tug will start to push in position $M_1$ and vessel has an appreciable speed forward, it can not turn the vessel. She will drift and she will keep initial direction as in position $M_2$. As soon as the tug will stop pushing in position $M_3$, the vessel will start to turn towards the tug. She will continue to turn in the same direction a certain time as is shown in position $M_4$. Due to reduced arm lever between tug and water resistance, tug and vessel will drift and no rotation will be recorded. When the tug will stop and will leave the vessel in position $M_1$ (Fig.17), her center of gravity $G$ will continue by inertia its drifting with speed $GI$. Due to arm lever $d$ between $GI$ and $WR$, it appears a couple which will start to turn the vessel towards the tug.

Figure 17. Forces responsible for “Donkey-like” effect

PP starts shifting from fore ward to mid ship PP2 (Fig.17).
The masses of water moved during action of the tug have their own inertia and will continue to generate a water flow directed to port quarter. In the same time, fore of the vessel is passing relatively undisturbed water which will keep the bow, amplifying the rotation.
The effects of water flow and pressures around the vessel and how they influences ship’s manoeuvre is still a possible subject of research.

5.3 Sideways manoeuvre - crabbing

An example of how ship handlers play with rotation and drift of the vessel is manoeuvre of sideways or “crabbing”, in our example a berthing on port quarter at an oil rig (Fig.18). We consider a vessel with limited bow-
thruster power. The thruster runs at constant speed.
To move the vessel sideways to oil rig, rudders (Rd) will be set hard starboard, starboard engine astern (P1), port engine ahead (P2) and bow-thruster to port at maxim power (Tcst). Usually stern sideways speed is greater than bow sideways speed, M1>M2 (Fig.18a) and the vessel will come with aft part closer to berthing place.

Turning couple of propellers depend of their arm, d. In order to increase bow-thruster effect, it will increase P1 and it will stop P2 which it will reduce aft turning effect and it will give an astern movement of the vessel. Effect of astern speed will be a shift of center of water resistance and the pivot point in PP2.
The arm lever of bow-thruster will increase, consequently its sideways effect and M2a become greater than M1a. The result will be astern movement for a while and a closer position of the bow to oil rig (Fig.18c). In this moment, it will be reduced starboard engine power and port engine will be set ahead at a greater rate than starboard. Vessel will start, finally, to move fore ward and the pivot point will take position PP3. Arm lever of bow-thruster will be reduced and M1b>M2b. Playing in above described manner, rudders can be kept in the same position.

For a stopped vessel, starting the engine ahead and setting rudder hard to one side, during turning, PP position will shift quickly, in evolution phase, from a location close to Center of Gravity and mid of the vessel, to fore ward, keeping the position of 0.10-0.25 of length between perpendiculars (Lpp) from stem before stabilization state of turning. Time of PP setting is about half of turning stabilization time, respectively sideways speed and turning rate stabilization time. PP final position and time of stabilization depend of underwater shape. It is a particularity of each vessel or category of vessels.

6. Pivot point in current and swell

To see the effect of the current on position of PP (fig. 19) one can consider a ship with rudder at a certain angle to starboard, moving with speed through water V, recorded in her center of gravity G. Speed V can be decompose longitudinally and transversally in u and v. The vessel swings around PP with angular speed r. PP, defined before, describes turning curve T, on which she moves with speed V'. The trajectory T has the momentary center of rotation Ci. It is considering the current W having opposite sense with ship’s bow swinging sense.

Figure 18. “Crabbing” using PP position
Figure 19. Changing of PP position in current

Figure 20. Swell effect upon sway speed

Acting on axis y-y', current speed will sum with sway speed \( v \) resulting new sway speed \( v_1 \). To this new sway speed corespond a new PP\(_1\), placed more forward \( (X_p = -v/r < X_p = -v_1/r) \), which will moves along trajectory \( T_1 \) with speed \( v'' \). For the case of current of the same sense with bow swing speed \( (W') \), sway speed will be reduced by current speed, resulting sway speed \( v_2 < v \). New PP\(_2\) will be located towards \( G \) and it will moves with speed \( V''' \) on the trajectory \( T_2 \) (the momentary radius, \( RT_2 > RT > RT_1 \)).

