Design and Construction of an Unmanned Craft with Capability of Installing Two Operation Mechanism in the Propulsion

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Abstract
Increasing speed, decreasing weight and having sufficient resistance are the most important parameters in design and construction of unmanned crafts. Current model of this fast craft has been constructed in the scale 1/15 of similar craft, which is a single-body racer craft. The craft design is preformed in various software such as Maxsurf marine software. The material of the craft is aluminum and has propeller propulsion system. Two types of steering operation mechanisms for the propulsion system are designed and tested, which are: steering by rudder and steering by propulsion system of moving shaft, in which provides capability of steering movement for the craft. At the first mechanism, craft maneuver is via deviation of positive flow of the propeller on the blade of rudder. But maneuver in the second mechanism is possible by positive propeller thrust (propeller movement laterally), which leads to increase of maneuver efficiency. In this craft, 2 motor with 1300 watt power are used. This craft considering the body shape and propulsion system can achieve up to 14 Knots speed. In rodent to examine propulsion system operation, speed and maneuver test have been done to the craft. Also the test of proper length position of center of mass in order to reduce porpoizing has been done, which finally, the result is 30 cm from the toe (considering length of craft is 95 cm). This craft has the capability of remote control and smart control in spiral and circular path. In this paper, the design, construction and testing stages of the craft has been done.
Keywords: Unmanned craft, single body, aluminum, rudder, moving shaft propulsion system, Maxsurf

1-Introduction

Using fast crafts with different applications of entertainment and sport is common for years in the world. This vehicle can be an effective vehicle in military and nonmilitary aspects because of the speed and high maneuverability and also less weight and construction costs than other crafts. The use of unmanned equipments, especially smart equipments which can perform various operations without operator are increasing. These crafts have large applications in marine relief and rescue, struggle with oil pollution, military operations, etc. In designing fast crafts, the selection, priority survey and various balancing between different components are mentioned, that each selection can be compatible with special goals and also can be un compatible with many other issues [1]. In order to reach the maximum speed which is needed and minimum energy consumption, it must be selected a proper body type and its propulsion system, in which can show an appropriate operation in various marine situations. In this single-body craft using propeller propulsion system and aluminum as a body material, the higher speeds are achieved. Considering happened problems in unmanned crafts which are using rudder as a steering mechanism (such as motor fracture and decrease in motor efficiency), for the propulsion system of this craft in addition to rudder, a steering mechanism of moving shaft is also designed and tested. In this paper, after design and numerical analyses descriptions, the method of construction and assemble and applied tests will be explained.

2-The process of designing of the craft

Design of the craft is done in several stages and in each stage the craft is optimized. In this process in order to achieve craft stability and calculating needed power of propulsion system to achieve expected speed, it is necessary to determine the shape and dimensions of the body. And then investigation of Hydrostatic and Hydrodynamic considering location of mass items needs to be done.

-The choice of body shape

In the choice of body shape, effective parameters such as speed, weight, cost and easy construction (according to aluminum for body material) have been considered. According to properties of plaining single-body crafts, the simple body with V shaped cross section has been chosen for the craft. These crafts are appropriate for high speeds, then the propulsion power must be so adequate in which the body separates from water and reaches to plaining state.

-Determining body dimensions

The model of the body considered for the craft, is based on the model of a racing plaining craft. The size of weight items needed to carry by the craft, is one of the most important parameters in determining body dimensions. Considering needed buoyancy and space to location of desired equipments, the dimensions of the craft is in the scale 1/15 of main craft, so that this craft is 95 cm in length and 27 cm in width and 16 cm in height.

-Determining body material

Using light and resistant materials in severe weather changes and high resistance is one of the key issues in construction of fast crafts [2]. The material of the unmanned crafts can be made of composite materials, aluminum etc. Aluminum sheets have many advantages such as high ratio of resistance per its weight, corrosion resistance, protecting the properties in low temperature and fatigue resistance [3]. Due to high costs of construction of the craft using composite materials, use of aluminum sheets in craft construction has been preferred.

-Hydrostatic calculations

Hydrostatic calculations has been done by a marine software Maxsurf . Initially, it is necessary to draw craft body by CATIA software and then, the geometric model of the body must be shifted to the Maxsurf media. Figure 1 shows drawn body by the CATIA software.

