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Project: Jenkin's Governor

In this project, you will model and derive the stability conditions for the mechanical control system "Jenkin's Governor". You will also simulate your model and experiment for various parameter values.

1.1 Introduction

1.1.1 Flyball Governor

One of the first industrial feedback control systems in modern Europe was the flyball governor, shown in Figure 1.1, which was invented in 1788 by James Watt for the speed regulation of a steam engine. The amount of steam (the controller output) supplied to the engine (the controller plant) was adjusted according to the difference (the error signal) between the desired value (the set-point) owing to variations in the driving power or resistance (the disturbances), then the increase in the centrifugal force of the flyball governor causes a contraction of the aperture of the steam valve through a link mechanism. This results in the supply of less steam, and the speed of the steam engine decreases until the desired value is attained. On the other hand, if the engine speed drops below the desired value, then the decrease in the centrifugal force of the governor causes the steam valve to open wider, supplying more steam, and the engine speed increases until the desired value is attained. The float valve in the governor acts as an actuator as well as sensor.

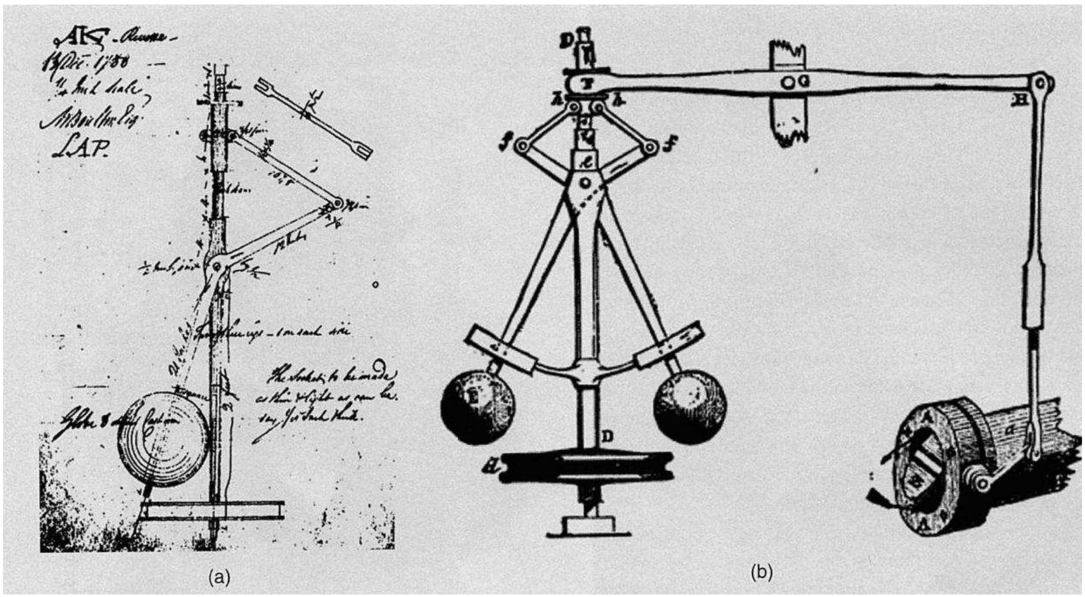

Figure 1.1 *Flyball Governor invented by James Watt in 1788*

1.1.2 Jenkin's Governor

Jenkin's Governor was used to regulate an experimental apparatus used to determine electrical resistance (ohms). It was essentially a friction governor and consisted of two rotating mechanisms capable of moving separately, as shown in Figure 1.2. If the principal axis rotates faster, the flyballs are extended and will rub against the inside surface of the friction ring, which will make the friction ring begin to rotate and lift the weight. If the speed decreases, the weight causes the friction ring to rotate in the opposite direction. The weight is suspended in a hydraulic cylinder to provide viscous damping. The movement of the friction ring is used to loosen or tighten a band brake through a worm gear, which acts on the brake drum of the principal axis. If the rotational speed of the principal axis varies from the nominal value, a torque proportional to the deviation of the speed is applied to the principal axis by the band brake until the speed reaches the nominal value (this is actually an integral action).

