

WATER SURFACE SHIP

Field of the invention

This invention relates to a means of water transport and communication, more particularly, it pertains to planing vessel.

Background art

General displacement ship has better stability and can meet the needs of various cargo tonnage. However, it has deeper draft and carries more cargo, its hull is more draft, which results in greater water resistance during ship in moving, that leads to large power consumption. Therefore, increase in its speed is difficult, it is difficult to navigate in the river with shallow water, rapid and strong current, and with submerged reef; the controllable range of speed change is small.

Hydrofoil craft shakes off a large part of water resistance, its speed is enhanced. But its load carrying capability, flexibility, maneuverability and seaworthiness are poor, it is difficult in operating smooth in the river with strong and rapid current, shallow water, as well as in rough waters.

Surface effect craft, as an example, hovercraft shakes off water resistance, its speed increases. But, it can not use the hydrodynamic buoyancy to support gross weight. the cargo tonnage isn't large. Besides, the power consumption is large to create dynamic air cushion. Particularly, its superiority disappears under a raid of lateral wind.

General planing boat having shallow draft in planing state increases the speed. Adopting the hull with  type cross section, its own course stability, lateral stability and maneuverability are improved. However, it leads to heighten the water resistance due to increase of the wetted area of the hull, moreover the lift surface at the stern is larger than at the stern, that results in the increase of resistance owing to heighten the swell height of water surface nearby the stern; it creates the tendency of bounce and pitching on rough waters (Fig. 12 - 1); It is unsuitable to operate in the river having strong and rapid current, shallow water as well as in the sea with rough waters. The certain improved planing boats, for example, U. S. Patent No. 5265554, 5016552 and 4722294, etc. . They have shallow - V hulls or partly deep - V bottom, have certain merits. However, their performances are still to be in the frame of general planing boats, the improvements are insufficient; particularly, that hull layout is sensitive to respond to the wave, its performance to overcome stormy wave is poor.

The sea - knife boat is the one of planing boats, its speed and performance to overcome stormy wave are better than general boats, But its hull with a pure triangle plane bottom results in shortage of course stability, manoeuvrability and seaworthiness thereof.



Features of the invention

In order to eliminate the drawbacks of the means of water transport and communication in present art mentioned above, a planing vessel is offered by this invention. The vessel comprises a hull, propulsion and control system, etc. The hull consists of a bottom 1, boards 2, deck 3, swell guidewaies 4 and wave - splash guards 5, the cabin and superstructure. Therein a flat bottom 1 is composed of an equicrural triangle ahead and a rectangle behind. Denting vertically into and lengthways throughout the bottom, in the space between bottom 1 and deck 3, one or more swell guidewaies 4 are set, their base plane longitudinal centerlines are parallel to the centerline of bottom 1 (if only one swell guideway is set, its base plane centerline coincides with the centerline of bottom 1). Its cross section takes  or  or  type, longitudinal section is  type, whose top line with inclination has lower front and higher rear; a pair of wave - splash guards 5 being the baffles with inclination have lower front and higher rear, which are symmetrically inlaid or dented one into either board 2 as an integral whole below the deck 3 above the bottom 1. The hull having these structures as mentioned here can arouse the hydrodynamic flow field and corresponding great enough hydrodynamic buoyancy with reasonable distribution as designed during the vessel in moving. That makes the hull shake off water resistance in maximum limit to heighten its own speed, at the same time, use the hydrodynamic buoyancy aroused to carry its own weight and load weight, to meet the needs of various cargo tonnage; and have fine course stability, lateral stability, flexibility, maneuverability and seaworthiness; and have advantages over existing various boats and ships in cutting through rough waters, reach the supercritical operation state to chop smooth on rough waters.

The stern may have a step. When the vessel is moving in displacement state at low speeds, the step is overspread by a step cover which forms a smooth streamline stern end to reduce the water resistance. The cover may be retracted, when the hull has been lifted out of the water and runs in planing state. The step uncovers, hence the race of the hull is separated from the hull behind the step. Thus the wetted area is reduced, so that leads to decrease the resistance greatly, as a result the vessel speed is increase further. The stern may be designed to be the stepless streamline or else.

For the planing vessel having the hull with the features of the invention indicated above, a layout of propulsion and control system provided by the invention may be disposed as follows: At the rear of the hull, inner side of both boards below the deck 3, in the space between the deck 3 and waterline during the vessel in planing state, one or more water - jet propulsion plants 7 are positioned near the water surface. The water jets are set at the stern end. The rudders 6 are set off the stern end slightly and one by one corresponded to the jets. Jets and rudders are located above, but near the water surface during



the vessel in planing state. The features of the hull provided by the invention can display perfect performance in navigating. In addition, the hull with features of the invention may also adopt propellor or other propulsion and control systems. This invention applies to various types of small - sized, middle - sized as well as large - sized boats and ships for different uses.

Description of the drawings

(Each figure from Fig. 1 to Fig. 16 - 2 expresses only the part of hull structure below the deck of planing vessel provided by the invention.)