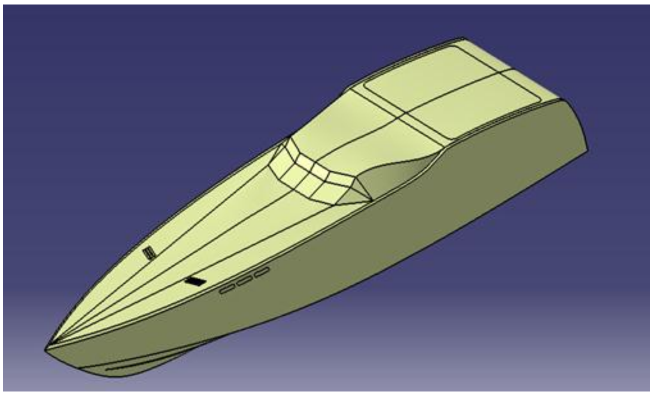

Figure 1: Body shape of the craft drawn by CATIA software

To perform calculations, the table of mass items is needed. By defining the characteristics of these items according to Table 1 to the software, Hydrostatic curves and the table of Hydrostatic characteristics have been elicited.

Table 1: Locating of mass items

Mass items	M*Z	M*Y	M*X	Z(m)	Y(m)	X(m)	M(kg)
Body	0.19	0	1.08	0.07	0	0.36	2.8
Load	0.42	0	1.2	0.14	0	0.4	3
Battery	0.02	0	0.43	0.03	0	0.62	0.7
Motor, Servo	0.04	0.22	0.05	0.09	+0.5	0.12	0.45
Motor, Servo	-.04	-0.2	0.05	0.09	-0.5	0.12	0.45
Propulsion equipment	0.02	0	0	0.05	0	0	0.5
Sum	-	-	-	-	-	-	7.9

Table 2 : Hydrostatic calculations

Displacement kg	7.9
WL Length m	0.839
WL Beam m	0.262
Wetted Area m^2	0.213
Waterpl. Area m^2	0.169
Prismatic Coeff.	0.689
Block Coeff.	0.491
Midship Area Coeff.	0.713
Waterpl. Area Coeff.	0.771
LCB from Amidsh. (+ve fwd) m	-0.112
LCF from Amidsh. (+ve fwd) m	-0.078
KB m	0.039

KG fluid m	0.07
BMt m	0.119
BML m	1.139
GMt m	0.088
GML m	1.108
KMt m	0.158
KML m	1.178
Immersion (TPC) tonne/cm	0.002

3-Hydrodynamic calculations

Hydrodynamic calculations of the craft has been done in Maxsurf software at two states; planning state and pre-planning state, using Savitsky method. The purpose of doing these calculations is determination of craft resistance and estimate of the power of the craft needed to reach to desired speed.

The diagram of power vs. speed (Figure 2) and resistance vs. speed (Figure 3) have been elicited [4]. Air resistance and wave resistance have been omitted according to small dimensions of the craft [5].

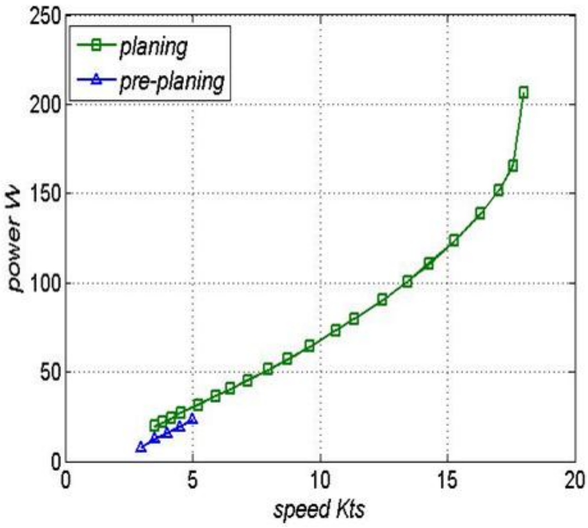

Figure 2: Diagram of power vs. speed

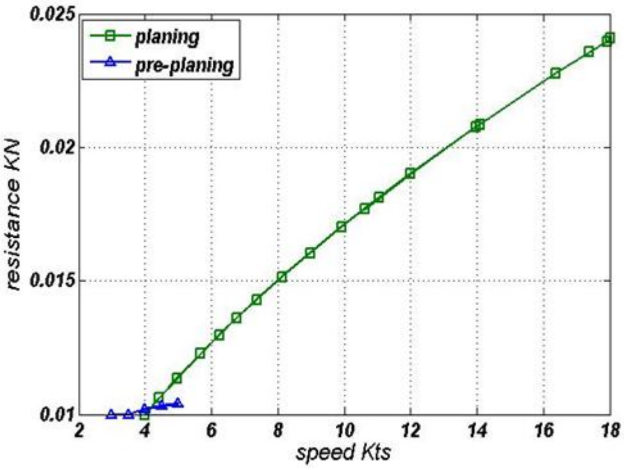

Figure 3: Diagram of resistance vs. speed

As shown in figure 3, as speed increases, upward trend of resistance- speed curve is associated with low slope (the increase of resistance versus the increase of speed is low), which represents high efficiency of the craft's body.

