Modeling, Simulation and Identification of Propulsion system of a Small UAV

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Abstract– Unmanned Aerial Vehicle (UAV) Modeling is very important part in designing an Autopilot to control the vehicle during its flight and predict its motion according to certain guidance law, the overall model consists of 5 important models which are atmospheric model, actuation model, geometric model, aerodynamic model and finally the propulsion model which is the case study of the paper. JAVAPROP is a simple tool for the design and the analysis of propellers, we analysis the propeller to calculate thrust generated by the propeller and to determine the coefficients needed in calculations of thrust force, two steps are needed in order to perform the analysis: determination of the geometric properties of the propeller, and choosing a working area for the propeller.

Keywords--UAV, Modeling, JAVAPROP, Propeller Scanner and Thrust force.

I. INTRODUCTION

Nowadays Unmanned Aerial Vehicles (UAVs) have become one of the most interests in the world. It has many applications either in military or in the civilian. The first step in developing navigation, guidance, and control strategies for UAVs is to develop appropriate dynamic models. Deriving the nonlinear equations of motion for a UAV we linearize the equations of motion to create transfer-function and state-space models appropriate for control design. It is necessary to make a model for the UAV to predict its motion. There are two methods of Modeling:

1-Physical Modeling:

A-Model each sub-system alone.

B-Integrate all models to get overall model.

2-System Identification.

To ensure high performance of the Autopilot, this model should be accurate.

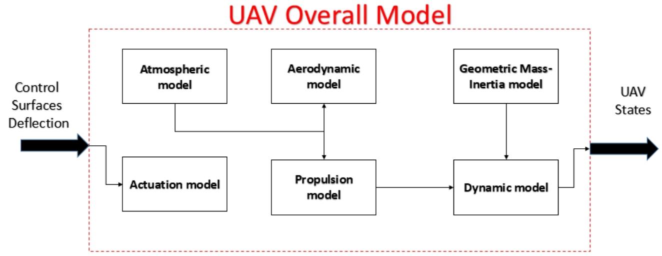

Fig.1. UAV Overall Model.

The paper contains the following: Section II presents the propulsion system model of the UAV. Section III discusses the results of simulation. Finally, the conclusions of this paper are given in Section IV.

II. PROPULSION SYSTEM MODEL

In this model we are analysis the propeller of the vehicle in order to calculate the generated thrust and torque forces using JAVAPROP tool which is a simple tool for the design and the analysis of propellers, this section contains a model of propeller. The model is derived using an implementation of the Glauret's Blade Element Theory (BET) to determine the thrust and torque at a given V∞ and angular velocity of the propeller. It is chosen to use JAVAPROP tool, which is a ready-made implementation of BET.

A. Blade Element Theory (BET)

The Blade Element Theory calculates thrust and torque forces for a propeller by summing up forces and torques for small sections of the blade, see fig 2.

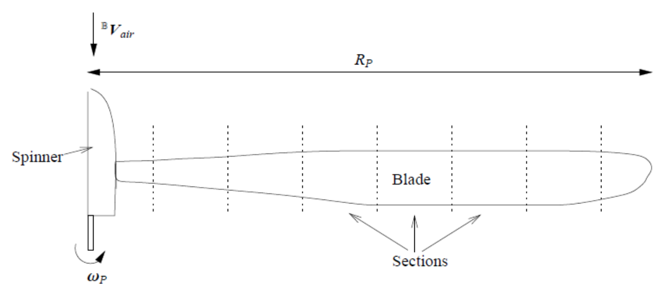

Fig.2. A blade on the propeller divided in sections with the propeller radius R_P.

Two components: $\boldsymbol{V}_{air}$ and $\boldsymbol{V}_W$ determine the velocity of the airflow coursed by the rotation of the blade $\boldsymbol{V}_P$,

$$\boldsymbol{V}_P = \boldsymbol{V}_{air} + \boldsymbol{V}_W. \quad (1)$$

When the propeller is rotating two aerodynamic forces are generated. Lift is perpendicular to the chord line of the airfoil, and drag is parallel to the chord line, in order to perform the analysis: determination of the geometric properties of the propeller, and choosing a working area for of the propeller.