Figs. 1, 2 are respectively a side elevation view, bottom plan view of a hull of the planing vessel provided by the invention, 1 - bottom, 2 - board, 3 - deck, 4 - swell guideway, 5 - wave - splash guard, α - the inclination of top line of swell guideway to the bottom plane, β - the inclination of wave - splash guard to the bottom plane, θ_1 - attack angle of the bottom plane against the horizontal during the vessel in static state, R - curvature radius at the stern, $2r$ - width of the base plane of swell guideway. Fig. 3 is a front elevation view of the hull shown in Fig. 1, Fig. 4 is the rear elevation view, therein wave - splash guards 5 denting into the surfaces of boards 2 as an integral whole.

Figs. 4 - 1, 4 - 2 are respectively a front, rear elevation view of the hull of Fig. 1, where a pair of wave - splash guards 5 are inlaid one into either board 2 surface;

Fig. 4 - 3 is a rear elevation view of the hydrodynamic flow field aroused by the hull shown in Fig. 1 during the vessel in moving, where vertical arrow expresses the additional lift offered by the swell guideway, two arrows symmetrically inclining inward express the additional forces offered by the wave - splash guards.

Figs. 4 - 4 is a rear elevation view of the flow field while the swell guideway has the  type cross section; therein the arrows symmetrically inclining outward express the additional forces offered by the swell guideway, arrows symmetrically inclining inward express the additional forces offered by the wave - splash guards.

Figs. 4 - 5, 4 - 6 are respectively the cross section view of the swell guideway with  type cross section, wherein h - top height of the section, $2r$ - width of the base plane of the swell guideway, ζ - arc length of the side, τ - arc length of the top, the arrows symmetrically inclining outward express the additional forces offered by swell guideway.

Fig. 4 - 7 is a base plan view of swell guideway while the $r < r''$.

Fig. 5 is a plane layout scheme of the bottom 1, therein 2a - overall length of bottom 1, 2b - width of bottom 1, S - equilateral length of the triangle part of bottom 1, O - mid-point of the centerline of bottom 1, OX - X axis coinciding with the centerline of bottom and taking point O as origin of coordinate, OZ - Z axis being perpendicular to the OX, l - projection of S on OX axis, t - length of rectangle part of bottom 1 in the direction OX, O_1



— coordinate of centre of the hydrodynamic buoyancy, O_2 — coordinate of gravity centre of the vessel.

Figs. 6-1, 6-2, 6-3, 6-4 are respectively the side elevation, bottom plan, front elevation and rear elevation views of the hull with a pair of swell guidewaies 4, where the wave-splash guards 5 dent one into either board 2 as an integral whole;

Figs. 6-5, 6-6 are the front, rear elevation view of the hull of Fig. 6-1 respectively, where a pair of wave-splash guards 5 are inlaid one into either board 2 surface.

Figs. 6-7, 6-8 are the rear elevation view of the hydrodynamic flow field aroused by the moving hull with a pair of swell guidewaies 4, therein in the Fig. 6-7 the vertical two arrows express the additional lifts offered by the swell guidewaies, in Fig. 6-8 the arrows symmetrically inclining inward or outward in the space inside both boards express the additional forces offered by the swell guidewaies; in Figs. 6-7, 6-8 the arrows symmetrically inclining inward at boards express the additional forces offered by the wave-splash guards.

Fig. 7-1 is a bottom plan view of the hull with three swell guidewaies 4, Figs. 7-2, 7-3, 7-4 are the rear elevation view of the hydrodynamic flow field aroused by the hull in moving, therein vertical three arrows express the additional lifts offered by the swell guidewaies, two arrows symmetrically inclining inward express the additional forces offered by the wave-splash guards; in Fig. 7-2 three swell guidewaies have the same height and inclination, in Figs. 7-3, 7-4 three swell guidewaies have different its own height and inclination.

Figs. 8-1, 8-2, 8-3 are respectively the bottom plan view, front and rear elevation views of the hull with wider swell guideway; Fig. 8-4 is a rear elevation view of hydrodynamic flow field aroused by the hull in moving, where two arrows symmetrically inclining outward express the additional forces offered by swell guideway, two arrows symmetrically inclining inward at boards express the additional forces offered by wave-splash guards.

Figs. 9-1, 9-2, 9-3 are respectively the bottom plan view, front, rear elevation view of the hull with swell guideway having large width; Fig. 9-4 is a rear elevation view of the hydrodynamic flow field aroused by the hull in moving, therein two arrows symmetrically inclining inward at the inside express the additional forces offered by swell guideway, symmetrically inclining inward at the boards express the additional forces offered by wave-splash guards.

Fig. 10 is a dynamic balance scheme during the vessel in moving, where L — hydrodynamic buoyancy, W_1 — its own weight of the hull, W_2 — load weight, F — total thrust, R_T — total resistance, O_1 — location of centre of the hydrodynamic buoyancy, O_2 — location of



centre of gravity of the vessel.

Fig. 11 is a side view of the additional hydrodynamic force offered by the swell guideway in the flow field aroused by the hull in moving, where α - inclination of top line of the swell guideway to the bottom plane, L_0 - additional lift, F_0 - additional thrust.

Fig. 12 - 1 is a sketch map of side view describing the attitude and relation of a planing boat having conventional hull to the ambient rough waters, where the arrow indicates the direction of advance of the boat;

Fig. 12 - 2 is a sketch map of side view describing the attitude and relation of a planing vessel with the hull having features of this invention to the ambient rough waters.

