ISSN: 1231-4005
e-ISSN: 2354-0133
DOI: 10.5604/12314005.1216480

SELECTION OF PROPULSION UNIT FOR A NEW CLASS OF TRANSPORT HOVERCRAFT AS A COMPROMISE BETWEEN TECHNICAL PERFORMANCE AND PURCHASE AND EXPLOITATION COSTS

Krzysztof Szafran, Zbigniew Pągowski

Institute of Aviation
Krakowska Avenue 110/114, 02-256 Warszawa, Poland
tel.: +48 228460011, fax: +48 228462912
e-mail: Krzysztof.Szafran@IoA.edu.pl, Zbigniew.Pagowski@IoA.edu.pl

Abstract

In this paper, the authors presented some technical and economic relations to which a team designing a new means of transport should pay attention. In the first chapter briefly describes the hovercraft designed and built at the Institute of Aviation, as well as showing the certification documents obtained in the process of certification by the Polish Register of Shipping and Inland Navigation Office. The second chapter shows some parts of the production process. In the third chapter shows the drive unit and the characteristics of the selected motor. Problems of selecting a drive unit for a newly designed hovercraft aimed at transporting people and goods were described. The choice of propulsion engine, its quality and the kind of fuel affect the cost of purchase as well as the time and exploitation costs. A user planning a transport network pays particular attention to minimizing operating costs and the consequent reliability and safety. The authors presented regulations and standards, which need to be met by the transport unit designed for use in the public area. Attention was also paid to ecology, noise and pollution. An algorithm, which takes into account the rules of conduct, requirements of the ordering party and conditions of the manufacturer, was proposed. In conclusion, the generalized technical and economic guidelines are proposed which, in the authors' opinion, may aid the development of a conceptual design of new modes of transport – not only the hovercraft.

Keywords: *transport, exploitation costs, propulsion unit, operational safety, production economics*

1. Introduction

A project of a rescue patrol hovercraft realized at the Institute of Aviation allowed gaining experience in issues related to an economic justification for starting a small series production. Designed and made in the research projects one copy of the hovercraft was used for an intensive promotion among users interested in the Polish market and foreign markets. This new and practically unknown product on our market was well publicized in local services taking care of security of the Polish population on internal waters. A research and analysis of the domestic market were conducted. A base of potential users was made and questionnaires were sent with questions concerning requirements for the equipment. Research on the global market for this class of hovercraft was also carried out.

The Hovercraft PRP-560 and PRC-600 produced at the Institute of Aviation, was designed mainly for rescue and patrol actions [3]. It can move on land, desert on inland waters, swamps and almost everywhere where use of car or boat is impossible. The primary users are police, fire departments, border guards, water rescue and flood service, and oil & gas investigation. The hovercraft is adapted to be used the whole year, in all weather conditions and strong winter too. It is economical and easy in use vehicle, with low level of noise, high safety level for crew and passengers. It enables efficient rescue missions as well as fun. Hovercraft PRP-560 and PRC-600 is intended to transport 5-8 persons (including driver). Optional hovercraft is completed car conditioner and special cower inside passenger cabin. In extraordinary situation hovercraft

transported six, seven hundred kilogram payload or fourteen people. We tested hovercraft in extreme air temperature + 50st. C on desert. Construction hovercraft PRC-600M is prepared to fly in Mountain River – a swift-flowing river. Special skirt is covert difficult scrape material. Hovercraft PRP-560M is perfect device on flooding and Shallow River.

One prototype “0 – zero” has been built in Institute of Aviation in Warsaw [1] for test new elements and construction. Full test was finished in 2003 and received a certificate in accordance with the requirements of the Act [2]. In August 2003, we obtained Polish Type Certificate PRS for “normal” category show in Fig. 1. Next hovercrafts had been manufactured by Prototype Workshops in Institute of Aviation. We had manufactured nine hovercraft. All finally, hovercraft had been tested in different grounds. We made test complete on lake, river, Mountain River, at the seaside. Flying on the grass, water, ice, desert and swamp in many countries around the world. Four hovercrafts are working on lake and river in Poland. Two hovercrafts were bought by Company Geophysics Serwis from India. One hovercraft is in Florida and one is in Sudan- Nil (Africa).

