Examination the possibility of controlling the orientation of the object by division of the air stream behind the propeller.

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Abstract

The main aim of this project is to check possibility of changing the orientation of the object by division of the air stream behind the propeller. During project realisation, device which allows to investigate this phenomena was built. Conducted tests confirmed the possibility of apply stable and setpoint forces. This allows to state that influence of stream on the device can be controlled.

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1 Introduction

The aim of the project is to build a prototype which allows to verify the hypothesis that it is possible to control the orientation of object by division of air stream behind the propeller. The main idea of construction is presented on the figure 1.

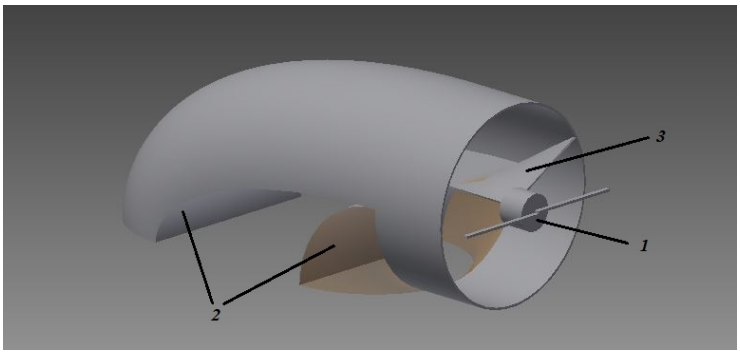

Figure 1: Main sketch of construction (1-engine with propeller, 2-tunnels, 3-dividing bulkhead)

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Air stream induced by rotation of the propeller is divided by bulkhead and directed to two tunnels. Then directions of air movement are changed which generate forces. All main forces are illustrated on figure 2.

Presumably it is possible to adjust the resultant momentum by changing amount of air moved through tunnels. Theoretically, orientation in one degree of freedom can be changed by mentioned control. In this project preceding statement is verified.

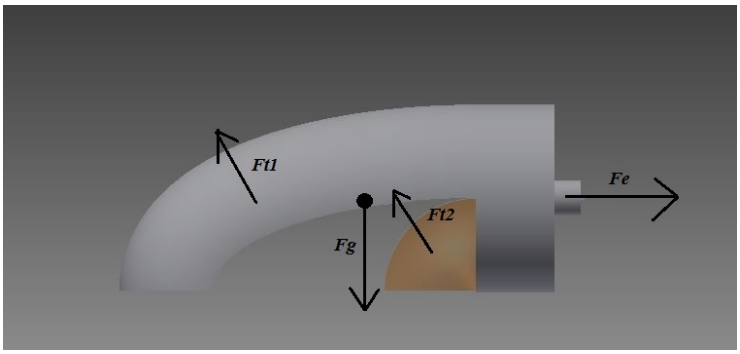

Figure 2: Forces which affects on construction (Fg-gravitation force, Ft1 and Ft2 forces affect on tunnels Fe-force affect on engine and propeller).

1.1 Goals to accomplish

Presented above project is complex and can be divided into the following stages:

1. Mathematical description of tunnels.
2. Building a mechanical structure. In this part of the project it is necessary to do tunnels, through which the air is flowing. The volume of flow which is entering the various tunnels will be determined by the setting of the bulkhead.
3. The programming of the control system which sets bulkhead and engine speed.
4. Preparing the test station and adjustment the structure for testing. This stage involves the establish of conditions which are as close as possible to simulate free movement of the object.
5. Examination of the characteristic of splitting factor to generated thrust.
6. A summary of achieved results.

2 Results

2.1 Mathematical model of tunnels

Shape of the tunnel was designed in the way that has as small as possible influence on air going through it. To obtain this effect it was established that cross-section shall have the same area along the entire length.

Pattern was obtained by few steps of mathematical computations. First step was a mathematical description general shape. Curvature was determined as ellipse.

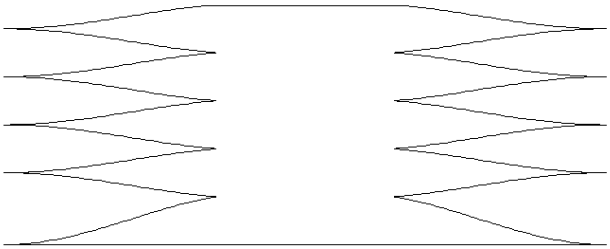

Figure 3: Pattern of the tunnel.

Then whole structure was divided to five segments. Amount of the material was determined in each segment. After connection of segments full pattern was created. It it shown on figure 3.

Figure 4: Tunnel after folding.

2.2 Mechanical structure

Prototype was built based on knowledge from previous subsection. Result is presented on the figure 5.

