MODELLING OF TWIN ROTOR MIMO SYSTEM (TRMS)

AIM:

To Determine a feedback controller of a twin rotor MIMO system.

TRMS DESCRIPTION:

As shown in Figure 1, the TRMS mechanical unit comprises of two rotors positioned on a horizontal beam with a counterbalance at the pivot. The whole unit is attached to the tower which ensures safe helicopter control experiments.

Figure 1 TRMS mechanical unit

Along with the mechanical unit, the electrical unit which is placed under the tower plays an important role for TRMS control. Its function is to allow measured signals to be transferred to the PC and control signal applications via an I/O card. The mechanical and electrical units provide a complete control system setup presented in Figure 2

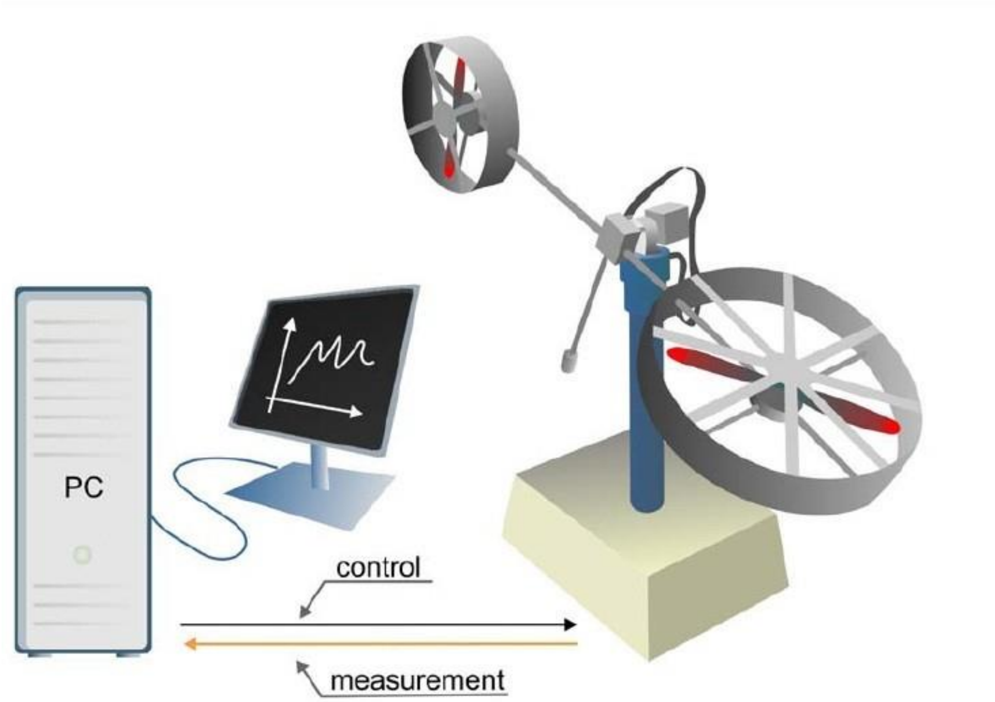

Figure 2 TRMS control system

TRMS MATHEMATICAL MODEL

The mechanical-electrical model of the TRMS is presented in Figure 3.

