The Validation and Displacement Analysis of a Flexure-Based Drilling Dynamometer.

Cormac Moloney

TUS Midlands Midwest

TUS Technological University of the Shannon: Midlands Midwest
Ollscoil Teicneolaíochta na Sionainne: Lár Tíre Iarthar Láir

Aim of the Project

The aim of this project is to validate the stiffness of a flexure-based drilling dynamometer and analyse its displacement response to applied torque and thrust forces

Objectives

- Validate the stiffness of a flexure-based Drilling Dynamometer using Finite Element Analysis In Ansys Workbench
- Calculate the torque and thrust forces the dynamometer will experience during the drilling process.
- Analyse the displacement response of the dynamometer by applying the calculated forces in Ansys simulation

Background

A drilling dynamometer is a technology used to measure the forces exerted on a workpiece during a drilling operation. Drilling dynamometers primarily operate on the principle of measuring the elastic deformation that occurs during the drilling process. As the drilling process generates torque and thrust forces, the dynamometer undergoes slight deformation. This deformation is measured using a sensor technology, in this case, a Hall effect sensor, to precisely measure the force-induced displacement.

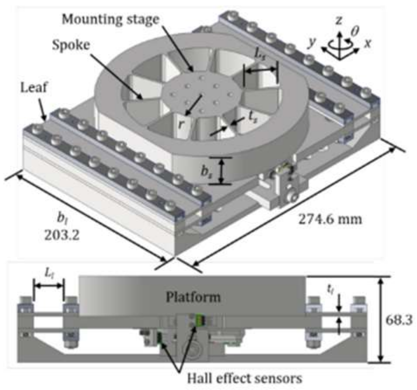

Figure 1 : Drill Dynamometer with hall effect sensor

A hall effect sensor works by detecting magnetic fields to measure position, speed, or electrical current. When a current flows through the sensor, a small magnetic field is created. If an external magnetic field is applied near the sensor, is disrupts the flows of electrons. The disturbance creates a small voltage known as the Hall voltage

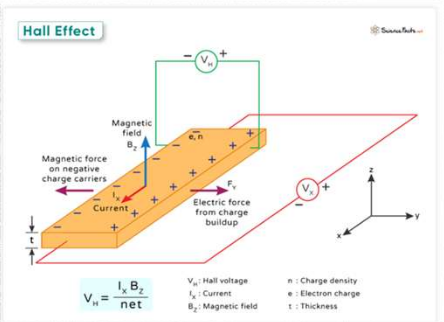

Figure 2 : Hall effect sensor principal

A flexure-based structure allows for slight deformation and bending when loads are applied. When a force is applied, the flexure material deforms due to the elastic properties of the material. The deformation that occurs is purely elastic, so the dynamometer returns to its original shape when the forces are removed. The deformation can be measured accurately, which allows for the detection of forces such as torque and thrust.

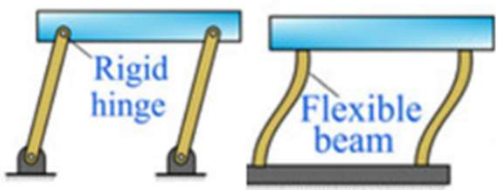

Figure 3 ; rigid design vs Flexible design

Methodology

The first step to this project was calculating the necessary forces that will be applied during the drill process using Excel and the Kennametal force calculator by determining key parameters such as cutting speeds, feed rates, depth of cut, and the material being drilled