First engine which generate thrust is SunnySky X3108s. The most important specification associated with this motor is listed below:

- Supply 14.8V
- Weight 81 g
- Max power 325W
- Propeller size 9x6 inch
- Thrust with mounted propeller up to 10N

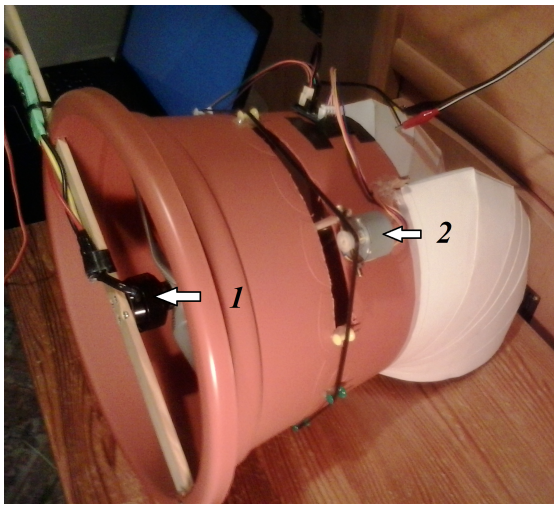

Figure 5: Prototype of the device (1- motor which generate trust, 2 - step motor which control the bulkhead).

Second engine is responsible for bulkhead movement. It was used motor 28BYJ. Characteristic of this motor is as follow:

- Type unipolar
- Supply 5V
- Gear 1:64
- Number of steps per one rotation 512

Gearwheel with 36 teeth is mounted on the shaft. Belt which transmit the movement has 780 tooth. As a result bulkhead can be set with accuracy of 0.032 degree.

2.3 Electronic

Electronics is responsible for controlling the speed of propeller and setting the position of bulkhead.

To control engines additional drivers were used. Brushless motor is controlled by EBC Multistar 40A. This device has PWM interface. Each step of motor 28BYJ is established via ULN2003 driver.

The main board is STM32F3Discovery. Algorithm of the process is located on STM32F303VCT6. This microcontroller has ARM Cortex M3 core. Features of this device are listed below:

- Clocking up 72 MHz
- interfaces: I2C, SPI, UART, USB

- 10 timers
- DMA
- 12-bit ADC
- PGA

Power supply is accumulator Turnigy 4C 5000mAh with maximal current up to 175A. Three different voltages are necessary to provide proper values for every component of the system . MCU is powered by 3V supply (using low-dropout regulator on Discovery board), brushless engine with 14.8V source (direct from battery) and step motor driver with 5V supply (additional circuit with regulator).

2.4 Tests

Tests were conducted by measuring the force which effects on prototype in relation to position of bulkhead. To measure this force exit of a tunnel was placed over the flat surface. Air that flow out of the device presses the surface with balance mounted below. In this way value of force is estimated. The result is presented on a figure 6.

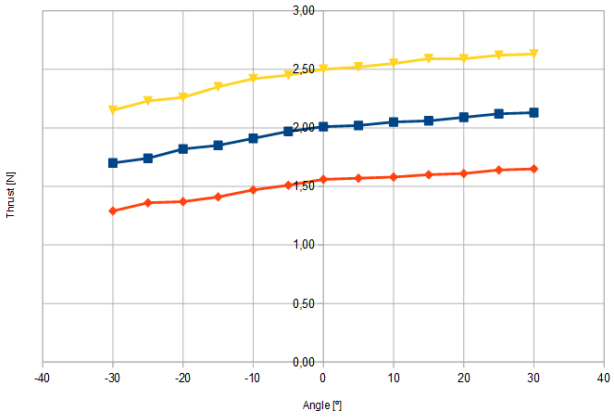

Figure 6: Thrust for different positions of the bulkhead.

Values below zero on X axis mean that tunnel cross-section is reduced. Otherwise cross-section is enlarged.

According to recorded data conclusion can be stated that relationship between investigated values is almost linear but every characteristic must be divided into two subregions.

3 Tools

During the realization of project many tools and programs were used.

To achieve goal of project some computations need to be conducted in Mathematica program. Moreover influence on structure by the stream was investigated in program for fluids computations CFD Simulation (to choice the proper shape of bulkhead).

Second part was performed by programming the STM32F303VCT6 microcontroller. To configure processor STM32CubeMX was used. Code was written in System Workbench for STM32. Furthermore version control system Git was used.

4 Summary

The main goals of project were accomplished. The prototype was built and it allows to carry out studies about how the division of the air stream impact on existing forces.

On the basis of tests, it was found that the relationship between the cross sectional area of the tunnel and the amount of air flow is linear. This allows to set such a division of tunnels, to achieve forces which changes the orientation of the object in desired manner. Due to this fact, realization of the control using discussed approach is possible. However, it was shown that changes in the forces occurring between opening and closing the tunnel are different. Probably the control parameters will differ for each of these zones.

5 Literature

- José C. Páscoa, Antonio Dumas, Michele Trancossi, Paul Stewart, Dean Vucinic "A review of thrust-vectoring in support of a V/STOL non-moving mechanical propulsion system", 2013.
- STM documentation:
  `http://www.st.com/en/microcontrollers/stm32f303vc.html`
- STMCubeMx documentation:
  `http://www.st.com/en/development-tools/stm32cubemx.html`