

Career Episode 3

Wear Testing Machine

Introduction

CE 3.1.1

I performed this project as part of my academic requirement for completing the degree of Bachelor of Engineering Technology. This project was the final year project of my degree. It began in [REDACTED] and came to an [REDACTED]

Background

CE 3.2.1

I understood from basic science that all surfaces, although how smooth they might look, are rough on a microscopic level and when two surfaces slide past each other, friction caused by intersection of these surfaces is overcome by applied forces, due to which, plastic deformation is caused between the intersecting parts of these surfaces causing material removal. This is called wear. I knew that as wear removes material from a surface and causes deterioration to the material properties, therefore, it is not desirable, and different efforts are made to minimize it. As the students undertaking this project would be the designers of mechanical equipment very soon, I was fully aware that as per the industrial requirement we had to understand the concept of wear to develop reliable machines. Therefore, I was very much invested into this project.

CE 3.2.2

I knew industries are made of machines which have complex moving parts and that wear is the principal reason of failure of most mechanical moving components, causing a loss of 1-4% of gross national product of developed nations which is in hundreds of billions of dollars. Therefore, as a student of mechanical engineering, the study of wear is very important as wear plays an important role in determining the life of any engineering component. Having a good grasp in wear study can be very promising for engineering career. I understood that there are different tools and methods available to measure wear including machinery testing as well as finite element analysis. Through this project I got the opportunity to study wear and the relevant tools in depth and was able to draw comparison between the tools.

CE 3.2.3

I understood that wear is a key performance indicator (KPI) in designing any machinery as it is accounted for calculating machine life. However, I knew estimating wear is quite complex since there are lot of factors affecting it at the same time. There can be surface defects due to metallurgical reasons, the impact area can be at high temperature leading to deterioration of material properties, chemical reactions etc. I understood that a wear testing machine (pin or disc machine) is very helpful for measuring a wear. As this machine is expensive, it is not often used. In this project, I decided to build the foundation of designing a simplified wear measuring device by evaluating the key performance factors, which I knew would be helpful for engineers to build their own wear testing machine and to get a better understanding of the performance and limitations of the existing one.

CE 3.3.4

We worked for this project in a team of 3 students, and I was the leader of this team.

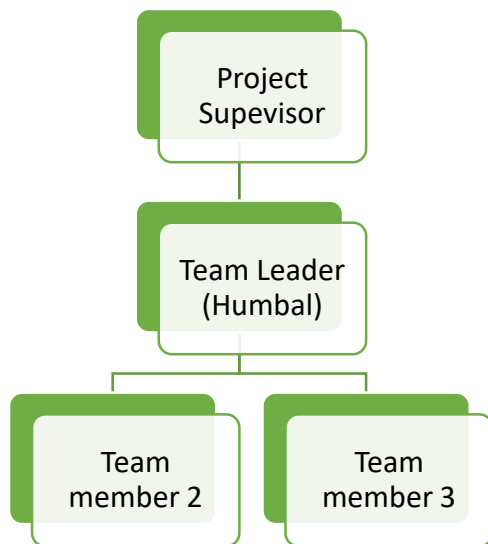


Figure 1: Project Reporting

Personal Engineering Activity

CE 3.3.1

In order to measure wear, I understood that physical testing is performed using a wear measurement apparatus, some of which is pin on disc and ball on flat test.



Figure 2: (a) WSP-polyester composite specimens prepared for sliding wear test (b) Pin-on-Disc machine

I calculated the wear rate by measuring the mass, length and volume at the start and end of the experiment. By measuring these dimensions, I worked out the material loss or wear produced. I knew wear rate is described by Reye-Archard-Khrushchov wear law also known as Archard's wear law. I understood that as per Archard law, wear volume is directly proportional to applied load and sliding distance and is inversely proportional to the hardness of the material. I used the below equation to calculate the wear.

$$Q = \frac{KPL}{H}$$

where K is dimensionless proportionality constant, P is the applied normal load (N), L is the sliding distance (m) and H is material hardness (MPa). Having understood the conceptual difference between the wear rate (measured in m^3/m) and specific wear rate (measured in m^3/Nm), I calculated both in order to not only consider the amount of material loss but to know the effect of loading as well.

CE 3.3.2

I also undertook the challenge of calculating wear through the Finite Element Method. I understood that FEM utilizes computational power to solve complex engineering problems. I addressed the problem by dividing the body into small elements onto which I applied boundary conditions including forces applied, supports etc. I knew that the technique of FEM lied in the development of appropriate models which can solve for the equations. I used ANSYS to perform Finite Element Analysis after simulating the actual conditions in the software. My main objective of performing FEM through software was to identify how precise it would be. I knew that there are so many factors and processes involved that it would not be possible to make an accurate model of wear. Also, due to high complexity of the problem, it would require high computational power also. I realized that due to this, FEM can help in providing additional data like stress generated which is not possible in physical apparatus.