To study the effect of the swell on the position of PP (fig.20-seeing from aft), we consider a vessel turning with sway speed \( v \), having swinging sense to port. The swell comes from starboard. During rising and falling of the ship on swell wave, displacement force acting in \( G \) will be decomposed in a plan parallel with floating plan, \( D \) and in a plan perpendicular on floating plan, \( A \), which is canceled by Archimedes buoyant force \( A' \).

Depending of the slope of the swell wave on which is the vessel situated, the component \( D \) will be composed with the sway speed \( v \), resulting a new sway speed \( D_v \). This new sway speed can be greater (fig.20.I) or smaller (fig.20.II) than old sway speed (between swell crests), depending of the sense of \( D_v \) which will be same or opposite with sway speed before arriving swell wave. Sway speed being involved in definition of PP position, it results that, during passing from one slope to the other of the swell wave, PP will have a “jump” in respect with its position before to arrive the swell wave.

7. PP and ship’s inertia
During turning of large and heavy vessels despite of starting swinging, due to huge inertia, ship will continue movement on direction she had before to set rudder on certain angle and to appear rudder force $F$ (fig. 21). The result of lateral movement will be a PP far forward. This has to keep in mind when it needs to anchor in a certain position. Starting engine will change direction of drifting but it will increase space swept by vessel. To reduce space of turning, it has to stop before turning point and to start swinging at almost “zero” speed. Kicks of engine to amplify rotation could be useful in this situation.

8. Experiments to find PP

Theory of PP is beautiful but it needs practice confirmation. To prove validity of PP theory it were performed few tests on a real vessel and on manoeuvring simulator on a virtual one.

To find PP position (fig. 22) it has used bridge ships equipment, two marine portable GPS, watches and cameras. The two portable GPS were placed at fore and aft extremities of an offshore multipurpose vessel (fore GPS above of fore perpendicular). During ship evolution it were made movies fore and aft to record time and GPS screens and pictures with bridge navigation informations were taken at about each change of $10^\circ$ of ship’s heading. After extracting of data from movies and pictures, position of fore and aft GPS were represented with connected linear speed. Using principles of mechanics, at intersection of perpendiculars on these speeds it was found Instantaneous Centre of Rotation $Ci$, around which the movement of the vessel is producing.

$Sa \ GPSa\ Ci = Sf \ GPSf\ Ci = 90^\circ$. GPS tangential speeds ($Sa$ and $Sf$) were decomposed on direction of ship’s centre line ($Sfl$ and $Sal$) and on a perpendicular on the centre line ($Sat$ and $Sft$). Transversal components $Sat$ and $Sft$ gives swinging movement of the vessel. Joining transversal components of GPS speeds $Sat$ and $Sft$, which correspond with angular rotation speed, at intersection with centre line it will be found the pivot point PP, as it is defined in ship’s handling (as point from where fore and aft are rotating with same speed).

The origin of pivot points measurements is fore perpendicular which in our case correspond with ship’s stem. PP abscissa $Xpp$, are negative inside of ship’s shape. PP position can be get also at intersection of diametrical plan (or center line) with a perpendicular from $Ci$.

There were performed few tests on real vessel and same tests on virtual ship (close as possible with particularities of real vessel), on Constanta Maritime University manoeuvring simulator. In this work we present a single test only due to limited space. Measurements done can be seen on figure 23.
The target of the test regarding PP was the evolution of its position in open sea, in real environment conditions and how this evolution can affect manoeuvring versus PP theory as it is presented in marine universities. Although here it is presented a simple turning manoeuvre in open sea, the tests were performed in various conditions and their results are presented in a separate research report. Special attention was paid for current effect.