Table 3: Hydrodynamic calculations

	Speed [Kts]	Savitsky preplaning resist. [KN]	Savitsky preplaning power [W]	Savitsky planing resist [KN]	Savitsky planing power [W]
1	0	-	-	-	-
2	0.5	-	-	-	-
3	1	-	-	-	-
4	1.5	-	-	-	-
5	2	-	-	-	-
6	2.5	-	-	-	-
7	3	0.01	7.82	-	19.4
8	3.5	0.01	12.51	0.01	24
9	4	0.01	15.71	0.01	28.8
10	4.5	0.01	19.17	0.01	32.7
11	5	0.01	23.14	0.01	35.89
12	5.5	0.01	-	0.01	38.64
13	6	-	-	0.01	41.18
14	6.5	-	-	0.01	43.7
15	7	-	-	0.01	46.3
16	7.5	-	-	0.01	49.15
17	8	-	-	0.01	52.26
18	8.5	-	-	0.01	55.7
19	9	-	-	0.01	59.5
20	9.5	-	-	0.01	63
21	10	-	-	0.01	68
22	10.5	-	-	0.01	73
23	11	-	-	0.01	79
24	11.5	-	-	0.01	85
25	12	-	-	0.01	92
26	12.5	-	-	0.01	99
27	13	-	-	0.01	107
28	13.5	-	-	0.02	115
29	14	-	-	0.02	124
30	14.5	-	-	0.02	134
31	15	-	-	0.02	144
32	15.5	-	-	0.02	155
33	16	-	-	0.02	167
34	16.5	-	-	0.02	179
35	17	-	-	0.02	192
36	17.5	-	-	0.02	206
37	18	-	-	0.02	220

Considering the speed of 15 Knots for the craft, the Reynolds number equals:

$$Re = \frac{VL}{\upsilon} = \frac{7.71*0.72}{1.09*10^{-6}} = 5.09*10^{6} \quad (١)$$

-Propulsion system

The propulsion system of unmanned crafts usually is propeller or water jet system. Considering high coasts and heavy weight of the water jet system, the propeller propulsion system is chosen. The elements of the propulsion system consist of propeller, propeller shaft, entrance shaft, rudder, couplings and headstocks and relevant waterproofs. For the propulsion system two types of steering operation mechanisms are designed and constructed. These two types are: steering by the rudder and steering via designing propulsion system of proper moving shaft, in which provides capability of steering movement for the craft.

In the moving shaft mechanism (figure 4), at first, there are two fixed shafts which are by one side connected to the motor, and by another side are connected to the moving shaft via a universal joint. Two moving shafts also are connected to the servo motor via a T shaped joint. As shown in figure 5, by rotating the servo motor, two moving shafts are simultaneously rotating with an equal angle, and this phenomenon causes lateral movement of the propeller and the craft rotates. At this mechanism propellers are connected to the moving shaft and by rotating the motor leading to rotation of the propeller, the needed thrust for the craft is provided

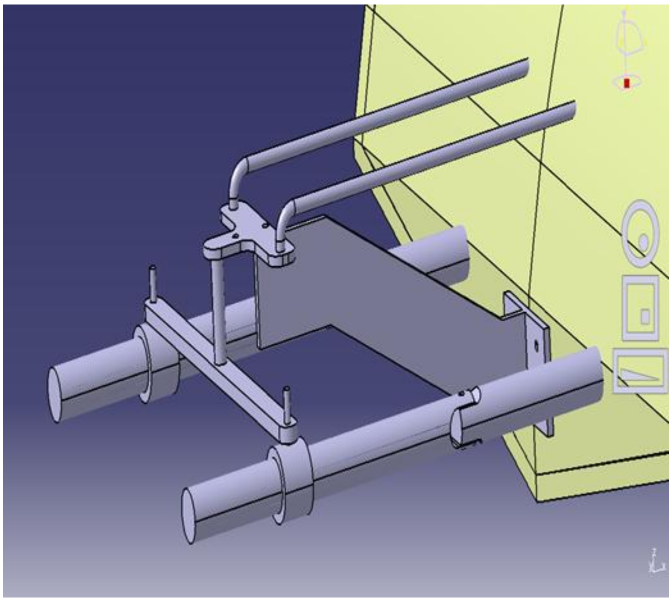

Figure 4: Designing the system of moving propulsion system

An advantage of this mechanism is decrease in frictional resistance of the craft which helps to the craft to reach plaining state quickly. At this mechanism, lateral movement of the propeller is possible, which leads to an increase in efficiency of the maneuver. In figure 5, a view of the moving shaft propulsion system is shown.