Figs. 13 - 1, 13 - 2, 13 - 3 are, respectively, a side elevation, bottom plan and rear elevation views of the hull with a swell guideway 4 and mobile rigid or semirigid step cover at the stern, where 6' - step cover;

Figs. 14 - 1, 14 - 2, 14 - 3 are respectively a side elevation, bottom plan and rear elevation views of the hull with a swell guideway 4 and flexible step cover at the stern;

Figs. 15 - 1, 15 - 2 are respectively a bottom plan view, rear elevation view of the hull having a pair of swell guideways 4 and a mobile rigid or semirigid step cover at the stern, the side elevation view of the hull is the same as shown in Fig. 13 - 1;

Figs. 16 - 1, 16 - 2 are respectively a bottom plan view, rear elevation view of the hull with a pair of swell guideways and a flexible step cover at the stern, the side elevation view of the hull is the same as shown in Fig. 14 - 1.

Fig. 17 is a side elevation view of a planing vessel with a swell guideway 4 and a pair of water-jet propulsion plants 7; Fig. 18 is its bottom plan view; therein 9 - superstructure, 10 - ship mast, 6 - rudder, 14 - water inlet, 19 - jet, 6' - step cover.

Fig. 19 is a top plan view as seen approximately from the deck plane of the planing vessel, where 7 - water-jet propulsion plant, 8 - power plant, 11 - engine room, 12 - passenger cabin, 13 - passenger seat, 15 - driver seat; Figs. 20, 21 are respectively a front, rear elevation view of the vessel, where 16 - ceiling.

Fig. 22 is a longitudinal section view of the power water-jet propulsion system, where 17 - water entry way, 18 - rotating axis of the rudder, U - ship speed.

Fig. 23 is a side elevation view of a traffic boat pertaining to series of planing vessel designed on the basis of the features of the invention and considering the needs of traffic boat cabin and superstructure.

Fig. 24 is a schematic plan view of the comparison between the turning radius of the planing vessel of this invention (with sharp head) and the turning radius of conventional ship (with blunt head) in turn.

Figs. 25 - 1, 25 - 2, 25 - 3 are respectively a side elevation view, bottom plan view,



top plan view as seen approximately from the deck plane of the boat of the invention, which has a pair of swell guidewaies 4 and a water-jet propulsion plant 7; Figs. 25-4, 25-5 are respectively a front, rear elevation view of the boat, in which the wave-splash guards are dented into the boards; but in Figs. 25-6 and 25-7, the guards are inlaid into board surfaces; therein 20 - windshield.

Figs. 26-1, 26-2, 26-3 are respectively a side elevation view, bottom plan view, top plan view as seen approximately from the deck plane of the boat having two swell guidewaies 4 and adopting one or two outboard motors as propellor; Figs. 26-4, 26-5 are respectively a front, rear elevation view of the boat with a pair of wave-splash guards denting into boards; Figs. 26-6, 26-7 are respectively a front, rear elevation view of the boat with a pair of wave-splash guards inlaying one into either board surface.

Description of the preferred embodiment of the invention

As shown in Figs. 1, 2, 3, 4, the part below the deck plane of the hull provided by this invention mainly comprises bottom 1, two boards 2, deck 3, swell guidewaies 4 denting vertically into the space between bottom 1 and deck 3, a pair of wave-splash guards 5 setting at the boards 2. Bottom 1 consists of an equicrural triangle ahead and a rectangle behind; referring to Fig. 5, the specific size of the bottom 1 is determined as follows:

The coordinate origin O is located at the centerline of bottom 1 and is the midpoint of overall length $2a$ of bottom 1, OX is the ordinate, OZ is the abscissa; l is the projection length of both equilateral length S of the triangle part of bottom 1 on OX axis, the length of the rectangle part in the direction OX is t , the width in the direction of OZ axis is $2b$. The specific sizes of l , $2b$, t are determined according to the needs of design and referring to the expressions (1), (2):

Expression (1) is $L = 2\rho U^2 a^2 P \sin\theta$, (L is the hydrodynamic buoyancy),

$$\text{where, } P = \int_{-a}^{a-t} T_1(x) dx + \int_{a-t}^a T_2(x) dx, \quad T_1(x) = \int_{-b(x)}^{b(x)} p(x, z) dz,$$

$$p(x, z) = \frac{Ka}{1-K\delta} \left\{ \frac{G \exp(-Gx) \cosh k_0 z}{k_0 \xi \cosh G \cosh k_0 b} + 2 \sum_{n=1}^{\infty} \frac{(-1)^{n-1}}{C_n^2} \left[-\sin C_n x + \right. \right. \\ \left. \left. k_0 R_n \cos B_n z (B_n \cos C_n x - k_0 \sin C_n x) + k_0 G b J_n \cos D_n z (D_n \cos E_n x - k_0 \sin E_n x) \right] \right\},$$

$$R_n = 1 / (k_0^2 + B_n^2) \cos B_n b, \quad J_n = 1 / (k_0^2 + D_n^2) \cos E_n, \quad B_n = G C_n,$$

$$\xi = \sqrt{1 + \varepsilon^2}, \quad C_n = (2n-1)\pi/2, \quad D_n = C_n / b', \quad E_n = C_n / Gb',$$



$$b(x) = bx/l, \quad x = X/a, \quad z = Z/a, \quad G = \sqrt{(1-K\delta)/K\delta}, \quad K = g/U^2,$$

$$T_2(x) = \int_{-b}^b p(x,z) dz, \quad \varepsilon = 0.0045, \quad \bar{G} = k_0/G, \quad b' = b/a,$$