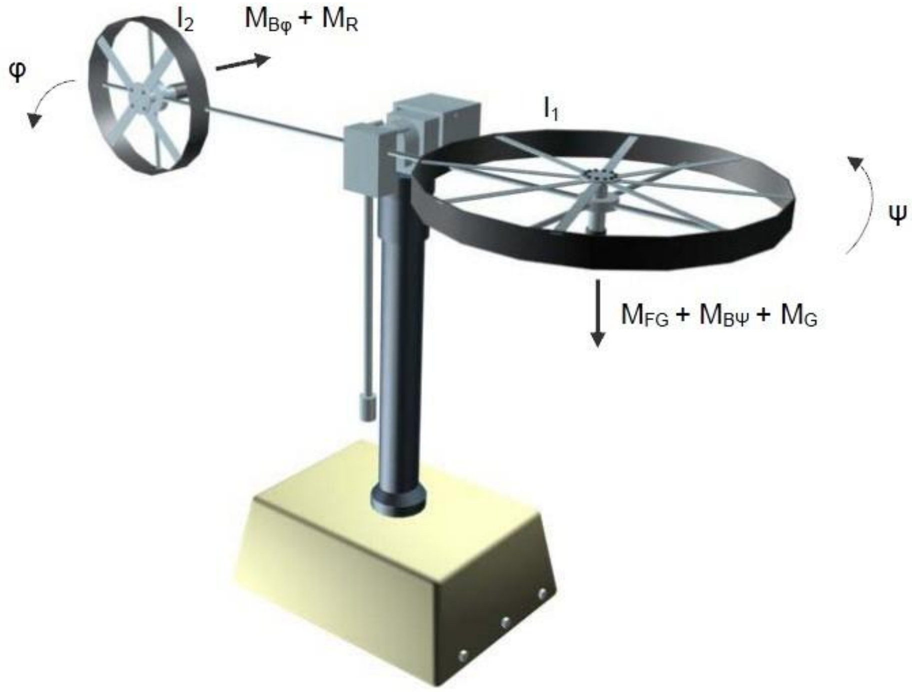

Figure 3 TRMS phenomenological model

Usually, phenomenological models tending to be nonlinear, which means that at least one of the states (i – rotor current, θ – position) is an argument of a nonlinear function. So as to present such a model as a transfer function (a form of linear plant dynamics representing a control system), it has to be linearised. As shown in the electrical-mechanical diagram in Figure 3 the following non-linear model equations can be derived.

$$I_1 \cdot \ddot{\psi} = M_1 - M_{FG} - M_{B\psi} - M_G, \tag{1}$$

where

$$M_1 = a_1 \cdot \tau_1^2 + b_1 \cdot \tau_1, \qquad \textit{– nonlinear static characteristic} \tag{2}$$

$$M_{FG} = M_g \cdot \sin\psi, \qquad \textit{– gravity momentum} \tag{3}$$

$$M_{B\psi} = B_{1\psi} \cdot \dot{\psi} + B_{2\psi} \cdot sign(\dot{\psi}), \qquad \textit{– friction forces momentum} \tag{4}$$

$$M_G = K_{gy} \cdot M_1 \cdot \dot{\varphi} \cdot \cos\psi. \qquad \textit{– gyroscopic momentum} \tag{5}$$

The motor momentum is described by an approximated first order transfer function in Laplace Domain:

$$\tau_1 = \frac{k_1}{T_{11}s + T_{10}} \cdot u_1. \tag{6}$$

Equations that refer to the horizontal plane motion are as follows:

$$I_2 \cdot \ddot{\varphi} = M_2 - M_{B\varphi} - M_R \tag{7}$$

where

$$M_2 = a_2 \cdot \tau_2^2 + b_2 \cdot \tau_2, \qquad \textit{– nonlinear static characteristic} \tag{8}$$

$$M_{B\psi} = B_{1\varphi} \cdot \dot{\psi} + B_{2\varphi} \cdot sign(\dot{\varphi}), \qquad \textit{– friction forces momentum} \tag{9}$$

M_R is the cross reaction momentum approximated by:

$$M_R = \frac{k_c(T_o s + 1)}{(T_p s + 1)} \cdot \tau_1. \tag{10}$$

Again the DC motor with the electrical circuit is given by:

$$\tau_2 = \frac{k_2}{T_{21}s + T_{20}} \cdot u_2. \tag{11}$$

The phenomenological model parameters having been chosen experimentally, makes the TRMS nonlinear model a semi-phenomenological model. The following table gives the approximate parameter values.

