T.C.
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ENG401 Project Final Report

Mechanical Mixer Project for Hydroxypropyl Methylcellulose Mixture

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CONTENTS

A. Introduction

This project presents a pioneering project aimed at advancing the functionality and expanding the scope of use of (Hydroxypropyl)methyl cellulose (HPMC), a multifaceted product widely embraced in the construction chemicals industry for its notable thickening, binding, and film-forming properties. The focal point of this initiative is to seamlessly integrate HPMC with an innovative mixing mechanism, with a special emphasis on augmenting its application within the healthcare sector.

Our overarching objective is to harness the distinctive properties of HPMC, culminating in a form suitable for injection into bone tissue after a carefully defined mixing duration. This ambitious goal is pursued through the meticulous design of a mixing mechanism centered around a screw shaft system. The integration of a stepper motor in the ball screw system offers precise control over the vertical movement of the propeller inside the beaker, optimizing the product's efficiency, adhesion, and strength. This endeavor not only aims to elevate the therapeutic potential of HPMC in the healthcare sector but also envisions an expanded utility across diverse industries.

At the heart of our project lies the development of an original system dedicated to uniformly mixing (Hydroxypropyl)methyl cellulose (HPMC) within a beaker. This system features a specialized propeller design, meticulously crafted using advanced 3D printing technology. The rotational force for the propeller is harnessed by a DC motor, ensuring a harmonious blending of HPMC within the beaker. To further enhance the homogeneity of the mixture, a screw shaft system, ingeniously driven by a stepper motor, is employed. This precision-driven vertical movement of the propeller inside the beaker plays a pivotal role in achieving the desired homogeneous consistency of the product.

The amalgamation of these cutting-edge technologies in our integrated system not only amplifies the intrinsic properties of HPMC but also sets the stage for a versatile product with enhanced therapeutic potential. Beyond its applications in healthcare, this innovative system is poised to elevate the efficacy of (Hydroxypropyl)methyl cellulose in a myriad of industrial settings, positioning it as a frontrunner in diverse fields. This report provides a detailed exploration of our methodology, design considerations, and the anticipated impact of this project on the future applications of HPMC.

B. Principle of Operation for the Project

In this section, we delve into the fundamental operational principles driving our project, with the overarching goal of attaining an injectable consistency for the (Hydroxypropyl)methyl cellulose (HPMC) mixture within bone tissue. The intricacies of our project are bifurcated into two distinctive components, each playing a pivotal role in achieving the desired outcome.

Propeller Section:

The first facet, the propeller section, places particular emphasis on the careful selection of a motor and its seamless integration into the system. A critical decision in this phase was the adoption of a robust servo motor, chosen for its strength and reliability. Leveraging the capabilities of the servo motor, we seamlessly integrated it into the system. This approach ensures a simplified and efficient blending process for (Hydroxypropyl)methyl cellulose (HPMC).

Ball Screw Mechanism:

The second component introduces the ball screw mechanism, strategically designed to facilitate mixing in containers of varying dimensions and grant us precise control over the propeller's position. The need for versatility in mixing, accommodating different beaker sizes, prompted the incorporation of a mechanism capable of moving the propeller along the vertical axis. Our choice fell on the Ball Screw mechanism, enabling the propeller's controlled vertical movement. However, the significant load borne by the Ball Screw necessitated the selection of a motor with robust torque capabilities. To address this, the high-torque Nema-17 Step Motor emerged as the preferred choice, ensuring the efficient handling of the load while maintaining operational integrity.

This dual-pronged approach, combining the servo motor-driven propeller section and the Nema-17 Step Motor-empowered ball screw mechanism, synergistically contributes to the project's success. The meticulous selection and integration of these components underscore our commitment to achieving optimal consistency in the (Hydroxypropyl)methyl cellulose (HPMC) mixture, ultimately fulfilling the primary objective of creating a form suitable for injection into bone tissue.

