AUTOMATION OF MANUAL REGRINDING OF CARBIDE TIPS OF GUNDRILLS

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TABLE OF CONTENTS

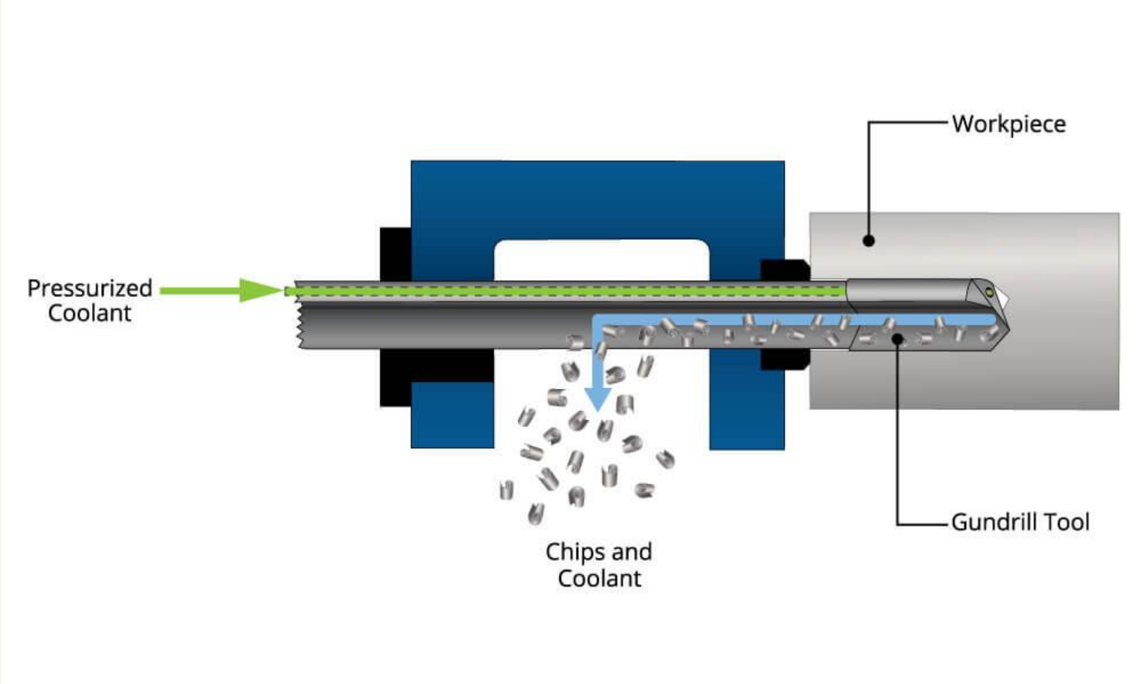
TABLE OF CONTENTS

TABLE OF CONTENTS

HALLIBURTON

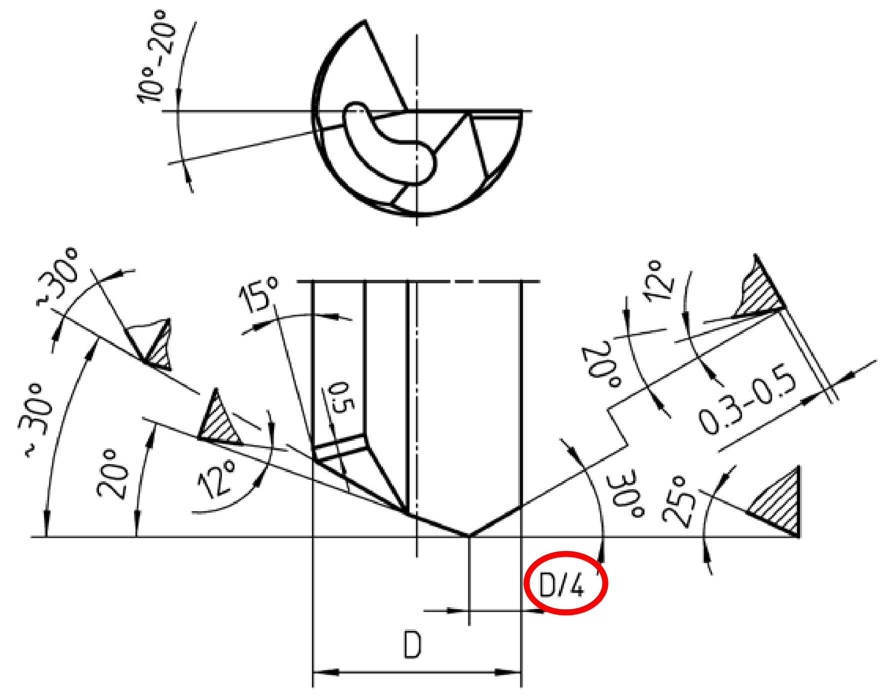
- One of largest energy product and services provider
- Provide services such as managing geological data, locating hydrocarbons, drill, and formation evaluation, and optimizing production throughout the life of asset
- Completion Technology and Manufacturing Centre (2013)

