**07/29/2022 – Friday – Helicopter Blade Coning and Feathering to Flapping**

**Coning as a function of blade lift:**

The coning angle of the rotor blade in many typical helicopters may be approximately equal to the collective pitch angle. However, they may be slightly different or could be very different. Since in the simplified analysis the lift is determined from these angles, it may cause some error in the analysis. The coning angle is a function of the centrifugal force and the lift of the blade as shown in the following figure:



Assuming a rotor system with a free moving flapping hinge, when the sum of the moments around its hub is zero, the coning angle is determined by the centrifugal force and the lift on the blade. The centrifugal force will be a function of the mass of the blade. The lift will be a function of collective and cyclic pitch. It is assumed the mass center of the blade will be in its center (R/2). When the force vector from the centrifugal force shown in green is equal to the force vector from lift shown in purple, the rotor blade will stop moving and settle to its coning position.

The centrifugal force will be:

The rotor blade will stop moving in coning when the sum of the moments is zero.

is the coning angle can be computed using the following equation.



Here is the pitch for each blade (feathering) that is used to compute lift:

Here is the Lift for each blade due to feathering:

is the coning angle can be computed using the following equation.

Z-Force (+ Down):

However, in many helicopters:

So, the following equation may work as well:

**Spreadsheet used to compute Coning Angle.**



**Feathering to Flapping Dynamics:**

Assume:

No Hinge Offset

Rigid Body, No Flexing

Small Angles – Linearized – Assume Flapping is a small angle

No Lead-Lag



Balance Equations:

**Moment from Centrifugal Force:**

Assume the mass Moment-of-Inertia for the Blade is:

However, it is really when you look it up on the mass Moment-of-Inertia tables:

But, for this analysis to simplify things, assume the mass Moment-of-Inertia is:

The average centrifugal force for the blade is: (Assume the mass is centered in the middle of the rotor blade.)

This is the moment from the centrifugal force. Assume the flapping angle β is small.

**Moment from Flapping Damping:**

The damping moment from the flapping rate. (Assume small angles):



Lift Equation:

Angle of Attack:

Flapping Damping Moment:

**Flapping Moment from Blade Pitch:**



**Getting the Transfer Function: (Sum of Moments = 0)**

Take the Laplace Transform:

**This transfer function has the following form:**

**Use Excel Spreadsheet to help perform analysis:**





**Conclusions:**

1. Flapping lags feathering by 90 degrees.
2. The gain is 1 deg/deg between flapping and feathering at 100% RPM.
3. Flapping is in resonance with feathering. – However the damping is good. On a conventional swashplate the frequency of operation is constrained to

However, with independent blade control, or additional actuators, higher harmonic control can be used to change the phase on the curve to better control the aircraft and control the flapping.