헬리콥터 설계용 사이징 및 성능해석 프로그램 개발

Integrated Program Development of Sizing and Performance Analysis for Helicopter Design

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1. Introduction

The most innovative and creative aspect of aerospace is during conceptual design of a new aircraft system. The word is heard most often during this phase of engineering design is Configuration Synthesisand can be thought of as putting together or combining of parts, elements, or disciplines so as to form a whole configuration. On the other hand, this definition can be thought as taking the best first level analysis from aerodynamics, propulsion, weight control, design, and cost, then combining these to obtain an aircraft configuration that will perform the required mission with the least weight, cost and in the most aerodynamic efficient manner.[1]
Regarding that motivation, the purpose of this program is to develop an analytical method providing helicopter sizing and mission performance data rapidly. The program is built to assist the design process as conceptualhelicopter Design.

It is made to be simple by using empirical formulas, quick method to get a rough configuration which is designed to meet specified mission requirements.

The program based on two codes which is sizing and performance analysis. They are developed separately and then integrated together. Therefore, itis also useful in sensitivity studies referring to parameters trade-off and performance trade-off.

2. Sizing Module Development

The sizing process based on graphical design techniques developed during the 1950's and 1960's and were initially utilized with nomographs. A graphical design method, called the fuel ratio or RF method, is typical of the developed techniques [2, 3]. This method was extended to become the whole process of sizing as shows in figure 1.

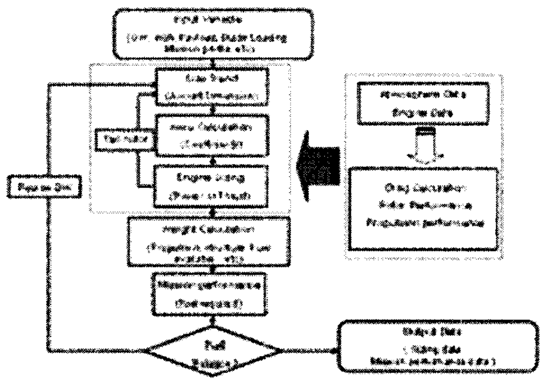

Fig. 1 Sizing Code Process

This process starts from analysis of mission and performance requirements. The performance requirements are specified in terms of hover capability and cruise speed requirement at a specified altitude and temperature, which reflect the environment where the vehicle is expected to operate. The mission requirements address the critical relationship between payload, range and hover time, which will determine the type of rotary wing aircraft. A typical mission is showed in figure 2.

Based on statistical data trend, basic design variables for the configuration and the mission profile are specified first.

An example of drag loading (gross weight over equivalent flat plate area) of helicopter trend is showed in figure 3. [4]

