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Automatic Flight Control System Control Law Development for Altitude Hold Mode in Helicopter by Using Matlab Simulink Method

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Abstract: *The helicopter is inherently unstable and exhibits unacceptable gust response. The helicopter can be stabilized through state feedback thus ensuring the desired response. This state feedback system is normally called Automatic Flight Control System (AFCS). AFCS reduces pilot work load by providing adequate stability, improved controllability and gust rejection. The purpose of the project is to develop control law of baro-altitude hold mode in pitch axis for Automatic Flight Control System for helicopter . The altitude hold range is within 60 meters to 6096 meters and baro-altitude hold should hold the altitude within ±10 m of the desired reference based on sensor tolerance/ flight test feedback. The control law of baro-altitude hold mode in pitch axis is based on Proportional-Integral-Derivative (PID) closed loop logic. PID is one of the traditional control algorithm to achieve desired control performance and has been chosen basically for the flexibility of implementing control gains on basic system parameters.*

Keywords: Helicopter, AFCS, Altitude Hold, Pitch Axis, MATLAB/SIMULINK.

1. Introduction

AFCS reduces pilot work load by providing adequate stability, improved controllability and gust rejection. Control actions of AFCS are holding attitude, altitude and velocity at desired operating conditions even during unacceptable gust condition. These parameters are also important for navigation and guidance purpose. The project helicopter which is a conventional helicopter with hinge less main rotor and bearing less tail rotor system, is fitted with 4-axis limited authority duplex autopilot system-AFCS. This AFCS incorporates Stability Augmentation System (SAS), Control Augmentation System (CAS), auto-trimming and mission specific autopilot modes. The SAS forms inner loop of AFCS and needs to be engaged all the time as pre-requisite for CAS and auto-pilot modes.

The design of the control law implementation of baro-altitude hold mode in pitch axis includes the following:

a) Implementation of the closed loop control block design with PID gains in MATLAB/SIMULINK
b) Derivation of test cases for validation of implemented control law both at unit level and integrated level. The integrated level comprise baro-altitude mode control law block interfaced to basic stabilization block and helicopter model.
c) Simulation and plotting of results as per derived test cases to ascertain compliance to performance criteria using MATLAB/SIMULINK.

2.Block Diagram

This block diagram shows the operating principle of AFCS.

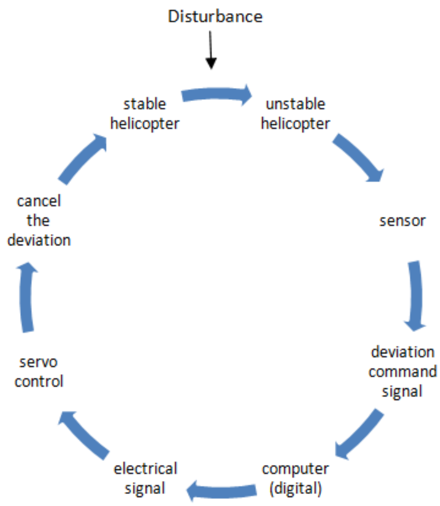

Figure 1: Block Diagram

The sensors are electrically interfaced to a digital computer. The sensor will measure the deviation and send the signal to the computer. The digital computer will process the information from the sensor and determine the corrections to the controls required to meet the objective of the engaged AFCS mode.

The digital computer is interfaced to the flight control system. It generates an electrical flight control signal and sends to the actuator. The respective control channel is actuated to correct the deviation of the helicopter. If the helicopter deviation is cancelled, it will be brought back to its original position. The operation of the actuator converts the electrical command signal to mechanical output. And it is interfaced to the mechanical flight control system. The mechanical output produces the required control input.

3 Parameter Consideration For ALT On Pitch Axis

To cater for operating ALT mode in all flight condition, following aerodynamic conditions can be considered:

i) Altitude

ii) Airspeed

iii) Vertical speed

iv) Bank angle

v) Centre of gravity variation

vi) Weight variation

vii) Wind direction

viii) Wind speed

From the above aerodynamic conditions the Altitude, Airspeed and the Vertical Airspeed are the primary consideration for controlling altitude on pitch axis of helicopter. The bank angle, C.G variation, weight variation, wind direction and the wind speed are ruled out. Because the AFCS does not have the C.G and weight variation values. The calculation of the same with available information is complicated and the effect is indirectly is measured through speed and altitude. The stabilization block does not need wind direction and wind speed. As the AFCS caters for these during other navigation modes for ex. Heading mode, VOR/ILS modes. The bank angle was creating derivation issues during implementation of control law, so the bank angle was ruled out. The vertical airspeed and the altitude changes are the major parameter for controlling helicopter. The following chapters are explanation of the implementation of control law for reference block, command block and the PID block.

