DESIGN AND OPTIMIZATION OF MPC SYSTEM FOR AN ULTRA-CENTRIFUGE SYSTEM

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Abstract **–**The paper deals with modelling of centrifuge for different types of inputs to obtain desired output. The inputs are the parameters that affect the working of centrifuge separator. The model responses are analyzed using model predictive controller with MPC toolbox and PID controller at a time in Simulink. The MPC outputs are obtained for various disturbance inputs and compared to PID response.

Keywords – Centrifuge separator, Model Predictive Control (MPC), PID.

I.INTRODUCTION

There are many types of separators in which centrifuge separator is chosen which is dependent on separation of materials according to their size, shape, density, viscosity and rotor speed based on gravitational force. Sedimentation rate of suspended particles are enhanced by centrifugation technique. Centrifugation comes under density difference separation technique. There are different types of centrifuges which are classified according to the range of angular velocities expressed in rpm. General types are micro-centrifuges, high-speed centrifuges and ultracentrifuges. Ultracentrifuges are sub-classified as preparative and analytical. For my work I have taken reference of Beckman Coulter preparative ultracentrifuge. The basic input parameters like speed, time and temperature are taken as reference to construct mpc controller for analyzing laboratory centrifuge model in simulink. Rotor is another important part of centrifuge. The separation depends on the type of rotor selected. There are three types of rotors namely fixed angle, vertical tube and swinging bucket. For my work fixed angle rotor of 45 degrees is chosen. Heterogeneous mixture components like liquids in liquids, solids in liquids, solids and liquids in gases are dissociated by centrifugation. I have selected liquid-liquid centrifuge separator for my task.

II. SYSTEM MODEL

In centrifuge separation, many output parameters are present like sedimentation velocity, feed flow rate, relative centrifugal force. In this paper, the feed flow rate is considered as output which is related to sedimentation velocity and residence time. Angular velocity is an internal parameter in the process of derivation.

$$q = \left\{ w^2(P_p - P)D_p^2 \Big/ 18\mu \ln\left(\frac{r_2}{r_1}\right) \right\} * V$$

$$= \left\{ w^2(P_p - P)D_p^2 \Big/ 18\mu \ln\left(\frac{r_2}{r_1}\right) \right\} * \left(\pi b(r_2^2 - r_1^2)\right)$$

- Residence time t_T is equivalent to the volume of liquid V (m^3) in the bowl divided by the feed volumetric flow rate q in m^3/s. The volume is given by :

$$V = \left(\pi b(r_2^2 - r_1^2)\right)$$

Reference readings are taken from Beckman Coulter ultracentrifuge where the fixed parameters are displayed on a desktop mounted on top of it. The readings are set for different values and examined. The problem in this method is that modelling cannot be done manually as it has inbuilt mechanisms specified by the manufacturer. So, this equipment is used only for getting reference output separations.

Fig.1. Front panel of Ultracentrifuge.

Fig.2. Beckman Coulter Ultracentrifuge equipment

Fig.3. Reference readings in front panel of Ultracentrifuge

III. Modelling using MPC and PID in Simulink

Simulation was done using Model Predictive Control toolbox in Simulink. In MPC different parameters are needed for getting results. External variables like reference input, measured output, manipulated variable and measured disturbance are present in MPC block. Apart from these internal parameters like constraints, weights, noise, unmeasured disturbances, unmeasured output will affect the performance of the plant response. Whenever MPC is implemented on any plant all these parameters are to be assigned with necessary values.

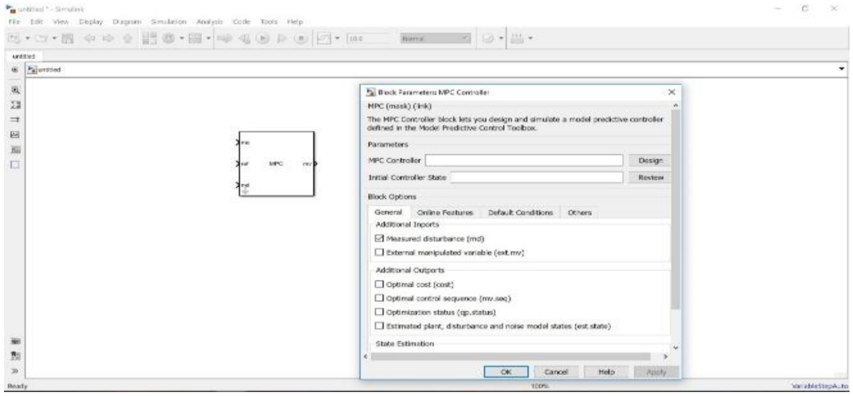

Fig.4. MPC block in simulink.