Abscissa PP (Xpp) was measured from fore perpendicular, where one GPS was placed and it is positive forward and negative aftward (it is a conventional notation).

Ordinate of momentary center of rotation (Yc) was measured from the diametral plan of the ship and its sign is positive when momentary center of rotation is on the side of rotation of ship’s bow.

Angle (Tc-Tw) between ship’s head and coming current (its direction, by navigation definition, is outgoing) has maximum value 180°, measured from the bow and being positive on the port side.

8.1 Vessels particularities

8.1.1 True vessel - Offshore Supply Vessel (SV)

LWL = 56.37 m; B = 14.60 m; h = 5.50 m; d = 4.75 m;
D = 1500 tdw; 2 engines 2 x 1641 Kw; 2 fix propellers in Kort nozzles;
2 balanced rudders; Bow thruster = 5 mt; Max. speed = 13 knts; Height of eye = 15.25 m.

Figure 24. General plan of the reference vessel

8.1.2 Simulation vessel (OS)

<table>
<thead>
<tr>
<th>Vessel</th>
<th>General Information</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hull form</td>
<td>Harbour tug (Ex: 409H)</td>
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<tr>
<td>Displacement</td>
<td>405 t</td>
</tr>
<tr>
<td>Max speed</td>
<td>13.8 kts</td>
</tr>
<tr>
<td>Dimensions</td>
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<tr>
<td>Length</td>
<td>35.7 m</td>
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<td>Breadth</td>
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<tr>
<td>Bow draft</td>
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</tr>
<tr>
<td>Stern draft</td>
<td>3.4 m</td>
</tr>
<tr>
<td>Height of eye</td>
<td>12 m</td>
</tr>
</tbody>
</table>

Figure 25. Virtual vessel
Figure 26. Controls and recording data during simulation

Abbreviations used in this work are:

- Time          - time of the record
- HDG/Hdg  - true course (through water)
- Spd            - true speed (through water)
- COG          - course over ground
- SOG/Vt      - speed over ground
- Lat              - latitude
- Long           - longitude
- Xpp   - abscissa PP from fore perpendicular (Ppv)
- Yc     - momentary center of rotation ordinate
- Ci    - momentary center of rotation
- PP    - pivot point

8.2 The tests

8.2.1 The test no.1 with reference vessel (SV) was a complete turning circle to starboard (fig.27), engine at minimum revolutions, in following conditions:

- Rudder 35° starboard;
- Staboard engine 676 rpm ahead;
- Port engine 680 rpm ahead;
- Bow thruster stop;
- Total drift 321°/1.1 nd;
- Apparent wind 0 nd;
- Swell 220°/0.5-1 m/6-8 sec.

Remark the boat landing on starboard

The results were recorded in table 1 from which were extracted the graphs presented in fig.28-32.

8.2.1.1 The results were recorded in table 1 from which were extracted the graphs presented in fig.28-32.

Variation of PP abscissa in respect with ship’s head is presented in fig.28 and its variation in respect with the angle between ship’s head and current in fig.29.

Analizing positions of PP (fig. 28) one can see that ship being all the time in ahead moving, PP approaches of stern and a good part of evolution it is out of the ship shape forward. Studing relation between PP position and incidence angle, ship-current (fig.29) one can observe that the highest values of the Xpp, positive or negative are placed to an angle of incidence between vessel and current of 70°-130°, the greatest positive value being recorded at 119.5° (tab.1), the highest negative at 90°-100° and the lowest values close to incidence angle 0° or 180°. This confirm mathematical definition of PP, when the current acts perpendicular on the vessel, drifting (sway) speed increases, value of the ratio \( v/r \) increases because angular speed of swinging does not record a proportional increasing.

From fig. 30 one can observe that the momentary centres of rotation (Ci) are grouped, this mean that the turning sweeps little space although momentary centres ordinates are of quite high values (ship’s trajectory is composed of large circle arches).

