Design Document for ECE445 Senior Design

Project Title	A device for evaluation of frictional properties of surfaces
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Project Proposal

1 Introduction

1.1 Objective and Background

1.1.1 Problem

Extensive research efforts have been devoted to understanding the complex mechanisms of friction wear to minimize their effects in sliding systems. Improvements in the instruments used to characterize the friction and wear phenomenon are required to enhance the effectiveness of the research method. In this project, our goal is to design and build an experimental platform that evaluates surfaces' frictional behavior.

1.1.2 Solution

The platform will be a modular friction test platform, which is capable of accurately measuring the friction, wear rate and contact behavior between surfaces of different materials. It will include high precision sensors, controllable condition system and data acquisition system and allow researchers to conduct experiments under a variety of conditions, such as load and angular velocity.

There are many circumstances when people can benefit from this platform. For instance, with this platform around, when carrying out an experiment that needs the friction data of unfamiliar materials, or multiple friction data sets under different conditions, instead of searching for the numbers for a long time, researchers could directly use the platform to get everything they need simply and quickly. In addition to measuring the friction, the platform could also quantize the wear condition of the materials.

There are many application scenarios for this platform. Fraction and wear measurement are needed in anywhere that relates to mechanical engineering, such as laboratory, factory and so on. The modular design of this platform is the key to its marketability. The platform will be divided into several parts that are independent from each other, and users can take any parts off in order to maintain or take it to other places. Both maintenance and transportation of the platform will be convenient. [1]

1.1.3 Visual Aid

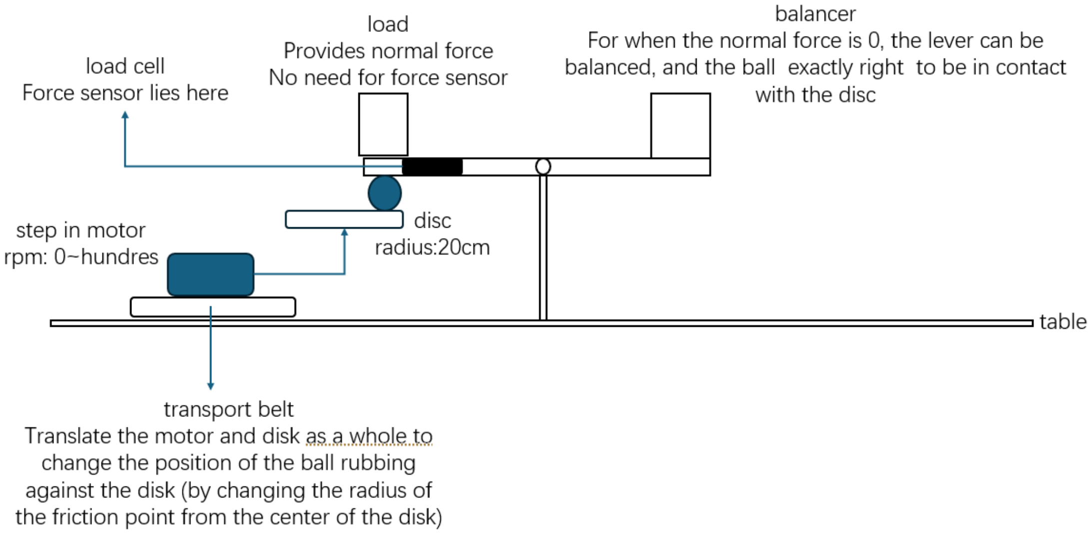

Fig 1. Simple Visualization of the Platform

1.2 High-Level Requirements List

- The lever system should be balanced when there's no load on the top of the ball, this should be manifested as that the ball exactly right touches the disc. [2]
- Sensors and motors can be connected to PC and can send data to the PC and can be controlled by it.
- The component disc, ball and load should be able to be removed from the whole platform and got repaired or changed.