In this paper the reference input of MPC and PID have combined outputs from temperature model and PWM based DC motor rpm output. The DC motor generates two outputs current and rpm which determines speed of motor. In the reference model of ultracentrifuge the rotor speed, time and temperature are taken as inputs. So, here time is given as input to temperature model and the output is given as one of the reference inputs to MPC block and rpm is given as inputs to centrifuge plant model and MPC block. The centrifuge plant model is designed according to the equation of feed flow rate. The inputs to the plant are acceleration, liquid density, particle density and diameter of the rotor. The rpm value from DC motor is given as input to acceleration input port In1, step signal is given as In2 which specifies liquid density value. In3 relates to particle density which is variable so mv output of MPC block is connected to it, similarly PID output is connected to In3 of other plant model. In4 corresponds to diameter whose value is fixed therefore a step signal is given as input. The plant model generates different responses for MPC and PID. In MPC the output of plant model is connected to mo i.e., measured output of MPC block. The disturbance codes are written in mpcobj of design section in command window which is specified in MPC controller of Simulink window.

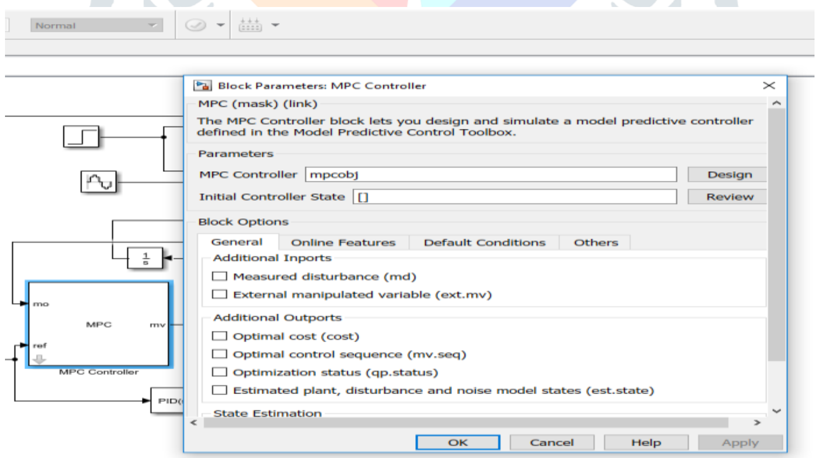

Fig.5. MPC controller indicating design option.

The disturbance can be introduced in two ways. One way is providing inputs with predefined blocks and other way is writing code in command window of MATLAB and calling that function in MPC controller design. Here three types of disturbance models are taken and analyzed their responses for the existing plant. The cases are as follows:

case-1: plant=rss(2,2,3);
case-2: plant=rss(3,2,3);
case-3: plant=rss(3,2,4);
rss is random continuous test model. The variables are in the order as states, outputs and inputs.

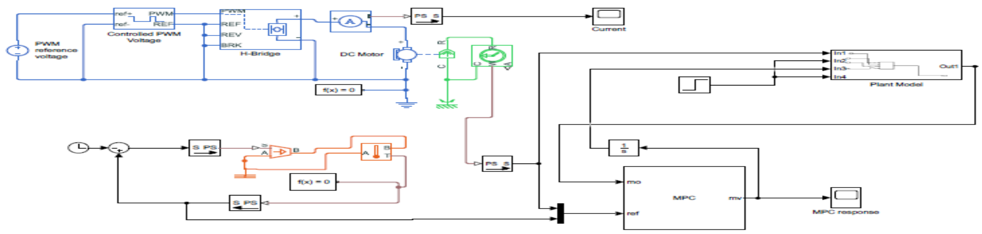

Fig.6. Simulink model of Plant using MPC.

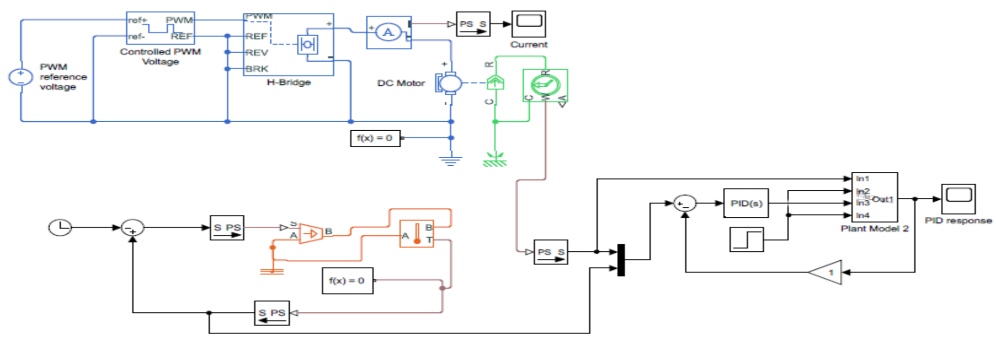

Fig.7. Simulink model of Plant using PID.

