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IMPROVEMENT OF HIGH-SPEED CRAFT PROPULSION BY USING OF PROPELLERS WITH SHIFTED BLADE CONNECTION ON THE HUB

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ABSTRACT

The description of the variable pitch propeller (VPP) is presented. An insight into this propeller operation is given. Its advantages which give the improvement of propulsion of different purpose ship in comparison with the traditional propeller are noted .To be said in the report it is confirmed by examples.

INTRODUCTION

About twenty years it has been already exhibited marked interest to unusual propeller – variable pitch propeller (VPP). The constructional feature of this propeller is a movable clamping between the propeller and the hub.

By the present day several concrete constructional of VPP have been offered. For their creation it has been carried out design, researches and full scale tests. The most completed works are related to VPP with "free" moving blades within the disk plane near the operating position. The last one of such propeller is defined by action of the hydrodynamic and of the centrifugal restorative force.

1. COMPARISON VPP WITH CPP

The interest to be arisen to VPP is explained by the fact that it can considerably fulfill the function of controllable pitch propeller (CPP), giving it in the first turn the effective processing power in wide range of changing mode of propeller operation. Such modes it is constantly met during the ship moving in the intervening running. In this case fixed pitch propeller (FPP) to be designed as optimal one with the condition of reaching maximum ship speed on the calm water does not allow to realize the having reserves in improving running qualities in wide range of service conditions. At the same time right designed VPP has not such drawback. The same is concerned with CPP. However, for the rotating its blades it is necessary to have forced (hydraulic) driven being very expensive and complex device and requiring special service about it during operating. Besides the changing of FPP by CPP in the vessels is connected with huge additional expenditure and with hard working with shaft line. Being with hydraulic driven of blades there is ecology's danger of environment due to oil leak.

2. THE OPERATING PRINCIPLE OF VPP

To illustrate the principle of the VPP operating a diagram is given in fig.1 showing the forces which act on one of the blades. The blade motion is provided within the disk plane in relation to point A at the hub. The research results have demonstrated that the relative displacement of the blade in direction opposite to that of the propeller rotation is accompanied by increasing in the moment M_1 caused by centrifugal force and decreasing in the moment M_2 caused by hydrodynamic forces. When the blade is deflected in the opposite direction the picture is reversed. This blade position on the hub is determined by equality of action of the mutually opposed moments. In depending on the propeller operation mode (advance ratio) the blade position will be different. As this take place the propeller hydrodynamic characteristics as compared with those of the propeller with fixed blades will change (see fig. 2) as the above motions (in relation to the pivoting point A located off the propeller axis) cause the changing of the propeller geometry (see fig 2). This very important quality of VPP opens the prospect in some cases to use it instead of FPP self-providing the optimal main engine load at the intervening modes of operation and correlation engine operation with the propeller at the service conditions without force driven only at the expense of action of hydrodynamic, inertia and, in general case, of elastic forces.

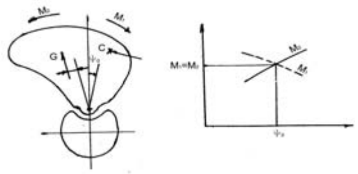


Fig. 1. The operating principle of VPP.

The typical feature of VPP is the fact that hydrodynamics characteristics of the propeller due to movable blades relative to hub have less of slope against the horizontal axe. Moreover the geometrical characteristics of VPP may be chosen in such a way that in all range of modes of its operations it is able to process full power of main engine without overloading at any conditions of ship going. This is important quality VPP as at the designing of FPP, as rule, it is tended to hydrodynamic decreasing of load in ship services due to acting of waves, getting hull roughness and so on. Here it is not need to take such care off. Excluding of this reserve in applying of VPP it is allowed to get maximum ship speed on calm water and in doing so to increased her propulsion qualities.

Fig.3. The general view of the sea-river going ship "Ladoga".