B. Propeller Scanner

This small program tries to reconstruct the blade shape of a two bladed propeller from bitmap (bmp) images. It takes a side view and a front view and traces the blade shape. The results are the chord and twist distribution along the radius. Both blades are taken into account and the average of both sides is presented as the nominal propeller geometry.

Fig.3. Propeller Front View.

Fig.4. Propeller Side View.

Inserting the front and side views of the propeller 8060 which is adjusted by Adobe Photoshop, the propeller RPM is 1400(1/min), the flight speed is zero, the diameter of propeller is 0.152 m and the white threshold is 65. The results of propeller scanner program are spreadsheet table which is used as input geometry data for JAVAPROP tool.

Spreadsheet | Chord Distribution | Twist Distribution | Pitch Distribution

No.	r/R	c/R	r	c	β	H	Re	Ma
1	-1.0000	0.0011	-76.0000	0.0819	0.0000	0.0000	64	0.03
2	-0.9750	0.0866	-74.0969	6.5830	0.0038	0.0311	5006	0.03
3	-0.9249	0.1224	-70.2908	9.3004	0.0000	0.0000	6709	0.03
4	-0.8748	0.1290	-66.4847	9.8012	0.3522	2.5682	6687	0.03
5	-0.8247	0.1322	-62.6785	10.0168	4.4816	30.8668	6443	0.03
6	-0.7746	0.1367	-58.8724	10.2958	7.7914	50.6142	6221	0.03
7	-0.7246	0.1432	-55.0662	10.5660	13.8571	85.3495	5971	0.02
8	-0.6745	0.1481	-51.2601	10.7781	16.7302	96.8128	5670	0.02
9	-0.6244	0.1558	-47.4540	11.0796	20.6747	112.5153	5396	0.02
10	-0.5743	0.1632	-43.6478	11.3621	23.6780	120.2603	5090	0.02
11	-0.5242	0.1703	-39.8417	11.6098	26.2095	123.2307	4747	0.02
12	-0.4742	0.1772	-36.0355	11.8875	28.0350	120.5662	4396	0.02
13	-0.4241	0.1836	-32.2294	12.1709	29.2926	113.6050	4026	0.01
14	-0.3740	0.1862	-28.4233	12.3175	29.4791	100.9546	3593	0.01
15	-0.3239	0.1858	-24.6171	12.3205	29.2227	86.5249	3113	0.01
16	-0.2738	0.1816	-20.8110	12.2097	27.7997	68.9407	2608	0.01
17	-0.2237	0.1729	-17.0048	11.8387	25.7363	51.5041	2066	0.01
18	-0.1737	0.1612	-13.1987	11.2886	22.8495	34.9448	1529	0.01
19	-0.1236	0.1471	-9.3926	10.3398	22.3551	24.2702	997	0.00
20	-0.0735	0.1513	-5.5864	8.4189	42.9141	32.6336	483	0.00
21	-0.0234	0.1476	-1.7803	7.9564	44.8082	11.1112	145	0.00
22	0.0267	0.1302	2.0258	8.4286	31.6209	7.8372	175	0.00
23	0.0767	0.1368	5.8320	9.2313	27.3735	18.9727	553	0.00
24	0.1268	0.1696	9.6381	11.4554	27.2760	31.2242	1133	0.00
25	0.1769	0.1921	13.4443	12.8169	28.5909	46.0386	1768	0.01
26	0.2270	0.2074	17.2504	13.6069	30.3139	63.3718	2409	0.01
27	0.2771	0.2151	21.0565	14.1116	30.3405	77.4367	3049	0.01
28	0.3271	0.2171	24.8627	14.2912	29.9754	90.1025	3646	0.01
29	0.3772	0.2140	28.6688	14.2164	29.0737	100.1517	4183	0.01
30	0.4273	0.2069	32.4750	13.9479	27.5082	106.2567	4648	0.01
31	0.4774	0.1980	36.2811	13.4942	26.2410	112.3736	5024	0.02
32	0.5275	0.1876	40.0872	12.9926	24.2891	113.6682	5345	0.02
33	0.5775	0.1783	43.8934	12.5129	22.5840	114.7102	5637	0.02
34	0.6276	0.1705	47.6995	12.0741	21.2619	116.6208	5910	0.02
35	0.6777	0.1622	51.5057	11.6222	19.4763	114.4489	6143	0.02
36	0.7278	0.1552	55.3118	11.2204	18.0123	113.0034	6369	0.02
37	0.7779	0.1496	59.1179	10.9027	16.5369	110.2883	6615	0.03
38	0.8279	0.1442	62.9241	10.6131	14.5012	102.2571	6854	0.03
39	0.8780	0.1382	66.7302	10.3130	10.8192	80.1271	7063	0.03
40	0.9281	0.1258	70.5363	9.5120	5.5829	43.3220	6886	0.03
41	1.0000	0.0162	76.0000	1.2278	0.0000	0.0000	958	0.03