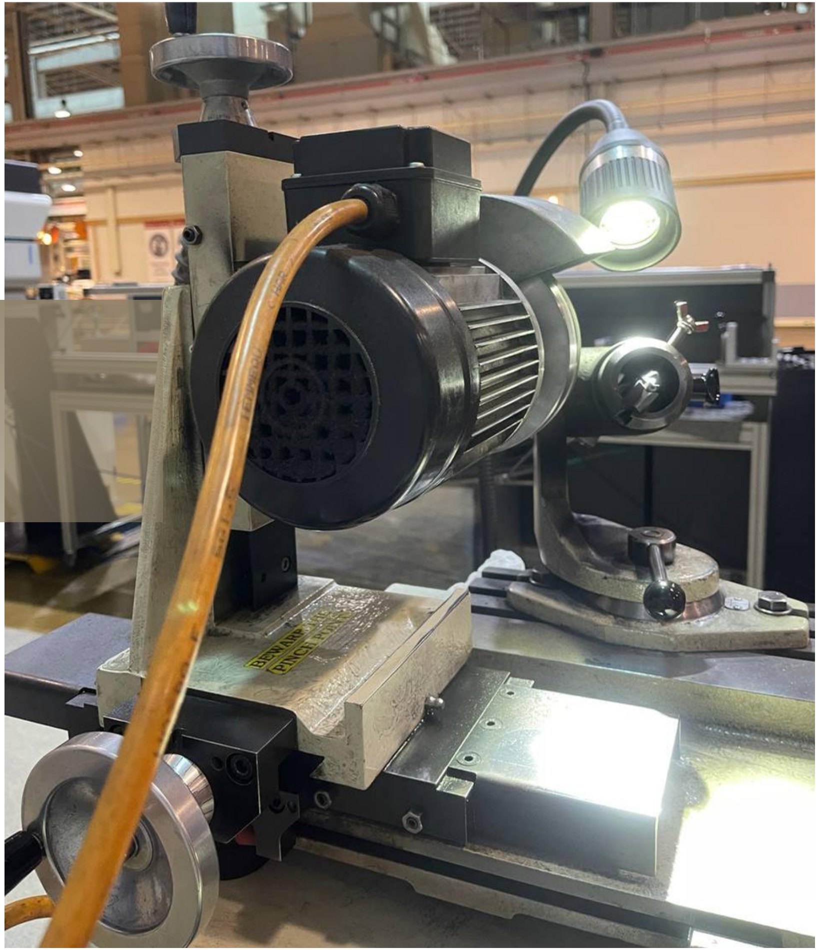
GUNDRILLING



GRINDING

GRINDING

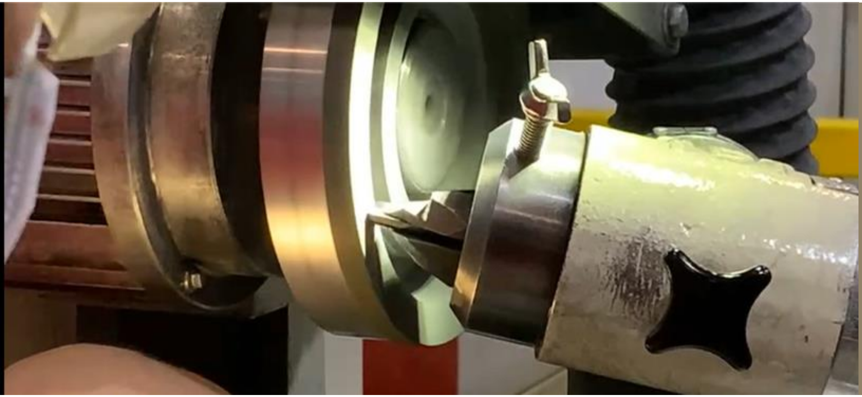




PROBLEM STATEMENT

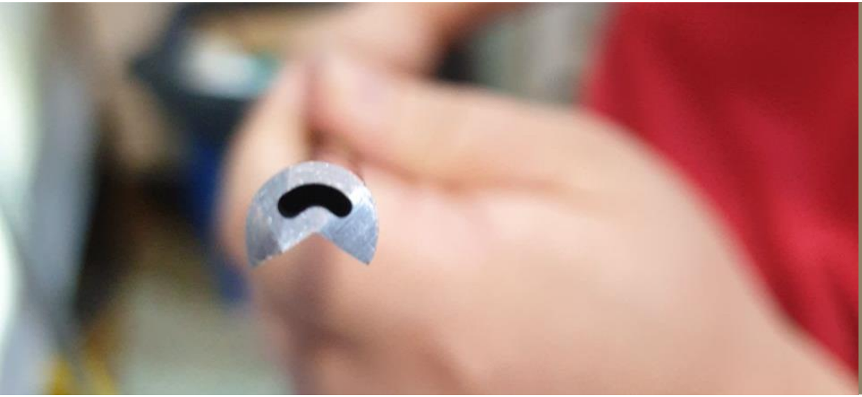
With automation, the current practice of manual regrinding of carbide tips for gun drills can be further improved in terms of safety, dimensional accuracy and process efficiency.

PROBLEM STATEMENT



SAFETY CONCERNS

Carbide particles released during the regrinding process are detrimental to health. Technicians might also hurt themselves in the process of regrinding, if they are not careful.



ACCURACY OF DIMENSIONS

The dimensions of the taper (¼ diameter) are estimated using the vernier caliper and micrometer screw gauge. Human error could affect accuracy.

PROBLEM STATEMENT

EFFICIENCY

The regrinding process ranges from 10-15 minutes, depending on experience levels. Automation enables the duration of the regrinding process to be consistent and more efficient, hence reducing human resources and costs.