Polski Rejestr Statków

ŚWIADECTWO KLASY ŁODZI

NR 96/SJ/2003 — Wa-II-1895 — 628163

Instytut Lotnictwa, al.Krakowska 110/114, 02-256 Warszawa — Warszawa

Instytut Lotnictwa, Warszawa — 2002

PRP-560 / IL-PRP560-03 — lps

5,00 m — 2,30 m — 0,60 m

5,50 m — — — 0,25 m

45,0 km/h — 5

Daewoo, Nubira 2000, benzynowy

96,0 kW — 5100

poduszkowiec

Przegląd dla nadania klasy zakończono w sierpniu 2002

* bKM 2 pat x

08-2007

22-02-2003

RZECZPOSPOLITA POLSKA

URZĄD ŻEGLUGI ŚRÓDLĄDOWEJ w Warszawie

ŚWIADECTWO ZDOLNOŚCI ŻEGLUGOWEJ MAŁEGO STATKU

NR Wa/3/303

Nazwa statku	Numer rejestracyjny	Port macierzysty
IL -PRP560/03	Wa-II-1895	Warszawa

Właściciel (użytkownik) statku i jego adres: INSTYTUT LOTNICTWA, Al.Krakowska 110/114, 02-256 Warszawa.

Wyposażenie techniczno-eksploatacyjne: Kotwica 1 szt.,8 kg.,lina kotwiczna 1 szt.,koło ratunkowe z rzutką., kamizelki ratunkowe 5 szt.,gaśnica 1 szt.,latarnie nawigacyjne kpl. reflektor 1 szt.,sygnał akustyczny 1 szt.,bosak.,wiosła 2 szt., apteczka 1 szt.,liny cumownicze 2 szt.,latarka elektryczna 1 szt.

Kwalifikacje kierownika statku: starszy sternik motorowodny

Liczba członków załogi 1, innych osób 4, łącznie osób 5

Stwierdza się, że statek został dopuszczony do żeglugi w rejonie (ach) bKM 2 pat x przy wyznaczonej wolnej burcie - cm, bez ograniczeń – żegluga całodobowa.

Świadectwo zdolności żeglugowej jest ważne do dnia 1 sierpnia 2007 roku

Warszawa dnia 07.08.2002r

Fig. 1. PRS certificate and a certificate of navigability licenses

2. Production preparation

Realized at the Institute of Aviation project hovercraft rescue patrol allowed gaining experience in issues related to economic justification to start small series production. Designed and made in Workshop prototype. Development organizations small series productions of the transport device on an air cushion, which will reduce the time required for the production of products, increasing the quality and lowering the unit cost, and thus increase the competitiveness of the market. An important aspect is also the ecology of technologies used and the safety of the working environment as discussed in detail in [6]. Carried out trials with biofuel – E85 bio of 85% ethanol content. Tests have shown a very low emission of harmful substances (nitrogen oxides, carbon dioxide and hydrocarbons) compared to unleaded gasoline Euro super Pb95. Bioethanol is easily biodegradable, which makes any leakage is safe for the environment. To achieve these objectives, it is necessary to collect the relevant data production, development schemes and schedules, as well

as become familiar with modern technologies of composite structures. During the development of technologies was estimated production data including time, type of position and operation description for each part of the team. The division process is given in Fig. 2.