2 Design & Requirements

2.1 Block Diagrams

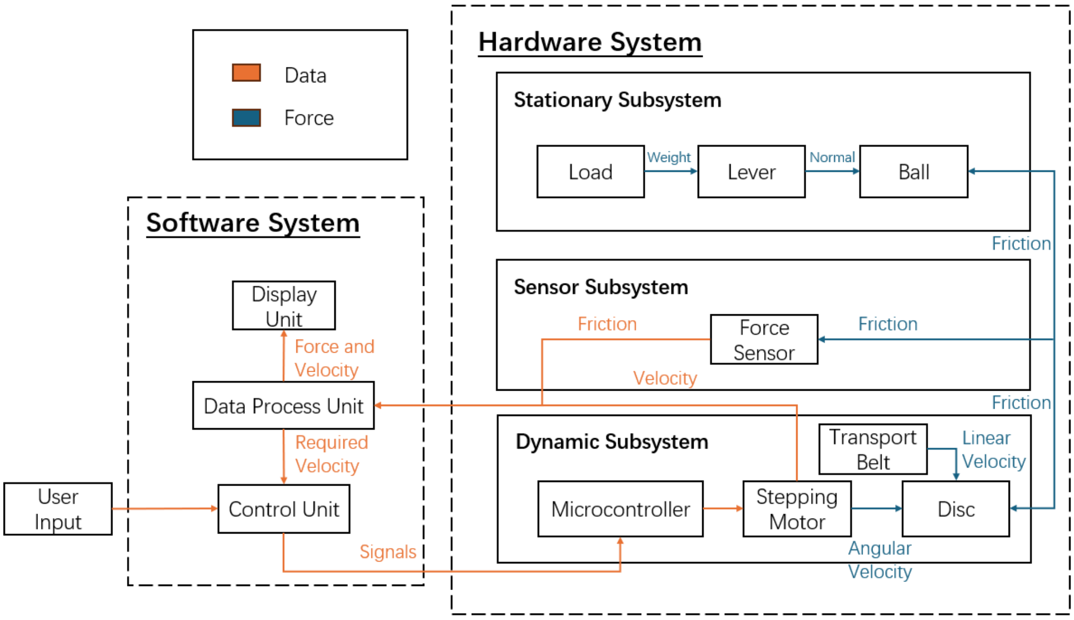

Fig 2. Block Diagram for the Project

2.2 Block Descriptions

The whole platform can be divided into two systems, hardware and software. Hardware system is where the user primarily operates on, while software system will automatically take in measurement data and control the hardware system.

2.2.1 Hardware System

It can be divided into three more subsystems:

- Stationary Subsystem: Consists of the load, lever mechanism and a stationary ball. The ball, typically made of a rigid substance, is the subject that interacts with the material to be measured. The ball's radius should be around 3 centimeters and its weight should be around 900 grams. The weight may be different based on the material used. When conducting measurements, users can set the quantity of normal force on the ball by changing the weight of load. The load's weight is changeable from 0 to 50 grams. The weight will be transported to the ball by a lever mechanism and become normal force that acts on the ball. The magnitude range of load should be from 0 to 0.5N and the ball is changeable, making it possible for measuring a wide range of materials.

- Dynamic Subsystem: Consists of a microcontroller, a motor, a transport belt and a disc. The disc is made of materials to be measured, its radius is 20 centimeters and height is around 1centimeter. When the disc is interacting with the ball, spinning the disc will produce friction. The motor is the power source that makes the disc spin, and it requires a voltage around 24V DC. Its power should be controllable so that users can control the angular speed of spinning within the range of 200 rpm. The transport belt allows users to change the position where the ball rubs against the disc. It moves the disc horizontally. The microcontroller receives signals from users through the software system and controls the power of the motor to obtain the spinning speed needed.