TIMELINE

WEEK 0
Design & Order Components & Demo at Hiwin

WEEK 1
Design & Review Components

WEEK 2
Risk Assessment

WEEK 3
Fabrication of Spindle at NUS & Receive Ordered Components

WEEK 4-5
Receive Ordered Components

TIMELINE

WEEK 6-RECESS
Receive Fabricated Components

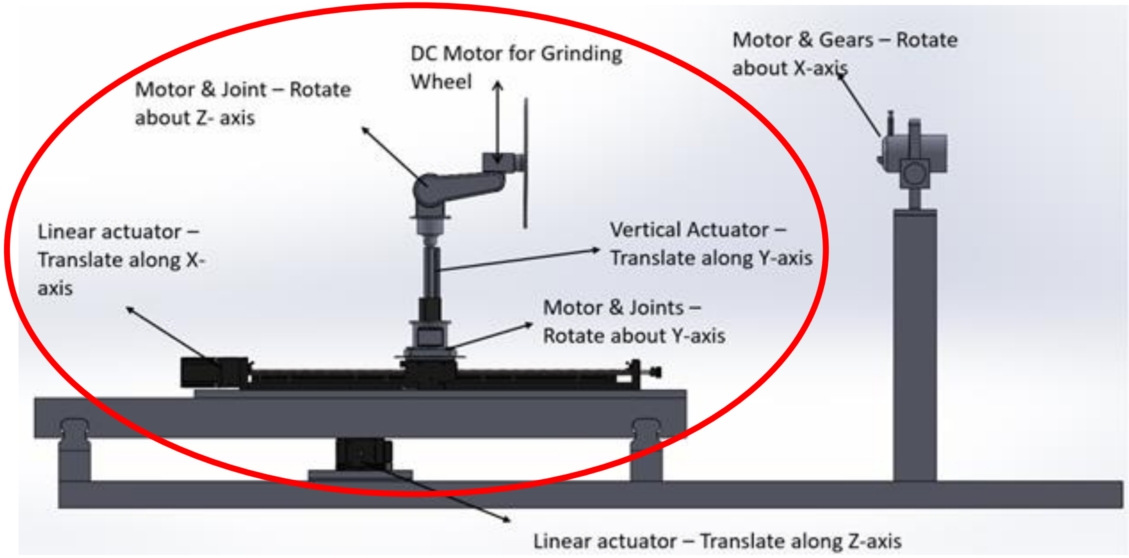
WEEK 7