IV. RESULTS

Figure 8 shows the responses of PID for the designed centrifuge plant model. Figures 9,10,11 display the response of MPC for different parameters like ref, mo, mv along with internal disturbances. As MPC involves feedback mechanism, where it considers past inputs along with present inputs so the response is obtained in this manner when compared to PID. In the graphs y-axis represents feed flow rate and x-axis represents time.

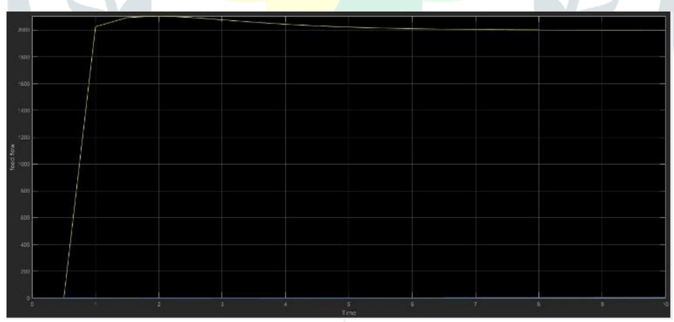

Fig.8. PID response of plant for different inputs.

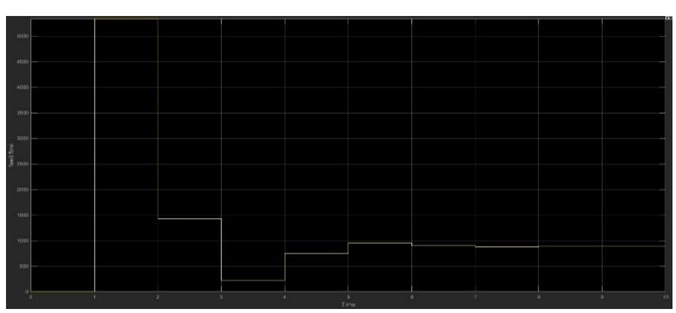

Fig.9. MPC response of plant for rss=(2,2,3)

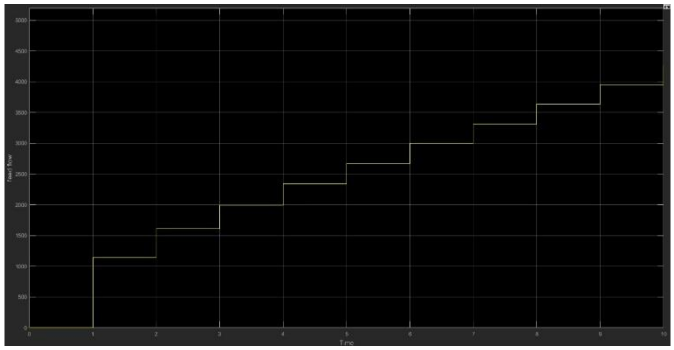

Fig.10. MPC response of plant for rss=(3,2,3)

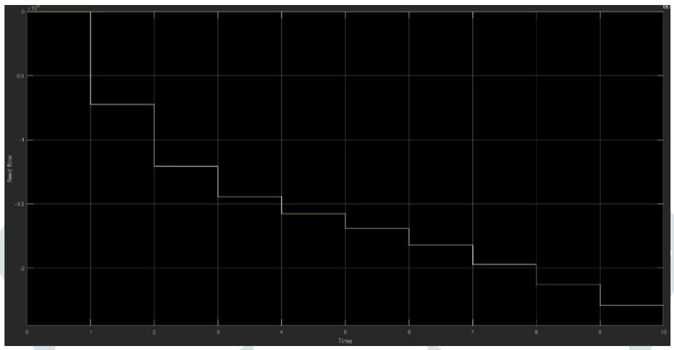

Fig.11. MPC response of plant for rss=(3,2,4)

V. CONCLUSION

In this paper it was observed that how a plant that resembles centrifuge separator behaved for different controllers like MPC and PID. Same inputs are provided for both controllers and plant but the main difference is with MPC that contains advanced and additional parameters than PID which results in better performance in terms of separations.

VI. ACKNOWLEDGEMENT

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