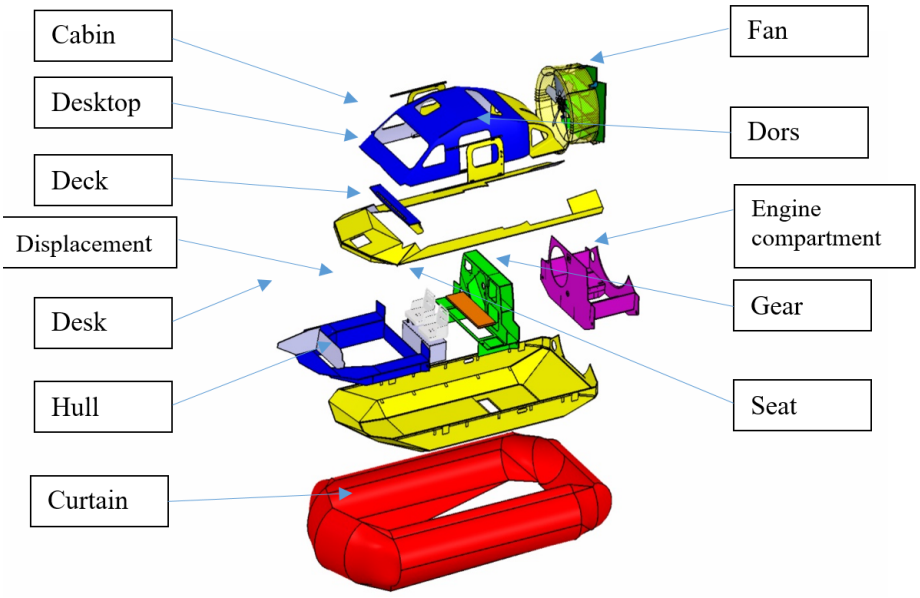

Fig. 2. The division of the technological hull hovercraft PRP-600

After analysing the periods of technological performance modules it found that some items would be transferred to production in cooperation. This will reduce the amount of hours thus increasing the production capacity of the plant with the same number of employees. These items will only be pasted or mounted in its place. The following table [4] shows the calculation of the technology for one of the modules hovercraft.

Tab. 1. Calculation of hull construction

Group:		Hull			
No.	Technology	Description of the operation	tpz [hr/team]	tj [hr/team]	State employees
1	P	Preparation and cutting of the material (foam mats). Drilling holes all foams R3 100 x 100	2	8	2
2	LAM	Covering foams	0.5	2.5	1
3	LAM	Applying a thin layer of gelcoat	1	0.5	4+1
4	LAM	Apply 3 layers of glass fabric and filtration	1	2	6+1
5	LAM	The assumption layer separation and vacuum	0.5	1	2
6	LAM	Curing in vacuum	0	10	0
7	LAM	Applying a thin layer of gel coat. After the merger foams rounded edges to R10	1	1	4+1
8	LAM	Location foam and plywood in form, the connection them gelcoat.	0.5	2	3
9	LAM	Apply vacuum	0.5	0.5	3
10	LAM	Curing in vacuum	0	10	0
11	LAM	Apply 3 layers of glass fabric and filtration	1	3	4
12	LAM	The assumption layer separation and vacuum	0	1	2
13	LAM	Curing in vacuum	0	10	0
14	SL	Grinding, cutting technological allowances	0.5	3.5	2
15	KT	Checking the execution. Issuing notices, enter weight	0	0.1	1
			8.5	25.1	
			33.6		

In the production process, it is necessary to draw up schedules that show the actual time frame they occupy production processes and assembly. The production process elements hovercraft starts at a certain date, and ends on time. Assembly process should start the next day. Example of partial schedule is shown in Tab. 2.

Tab. 2. Example schedule production of hovercraft elements

ID	Task	Start [dd-mm]	Finish [dd-mm]	Duration [h]	Reserve time [h]
1	Hull	03-03	07-03	33.6	4.35
2	Displacement	07-03	11-03	15.4	4.3
3	Seat	11-03	12-03	11.65	4.35
4	Deck	03-03	05-03	22.5	9.3
5	Engine compartment	06-03	10-03	17.2	9.3
6	Gear box	10-03	12-03	16	9.35
7	Cabin	03-03	05-03	24.8	13.3
8	Desk	05-03	11-03	23.7	13.3
9	Desktop	11-03	11-03	3.2	13.3

Already at the design stage, it is assumed unification of parts and components. For example, in the described production process hovercraft PRP-560 significantly reduced manufacturing time.

All these modifications and to introduce some order in production helped reduce the number of hours required to complete one copy of about 1,200 to 755, while the period of technological 5.5 months to less than two months. This enabled the implementation of the plan 8 hovercraft for 16 months, which meet and exceed more than 1 month, founded in the early design requirements. Substitution technologies enable not only to achieve lower production costs, but also to improve the quality of the final product.

3. Concept the drive unit for hovercraft PRI-760

Starting from the initial assumptions consumables developed for hovercraft PRI-750 as a hovercraft transport [8], and more detailed technical conditions for the drive module assembly. The conditions adopted maximum values of parameters such as the power drive unit, the motor and fan, the minimum necessary thrust required for the hovercraft. The strength calculations assumed extreme maximum load rotating assembly occurring during the most probable failure. Adopted factors should protect newly designed drive unit before the construction of the hull research platform on an air cushion.