Figure 5: The moving shaft propulsion system

At the propeller propulsion system using a rudder is prevalent. At this mechanism (figure 6), the propellers are connected to two fixed shafts, which are connected to the motor. The rudder is connected to the servo via two rods, and as servo rotates, the rudder also rotates equally, and this phenomenon leads to rotation of the craft.

Figure 6: Propulsion system by the rudder

4-Manufacturing and assemble

Body construction needs an accuracy and sufficient time because material of the body is aluminum. The construction method is as follows: at first, the frame of the body based on 3D body plans which were designed by the software media is made. Aluminum sheets at first are cut with specific dimensions and then curvatures of the body are applied by a shaping machine and finally, these sheets are connected together by aluminum welding.

Figure 7: Construction of the craft body

For more strength, lateral reinforcing sheets can be used. After installing these sheets, the body is ready to assemble mechanical and electronic equipments. The craft has two propeller with two blades (figure 8) with a rudder and universal joint, considering small dimensions and design complexity, the smart lathe machine CNC is used to construction of these segments.

Figure 8: Propeller of the craft (right) and rudder of the craft

5-Testing

After construction of the craft's body, at the first step, the body was tested about probable pores and water seepage into the body, in which were not any. At the second test, the Porpoizing phenomenon which created due to incorrect equipment location in the body leading to unbalanced coupling between pitch and heave was studied. At this test by different positioning of weight items in three stages, optimized position of mass center which is 30 cm from the toe was obtained. At the third test the propulsion system operation of the craft was examined at two states: steering by the rudder, and steering by moving shaft mechanism. This test consists of two stages: determination of speed, and capability of craft maneuver for above mentioned states (this test is performed to determine speed and capability of craft maneuver at each above mentioned states). At the stage of speed determination, the craft passed a 60 m direct path and it's results are shown in table 4.

Table 4: test results of the craft speed

Type of propulsion	Recorded time
Rudder propulsion system	12 Sec.
Moving shaft propulsion system	9 Sec.

At the maneuver test, it is necessary to pass the craft a 10 m path in which there are 5 barriers by distance of 2 m from each other, and return to the starting point. The test results are written in the table 5.

Table 5: test results of craft maneuver

Type of propulsion	Recorded time
Rudder propulsion system	15 Sec.
Moving shaft propulsion system	10 Sec.

As anticipated, using moving shaft propulsion system at each two stages, better results were obtained. The highest speed score of the craft was 14 knots.

-Reasons of design optimality

This craft named Jamaran, achieved the second ranking in maneuver by radio control and the fourth ranking in speed in the radio control part, at the third tournament of smart crafts at Sharif University of Technology. In the summary of two radio control and intelligence parts, it achieved fifth ranking. As anticipated in designs, the craft considering body type and propulsion system type can reach flight mode in low speeds, and this matter causes better operation of the body and reach to high speeds. The craft using moving shaft propulsion system has high capability of maneuver. This craft in high speeds due to apply relevant tests and determining the exact location of the mass center, will not experience porpoizing phenomenon. Advantages above causes excellence of this craft among other unmanned crafts.

Figure 9: final test of the craft

6-Summary & Conclusion

- According to preformed tests on the model craft, these results can be obtained:
Aluminum body has capability of radio waves transition and therefore it is possible to locate radio control receiver into the body. Also this material don't need cooling system of the body inside.
- considering that the high speed is an important factor in unmanned crafts, use of partially submerged propeller propulsion system with steering mechanism of moving shaft can help to achieve this factor. Also using this type of propulsion can resolve the use of the craft in shallow water.
- The craft using propulsion system of moving shaft, because of ability of propeller rotation in horizontal direction, has high capability of maneuver which leads to be safe from radars and marine patrols.
- This craft due to its low costs and low weight, can be used in various fields such as military operations, rescue, imaging and etc .
- According to the problems encountered in the use of rudder as a propulsion mechanism in unmanned crafts (e.g. fracture, etc.) use of propulsion system of moving shaft in unmanned crafts is recommended.

7-References

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