Bob Weight Effect

Bob Weight Effect (Mechanical Control System Unbalance)

A bob weight is a weight added in the pitch mechanical control system in order to give pilot appropriate stick force per G during pitch maneuver.
When an airplane maneuvers and vertical or longitudinal acceleration changes, every movable part (bellcrank ,quadrant,cable tension regulator,rod,control column etc.) of the pitch control system gets some inertial force and tends to move.
In order to prevent such unintended movement of the control system,it should be sufficiently balanced. (Ref.[1])
If some amount of unbalance exists in the control system, it may have same effect as a bob weight,so it may be called “bob weight effect”.

Column Force due to Bob Weight Effect

When an airplane maneuvers in pitch,vertical acceleration differs depending on the distance from the center of gravity and the pitch acceleration level.
Such local vertical G is calculated as follows;

$$Nz_{local} = Nz_{CG} + DX_{local} * qdot / g_0$$

Nz_{local}: local vertical G
Nz_{CG} : vertical G at the center of gravity of the airplane
DX_{local} :distance from the center of gravity (+:forward of CG,-:aft of CG)
qdot :pitch angular acceleration (rad/sec^2)
g_0: standard gravitational acceleration

If major parts of the control system are arranged around two places;cockpit and stabilizer,the column force due to bob weight effect is calculated as follows.

$$F_{bob} = Kbob_{FWD} * Nz_{FWD} + Kbob_{AFT} * Nz_{AFT}$$

F_{bob} : column force due to bob weight effect (lbs)
$Kbob_{FWD}$ ($_{AFT}$) : column force per unit local vertical G (lbs/G) (forward or aft)
Nz_{FWD} ($_{AFT}$) : local vertical G (forward or aft)

To know the value of Kbob exactly,mass property and dimension of the parts of the control system are needed.

Mechanically Induced Oscillation (MIO)

If initial pitch maneuver is enough to make F_{bob} larger than the breakout force of the aritificial feel system,the control column moves by itself and the elevator deflection changes.If the aircraft's pitch maneuver and the control system movement enhance each other,the pitch oscillation develops and continues.
This phenomenon could be called "Mechanically Induced Oscillation" (MIO).
Our latest in-house investigation on JL706 accident suggests that MIO is the most probable cause of that violent pitch oscillation.

References

[1] Jan Roskam : "Airplane Design Part IV : Layout Design of Landing Gear & Systems"