Expression (2) is $X = M/L$, (X is the distance between the point O and the centre O_1 of the hydrodynamic buoyancy),

$$\text{where, } M = 2\rho U^2 a^3 N \sin\theta, \quad N = \int_{-a}^{-1} x T_1(x) dx + \int_{-1}^a x T_2(x) dx,$$

ρ is density of water; U is ship speed; θ is attack angle of the bottom plane against the horizontal during the vessel in moving; W_1 is its own weight; W_2 is load weight; M is force moment of lift pressure $p(x, z)$ on the bottom plane with respect to the midpoint O of the bottom centerline; θ_1 is attack angle of the bottom plane against the horizontal during the vessel in static state, general, about 5° is taken, it may also be determined by the permissible static draft at the stern end, length of the vessel and other factors; $0.1 \leq k_0 \leq 1$ (or determined by the needs of design); g is acceleration of gravity; δ is half depth of the stern end draft (determined by the needs of design). $L = W_1 + W_2$ when the vessel is in planing state.

one or more swell guideways 4 are set by denting vertically into and lengthwise throughout the bottom 1 in the space between deck 3 and bottom 1. Each swell guideway 4 is a groove having the cross section with circle-arc, or triangular, or -shaped top, and having the -shaped longitudinal section. The depth denting vertically into bottom 1 at the front end of the groove is on the waterline during the vessel in static state. For the vessel with deeper draft in static state, the concave depth may be slightly lower than the waterline according as the needs of design. The top line of swell guideway 4 having lower front and higher rear forms an inclination α to the bottom plane.

The inclination α and the width $2r$ of the base plane of swell guideway 4 are determined in accordance with the needs of design and referring to the expressions (3), (4).

Expression (3) is $F_0 = 4\rho U^2 a^2 Q \sin\theta \sin\alpha$, (F_0 is the additional thrust offered by the swell guideway),

$$\text{where, } Q = \frac{H_1 \tanh \bar{G}}{k_0^2 \xi \cosh k_0 b} - k_0 \sum_{n=1}^3 \left[(-1)^{n-1} J_n H_2 \sin E_n + R_n \frac{H_3}{G} \right],$$

$$H_1 = 4r' + Ak_0^2, \quad H_2 = \frac{A}{b'} - \frac{4b'r'}{C_n^2}, \quad H_3 = AG^2 - \frac{4r'}{C_n^2},$$

$$A = 2r'b'^2 + 4b'r'^2 + 8r'^3/3, \quad r' = r/a.$$



Expression (4) is $L_o = 4\rho U^2 a^2 Q \sin\theta \cos\alpha$, (L_o is the additional lift offered by the swell guideway).

It is known from Figs. 1, 3 and 4, a pair of wave-splash guards 5 are set one on either board 2 fore and aft. The wave-splash guard 5 with lower front and higher rear has an inclination β to bottom 1. β is the matching angle of α , its specific degree is determined according to design and referring to the angle α . The lowest point of front end of the guard 5 is on the waterline during the hull in static state, for the hull with deeper draft in static state, it may be slightly lower than the waterline according to the design. Wave-splash guard 5 is a baffle having an arc, $\wedge$ type or $\frown$ type cross section and is inlaid one into either board surface (Figs. 4-1, 4-2, 6-5, 6-6), or dented one into either board 2 at the relevant location and formed as an integral whole with board 2 (Figs. 3, 4, 6-3, 6-4).

In this invention the bottom 1 is designed to be a plane base comprising equicrural triangle and rectangle, but not to be V bottom, correspondingly the stem is also sharp, but the stern is wide. A corner of the stem base is cut, which becomes arc, its curvature radius is R (Fig. 1), so the lift surface of the stem is very small during the vessel in planing state. When the stem enters waves, there is not big slamming disturbance; a small force moment of trim by stern may arise when the vessel continues to cut through waves. But this force moment of trim by stern is eliminated by the force moment of trim by stem, which arises from the large lift surface at the stern, thus the trim is small. Moreover, at the stem, below deck 3 the fore foot is cut (Fig. 1), lower part of the boards is nearly vertical (Figs. 3, 4, 4-1, 4-2), thereby the sensitivity responding to the waves is lowered greatly. An important condition is provided to make the vessel chop smoothly on the rough waters over which it moves (Fig. 12-2). The front of bottom 1 is designed as an equicrural triangle, which is beneficial to cut through the rough waters. The rear of bottom 1 is designed to be a rectangle, which is advantageous to increase usable space of the hull and to move the centre O_1 of hydrodynamic buoyancy forward appropriately. That is to make O_1 be located in a best range by regulating the sizes of s, t, b in design. So as to regulate the location of O_2 in operation: when the force moment consisting of the total thrust, total resistance and hydrodynamic buoyancy with respect to the centre O_2 of gravity of the vessel has counterclockwise direction, O_1 is slightly ahead of O_2 (Fig. 10A); if the force moment has clockwise direction, O_1 is slightly behind (Fig. 10B). Then, a fine planing attack angle may be formed during the vessel in moving.