CE 3.3.3

In order to analyze the wear problem through FEM on ANSYS, I first made a 3D geometry, which had two components: one was a circular disc and other was a pin. It was a disc with the hole at the center. I knew actual discs are not like it, but I did it this way because it simplified the model. The material inside did not have a role, so I removed to simplify the model.

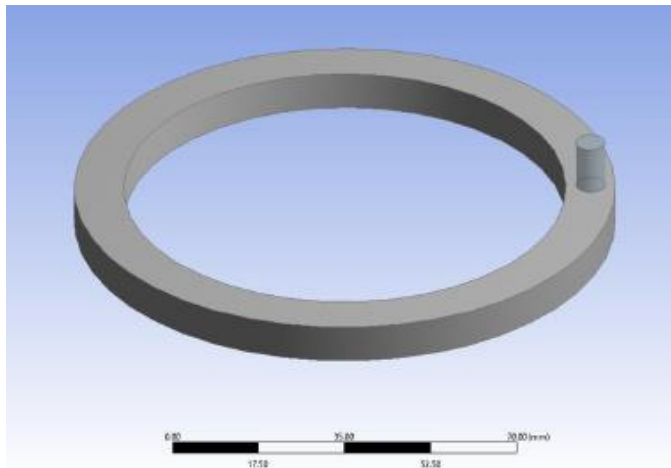


Figure 3: Pin Disc Assembly

After modelling, I made contact between the pin and disc and defined the properties for them. For the pin on disc wear machine, I had a frictional contact, as shown in the below image. It was be similar for the case of pin as well.

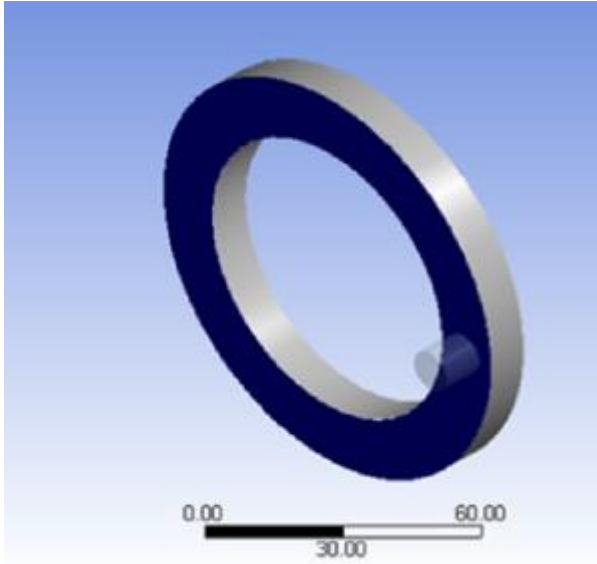


Figure 4: Contact between pin and disc

CE 3.3.4

After the 3D model and contacts, I meshed the model. I knew the size of elements, aspect ratio and many other mesh parameters play an important role. If the meshing is not right, I knew the results would not be accurate. After the problem was solved, I converged the mesh i.e. increased the number of elements to check if the results are accurate, which was the convergence test. After the meshing was done, I applied the boundary conditions. The boundary conditions included support and loadings. In our case, the disc was rotating and there was normal force on the pin. The final step was solving the simulation for the required results. I post processed the results for further information. I was fully aware of the limitations of the FEM as it is highly simplified sometimes and may neglect key areas. I knew that we can still obtain useful data like stresses and temperature which can give us a better understanding of the wear.

CE 3.3.5

I was the team leader so I was responsible for managing how the project would flow. Having understood that in order to make any project or product, a systematic approach needs to be followed, I followed the steps as outlined below:

1. Identify the problem
2. Research problem
3. Develop solution(s)
4. Select best solution(s)
5. Construct prototype
6. Evaluate solution(s)
7. Communicate the solution(s)
8. Redesign

After successfully identifying the problem, I moved towards searching the solutions. After shortlisting the solutions, I developed a solution which would satisfy the problem. After it, I tested and when

everything was found to be right, I proceeded towards delivering the solution. Otherwise, I made some necessary changes. I understood that there is a possibility that a new problem comes which was not detected before and changes or improvements need to be done. After it, I knew that the cycle would continue.

CE 3.3.6

In order to design a pin on disc machine, I preferred that I first saw the already available designs. I knew the simple operation of pin on disc machine is a rotating disc on which a pin is held and a force is applied onto the pin. There are also some lathe type pin on disc wear machines, in which the pin is placed in the place of a tool with the rotating workpiece. Each design has its own advantages and disadvantages which includes type of testing, loading, design and cost. While some designs use a direct motor beneath the disc rotator, this design simplifies the drive assembly which includes pulleys and belts. These components require frequent maintenance. The disadvantages of such a design and direct drive from the motor is that there is not any safety for the motor. If motor stuck, it would break the motor shaft or any other expensive component. In the first case, the belt would slip. The selection of which system to use depends upon designer and what are the requirements for the pin on disc machine.