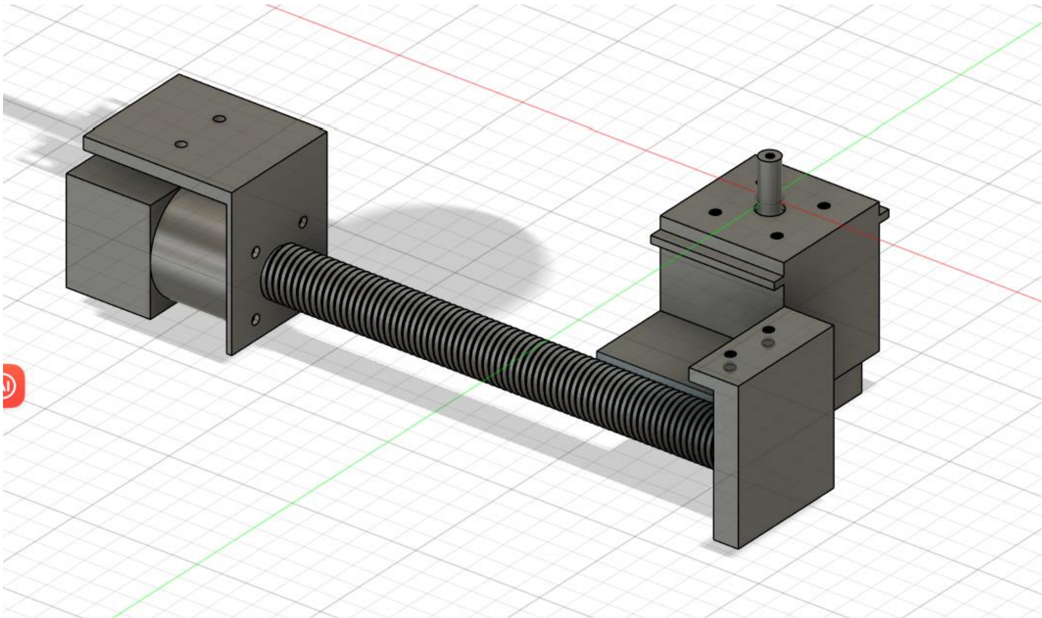

Fig 3. Model of the Transport Belt

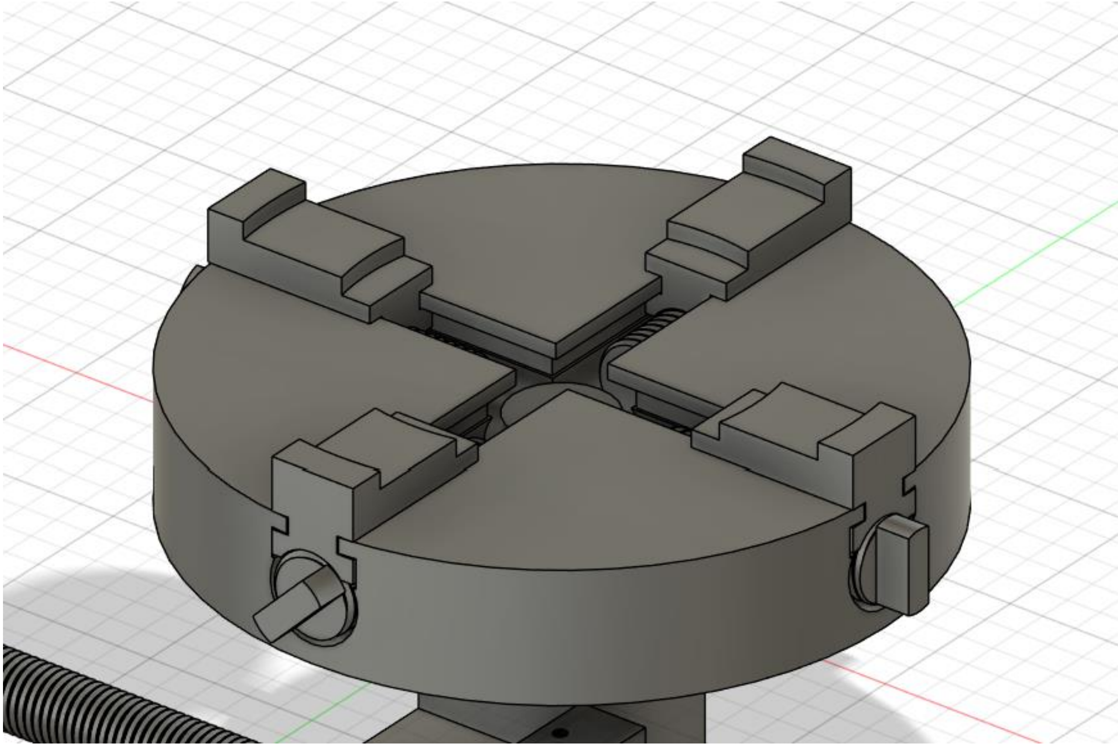

Fig 4. Model of the Disc Platform

- Sensor Subsystem: Consists of a force sensor. This subsystem is the bridge between hardware and software. It gathers data from the hardware system and sends them to the software system. Force sensor measures the friction force between the ball and the disc.

2.2.2 Software System

This system consists of three units: data process, control and display. The data process unit is the core unit that takes in data collected by sensors and processes them into the form needed by the other two units. The control unit is controllable by users, where users can set the speed they want here before starting the platform. After the platform starts working, it will receive data from data process units and automatically adjust the microcontroller in the hardware system according to the real time data and the target.

The display unit shows users real time data, such as the friction force, spinning speed of the disc and so on, ensure that users are in control of the platform's status at all times.