In order to reduce the water resistance, increase the additional lift and thrust and improve the course stability, lateral stability, one or more swell guideways 4 having $2r$ width and paralleling centerline of bottom 1 are set by denting vertically into and lengthwise



throughout the bottom 1. (Figs. 1, 2, 4, 6-2, 6-4, 7-1, 7-2). When the hull moves, the hydrodynamic buoyancy buoies the hull up, and enters planing state, nearby the stern a part of the water pushed by moving hull would enter the swell guideway 4 and flow smooth out of the stern. So the swell height of water surface nearby the stern is lowered, then the water resistance is correspondingly reduced greatly. Seeing from the base plane of bottom 1 (Fig. 2), there are twin planing plates with $2r$ width interval between them. A part of the pushed water must gush into the space with $2r$ width, another part gushes to the outside of both plates. Hence, nearby both boards 2 the swell height of the water surface caused by the water pushed to both boards 2 by bottom 1 would lower, because a part of water gushes into the swell guideway 4. Thus the energy loss would lower, as a result, the water resistance is reduced. The water gushing into swell guideway 4 not only reduces the resistance, but also arouses additional lift and force moment of lateral stability (Figs. 4-3, 6-7, etc.). Thereby the course stability, lateral stability and manoeuvrability of the hull are improved. The top of swell guideway 4 having lower front and higher rear forms inclination α to bottom 1, that makes the additional force offer a part of forward thrust (Fig. 11). It leads to heighten the vessel speed further. As seen from the cross section shown in Figs. 2, 3 and 4, the length of concave arc is larger than $2r$, that is to say, setting of swell guideway 4 increases the wetted area of bottom 1, so it may lead to increase the frictional resistance. But in fact, selecting appropriately the inclination α of top line, the additional thrust offered by swell guideway 4 is larger than the increased frictional resistance greatly. Moreover, lowering the swell height of water surface nearby the stern and both boards 2, the water resistance would reduce greatly. The advantages of swell guideway 4 in reducing resistance, increasing thrust and lift are shown clearly.

Cross section of swell guideway 4 may be designed as $\sim$ type (Figs. 9-4, 4-4, 4-5, 4-6) and $\zeta < r$ (Fig. 4-5), then, when the hull enters planing state, the water gushes upward and rolls along the arc ζ (Fig. 4-6), hence the arc τ avoids wetting. As such, setting swell guideway 4, in fact, owing to decrease of the wetted area, the frictional resistance of water is reduced; thus the vessel speed would heighten further. For the bottom 1 with large $a : b$, the base plane of swell guideway 4 may be made as the shape shown in Fig. 4-7. But its taper must be limited in a small range for the purpose of more lowering the swell height of water surface nearby both boards 2 but without emergence of vortex and turbulent flow in the groove. It may be adopted only when reduction of resistance and increase of thrust have advantages over that of a long rectangle base plane through checking the computations and experiments.

For middle-sized and large-sized vessel, many swell guideways 4 may be set according to the needs (Figs. 6-2, 6-4, 7-1, 7-2, or more), or wider, or very wide



swell guideway 4 may be set (Figs. 8-1, 8-2, 8-3; Figs. 9-1, 9-2, 9-3). For small - sized tour boat having the particular needs in lateral stability, two swell guideways may be set symmetrically (Figs. 25-1, ..., 25-7, Figs. 26-1, ..., 26-7).

In a few words, setting of swell guideway 4 makes the hull reduce the water resistance greatly, moreover, create the additional lift and thrust, hence, heighten its own speed, course stability and lateral stability, also improve its own maneuverability, flexibility and seaworthiness, lower sensitivity to cut through rough waters.

In this invention, the wave - splash guards 5 are set at both boards 2 (Figs. 1, 2, 3, 4, 4-1, 4-2, etc.), which extend from stern forward and downward, form an inclination β , fix at both boards, may also dent into both board surfaces as an integral whole. Then the wave or splash rising along both boards 2 are roll downward along the surfaces of guard 5 (Figs. 4-3, etc.), that not only reduces the wetted area of both side wall, thereby decreases water frictional resistance; but also creates additional lift, thrust and force moment of lateral stability. Besides, the guards may reduce or nearly eliminate the spray or splash interference in the field of vision of passengers during the vessel in operating.

The hull of the planing vessel provided by the invention may have a step at the stern (Figs. 1, 6-1). When the vessel is operating in displacement state at low speed, the step must be overspreaded by a step cover 6', then the stern end is streamlined smooth to make water flow out of the stern unhindered, thereby the water resistance at the stern is reduced. When the hull lifts out of the water, enters planing state, step cover 6' is retracted, the step is revealed. Now, the race of the hull is separated from the hull behind the step, hence the wetted area of the hull is reduced, so that leads to decrease the resistance greatly, and the further increase of vessel speed ensues. The step cover 6' may be rigid, or semirigid, or flexible. The rigid cover is made of thin metal plate, which is stretched out and opened to cover the step by the transmission mechanism when the vessel moves at low speed. When the vessel enters planing state, the cover 6' is retracted, the step is revealed. Semirigid cover 6' is made of rigid metal plate and flexible rubber cloth, the rigid plate is stretched out or retracted by transmission mechanism, but the flexible rubber cloth by compressed air (Figs. 13-1, 13-2, 13-3, 15-1, 15-2). The flexible step cover 6' is made of flexible rubber cloth, which is air - filled and opened. The step is overspreaded during the vessel moving in displacement state. When the vessel enters planing state, cover 6' inhales and is retracted, the step is revealed (Figs. 14-1, 14-2, 14-3, 16-1, 16-2). For the small boat with shallow draft in static state, step cover 6' is needless. The stern may be streamlined without step, or other types.