The drive module is divided into:

- drive unit, diesel engine (after analysing the purchase price of selected motor vehicle),
- single-belt drive with high efficiency reduces the maximum engine speed to the maximum allowable fan speed (several times cheaper than the bevel gear),
- industrial fan with increased strength parameters (instead of propellers),
- composite fan housing profile developed in IoA.
  Detailed design parameters of the reserved utility are given in [5],
- compensation and suspension bearing fan in the tunnel (light and cheap),
- light truss unit (version with commercial elements),
- composite rudders and slips built-in fan housing (technology of IoA).

The entire drive unit is compact mounted to the hull of the hovercraft. Installation is made unification handles the same security. Sketch of the drawing unit of the drive unit shown in Fig. 3 [7].

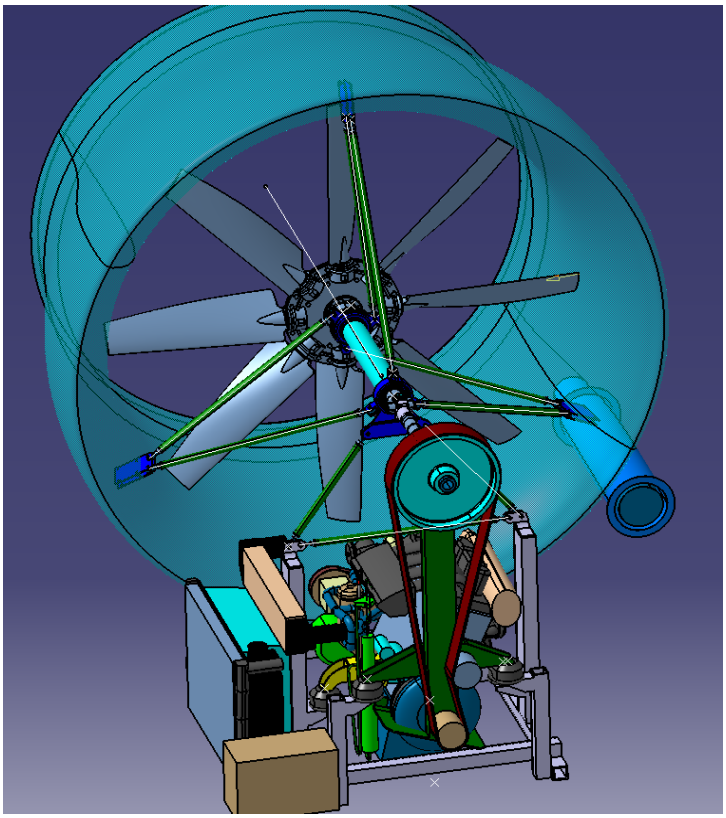

Fig. 3. The innovative module to drive a hovercraft PRI-760

The module is equipped with specialized lifting, which greatly facilitates the removal of the entire team and transport with the help. The crane industry. Removal of an engine failure, e.g. Snap fan blades or adjustment or repair of the engine is facilitated by the rapid removal of a drive unit with the hull and repair at a specialized workshop. With this solution, the user need not have a large hall comprised the hovercraft to make repairs. Connection strings Control system power supply and fuel technologies designed quickly. This solution does not require draining fluids from the hydraulic system and fuel. The project also considered the concept of power research platform alternative fuels as detailed quoting the results of bench studies and field in [9].

4. Economic aspects of the selection engine

The hovercraft PRI-760 decided to use the engine M47-Tu -320De46.
It is a turbocharged engine powered by diesel, liquid cooled.
Its main characteristics are:

- maximum power – P_{max} = 110 kW (150 hp),
- the speed at maximum power: – n (P_{max}) = 4000 rpm. TQ (P_{max} = 230 Nm),
- speed at idle – max n = 460 rpm. – Maximum torque – TQ max = 330 Nm (n = 1700-2400 rpm).

The direction of rotation is counter-clockwise when viewed from the clutch in the drive unit will be used engine with the clutch (no gearbox), radiator and intercooler, 12V, 100Ah VETUS AGM („locker"), muffler, stainless steel 150 mm, L = 650 mm for the lecture. The company EL-TEC. Fig. 2 shows the distribution of equipment. Fig. 4 shows characteristics of the engine.

5. Conclusions

Depending on the technical – economic in the design of new means of transport have a decisive impact on the success of the project and product competitiveness in the market. The ultimate goal of any new project is to increase safety, lower operating costs and minimize production costs. New

materials and technologies and innovative designs allow for the optimization of production processes. Manufacturing automation and unification of parts of machines may significantly shorten the manufacturing time. The production time is an important parameter influencing the final price of the product, which is an indispensable factor for a successful project. The contemporary design of new means of transport is closely linked with the optimization of the subsequent stages of product development.