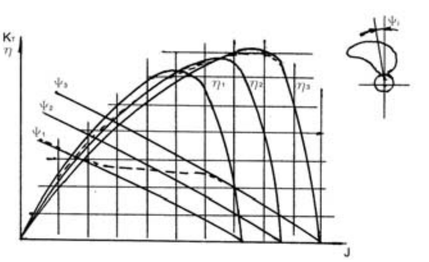


Fig. 2. Hydrodynamic characteristics of VPP.

Notations are related to:
—— fixed blades; – – – "free" blades.

3. RESULTS OF DESIGN

3.1. Low speed ship. The fulfillment of design researches of VPP in applying to "Ladoga" (see fig. 3) of sea-river going ship shown that year economical effect is more than 10000$ in year. This result has been gotten in service conditions which was out of the calm deep water and was connected with the decreasing of service consumption with the equality of freight turn-over. This result may be considerably increased if operating economy is connected with freight of vessel. However, in this case the quantity will be considerably depended on market interest to be taken place in the region.

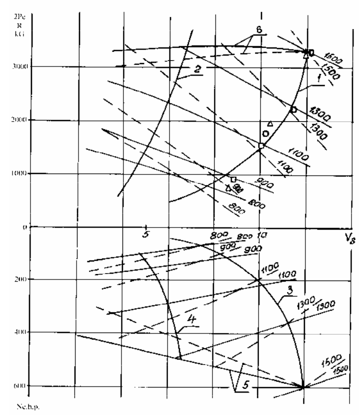


Fig. 4. The passport diagram of the trawler with VPP.
Notations are related to:
—— VPP; – – – FPP; □ ,O full scale data.

Another way to use VPP may be connected with improvement of pulling characteristics of ship. The matter is that FPP being design for processing full power with aim for reaching maximum speed does not allow to use available power reserve in the conditions of towing of any object due to restriction power consumption in depending of shaft rotation. In fig. 4 it is shown calculation data relating to trawler with the results of full scale tests. They are confirming that to be said. From this results it is seen that propulsion ship qualities in the case of VPP with fixed and "free" blades on the hub are practically the same (curves 1,3). At the same time at the mode of pulling (curve 2,4) due to restriction characteristics of main engine (curve 5) VPP allows to process more power. It gives the trawler more high pulling characteristics. In this example the speed of trawling increase by 0,4 knots and pulling of towing hook – by 350 km. The general view of VPP arranged on trawler is shown in fig. 4.

This result is explained by moveable of blades on the hub. With the increasing of propeller load the blades move to decreased pitch (negative angle ψ, see fig. 2) what resulted in to decreasing hydrodynamics moment on the VPP and in the case of keeping the taking up the power to need for increasing rotation that is to change operation mode of engine in high rotation domain (see fig 5) where its restriction curves allow to take off more power what result in to increasing pull characteristics of trawler.

Fig. 5. The general view of VPP arranged on trawler.

3.2. Hydrodynamics characteristics of VPP. In the course of VPP design as applied to sea-going ship and to trawler it was widely utilized the program product "Flow Vision" (FV) which able to define hydrodynamics characteristics of VPP. The FV is dedicated to flow simulation at high Reynolds number and small changed density. Utilized turbulence model is based on standard K-ε model. During the calculation the equations of Navie-Storks, turbulence energy and disperse this energy are used. In FV it is used right angled cells for calculation. This cells are adapted to solution and to boundaries of calculation domain. Approximation of non-linear boundaries with the high accuracy to be given with method of under cell geometry solution. The calculation's cell is automatically generated. In fig. 6,7,8 and 9 it is shown as an example of the results of hydrodynamics simulation. The needs of simulation was caused by getting of hydrodynamics propeller characteristics in deflecting of blades from constructional positional on the hub.

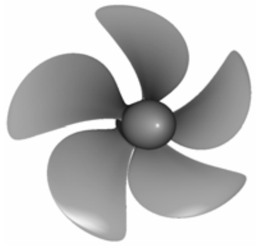


Fig.6. Model of calculation's propeller.