Parameter	Value
$\mathbf{I_1}$ - *moment of inertia of verical rotor*	$6.8 \cdot 10^{-2}\ kg \cdot m^2$
$\mathbf{I_2}$ - *moment of inertia of horizontal rotor*	$2 \cdot 10^{-2}\ kg \cdot m^2$
$\mathbf{a_1}$ - *static characteristic parameter*	0.0135
$\mathbf{b_1}$ - *static characteristic parameter*	0.0924
$\mathbf{a_2}$ - *static characteristic parameter*	0.02
$\mathbf{b_2}$ - *static characteristic parameter*	0.09
$\mathbf{M_g}$ - *gravity momentum*	$0.32\ N \cdot m$
$\mathbf{B_{1\psi}}$ - *friction momentum function parameter*	$6 \cdot 10^{-3} N \cdot m \cdot s/rad$
$\mathbf{B_{2\psi}}$ - *friction momentum function parameter*	$1 \cdot 10^{-3} N \cdot m \cdot s^2/rad$
$\mathbf{B_{1\varphi}}$ - *friction momentum function parameter*	$1 \cdot 10^{-1} N \cdot m \cdot s/rad$
$\mathbf{B_{2\varphi}}$ - *friction momentum function parameter*	$1 \cdot 10^{-2} N \cdot m \cdot s^2/rad$
$\mathbf{K_{gy}}$ - *gyroscopic momentum parameter*	$0.05\ s/rad$
$\mathbf{k_1}$ - *motor 1 gain*	1.1
$\mathbf{k_2}$ - *motor 2 gain*	0.8
$\mathbf{T_{11}}$ - *motor 1 denominator parameter*	1.1
$\mathbf{T_{10}}$ - *motor 1 denominator parameter*	1
$\mathbf{T_{21}}$ - *motor 2 denominator parameter*	1
$\mathbf{T_{20}}$ - *motor 2 denominator parameter*	1
$\mathbf{T_p}$ - *cross reaction momentum parameter*	2
$\mathbf{T_0}$ - *cross reaction momentum parameter*	3.5
$\mathbf{k_c}$ - *cross reaction momentum gain*	-0.2

Table 1 TRMS model parameters

The limits of the control signal are set to [–2.5V- +2.5V].

TRMS SYSTEM SCHEMATIC

The TRMS is a MIMO plant — multiple input multiple output. Figure 4 presents a simplified schematic of the TRMS.