2.3 Requirements and Verifications

Requirements	Verification
Lever System 1. When there is no load, the lever must be balanced.	1. When choosing the weight for the ball and the balance load, make sure they satisfy the equation: $F_{ball} \times L_{ball} = F_{load} \times L_{load}$
Disk 1. The disc's weight must lie within the maximum force capacity limit of the motor.	1. When producing discs of new materials, calculate its weight by the equation: $W = \pi \times r^2 \times h \times \rho$ r is the radius of the new disc, around 10 cm, h is its thickness, and p is the density of the material.
Motor 1. The power source for the motor must be in 23V to 25V DC to make it work normally	1. Every time before starting up the motor, check the power source to see if it has been set correctly.
Transport Belt 1. The length of the belt should be longer than the max radius of the disc, which is 20cm 2. The motor that drives the belt must be able to stand the weight of all the stuff on it, approximately 30N	1. When producing the belt, set its length longer than 20cm, best length is 25cm 2. Use motor with relatively large torque, around 50Nm.

2.4 Tolerance Analysis

The dynamic subsystem must be the one that poses a risk to the success of our project. The first problem is that the sample material on the disc must be changeable because it's the material to be tested, which makes its volume and weight variable. However, the motor that spins it cannot be changed easily. Thus, if the user puts some heavy samples on the disc, the motor may not be able to make it move because it cannot provide enough torque. Another problem is related to the transport belt. We use it to make the motor and disc move horizontally, but we cannot stick them on the belt. Therefore, if the force from the belt is too heavy, those things won't be stable and they will fall, causing damage. Also, since the belt is driven by a motor, the problem mentioned before works on this part as well.

Here is the equation for how to compute the force provided by the motors:

$$F = T \times l$$

T is the torque provided by the motor and l is the length of the arm of force. From this formula, we could know that if we can change the length of the force, we don't have to worry about the magnitude of the force even if the torque of motor is fixed.

3 Cost and Schedule

3.1 Cost Analysis

- Labor Fee: After careful discussion in our project group, we decided that every of us works for the project voluntarily. No one poses a request for a salary. Thus, we can save some budget for buying equipment, materials and all the other stuff we need to complete the project.

- Parts Fee:

Name	Material	Labor Time	#	Cost / ¥
Screw Stick	PLA	4 days	1	30
Pulley Bracket	PLA	4 days	2	60
Support Frame	PLA	4 days	1	39
Chassis	PLA	4 days	1	518
Lever	PLA	4 days	2	60
Motor	/	/	1	298
Motor Driver	/	/	1	269
Total Cost				1,274

3.2 Schedule

In April's third week, we will buy and produce all the parts we need and try to complete the upper part of our platform, which includes the lever, the ball, loads and the force sensor. We will learn how to control the force sensor through connecting it to a PC. In April's fourth week, we'll complete the lower part, which includes the disc, motor and the transport belt. Also, we will learn how to use the motor and write driver for them. Next week, we'll test our protype, fix it if there's any bug and improve its stability. In the team, the student from Mechanical Engineering major is responsible for modeling of all components and producing some of them in the laboratory. The students from Electrical Engineering major are responsible for the design and development of the PCB board to control the motors and making the motors work properly. The Electrical and Computer Engineering student writes all codes needed by the software system.

4 Ethics and Safety

4.1 Ethics

If our platform causes harm to anyone, we will compensate and apologize accordingly. Our platform may need to collect data from users to see what weights, speeds, and materials they generally use to improve the platform. In addition to this, we will never cause any privacy breach of our users. Our platform also won’t have any problems with fairness and discrimination.

4.2 Safety

We believe our platform has very few security risks. The loads’ weight of our platform is too small to cause any damage to the user. The spinning speed is also too slow to hurt the user. The voltage needed for the electrical components is too low to cause any substantial harm. We could add some warning marks on the display unit or on the platform to tell users how to operate the platform properly.

References

[1] Muralidharan, K., et al. "Comprehensive Overview of Nano, Micro, and Macro Tribometers in Practice." Journal of Bio- and Tribo-Corrosion, vol. 10, no. 3, May 2024, https://doi.org/10.1007/s40735-024-00849-x.

[2] Mahmud, Dayang nor Fatin, et al. "Influence of Contact Pressure and Sliding Speed Dependence on the Tribological Characteristics of an Activated Carbon-epoxy Composite Derived From Palm Kernel Under Dry Sliding Conditions." Friction, vol. 7, no. 3, May 2018, pp. 227–36. https://doi.org/10.1007/s40544-018-0205-y.