On the basis of the hull with the features of the invention illustrated as before, a kind of propulsion and control system layout is presented as follows: At the hull rear, inner side



of both boards 2 below deck 3, in the space between deck 3 and waterline during the vessel in planing state, near the water surface one or more water - jet propulsion plants 7 are positioned (Figs. 18, 19, 25 - 2, 25 - 3); water jets 19 are located at the stern end; the water inlets 14 are set at the appropriate locations at bottom 1, here the necessary distance between water inlet 14 and swell guideway 4, bow, stern end, both boards 2 must be kept to ensure that the air can not enter water inlet 14. In addition, the loss of water head along the way and for local area in the water entry way 17 (Fig. 22) is made to be least. The acceleration of water may be achieved by use of water pump or other way. Corresponding to water jet one by one, rudders 6 are set away from stern end slightly. The rudder surface is acted by the water - jet flow, which makes the vessel turn, or stop. Rudders 6 are fixed at stern, their rotating axis 18 is linked up with steering engine to control rudder 6 in turn. Rudder 6 may also be designed as that it may rise or descend along rotating axis 18, that is, rudder 6 may be elevated out of the water - jet flow while it doesn't work, descended and dovetailed with the water - jet flow when the vessel turns or stops. Water jet 19 and corresponding rudder 6 are set above, but near the water surface during the vessel in planing state. For such layout, one of the advantages is that the resistance at stern is made to be the least, the other advantages are that the manoeuvrability, flexibility and seaworthiness of the vessel are heightened greatly. The vessel turns flexibly on the planing surface, with the least water resistance and small turning radius (Fig. 24) under the acting of turning force moment given by rudder 6. Swell guideway 4 makes the hull heighten the lateral stability in turning with shallow draft. Therefore, the vessel, particularly small boat, with the features of the invention may smoothly navigate in the river or sea with deep water, rough waters, as well as shallow water, strong and rapid current, or with submerged reef.

As mentioned above, the hull of planing vessel offered by the invention adopts plane bottom 1 consisting of an equicrural triangle ahead and a rectangle behind. That makes the lift coefficient largest, wetted area and corresponding frictional resistance least, lift surface at stem lesser and at stern larger. Accordingly, the trim is small. Besides, the swell guideway 4 makes the swell height of water surface nearby the bow and boards 2 lower, then the water resistance reduces greatly, makes the hull have better course stability, lateral stability and fine manoeuvrability; flexibility, seaworthiness. Furthermore, the hull, which is dull of responding to the wave, can smooth cut through the wave, chop on rough waters and achieve the supercritical operation state (Fig. 12 - 2).

In comparison with existing various hulls, the planing vessel hull provided by the invention can shake off water resistance in maximum limit, thus heighten its own speed greatly, at the same time, can also meet the needs of various cargo tonnage, therefore



greatly better than the displacement type hull. The lift surface area and its layout of the planing vessel bottom can overcome hydrofoil craft drawbacks created by the layout of lift surface and its structure, can conquer hovercraft defects caused by depend on dynamic air cushion to support gross weight, furthermore, the bottom comprising equicrural triangle, rectangle and setting swell guideway can overcome the shortcomings of general planing boat hull, and conquer drawbacks of sea - knife boat in course, lateral stability and manoeuvrability, which are created by its pure triangle plane bottom. Consequently, the hull of planing vessel of the invention has advantages over almost all the hulls of conventional ships. In the same power consumption it has not only higher speed, but also in course, lateral stability, and in manoeuvrability, flexibility, seaworthiness, in smooth chopping on rough waters has advantages over various existing ships and boats.

Owing to the hull provided by the invention, particularly the hydrodynamic layout in the space between bottom 1 and deck 3, that makes force moment of trim by stern be small, water resistance be small and the vessel enter planing state faster. As a result of shallow draft, the vessel of the invention not only can navigate on general sea and inland river, but also for small - sized boat such as tour boat and fast boat, it may be designed to be able to navigate on the inland river having strong and rapid current, submerged reef, shallow water and on littoral sea. The hull of the invention is low in power consumption, large in controllable range of change of speed and load carrying capability, and is smooth, safe and flexible in operating.

Applying example 1. In accordance with features of the invention a tour boat is designed (Figs. 17, 18, 19, 20, 21, 22). The hull has a plane bottom 1 consisting of an equicrural triangle and a rectangle. Denting vertically into and lengthwise throughout bottom 1, a swell guideway 4 having top line with inclination α is set, the cross section thereof is  type, longitudinal section is  type, width of its base plane is $2r$. A pair of wave-splash guards 5 are dented one into each board 2. At the stern, a semirigid step cover 6' is set. At the hull rear a pair of water-jet propulsion plants 7 are set, which are symmetrically parallel to the hull centerline. A pair of rudders 6 and power plants 8 are set one by one corresponding to the water-jet propulsion plants 7. The jets 19 are set at the stern end. The jets 19 and rudders 6 are located above, but near the water surface during the vessel in planing state. A pair of water inlets 14 are positioned one on either side of the bottom centerline. The superstructure 9 is streamlined. In the passenger cabin 12 there are driver seat 15, several passenger seats 13. The boat can navigate on general sea or inland river, as well as on the river or littoral sea with shallow water or strong and rapid current or submerged reef. The boat is large in controllable range of change of speed, and is smooth, safe in operating, and can smooth chop on rough waters, achieve the supercritical



operation state.