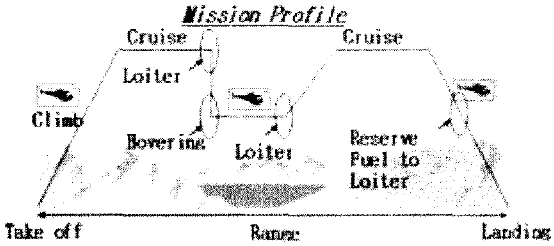

Fig. 2 Mission Profile

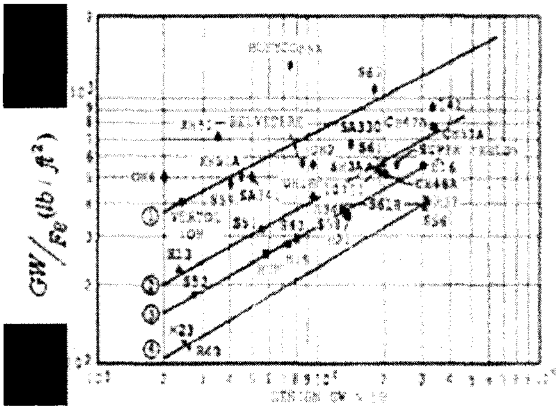

Fig. 3 Drag Loading Trend

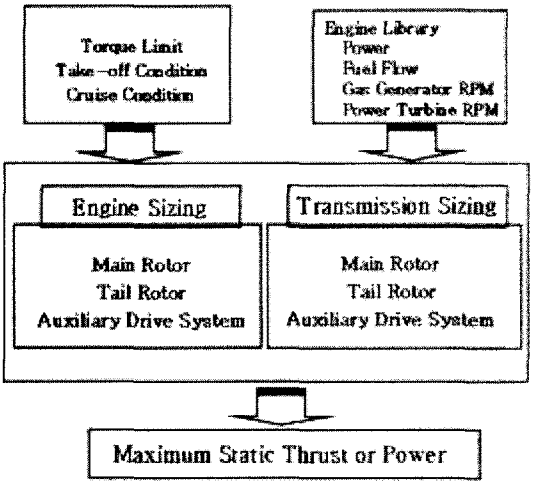

Fig. 4 Engine Sizing Process

Parameter	*UH-60A*	*Data from Sizing Module*
Gross Weight lb	22000	21409
Empty Weight lb	10901	11241
Disk loading lb/ft²	9.7	10.0
Main rotor diameter ft	53.66	54.2
Solidity	0.084	0.089
Main rotor tip speed ft/sec	725	722.3
Number of main rotor	4	4
Tail rotor diameter ft	11	11.7
Tail rotor tip speed ft/sec	685	703.6
Fuselage length ft	50.6	48

Fig. 5 Sizing Module Validation

By initially estimating the gross weight, payload, and disk loading, the sizing of the helicopter isestimated and the required power is specified. The required engine size is specified by following process in figure 4.

From the mission profile and the required fuel weight, the empty weight and the gross weight are estimated. This process is repeated until the available and required fuel weights converge within given error tolerances.

Based on empirical formulas, this program is able to generate following sizing result.

- *Geometry data: main rotor, tail rotor, fuselage, tail fin.*
- *Weight data: gross weight, empty weight, fuel weight.*
- *Mission performance data: Each mission segment fuel requirement.*

3. Performance Analysis Module Development

To quickly understand and image the helicopter behavior, the performance analysis module has been developed. An analytical method was developed to provide the designer with a reliable tool of sufficient fidelity to assist in the design process. The module based on an energy approach, and it has been written to yield results quickly and inexpensively. [5, 6]

All requirement data of ADS-40A-SP (Aeronautical Design Standard, Standard Practice, *Air Vehicle Flight Performance Description) are included in performance analysis module. The format of program output performance data and performance data figure of flight manual are expected to be compatible. [7]*

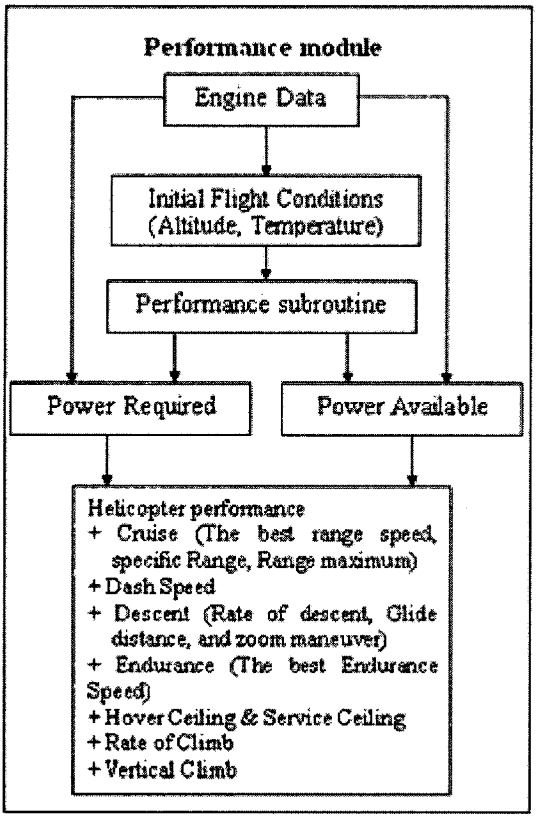

Fig. 6 Performance Module Structure

he process of the performance module is showed in figure 6. This process starts from specifying engine data. This module provides two ways to get engine data which are engine library and empirical formulae [1, 10]. Series of engine data are list in figure 7 and the empirical formulae to get Power available which proposed by Daniel P. Schrage as showed below.

