# HELICOPTER SIMONA Practical - AE4-314P

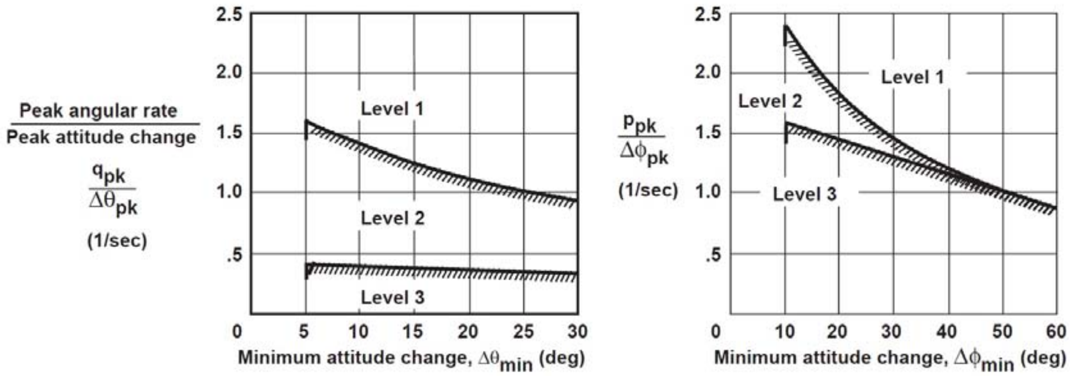
(individual or in a group of 2)

## *Designing for Agility and Manoeuvrability – Attitude quickness*

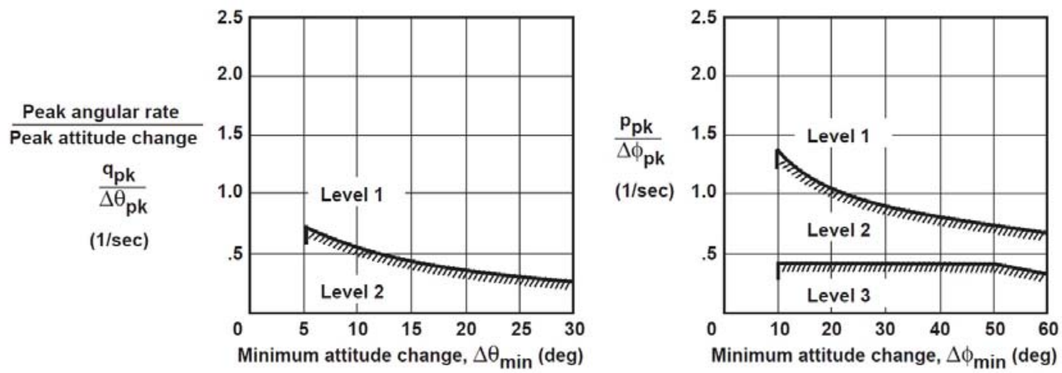
### Background

Helicopter handling qualities used to be assessed with requirements defined for fixed-wing aircraft, as stated in the FAR (civil) and MIL (military) standards. In the 1960's, however, it became clear that these standards were not sufficient. Helicopters have strong cross-coupling effects between longitudinal and directional controls, their behaviour is highly non-linear and requires more degrees of freedom in modelling than the rigid-body models used for aircraft. Therefore, the MIL-H-8501A standard (1962) was developed. This standard was used up until the mid 1980's. From a safety perspective, these requirements were merely 'good minimums', and a new standard was developed in the 1970's, that is used up until today, the **Aeronautical Design Standard ADS-33** (2000). The crucial point, understood by ADS-33, is that helicopter HQ requirements need to be related to the mission executed, as this will determine the needed pilot effort. E.g., a shipboard landing at night and in high sea with strong ship motions demands more precision of control from the pilot than when flying in daytime and good weather. ADS-33 introduced handling qualities metrics (HQM), a combination of flight parameters such as rate of climb, turn rate, etc., that reflect how much manoeuvre-capability the pilot has per specific mission. These metrics are then mapped into handling qualities criteria (HQC) that yield boundaries between 'good' (Level 1), 'satisfactory' (Level 2) and 'poor' (Level 3) HQs. Level 1 aircraft means that the aircraft is satisfactory without improvement required from pilot's point of view. Level 2 aircraft means that the pilot can still achieve adequate performance and has to use moderate to extensive compensation in the given controls (At the extreme of Level 2 (HQR 6) the mission is still flyable, but the pilot has little spare capacity for other duties and will not be able to sustain the flying for extended periods without the danger of pilot error). Level 3 aircraft is unacceptable as task performance. This level is necessary to describe the aircraft's behaviour in emergency conditions or following the loss of critical flight systems.