C. Conceptual Design

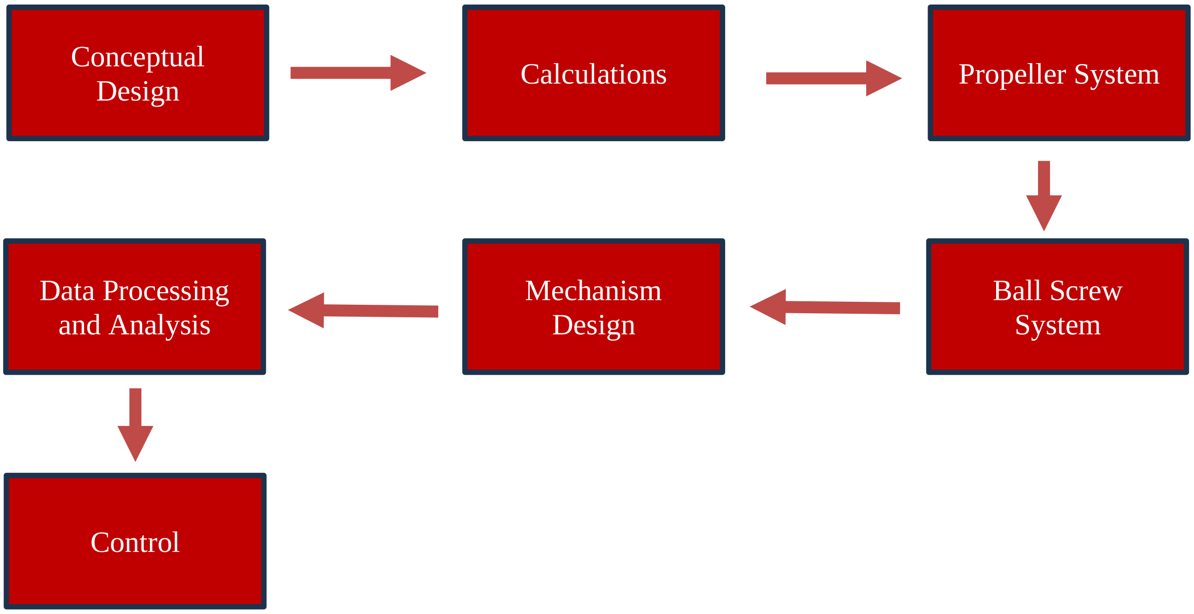

Figure C.1 Block-Diagram

D. Calculations

CONCENTRATION (%)	VISCOSITY (Pa.s)
1,00	0,438
0,80	0,238
0,50	0,085
0,30	0,022
0,20	0,021
0,10	0,018

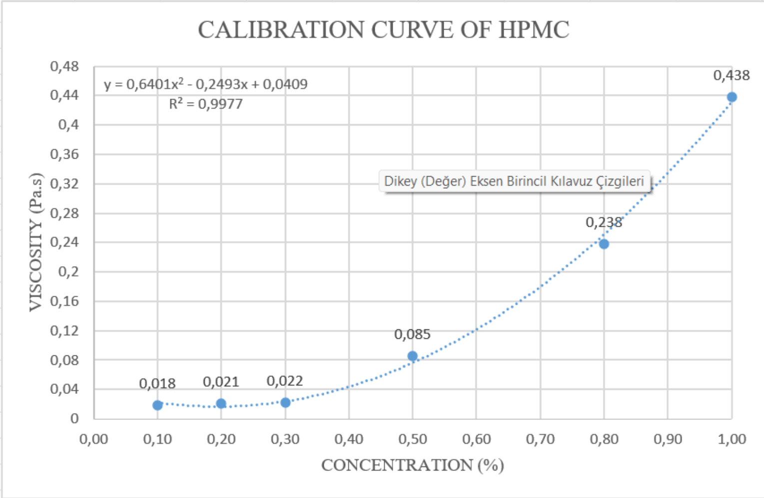

Figure D.1 Reference Data (Calibration Curve of HMPC)

D.a) For the Dremel Motor Calculations

1. Determine Material Properties:

• Material density (p)
• Viscosity (p)
• Fluid behavior of the material during mixing

2. Specify Mixing Speed and Time:

• Desired mixing speed (N) and duration (t)

3. Determine Mechanical Properties:

• Shaft diameter (d) and length (L)
• Blade dimensions and design (typically width and length)

4. Calculate Moment of inertia (I):

$$I = \frac{1}{2}\, x\, m\, x\, r^2$$

Here, m is the mass of the shaft, and r is the radius.