Example 2. According to the features of the invention, a boat is designed (Figs. 25 - 1, 25 - 2, 25 - 3, 25 - 4, 25 - 5, 25 - 6, 25 - 7) with a plane bottom 1 comprising an equicrural triangle and a rectangle. A pair of swell guidewaies 4 are set one on either side of the bottom centerline symmetrically. A pair of wave - splash guards 5 are set one on either board. Driver seat 15, passenger cabin 12 and seat 13 with five seats are set. A water - jet propulsion plant 7, power plant 8 and rudder 6 are set in mid location and parallel to the hull centerline. Water inlet 14 is set on the bottom centerline. Jet 19 and rudder 6 are located above, but near the water surface during the vessel in planing state. Windshield 20 is set at the stern. Boat is open, mobile ceiling may be set, opening the ceiling for covering the cabin when it is need, taking back the ceiling while it is needless. The draft of this boat is particularly shallow. It may run smooth and safely on the inland rivers or in lakes with shoal.

Example 3. According as features of the invention, adopting layout of the hull shown in example 2, passenger seat 13 with 7 seats is set in passenger cabin 12. Mono - propeller may be adopted, which is set at the stern end with seat 22 of outboard motor. Twin - propeller may also be set at the stern end with two seats 21 of outboard motors. The outboard motor is taken as propeller, as seen in Figs. 26 - 1, 26 - 2, 26 - 3, 26 - 4, 26 - 5, 26 - 6, 26 - 7.

On the basis of the hull having features offered by the invention, in accordance with different use, the water - jet propulsion, propellor or other propulsion and control systems may by adopted, corresponding cabin, deck, and superstructure may be positioned, etc. . The traffic boat (Fig. 23), salvage vessel, patrol escort and other various type small boats, middling and large, manifold vessels may be designed and builded. They may reach the speed range designed, may also reach high speed designed, may have fine course, lateral stability, seaworthiness, manoeuvrability, may reach supercritical operation state and cut through rough waters smooth in moving (Fig. 12 - 2), have fine flexibility in changing direction with small turning radius (Fig. 24). The performance of the planing vessel having the hull offered by the invention is more better than the that of existing boats and ships.

The planing vessel provided by the invention may directly apply to ship building industry.



**Claims:**

1. A planing vessel consists of a hull; a system of propulsion and control; said hull comprising a bottom 1, board 2, deck 3, cabin and superstructure, features thereof are: a plane bottom 1 is composed of an equicrural triangle ahead and a rectangle behind; one or more swell guidewaies 4 denting vertically into and lengthwise throughout said bottom are set in the space between said bottom 1 and deck 3, the base centerlines of said swell guidewaies symmetrically parallel the bottom 1 centerline (if only one swell guideway is set, its base centerline coincides with the bottom 1 centerline), each swell guideway has the cross section with  or  or  type, the longitudinal section with  type, whose top line with inclination has lower front and higher rear; a pair of wave-splash guards 5 having lower front and higher rear are set one on either board 2, the guards 5 being the baffles with inclination are inlaid into surfaces of boards 2 or dented into boards 2 as an integral whole below the deck 3 and above bottom 1;

2. A planing vessel as claimed in claim 1 wherein for said bottom 1, the sizes of length l which is the projection of the equicrural length S of the triangle part in said bottom on OX axis, the length t of the rectangle part in direction of OX axis and width $2b$ in direction OZ are determined according to the needs of design and referring to the expressions (1), (2):

Said Expression (1) is $L = 2\rho U^2 a^2 P \sin\theta$, (L is the hydrodynamic buoyancy),

$$\text{where, } P = \int_{-a}^{a-t} T_1(x) dx + \int_{a-t}^a T_2(x) dx, \quad T_1(x) = \int_{-b(x)}^{b(x)} p(x, z) dz,$$

$$p(x, z) = \frac{Ka}{1-K\delta} \left\{ \frac{G \exp(-\bar{G}x) \cosh k_0 z}{k_0 \xi \cosh \bar{G} \cosh k_0 b} + 2 \sum_{n=1}^{\infty} \frac{(-1)^{n-1}}{C_n^2} \left[-\sin C_n x + \right. \right. \\ \left. \left. k_0 R_n \cos B_n z (B_n \cos C_n x - k_0 \sin C_n x) + k_0 G b J_n \cos D_n z (D_n \cos E_n x - k_0 \sin E_n x) \right] \right\},$$

$$R_n = 1 / (k_0^2 + B_n^2) \cos B_n b, \quad J_n = 1 / (k_0^2 + D_n^2) \cos D_n z, \quad B_n = G C_n,$$

$$\xi = \sqrt{1 + \varepsilon^2}, \quad C_n = (2n-1)\pi/2, \quad D_n = C_n / b', \quad E_n = C_n / G b',$$

$$b(x) = bx / l, \quad x = X / a, \quad z = Z / a, \quad G = \sqrt{(1-K\delta)/K\delta}, \quad K = g / U^2,$$

$$T_2(x) = \int_{-b}^b p(x, z) dz, \quad \varepsilon = 0.0045, \quad \bar{G} = k_0 / G, \quad b' = b / a,$$