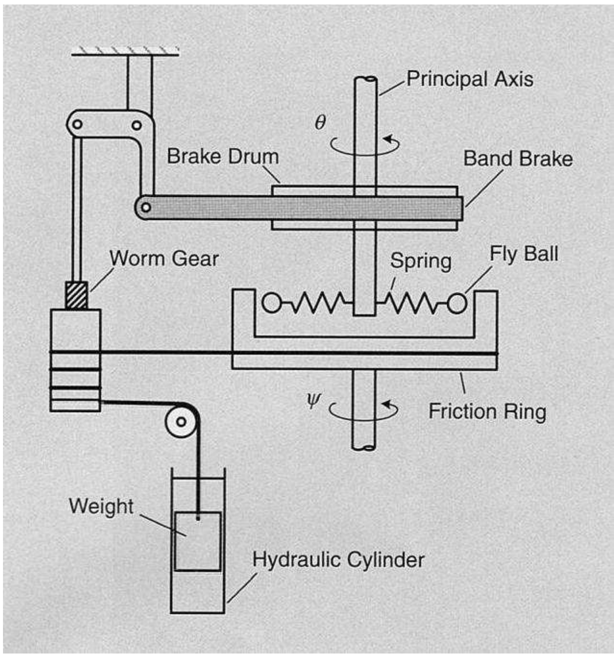

Figure 1.2 *Jenkin's Governor*

1.1.3 Free Body Diagrams

The free-body diagrams of Jenkin's Governor is shown in Figure 1.3. The description of the model variables are as listed in Table 1.1.

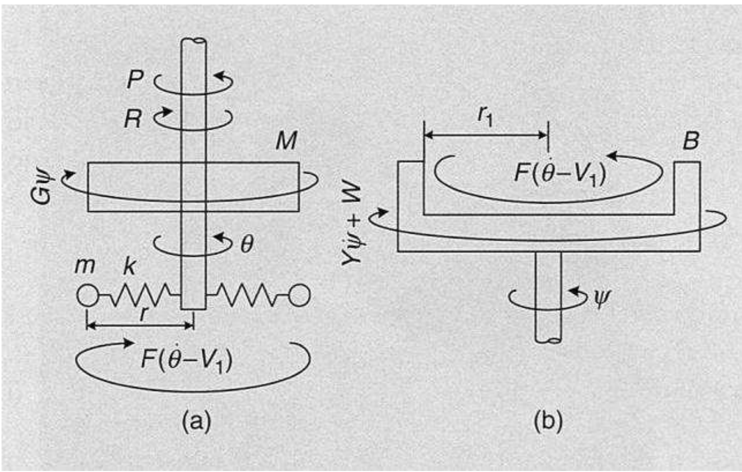

Figure 1.3 *A free body diagram of Jenkin's Governor*

Symbol	Definition
θ	rotation angle of the principal axis
m	mass of a flyball
k	spring constant
r	distance between the flyball and the center of the axis of rotation
$V1$	lowest angular velocity at which the friction ring starts to rotate
P	driving torque
R	resisting torque
G	constant
ψ	rotation angle of the friction ring
B	total moment of inertia of the friction ring and the attached parts
Y	coefficient corresponding to viscous friction torque due to hydraulic cylinder
W	constant torque acting on the friction ring owing to the weight
M	total moment of inertia of the principal axis, brake drum and all the rotating parts with respect to the principal axis

Table 1.1 *Jenkin's Governor variables*

1.2 Problem sets

The problem tasks are as follows (to be submitted by **Saturday 17th of Khordad 1399**). Please note the following:

- You need to present your results in a report. The report should include all your results. **Marks will only be awarded to results which are present in your report**.
- Your report should be typed, **no longer than 20 pages AND 2000 words**.
- All your m-files should also be submitted.
- Please check that your files run correctly and are **compatible with 64-bit MATLAB 2013b**, prior to submission. If your file do not run correctly no marks will be awarded at all.
- You should have **one main m-file from which all other m-files may be run**. Your main m-file should produce figures and results in exactly the same order in which they appear in your report. Failure to do so will result in a loss of marks

Q1). Derive the equations for ψ and θ using the free body diagrams shown in Figure 1.3. Combine these two to obtain the differential equation of velocity w ($\dot{\theta}$).

Q2). Linearize your model assuming that the velocity $\dot{\theta}$ varies within very narrow bound around the $V1$. That is, by assuming $\dot{\theta} = V1 + \Delta\dot{\theta}$, and neglecting the term $\Delta\dot{\theta}^2$.

Q3). Find the stability condition for the model you have derived in the previous section using Routh's array, explain how system parameters affect the stability.

Q4). In Jenkin's governor the centrifugal piece is at a constant distance from the axis of rotation. However, there are other kinds of governor in which the centrifugal piece is free to move from the axis of rotation but is balanced by a centrifugal force and the force of gravity (or by the spring force, in some cases).

  (a). Name an example of this alternative type of Governor system.

  (b). Explain how this difference can affect the stability conditions of the system.

Q5). Draw a block diagram of the Governor control loop. Specify the actuator, controller input and controller output and name all signals.

Q6). Simulate the system using Simulink based on the model you have derived in the previous section. Choose reasonable values for your parameters and justify your choices in your report.

Q7). Identify the time constant of the system. Experiment with different values of m, r, k. Explain the impact of the above-mentioned parameters on the system's performance. Justify your observations.