5. Torque and Power Calculations:

$$Torque\ (T) = I\ x\ \alpha$$
$$Power\ (P) = T\ x\ \omega$$
$$Motor\ Power = \frac{P}{Motor\ Efficiency}$$

6. Flow Velocity Calculation:

$$Flow\ Velocity = \frac{Mixing\ Speed}{60\ x\ 2\pi\ x\ Length\ of\ the\ Shaft}$$

7. Calculate RPM:

$$RPM = \frac{60 \times t}{\pi \times d \times \mu}$$

- t: thickness of the fluid , d: diameter of the cylinder , μ: viscosity of the liquid

D.b) Ball Screw Calculations

1. **Maximum forward speed according to motor speed:**

$$V = \frac{\pi\ x\ d\ x\ N}{60x1000}$$

• Shaft Diameter (d) • Motor speed (N)

$$V = \frac{\pi \times 0{,}005 \times 200}{60x1000} = 0.0000523\ m/s$$

2. **Thrust force calculation according to motor torque:**

2.1. Circular area of ball screw:

$$A = \pi\ x\ r^2$$

• r = Radius of shaft

2.2. Formula for Shaft torque and Shaft Radius:

$$F = \frac{T}{r}$$

• Motor torque (T) • r = Radius of shaft

2.3. Effective Force formula:

$$Effective\ Force = \frac{Calculated\ Force}{Efficiency}$$

E. Materials and Methods

In the pursuit of optimizing the mixing process for the (Hydroxypropyl)methyl cellulose (HPMC) mixture within the scope of our project, meticulous attention has been dedicated to both the selection of materials and the development of a methodological approach. The success of our endeavor hinges on the judicious choice of components and the precision in executing our methods. Herein, we provide a detailed account of the materials employed and the methodology adopted for achieving the desired outcome.

Materials:

1. **(Hydroxypropyl)methyl Cellulose (HPMC):**

    - The cornerstone of our project, HPMC serves as the primary material for the mixture. Sourced for its versatile properties, including thickening, binding, and film-forming capabilities, HPMC acts as the focal point for our innovative mixing mechanism.

2. **Servo Motor:**

    - A robust servo motor is selected for the propeller section of our system. Its strength and precision ensure optimal blending of the HPMC mixture.

3. **DC Motor:**

    - Employed in the propeller system, the DC motor powers the rotation of the specialized 3D-printed propeller, contributing to the uniform mixing of HPMC within the beaker.

4. **Ball Screw Mechanism:**

    - The heart of our vertical movement system, the Ball Screw mechanism is instrumental in controlling the propeller's position within the beaker, allowing for versatile mixing in containers of different sizes.

5. **Nema-17 Step Motor:**

    - Chosen for its high torque capabilities, the Nema-17 Step Motor plays a crucial role in driving the Ball Screw mechanism, effectively handling the substantial load imposed during the mixing process.

6. **3D-Printed Propeller:**

    - A specialized propeller design, crafted using advanced 3D printing technology, ensures efficient rotation and mixing of the HPMC within the beaker.

Methods:

1. **Temperature Control:**

    - To ensure optimal mixing conditions, the HPMC mixture is maintained at an average temperature of 80 degrees Celsius. This controlled temperature environment is crucial for achieving the desired consistency in the mixture.

2. **Propeller Section Operation:**

    - The servo motor operates the propeller section, contributing to the uniform mixing of HPMC within the beaker.

3. **Ball Screw Mechanism Operation:**

    - The Nema-17 Step Motor powers the Ball Screw mechanism, enabling precise control over the vertical movement of the propeller. This ensures uniform mixing and accommodates different beaker sizes.

4. **Integration of Components:**

    - The various components, including the servo motor, DC motor, Ball Screw mechanism, and 3D-printed propeller, are intricately integrated to form a cohesive system. Rigorous testing and calibration are conducted to ensure seamless collaboration among these components.

In summary, the materials and methods employed in our project are carefully curated to harness the unique properties of (Hydroxypropyl)methyl cellulose (HPMC) and achieve optimal mixing conditions. The systematic integration of these components forms the backbone of our innovative approach, aiming to revolutionize HPMC applications in the healthcare sector and beyond.