4 Design Criteria For Altitude Hold Mode

The following design criterion need to be addressed while designing the Altitude hold mode control law:

1. Pilot should be able to engage/disengage mode through a dedicated mode button on AFCS Control Unit.
2. Pilot should not feel any jerk on engagement/disengagement of Altitude hold mode.
3. The helicopter should reach desired altitude reference with minimal overshoot and no oscillation at altitude reference.
4. The baro-altitude to be held within a tolerance based on the ADU sensor accuracies i.e ± 10m in all flight conditions different speed, different bank angles and different altitudes.
5. Altitude hold mode should be engageable above 100 kmph and for altitude range 60 meter to 6096.
6. The altitude hold mode should cater for change in reference during operation and the changeover should be executed smoothly.

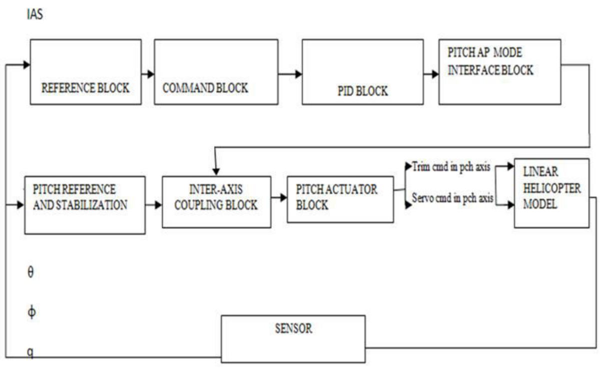

Figure 2: Block Diagram For Altitude Hold Mode In Pitch Axis

5 Implementation of Altitude Mode Control Law

The ALT control law blocks is described namely reference, command, order and interface blocks are implemented in MATLAB Simulink. The input to the block comprise of input signals required for ALT mode namely Baro_ALT, Current_Baro-ALT, CMD_Baro-ALT, Current_SPEED, CMD_ VER_AIRSPEED, Ref_Baro_alt, VER_AIRSPEED, Current_BANK, I_TERM-ALT-PCH, D_TERM-ALT-PCH, REF-ALT-PCH, ALT-PCH-REF-BLOCK, ALT-PCH-CMD-BLOCK, ALT-PCH-PID-BLOCK, P-TERM_BANK, , these are the inputs used for the implementation of ALT on pitch axis.

6 Test Purpose

The final test plots will show the path of controlled helicopter. How the helicopter vertical airspeed was changing with time and altitude changes with respect to our commands will show in the plots. The test purpose was checking the AFCS will properly controlling the altitude mode when it was engaging with respect to the logical condition.

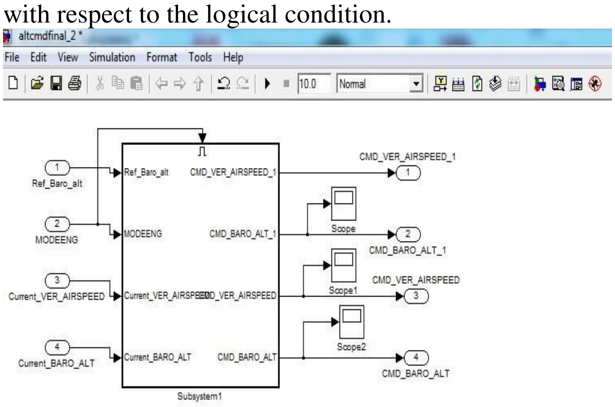

Figure 3 Command Block Implementation

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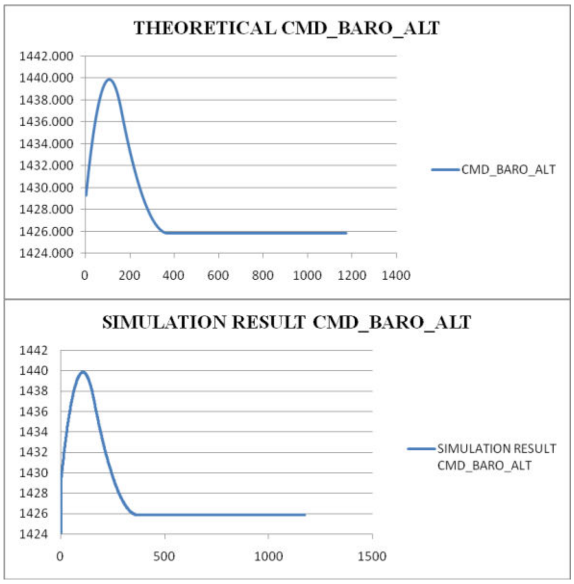
The command block implementation input consist of Ref_Baro_ALT, MODEENG, Current_VER_AIRSPEED AND Current_Baro_ALT.The input of mode engage input connected through the enable function.The subsystem have the logic condition of if else function. The outputs are CMD_VER_AIRSPEED and CMD_Baro_ALT. The scope is connected to the output of CMD_VER_AIRSPEED and CMD_Baro_ALT to shown the graph of velocity and altitude changes. The input values are fed through the excel data sheet to the system testing of simulink block. Finally the simulation result and the theoretical calculation are compared. Both having the same values was shown, the test was run successfully without the error. It was plotted as a graph.