CE 3.3.7

Similarly, I conducted research into the designs for load application on pin also. I understood that the column supports the beam. The purpose of the beam is to support the pin and the loading applied on it. When loading is applied on the pin, a part it is also transferred to the column. The reason of that it is like a fixed beam which is supported by pin on one side and column on other side. When a load is applied on the pin, it is done through the beam. Therefore, the configuration has to be made such that it is transferred to the pin. Therefore, different approaches are used. Some of these are simple to design and some are complex. It uses a lever mechanism with pulley drives. Some pin on disc machines also uses a lever arm and it also uses a counterweight to balance it. We can do the arrangement to measure the frictional force with the help of a load cell. However, I decided that we would simplify the assembly and use a simple mechanism so that the objective of keeping the cost minimal is met.

CE 3.3.8

Considering all the designs and requirements, I shortlisted a number of design features. Firstly, I decided to direct drive from motor to disc to remove the pulley and to reduce the components. I assumed that this machine would not be used for too much heaving testing. For that, I preferred a pulley with belt drive system as it has inherent safety for motor shaft. Secondly, a simple design for the application of load which does not involve any complex lever or pulleys with it, therefore, I decided to design it such that the load is directly placed above the pin. Moreover, an easy to use vertical and horizontal adjustment, so that the pin can easily be adjusted as well as track can also be set according to the requirement. For vertical displacement, I decided to use a slider mechanism which can be adjusted. For horizontal adjustment, I made a lead screw mechanism with the help of which the radius can easily be set. For the holding of disc, I designed a disc holder to which disc can be attached using screws or some other locking mechanism. Furthermore, I designed an easy-to-use pin locking system. It had internal threads to which any threaded pin can easily be tightened.

CE 3.3.9

I made the CAD model using Fusion 360 software. It had all the features I have discussed in CE 3.3.8 and was a simplified version of pin of disc machine with all the necessary features. Notably, I made a tangible design but did not optimize it yet since as a first step, the motivation was to design a machine with all the necessary requirements. Optimization of the components would come next. The computation of stressed and performing FEM on it would be the next logical steps.

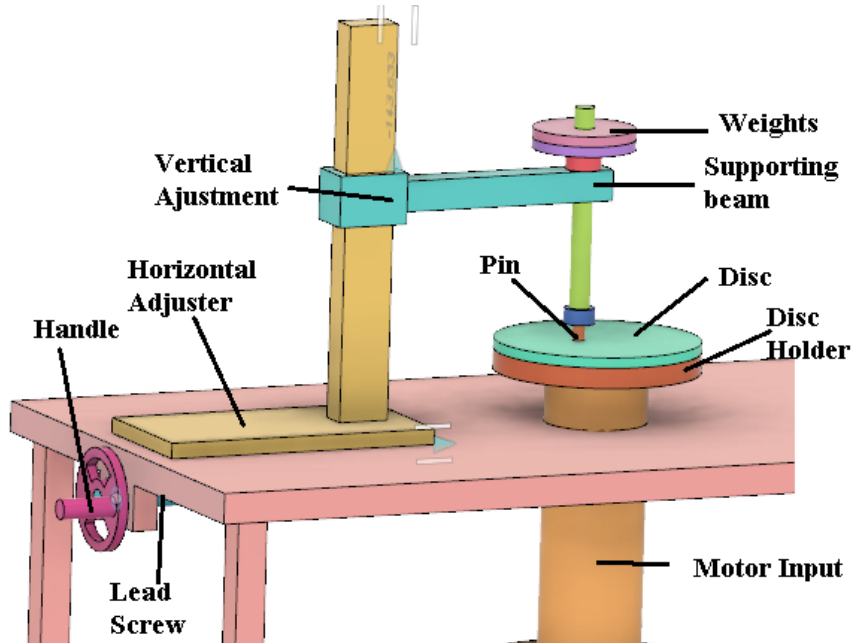


Figure 5: CAD model prepared with Fusion 360

CE 3.3.10

For this project, I was able to perform an in-depth literature review including the history of wear study, different wear types and mechanisms through which wear happens. I did design analysis of pin on disc wear machine after evaluating different design approaches and their advantages. I then designed a pin of disc machine which tries to get best features of all designs. I researched on the use of FEM for the use in wear and studied its advantages, limitation and proposed methodology. Moreover, I did the FEM and got some helpful output from it, albeit limited.

Summary

CE 3.4.1

As the leader of this project, I considered it my responsibility to take the team along in each step of the project. I coordinated with the Supervisor about the project progress over formal emails, and communicated the updates to my team members in a regular team meeting. From this project, I was significantly hone my management skills as well as my communication skills. Moreover, the technical learning from the project was immense and something that I believe would be very significant during my professional career. I fully understand that the technical expertise I have gained in this project is very

much valued in the machine design industry and I might have set my career pathway by working on this project.