Said Expression (2) is $X = M/L$, (X is the distance between the midpoint O of the bottom centerline and the centre O_1 of hydrodynamic buoyancy),

$$\text{where } M = 2\rho U^2 a^3 N \sin\theta, \quad N = \int_{-a}^{+a} x T_1(x) dx + \int_{-a}^{+a} x T_2(x) dx,$$

Note: the expressions mentioned above are based on: coordinate origin O is put on the bottom centerline and is the midpoint of overall wetted length $2a$ of said bottom, OX is the ordinate, OZ is the abscissa; ρ is density of water, U is ship speed, θ is attack angle of said bottom against the horizontal during the vessel in moving; W_1 is its own weight; W_2 is load weight; $L = W_1 + W_2$ during the vessel in planing state; M is force moment of lift pressure on said bottom with respect to the centerline midpoint O ; θ_1 is attack angle of said bottom against the horizontal during the vessel in static state, generally about 5° is taken, it may also be determined by the permissible static draft at the stern end, length of the hull and other factors; $0.1 \leq k_0 \leq 1$ (or determined by the needs of design), g is acceleration of gravity, δ is half depth of the stern end draft (determined by the needs of design).

3. A planing vessel as claimed in claim 1 wherein said swell guideway 4 is a groove. Said groove has cross section with circle-arc top, or with triangular top, or  shaped top and longitudinal section with top line having lower front and higher rear, which forms inclination α to said bottom 1. The base width of said groove is $2r$. The concave depth of the front end of said groove denting vertically into said bottom is on the waterline or slightly lower during said hull in static state. Said α and $2r$ are determined according as the needs of design and referring to expressions (3), (4):

Said Expression (3) is $F_o = 4\rho U^2 a^2 Q \sin\theta \sin\alpha$, (F_o is the additional hydrodynamic thrust offered by the swell guideway),

$$\text{where, } Q = \frac{H_1 \tanh \bar{G}}{k_0^2 \xi \cosh k_0 b} - k_0 \sum_{n=1}^3 \left[(-1)^{n-1} J_n H_2 \sin E_n + R_n \frac{H_3}{G} \right],$$

$$H_1 = 4r' + A k_0^2, \quad H_2 = \frac{A}{b'} - \frac{4b'r'}{C_n^2}, \quad H_3 = A G^2 - \frac{4r'}{C_n^2},$$

$$A = 2r'b'^2 + 4b'r'^2 + 8r'^3 / 3, \quad r' = r/a.$$

Said Expression (4) is $L_o = 4\rho U^2 a^2 Q \sin\theta \cos\alpha$, (L_o is the additional hydrodynamic lift offered by the swell guideway).

4. A planing vessel as claimed in claim 1 whereby the said pair of wave-splash guards 5 having lower front and higher rear, which forms inclination β to said bottom, are set one on either board 2 fore and aft. Said β is the matching angle of said α , and its specific degree is determined according to the needs of design and referring to said angle α .





The lowest point of the front end of said wave - splash guard 5 is on the waterline or slightly lower during said hull in static state.

5. A planing vessel as claimed in claim 1 whereat the base plane of said swell guideway may also be a long cone having a narrower front end and a wider rear end.

6. A planing vessel as claimed in claim 1 wherein said propulsion and control system comprises water - jet propulsion plant 7, power plant 8 and rudder 6. In the space between said deck 3 and waterline during the vessel in planing state, at the rear of said hull, in inner sides of said both boards 2 below said deck 3, near the water surface one or more water - jet propulsion plants 7 are positioned, whose centerline is in the middle and parallel to the hull centerline (when only one water - jet propulsion plant is set) or whose centerlines are symmetrically parallel to the hull centerline (when a pair of or more water - jet propulsion plants are set). They are fixed on the necessary place by joining component. Jets 19 are set at the stern end. Said rudders are set one by one corresponding to said jets 19 and near them. Said rudders 6 are fixed at the stern by the component with enough strength. The rotating axis 18 of said rudder 6 is linked up with steering engine. Said rudder may also be designed as that it can rise or descend along said rotating axis, that is to say, it may be elevated out of the water - jet flow when it doesn't work, descended and dovetailed with the water - jet flow when the vessel turns or stops. In the engine room 11 said power plant 8 is put for driving said water - jet propulsion plant 7. Said power plant 8 may be diesel or other power equipment. The longitudinal centerline of the water inlet 14 coincides with the bottom centerline (there is a water - jet propulsion plant) or the water inlet centerlines are symmetrically parallel to the bottom centerline (when there are a pair of or more water - jet propulsion plants). Said water inlet is set at an appropriate place of said bottom 1 for keeping enough distance between said water inlet and said swell guideway, bow, stern end, said both boards to ensure that the air can not enter said water inlet 14 during the vessel in planing state and the loss of water head along the way and for local area in the water entry way 17 is made to be the least.

7. A planing vessel as claimed in claim 1 wherein said propulsion and control system may also adopt propellor or other propulsion and control systems.