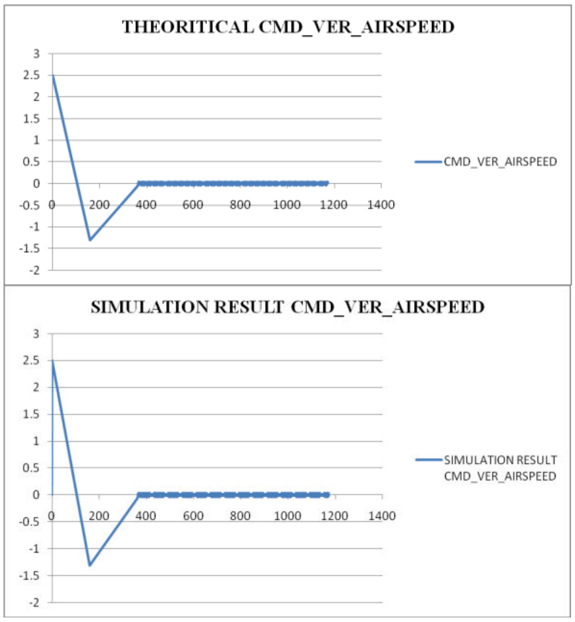


Figure 4 Controlled Helicopter Path Graph

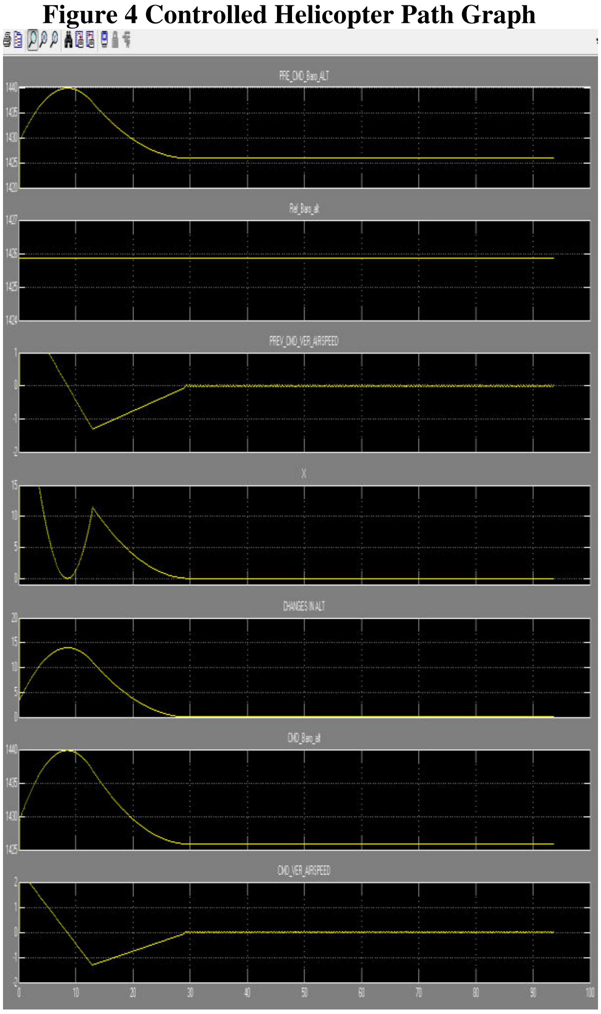


Figure 5 Simulink Graph For Block Implementation

7 Conclusion

A Control law was developed to maintain the constant altitude during forward speed in helicopter by using the MATLAB\SIMULINK method. The project has a detailed study on the auto pilot mode engagement and designing of block meeting the design criteria.

8 Scope For Further Studies

1. Gain scheduling is to be incorporated for studying the stability in different flight conditions (speeds, altitude and bank angle).
2. Simulation of developed altitude hold control law with Non-linear Helicopter model and basic sensors.
3. A corrective gain or update on PID gains to be employed if mode hold is detected to vary between ± 12m for duration of 5 sec.

9 Acknowledgements

It is a pleasure for us to acknowledge all those

10 References

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