MAK498 SENIOR DESIGN PROJECT
TRACKING CONTROL OF A BALL ON BEAM AND PLATE STRUCTURES

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ABSTRACT

The Ball & Beam project aims to get a ball to the target spot quickly and accurately. It's important because it resembles control systems used in major sectors like space and aviation. An Arduino UNO is used as the microcontroller. A mathematical model is developed to represent the system's behavior. Another phase involves designing a ball-and-plate balancing system using a closed-loop control mechanism with a digital PID controller. The system's mathematical model is nonlinear, and both theoretical and experimental analysis are conducted to evaluate its performance.

METHOD

First, project requirements were received from project supervisor and literature review was made. Then, CAD models of beam and plate structures were made considering the requirements. MATLAB code was written in order to simulate the plate structure. Static structural analysis was conducted for beam structure to determine stress and deformation values on critical parts. Exploded views of beam and plate structures are given in Figure 1 and Figure 2.

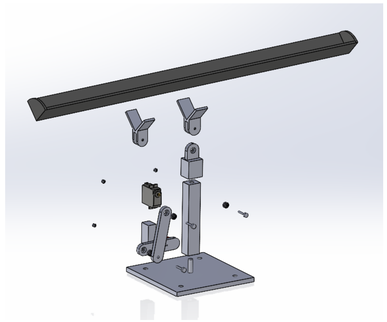

Figure 1. Exploded View of the Beam Structure

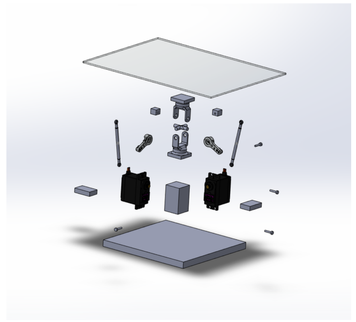

Figure 2. Exploded View of the Plate Structure

RESULTS

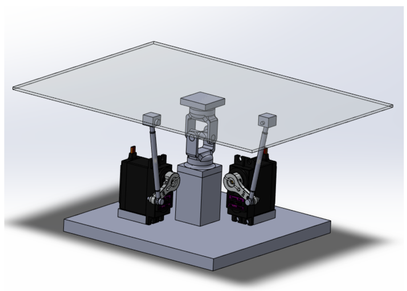

Figure 3. CAD Model of Plate Structure

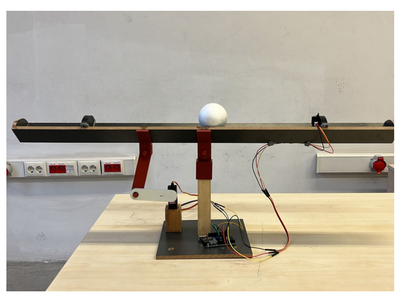

Figure 4. Beam Structure

CAD models for beam and plate structures designed in accordance with the project requirements are given in Figure 3 and Figure 4. The beam structure was constructed with PLA and wood materials. The plate structure does not have a physical sytem, it has simulated in MATLAB.

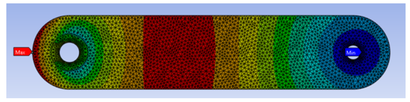

Figure 5. Deformation Analysis of Servo Transfer Arm

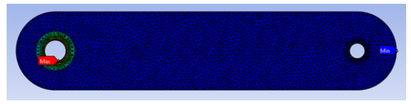

Figure 6. Stress Analysis of Servo Transfer Arm

Static structural analysis of one of the servo transfer arms is shown in Figure 5 and Figure 6. According to the static analysis maximum deformation (Figure 5) is measured to be 3.05x10^-11 mm which is very low. The maximum value of the Von Mises Stress (Figure 6) is 1.39x10^-8 MPa. Because of the properties of the material and the fact that it is not hollow, low deformation and stress values are expected results.

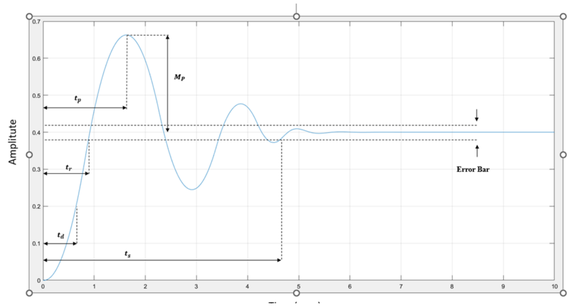

Figure 7. Transient Response Graph

In this section, transient system response simulation for ball and beam is created on MATLAB. Afterwards, the effects of PID coefficients on the behavior and parameters of the system response are observed.

In the MATLAB codes written for the plate structure, a circle and a midpoint were created to reference the ball. The effect of PID coefficients, maximum plate angles and ball velocity on the system response were observed.

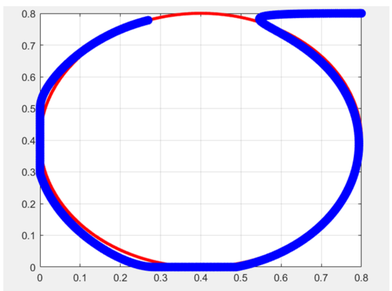

Figure 8. Animation Example of the Movement of a Circle in the Ball and Plate System

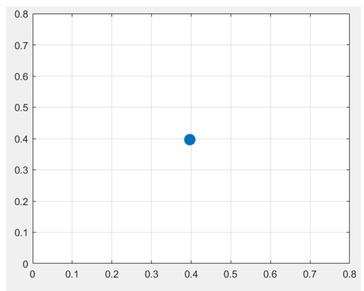

Figure 9. Animation Figure Example of Ball and Plate Simulation

	K_P ↑	K_D ↑	K_I ↑
t_d	Constant	Constant	Constant
t_r	Decreases	Increases	Decreases
t_p	Increases	Decreases	Increases
t_s	Increases	Decreases	Increases
M_P	Increases	Decreases	Increases

Figure 10. Effect of PID Coefficients on System Response Parameters

In Figure 10, the impact of the proportional-integral-derivative (PID) coefficients on the system response parameters, which are crucial for controlling the ball's movement on the beam and plate structure, are demonstrated and visually represented.

CONCLUSION

Our project aims to track a ball on beam and plate structures. During the design process, we conducted a literature search and selected components such as servo motors, infrared distance sensors, and an Arduino UNO for their low cost and ease of use. Wood and PLA were chosen as materials, and Excel was used for geometric analysis and calculating loads. ANSYS was used for structural analysis, and MATLAB was used to simulate the system's response to various parameters.

ACKNOWLEDGEMENT

We would like to thank our supervisor Dr. Hüseyin Enes SALMAN for his support.