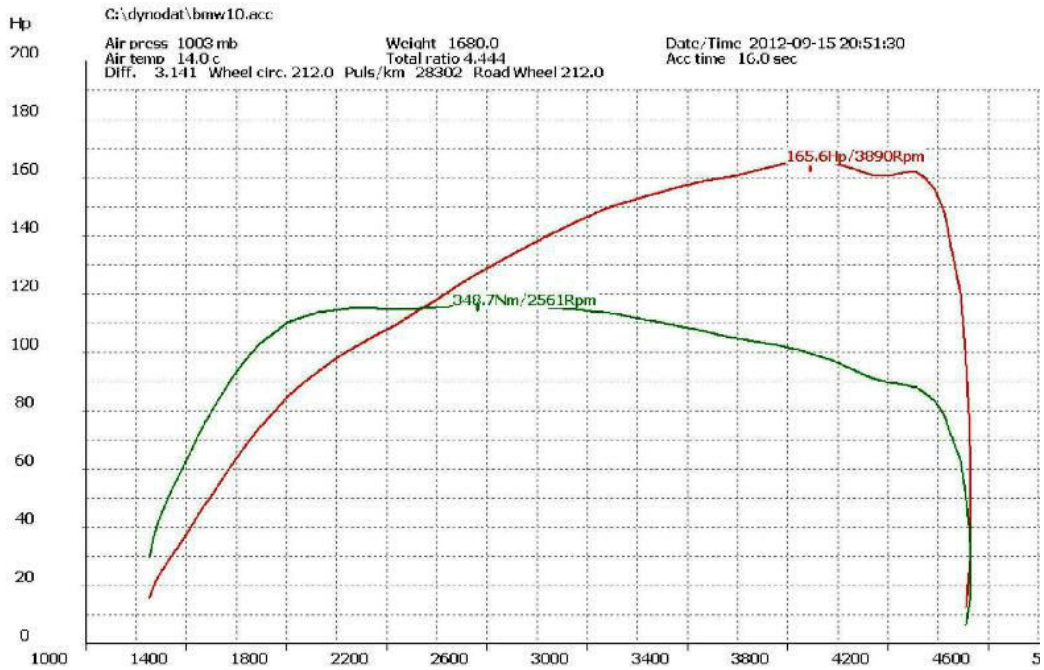

Fig. 4. The M47-TU engine characteristics to drive a hovercraft PRI-760

References

[1] CAA – *British Hovercraft Safety Requirements*, Is. 4, August 1981.

[2] Dz. U. 2001 Nr 5 poz. 43, *USTAWA z dnia 21 grudnia 2000 r. o żegludze śródlądowej*.

[3] Amyot, J. R., *Hovercraft Technology, Economics and Aplications*, Elsevier 1989.

[4] Grybowski, R., *Projekt organizacji produkcji małoseryjnej urządzeń transportowych na poduszce powietrznej*, Praca Inżynierska Instytut Lotnictwa, 2014.

[5] Szafran, K., Shcherbonos, O., Ejmocki, D., *Effect of duct shape on ducted propeller trust performance*, Transaction of the Institute of Aviation, No. 4(237), pp. 85-91, 2014.

[6] Pągowski, Z. T., Szafran, K., *The Ecological Hovercraft – Dream or Reality!* Marine Transport &Shipping, Marine navigation and safety of sea transportation, pp. 44-48, 2013.

[7] Szafran, K., Kramarski, I., *Safety of Navigation on the Approaches to the Ports of the Republic of Poland on the Basis of the Radar System on the Aerostat Platform*, The International Journal on Marine Navigation and Safety of Sea Transportation, Vol. 9, No. 1, pp. 131-136, 2015.

[8] Pągowski, Z. T., Szafran, K., *Ground effect Inter-Modal Fast Sea Transport,* The International Journal on Marine Navigation and Safety of Sea Transportation, Vol. 8, No. 2, pp. 317-320, 2014.

[9] Iwaniuk, A., Wiśniowski, W., Żółtak, J., *Multi – disciplinary optimization approach for a light turboprop aircraft – engine integration and improvement*, Aircraft Engineering and Aerospace Technology: An International Journal, 88/2, pp. 348-355, 2016.