Paper Material	Kennmetal Material	Drill Diameter (mn	Hole Depth (mm	Feed (mm/rev)	Cutting speed(m/min)	Torque(Nm)	Thrust (N)
Aluminium Alloy 6060 T6	Automotive aluminium, Si<12% (75HBN)	8	12	0.16	90	0.953	164
Aluminium Alloy 6060 T6	Automotive aluminium, Si<12% (75HBN)	8	12	0.20	90	1.128	173
Aluminium Alloy 6060 T6	Automotive aluminium, Si<12% (75HBN)	8	12	0.24	90	1.295	181
Aluminium Alloy 6060 T6	Automotive aluminium, Si<12% (75HBN)	12	18	0.24	90	2.914	271
Aluminium Alloy 6060 T6	Automotive aluminium, Si<12% (75HBN)	12	18	0.32	90	3.622	290
Stainless Steel 14301	Stainless Steel Aust/Fer(130.000PSI / 260 HBN)	8	12	0.09	40	0.617	144
Stainless Steel 14301	Stainless Steel Aust/Fer(130.000PSI / 260 HBN)	8	12	0.12	40	0.767	154
Stainless Steel 14301	Stainless Steel Aust/Fer(130.000PSI / 260 HBN)	12	12	0.12	40	1.725	231
Stainless Steel 14301	Stainless Steel Aust/Fer(130.000PSI / 260 HBN)	12	12	0.16	40	2.144	247

Figure 4. Force Calculations

A SolidWorks model of the drill dynamometer was then imported into the simulation software Ansys, and the necessary material Aluminium 6061 T6 was applied to the model. The prescribed loads from Figure 4 were applied to the model to simulate the deformation of the dynamometer under drilling forces . The results of the deformation were then compared to the effective sensing range of the hall effect sensor to evaluate the suitability of the hall sensor for measuring displacement across different-sized bits, feed and cutting speed rates. The results were then compared to the Ross Zameroisk paper findings for the displacement due to the force applied.

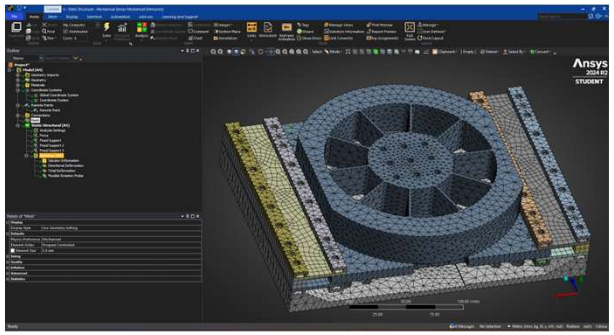

Figure 3 ; rigid design vs Flexible design

Results / Analysis / Findings

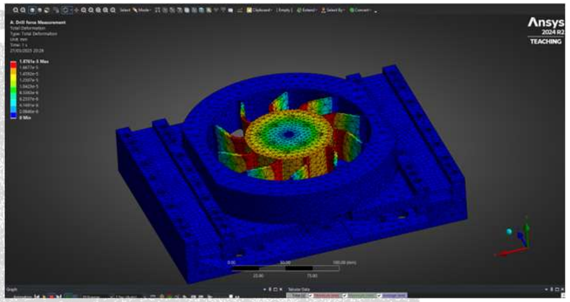

Figure 3 ; rigid design vs Flexible design

From the simulation conducted on Ansys based on figure 5 with a torque force of 2.144 Nm the drill dynamometer will experience a maximum deformation of 18..7 µm when a 12 mm drill bit is used for a drilling operation at a feed rate of 0.16 mm/rev and a cutting speed of 40m/min. The Hall Effect sensor is capable of sensing up to 250 µm. This is well within the range of the hall effect sensor range and will ensure accurate measurement. Based on the simulation carried out, a 25 mm drill bit producing a torque force od 166.6 Nm will be to large for the hall effect sensor to accurately measure.

Conclusion

The FEA analysis of the drill dynamometer confirmed the stiffness calculation present in the Zameroisk paper, with only a 10 % difference observed in the simulation. This discrepancy may be attributed to constraints applied during the simulation and rounding during the calculation process. The simulation revealed that a 25 mm drill bit would generate too large a displacement for the hall effect sensor to measure

Acknowledgments

-Thanks to my project supervisor, Ciaran O' Loughlin, my lecturers, Lisa Henihan and Daniela Butan