F. Propeller Design for Mixing

We first thought about what kind of design we needed to perform the necessary operations. We decided on the necessary steps as follows and reached the results of our work as follows:

1. CAD Design:

Your CAD design includes the propeller component and the motor bed. This design has specific dimensions and features tailored to the requirements of your project. Below is a simplified example:

- **Propeller Component:**
  - Shape: It can be cylindrical or designed with shapes optimized for mixing efficiency.
  - Dimensions: Specific dimensions such as diameter and length, depending on design requirements.
  - Material: Choosing a material based on chemical resistance and strength properties is crucial.
- **Motor Bed:**
  - Shape: A design securely holding the motor.
  - Mounting Points: Points where the motor is fixed or adjusted.

These designs provide general information and need to be customized according to your specific requirements.

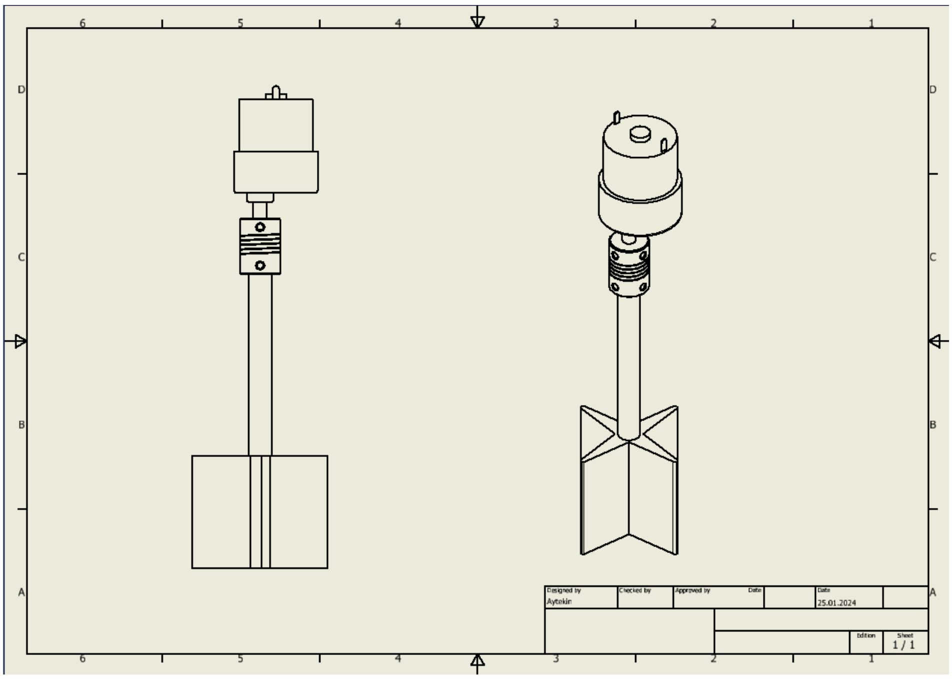

Figure F.1 Propeller Technical Drawing

2. Electronic Circuit Design:

Your electronic circuit includes Arduino, motor driver, and DC motor.

Hardware Components:

- Arduino UNO or a similar microcontroller.
- DC motor driver (L298N)
- DC motor.
- Power supply.

- **Connections:**
  - Connect the digital pins of Arduino to the inputs of the motor driver.
  - Connect the motor driver to the DC motor.
  - Connect the power supply to the motor driver and Arduino.

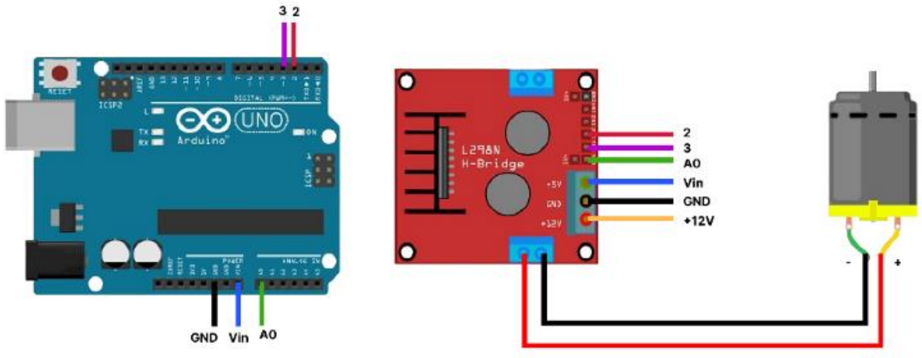

Figure F.2 Electronic Circuit Diagram

G. Ball Screw Design for Control Position

A mechanical mixer with a ball screw mechanism is a device designed to mix or blend substances by utilizing the rotational motion of a ball screw. The ball screw mechanism is a type of linear motion mechanism that converts rotary motion into linear motion or vice versa.