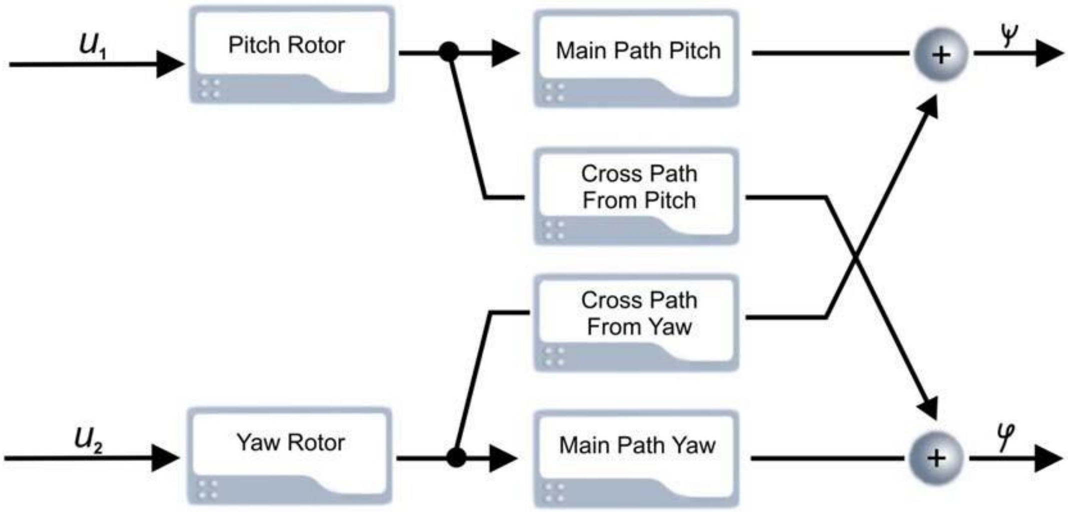

Figure 4 TRMS simplified system schematic

The TRMS is controlled with two inputs the u_1 and u_2. The dynamics cross couplings are one of the key features of the TRMS (Figure 4). The position of the beams is measured with the means of incremental encoders, which provide a relative position signal. Thus every time the Real-Time TRMS simulation is run one must remember that setting proper initial conditions is important.

PATH PITCH & YAW ROTOR IDENTIFICATION

This model describes the relation between the control voltage U1 and the angle ψ. Generally all the real time simulations are carried out using a sampling time of Ts = 0.001 [s]. But since plant dynamic response is relatively slow, the identification of the discrete model is carried out with the sampling time of Ts = 0.1[s].

PITCH ROTOR:

The identification experiment is carried out using the model called **MainPitch_Ident.mdl** in the Matlab Toolbox. The function of the model is to excite the TRMS and record its response.

YAW ROTOR:

The identification experiment was conducted using the **MainYaw_Ident.mdl** in Matlab and data was collected.

RESULTS:

REAL TIME DOF PITCH AND YAW ROTOR CONTROL:

The pitch rotor position will be controlled. It is tested in real time. For this use the ***TRMS_PID_pitch.mdl*** presented as follows

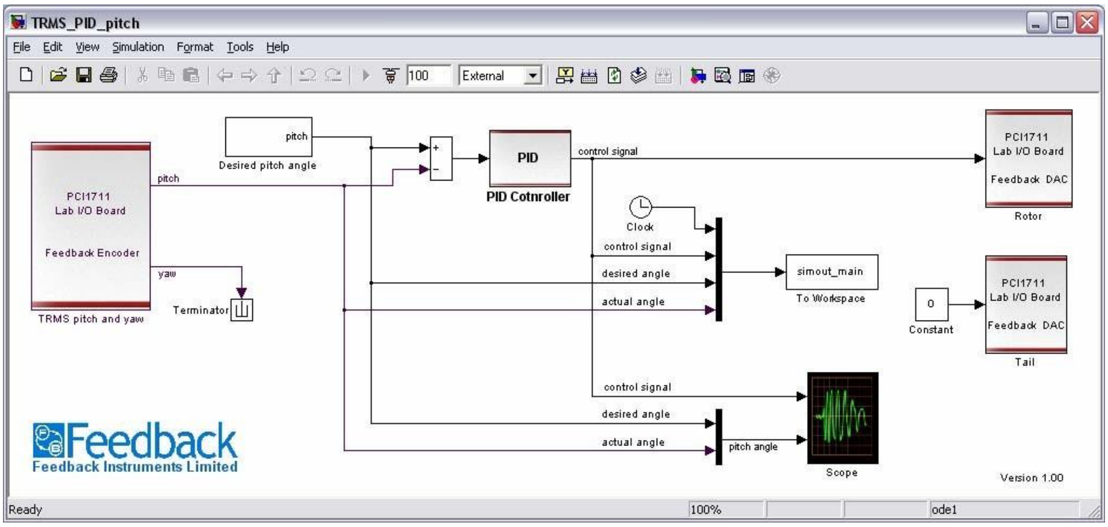

Figure 15 Real time TRMS pitch position control

As you open the ***TRMS_PID_pitch.mdl*** you will notice that this simulation is directed to an external module, which is indicated in the upper part of the simulation window.

The yaw rotor position will be controlled. use the ***TRMS_PID_yaw.mdl.***

Before you run the real time simulation make sure the TRMS setup is properly connected and that the Power Source is turned off.