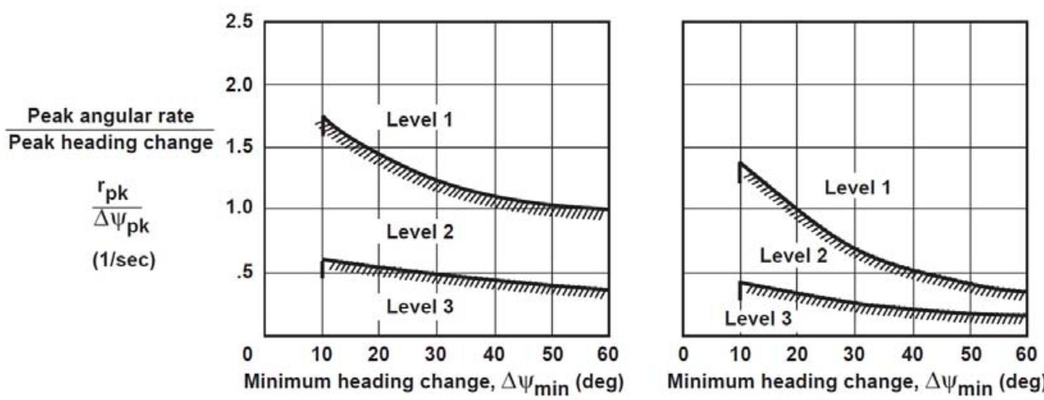
One of the important HQ Metric (HQM) introduced by ADS-33 in order to characterise the helicopter roll/pitch or yaw response during hover and low speed missions, is the "quickness metric". The figures below present the HQs levels of roll, pitch and yaw quicknesses. From pilot point of view, if the maximum achievable quickness is too small, then the pilot may complain that the aircraft is too sluggish; if the quickness is too high, then the pilot may complain of jerkiness or over-sensitivity.



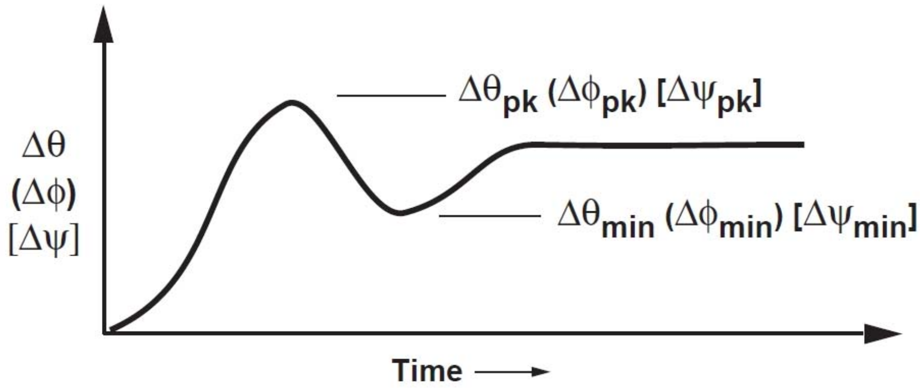

*Requirements for moderate-amplitude pitch attitude changes – hover and low speed (from ADS-33)*
*Left hand side Target acquisition and Tracking (pitch)*
*Right hand side Target acquisition and Tracking (roll)*




*Requirements for moderate-amplitude pitch attitude changes – hover and low speed (from ADS-33)*
*Left hand side All Other MTE (pitch)*
*Right hand side All Other MTE (roll)*




*Requirements for moderate-amplitude heading changes – hover and low speed (from ADS-33)*
*Left hand side: Target Acquisition and Tracking*
*Right hand side: All other MTEs*




*Definition of moderate-amplitude criterion parameters*

## Assignment

You are asked to write a small report and analyse the effects of flight dynamics on helicopter handling qualities. You have received 3 helicopter simulation programmes including 3 models corresponding to a helicopter performing a pulse manoeuvre in the following cases: 1) without any controller, 2) with a P-controller and 3) with a PD-controller. Now it is asked that you calculate the ADS-33 **attitude** quickness parameter of the helicopter using the 3 given simulation models for the pulse manoeuvre.

## Question 1 Design parameters calculation

Calculate the disc loading DL, tip speed, solidity and Lock number of the helicopter used in the simulation program.

## Question 2 Discussion on the design space of the helicopter

Consider now that you change each design parameters of your helicopter as followings:

- Rotor disc loading DL by ±10%, ±20% and ±30% of the baseline value considered in the simulation model,
- Rotor tip speed $V_{tip}$ by ±10%, ±20% and ±30% of the baseline value considered in the simulation model;
- Blade solidity $\sigma$ by ±10%, ±20% and ±30% of the baseline value considered in the simulation model;
- Lock number $\gamma$ by ±10%, ±20% and ±30% of the baseline value considered in the simulation model.

Discuss on how the design space of the helicopter is changing when changing each of the parameters mentioned above. Design space relates to the design parameters of the helicopter.

## Question 3 Handling Qualities considerations

Calculate the pitch attitude quickness for the baseline simulation models by running each time the 3 simulation models for the pulse manoeuvre. How does the quickness changes as we include a controller?

### Question 4 Handling Qualities –design considerations

Calculate the pitch quickness for every point of the design space defined at Question 2. How does the quickness modifies now as we are changing the: 1) DL of the helicopter? 2) tip speed 3) blade solidity 4) Lock number ? Plot the effects of different helicopter designs into the pitch quickness charts given above.

Note
For the minimum pitch change $\Delta\theta_{min}$ in the ADS-33 attitude quickness criterion you can consider that $\Delta\theta_{min}$ in a pulse manoeuvre is the value of pitch angle corresponding to the time to a 10% decay from the maximum pitch rate $q_{pk}$.

Note
During SIMONA simulation session you as a pilot will fly different manoeuvres in an non-augmented and augmented Bo-105 helicopter and you will experience on your own how is to fly a helicopter.

## References

1. AVSCOM, Aeronautical Design Standard (ADS) 33C – Handling Qualities for Military Helicopters, US Army AVSCOM, 2000

2. Padfield, Gareth, D., "Helicopter Flight Dynamics", Blackwell Science, 1996