- **Ball Screw Mechanism:**

A ball screw consists of a screw shaft and a nut, with steel balls in between. The screw shaft has helical grooves, and the nut has matching helical grooves.
When the screw shaft rotates, it causes the balls to move along the grooves, translating the rotary motion into linear motion.

- **Mixer Structure:**

The mixer would have a container or mixing chamber where substances are placed for mixing.
The ball screw mechanism would be integrated into the mixer structure, with one end connected to a motor or some source of rotary motion.

- **Motor and Control System:**

The mixer powered by a Step Motor capable of rotating the ball screw. The motor can be controlled to adjust the speed and direction of the rotation.
The rotary of the ball screw mechanism will be adjustable with the help of a button.

- **Mixing Process:**

As the ball screw rotates, it causes linear motion in the mixing chamber or agitator, effectively stirring or mixing the substances inside.
The direction of the rotation can be controlled to achieve the desired mixing intensity and pattern.

Electronic Circuit Design

Designing the electrical circuit for a mechanical mixer with a ball screw mechanism and a stepper motor involves creating a system that controls the stepper motor to achieve the desired mixing action.

Components Needed:

Stepper Motor:

Nema17 Step Motor BYGHW609 A 1.7A 1.8 Degree Technical Properties:

- Model: BYGHW609 A
- Motor Type: Nema17
- Angle of pitch : 1.8 degree
- Current: 1.7A
- Working Voltage: 12V
- Holding Torque: 4.4 kg.cm
- Acceleration Torque: 3.2 kg.cm

Stepper Motor Driver:

A dedicated stepper motor driver is required to control the stepper motor. In this project, L298N was used as the motor driver.

Microcontroller:

In this project, Arduino Uno was used as a microcontroller for stepper motor control.

Power Supply:

A stable power supply that provides the required voltage and current for both the stepper motor and the control circuit.