Momentary fluctuation, both for PP and Ci are induced, at the slow speed of the vessel, besides the current, by the swell too, this increasing or decreasing ship’s sway or yaw rate.

Momentary centres of rotation abscissa were not recorded, theoretically being of the same value as PP abscissa although during their measurements, it was observed that these two kind of abscissa are not equals, probably due to summonting of all errors of devices and graphic work precision.
Figure 27. Ship’s trajectory during the test

8.2.2 Test with virtual vessel (OSi) was performed for the same conditions as for the real vessel. Unfortunately it was not found a virtual vessel with the same particularities as the reference vessel and difference between the two ships is very big LSV – LSi = 21 m, without considering that the vessel S1 has only one propeller but the vessel SV has two in nozzle. Against these differences, the results of the simulation (tab.2) confirm trajectory shape (fig.31).

To be more clear how position of PP is moving during the test in fig. 32 A-G were presented PP positions at nozzle. Against these differences, the results of the simulation (tab.2) confirm trajectory shape (fig.31).

Table 1. Test data
Figure 28. PP abscissa variation during the test

Position of PP in respect with angle between current and ship’s head was presented in fig. 33.

The comparison between results of the test performed by real vessel and virtual vessel is not relevant because, in fact, they are two different vessels and analysis of the results is in principle.

It has not to forget that the virtual vessel has not a boat landing as appendix and her results are not influenced by a supplementary unsymmetrical resistance through water.

Figure 29. PP in respect with the current

Figure 30. Momentary centres of rotation

Table 2 Simulator test data
Figure 31. Trajectory of the virtual vessel OS1
9. Conclusions
During documentation for this work it came out that there are a clearly discrepancy between shipbuilding research results and perception of ship operators training system about pivot point of the ship turning in different conditions. Theory of the pivot point is presented only for a stable turning in calm water and it is extended as each interpreter consider, below scientific level, although nowadays there are all facilities to find a complete statement of the question (manoeuvring simulators in large numbers).

Effect of controllable or uncontrollable forces upon a vessel is function of the arm lever between Water Resistance force and resultant of others forces.

If effect of the forces has a rotation motion, this rotation has a center, inside or outside of the ship’s shape, function of ratio between rotation and sideways motion, call Pivot Point.

Position of Pivot Point depends of position of Water Resistance application point which is function of direction of movement, speed, environment conditions and ship’s shape.

There are particular positions reported to Water Resistance application point where if a force is applied the effect upon a vessel is special.

The tests, among the others unpublished here, was performed with an important appendix fixed on the hull which it affected substantially the results of the tests. In the same time the tests clearly demonstrated the complexity of the factors which affect the evolution of the pivot point during real sea conditions manoeuvres against still waters manoeuvres and they show obviously that the pivot point can not be treated so simply as it is in the most works in training system of the seafarers, unchanged for more than hundred years.

It is clear that very often the pivot point is located outside of the ship’s shape and unknowing very well its position it is not practically to try to calculate forces momentum which act on the vessel in respect with this point. The affirmations regarding moving of the pivot point up 1/5 or 1/4 L from bow has to be completed with specification that it is valid for a stabilized turning manoeuvre in water area with ideal conditions and it is not a general statement as it is understanding from the most works regarding the matter or completely wrong to assert that the pivot point is located in a certain place during straitway walk ahead or astern.

It was demonstrated, in special for low speed, huge influence of the current and the swell on the pivot point abscissa evolution.

Paraphrasing prof. Rayleigh who said: “It happens not infrequently that results in the form of 'laws' are put forward as nobelties on the basis of elaborate experiments, which might have been predicted a priori after a few minutes consideration”, we can say: the results of the pivot point study which could be enunciated after a few minutes consideration, they needed experiments of which one was presented in this work and may be they will need more experiments on the ship models and manoeuvring simulators and may be even then it will not be sure that the complete theory of the pivot point will be assimilated by the seafarers training system.

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