Fig.5. Spreadsheet table of an 8060 propeller.

The used motor is A2212/10T,1400kV.

C. JAVAPROP tool

The Analysis of the propeller over its complete useable operating range, the output consists of the propeller data like thrust, power or efficiency versus advance speed.

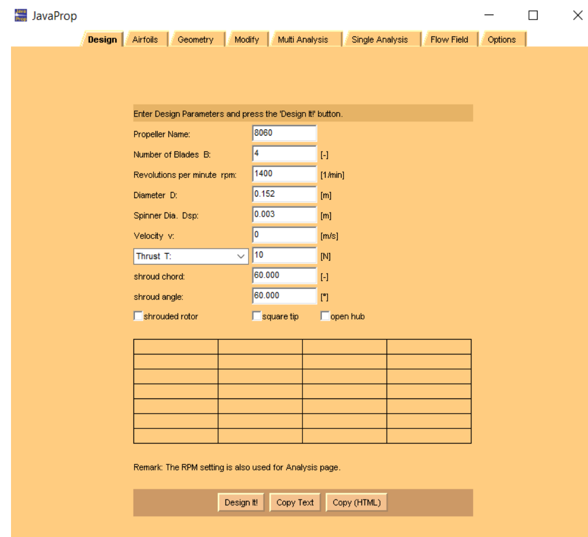

Fig.6. JAVAPROP program window.

Insert the data of used propeller and motor as shown in fig 6, we can use geometry card to get the spreadsheet data then analysis the propeller to get the thrust and torque.

III. THE RESULTS OF SIMULATION

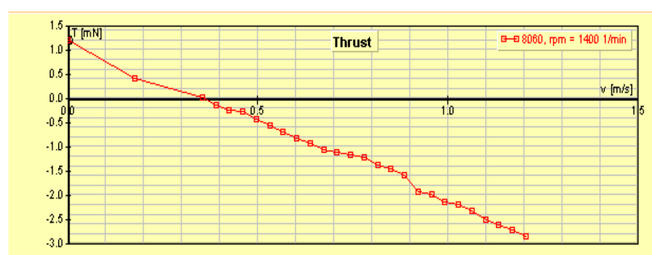

FIG.7. THRUST O/P OVER V.

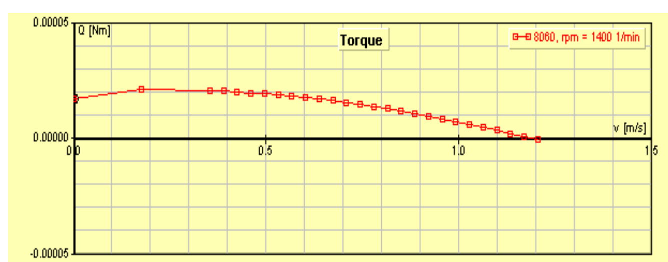

FIG.8. TORQUE O/P OVER V.

IV. Conclusion

The paper discusses Modelling propulsion system of a small fixed-wing UAV, determining thrust and torque forces using JAVAPROP program. This program is a simple tool and not very precise because the simplifications and assumptions behind, so have to check the results by experiment the generated thrust. In this experiment we get thrust at Arduino spreadsheet and the Arduino plot the resultant thrust to be a reference and starts to compare.

Acknowledgment

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References

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