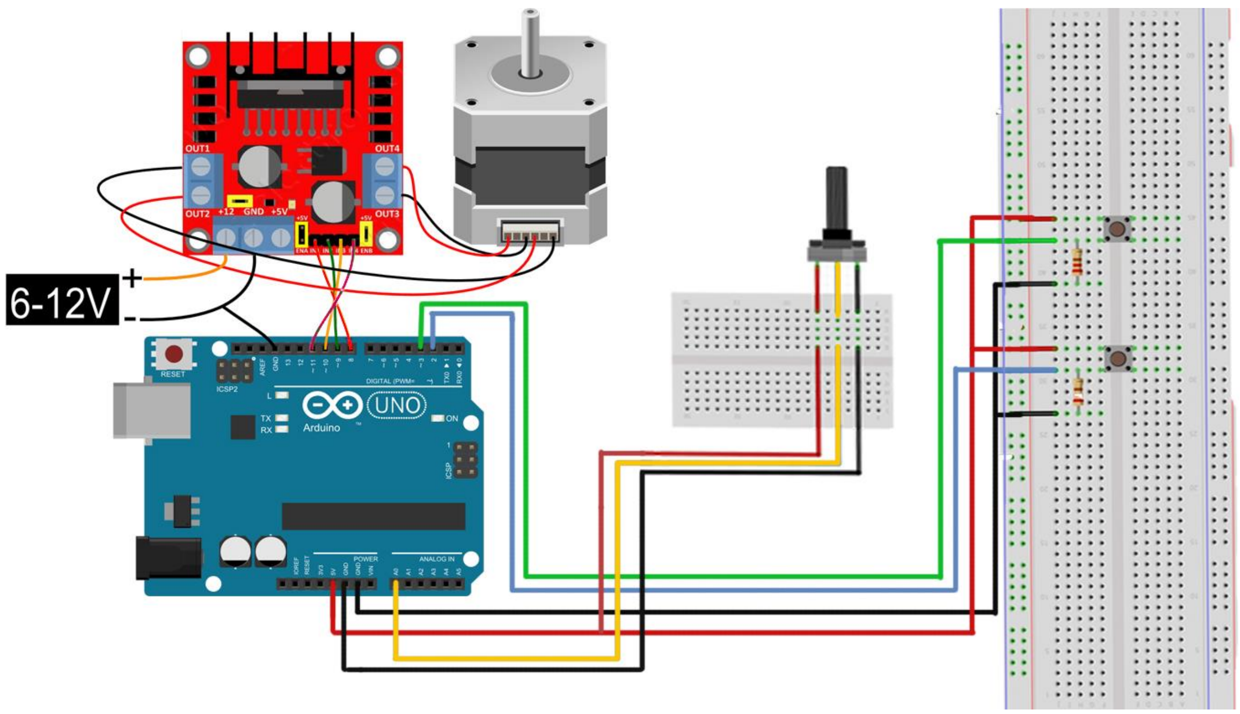

Figure G.2 Electronic Circuit Design

Arduino Code:

This Arduino code is designed to control a stepper motor using an L298N driver. The stepper motor can rotate in either the clockwise (CW) or counterclockwise (CCW) direction based on input from two push buttons, namely switchCW and switchCCW. The code employs a specific sequence of signals to drive the stepper motor through its steps.
Let's break down the modified code:

Global Variables:

- **Pin1**, **Pin2**, **Pin3**, **Pin4**: Pins connected to the input pins (IN1, IN2, IN3, IN4) of the L298N driver.
- **switchCW**: Input pin for the CW (Clockwise) push button.
- **switchCCW**: Input pin for the CCW (Counterclockwise) push button.
- Arrays **pole1**, **pole2**, **pole3**, **pole4**: Represent the sequence of signals for each pole in an 8-step sequence, driving the stepper motor.
- **poleStep**: Variable to keep track of the current step in the sequence.
- **dirStatus**: Variable to store the direction status (1 for CCW, 2 for CW, 3 for stop).

Setup Function:

- Configures the pin modes: **Pin1**, **Pin2**, **Pin3**, and **Pin4** are set as OUTPUTs. **switchCW** and **switchCCW** are set as INPUT_PULLUP, utilizing internal pull-up resistors.

Loop Function:

- Checks the status of the CW and CCW push buttons.
- If **switchCCW** is pressed, **dirStatus** is set to 1 (CCW).
- If **switchCW** is pressed, **dirStatus** is set to 2 (CW).
- If neither button is pressed, **dirStatus** is set to 3 (stop).
- Calls the **driveStepper** function based on the direction status.

driveStepper Function:

- Drives the L298N driver by setting the appropriate signals (HIGH or LOW) to **Pin1**, **Pin2**, **Pin3**, and **Pin4** based on the current step in the sequence (**poleStep**).
- Updates the step counter (**poleStep**) for the next iteration.

The stepper motor advances through its sequence of steps according to the direction set by the push buttons, providing a straightforward user interface for controlling the stepper motor's movement and direction using the L298N driver.

```
int Pin1 = 8;//IN1 is connected to 10
int Pin2 = 9;//IN2 is connected to 11
int Pin3 = 10;//IN3 is connected to 12
int Pin4 = 11;//IN4 is connected to 13
int switchCW  =2;//define input pin for CW push button
int switchCCW =3;//define input pin for CCW push button


int pole1[] ={0,0,0,0, 0,1,1,1, 0};//pole1, 8 step values
int pole2[] ={0,0,0,1, 1,1,0,0, 0};//pole2, 8 step values
int pole3[] ={0,1,1,1, 0,0,0,0, 0};//pole3, 8 step values
int pole4[] ={1,1,0,0, 0,0,0,1, 0};//pole4, 8 step values


int poleStep = 0;
int  dirStatus = 3;// stores direction status 3= stop (do not change)

void setup()
{
  //Stepper Motor Code STPB-2
 pinMode(Pin1, OUTPUT);//define pin for ULN2003 in1
 pinMode(Pin2, OUTPUT);//define pin for ULN2003 in2
 pinMode(Pin3, OUTPUT);//define pin for ULN2003 in3
 pinMode(Pin4, OUTPUT);//define pin for ULN2003 in4

 pinMode(switchCW,INPUT_PULLUP);
 pinMode(switchCCW,INPUT_PULLUP);
```

```
 void loop()
 {
   // Stepper Motor Code STPB-2
   if(digitalRead(switchCCW) == LOW)
   {
     dirStatus =1;
   }else if(digitalRead(switchCW) == LOW)
   {
    dirStatus  = 2;
   }else
   {
     dirStatus =3;
   }
  if(dirStatus ==1){
    poleStep++;
     driveStepper(poleStep);
  }else if(dirStatus ==2){
    poleStep--;
     driveStepper(poleStep);
  }else{
   driveStepper(8);
  }
  if(poleStep>7){
    poleStep=0;
  }
  if(poleStep<0){
    poleStep=7;
  }
  delay(1);
 //
 }//

 void driveStepper(int c)
 {
   // Stepper Motor Code STPB-2
      digitalWrite(Pin1, pole1[c]);
      digitalWrite(Pin2, pole2[c]);
      digitalWrite(Pin3, pole3[c]);
      digitalWrite(Pin4, pole4[c]);
 }//driveStepper end here
```