$$HP_{AV} = HP_{AV_{SL}}\left(1 - 0.195 * \frac{ALT}{10000}\right)\left(1 - 0.005\Delta T_S\right)$$

Where:

HP_{AV} : *Power available of engine.*

$HP_{AV_{SL}}$: *Power available of engine at sea level, international standard day.*

ALT: *Altitude in ft*

ΔT_S : *The different temperature between off standard and standard day.*

IENG	Engine model
1	ALLISON MODEL 250-C20B 109A
2	ALLISON MODEL 250-C30R
3	TEXTRON LYCOMING LTS-101
4	PRATT & WHITNEY PT6B-36 (CANADA)
5	LYCOMING T53-L13B SPEC LTC1K-4F, 30 SEPT 1969
6	LYCOMING T53-L703
7	ALLISON T63-A-720
8	ALLISON T63-A-5A
9	GENERAL ELECTRIC T700-GE-700
10	LYCOMING T702-LD-700
11	GENERAL ELECTRIC T58-GE-5
12	NEWENG3
13	GENERAL ELECTRIC T64-GE-7A
14	WRIGHT R-1300-3 PISTON ENGINE
15	ISOTOV TV3-117-3
16	ALLISON 250-C28C
17	GM ALLISON T800-LHT-800
18	GENERAL ELECTRIC T64-GE-100
19	MCCULLOCH MC-101
20	GENERAL ELECTRIC T700-GE-701
21	SOCIETE TURBOMECA TU-A-14

Fig. 7 Engine Model List

After getting the engine data, the process specifies what kind of output data are. These options are control by some control variables which are assigned by user through input file.

Without changes of the normal process by user, series of performance tables are yielded as figure 8which presents an example of normal output data from performance module.

The normal process calculates performance of helicopter response to ADS-40A-SP which is behaviors of helicopter in international standard day and hot day… Moreover user can control the module to yield performance data in difference atmosphere conditions as user wants.

The current performance module development predicted following performance of helicopter. [6, 8]

- *Vertical Climb (Maximum vertical climb speed)*
- *Rate of Climb (Maximum Rate of climb)*
- *Ceiling (Hover Ceiling, service Ceiling)*
- *Dash speed, Maximum cruise speed*
- *Cruise Flight (Maximum range, cruise speed for maximum range, Endurance, cruise speed for maximum endurance…)*

- *Descent, (Rate of descent vs. cruise speed at specific gross weight, Glide distance vs. cruise speed, Speed for min descent angle in autorotation, Best autorotative speed, Benefits of zoom maneuver)*
- *Autorotation, Height-Velocity diagram*
- *Acceleration and deceleration*

The module is able to yield not only specific performance but also series tables of helicopter performance in different operating environment such as weight of helicopter, altitude, temperature, forward velocity.

This module is developed separately with sizing module, so that an engine required subroutine is also developed to predict performance of the specific helicopter data.

The engine required should be calculated based on trim analysis data. Because of independent development of modules, performance module supposes some typical data for trim analysis such as cruise angle of attack $\alpha_f = -3$ *degree.*

*** VROC CAPABILITY AT 14949.5 LBS. STANDARD DAY

ALT FT	VROC FT/MIN	ETAC|
0.0	2637.2	1.19
1000.0	2477.7	1.21
2000.0	2313.2	1.24
3000.0	2143.0	1.26
4000.0	1966.6	1.28
5000.0	1783.1	1.31
6000.0	1591.8	1.34
7000.0	1391.7	1.36
8000.0	1181.6	1.39
9000.0	960.0	1.42
10000.0	725.3	1.45

*** VROC CAPABILITY AT 15697.0 LBS. STANDARD DAY

ALT FT	VROC FT/MIN	ETAC
0.0	2306.6	1.24
1000.0	2139.3	1.26
2000.0	1966.2	1.28
3000.0	1786.6	1.31
4000.0	1599.8	1.34
5000.0	1405.1	1.36
6000.0	1201.6	1.39
7000.0	988.1	1.42
8000.0	763.2	1.45
9000.0	525.4	1.48
10000.0	272.5	1.51