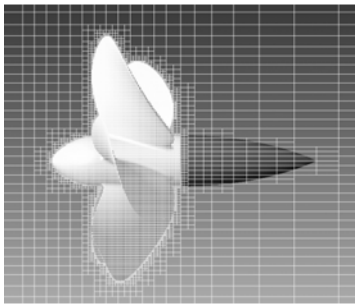


Fig.7. Cell of calculation.

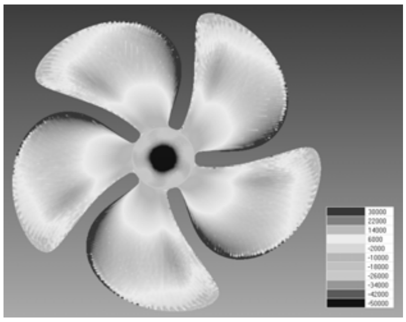


Fig.8. Pressure distribution on pressure side of blades.

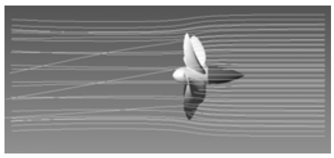
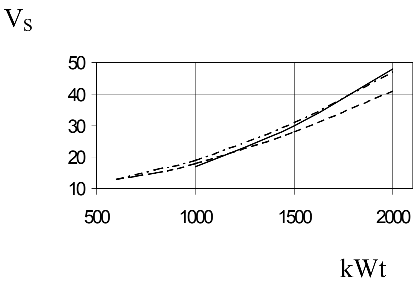


Fig.9. Streamlines

3.3. High-speed crafts. The design work of VPP as applied to high-speed crafts it was carried out for patrol boat(see fig. 10) and for the craft with underwater wing (see fig. 11). The patrol boat had three shaft lines: two side one's and another middle one. Total power of boat engine was $\Sigma Ne = 2*10000 + 20000kWt$. The design developments show that maximum reached speed of patrol boat equipped with fixed propellers amounts about 50 knots. As this take place the patrol speed is 14 knots is not given by side propellers because of their hydrodynamics overload. Design of sided fixed pitch propellers for patrol speed comes to notable loss of maximum speed velocity. Along with utilizing of VPP as side propeller allow to get no lost of full speed and simultaneously to boat movement with minimum of consumption of energy.

Results of propeller design for the craft with under water wings show that overcoming of "hump" resistance and giving craft to move at wing mode it is possible to get due to using of VPP. In the case of using fixed pitch propeller it is come to loss of maximum speed of craft or to overloaded propeller at the transitional mode of operation.

Fig.10. Patrol boat.



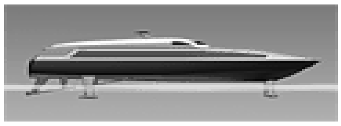


Fig.12. High-speed craft.

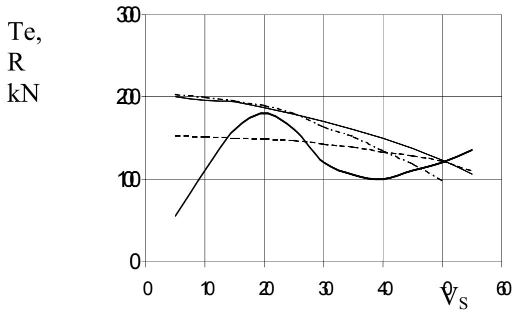


Fig.13. Resistance of craft (R) and pulling characteristics of propellers (Te) against speed.
_____ R; ---- Te for FPP designed for max. speed;
__ . _ Te for FPP designed to overcome "Hump" resistance; ___ Te of VPP.

4. CONCLUSION

Making an estimate of the prospects for applications of VPP it should be noted that nowadays it has been carried out methodical materials, it has been accumulated experience of their manufacture. It gives grounds in the present conversion conditions to ensure carrying out the creation of non-traditional propeller – VPP as applied to different purpose ships on short notice.

REFERENCES

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