Figure G.3 Arduino Code

H. CAD Model

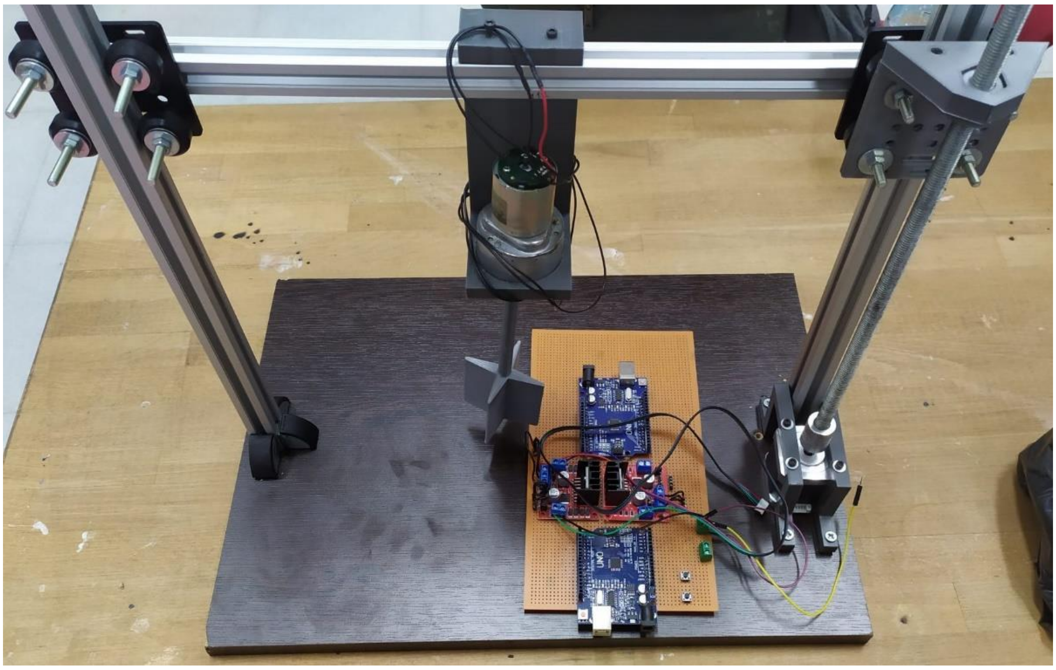

Figure H.1 System Photo

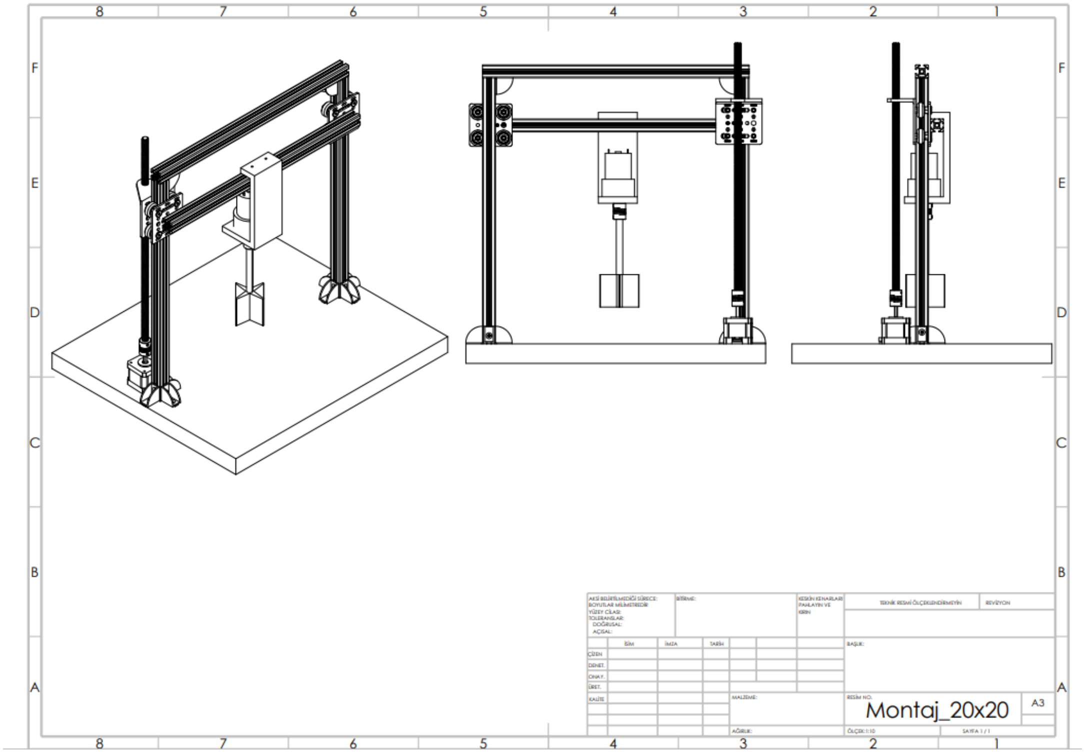

Figure H.2 System Technical Drawing

During the design phase of our project, establishing a solid foundation was paramount for the efficient integration of various components. To achieve this, we opted to utilize a sturdy wooden board as the base for our system. This strategic decision allowed us to seamlessly mount and arrange all components, ensuring a cohesive and organized structure.

The wooden board served as the canvas for our project, providing stability and support for the intricate elements comprising the mixing mechanism. This foundational base not only simplified the assembly process but also facilitated the precise placement of components, enhancing the overall structural integrity of the system.

With the wooden board as our starting point, we meticulously designed and arranged the servo motor-driven propeller section and the Nema-17 Step Motor-empowered ball screw mechanism.

i. Conclusion

In the culmination of our exploration into enhancing the functionalities of (Hydroxypropyl)methyl cellulose (HPMC) for diverse applications, this project has unveiled a promising avenue for the healthcare sector and beyond. Our journey began with a focus on HPMC, a versatile compound with inherent thickening, binding, and film-forming properties, widely employed in the construction chemicals industry. Recognizing its potential, we embarked on a mission to augment its utility through a meticulously designed mixing mechanism.