Fig. 8 An Example of Output Data

Momentum and blade element theory was applied to calculate the power required in different operations of helicopter which are hover, climb, cruise, descent, autorotation. [6, 9]

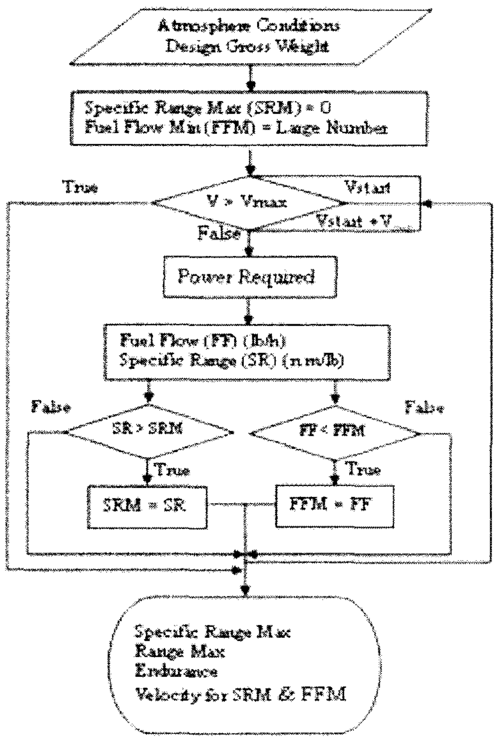

Fig. 9 Algorithm for Cruise Flight Analysis

Figure 9 shows a typical algorithm developedin performance module to predict the behavior of helicopter in cruise flight. Exceed power decides the helicopter performance in each environment where the vehicle is expected to operate.

Therefore, Power required and power available was calculated in each subroutine and then

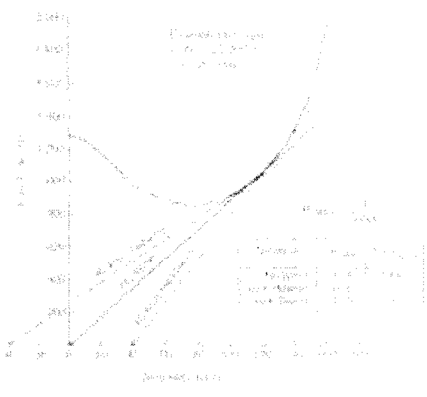

Fig. 10 Fuel Flow vs. speed

compared them together.

These algorithms are constructed, based on physical relationships of helicopter performance as show in figure 10 for example. [8]

Regarding fuel flow vs. speed figure, the fuel flow was calculated with respect to different forward velocity and then the algorithm found out the best fuel flow for maximum range and endurance. The same process was applied for others performance prediction algorithm.

4. Integrated Program

As mentioned in preceding sections, each module was developed respectively and integrated together. Future prospect of KHDP development was depicted in figure 11 in which the bold modules are already developed module. The relationship between KHDP and each module are represented by an straight line and an arrow which shows the module has been integrated in KHDP.

The preceding paragraph told that Sizing and Performance Analysis module have been integrated in KHDP. Therefore, KHDP is able to construct size of helicopter and performance analysis simultaneously.

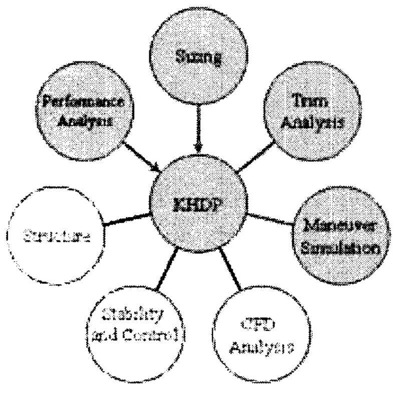

Fig. 11 Konkuk Helicopter Design Program (KHDP)

5. Conclusions

Nowadays, with supporting of computer, design process is more and more rapid. An effort had taken place at Konkuk University to develop an program providing quick tool to assist in the design process.

Future Prospect of this research was represented in figure 11 is our target and a haft of this task had taken successfully.

Trim analysis and Maneuver Simulation module were developed. However, they have not been integrated in KHDP. Next step of the development are code Structure, Stability and Control module and integrated all modules together to be full KHDP Program.

Acknowledgements

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