The underlying principle of our project revolves around a dual-system approach: the propeller section, driven by a servo motor, and the ball screw mechanism, powered by a Nema-17 Step Motor. The servo motor's robust design and PWM speed control capability, facilitated by the L298N Motor Driver, ensure precise control over the mixing speed. Concurrently, the Nema-17 Step Motor handles the substantial load imposed on the Ball Screw mechanism, facilitating controlled vertical movement for uniform mixing within the beaker.

Our material selection underscores the importance of each component in the system. HPMC serves as the primary substance, while the 3D-printed propeller, servo motor, and Nema-17 Step Motor are integral to the mixing process. The careful integration of these materials has resulted in a cohesive system poised to elevate the properties of HPMC, rendering it suitable for injection into bone tissue.

Temperature control at an average of 80 degrees Celsius plays a crucial role in optimizing the mixing process. This methodological choice ensures the HPMC mixture reaches the desired consistency for effective application.

As we reflect on the journey from conception to execution, it becomes evident that our project not only introduces innovation in the realm of material science but also paves the way for novel applications in healthcare. The integration of advanced technology, precision control mechanisms, and the versatile nature of HPMC positions our system as a potential game-changer. While our initial focus remains on healthcare applications, the adaptability of our design suggests broader implications across various industries.

In conclusion, this project signifies a harmonious fusion of theoretical knowledge, innovative design, and meticulous execution. The successful amalgamation of (Hydroxypropyl)methyl cellulose with our advanced mixing mechanism marks a significant stride towards revolutionizing material applications, offering unprecedented possibilities in healthcare and beyond.