Programming

WEEK 8
Perform Testing & Troubleshooting (ARC Lab)

WEEK 9-10
Troubleshooting (ARC Lab)

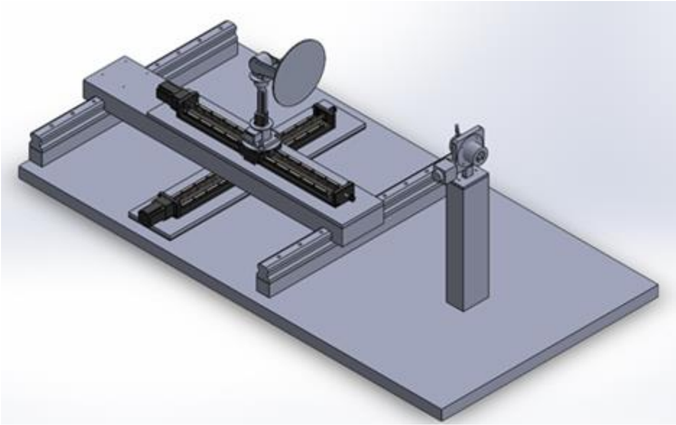
WEEK 11-13
Preparation of Final Slides, Report & Presentation

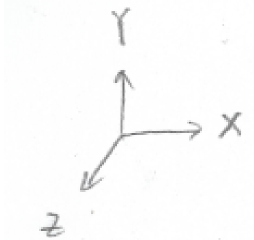
FINAL DESIGN



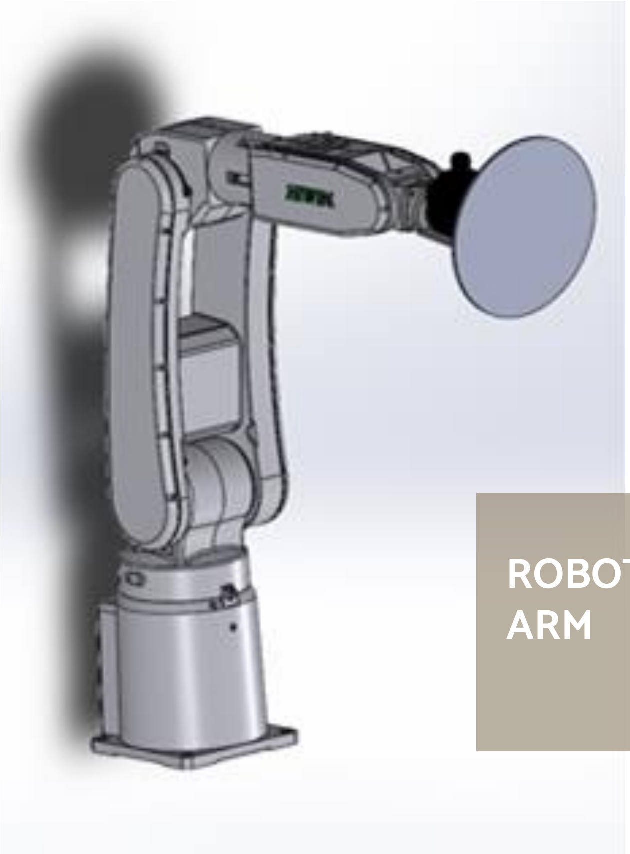
Assembly View

Isometric View



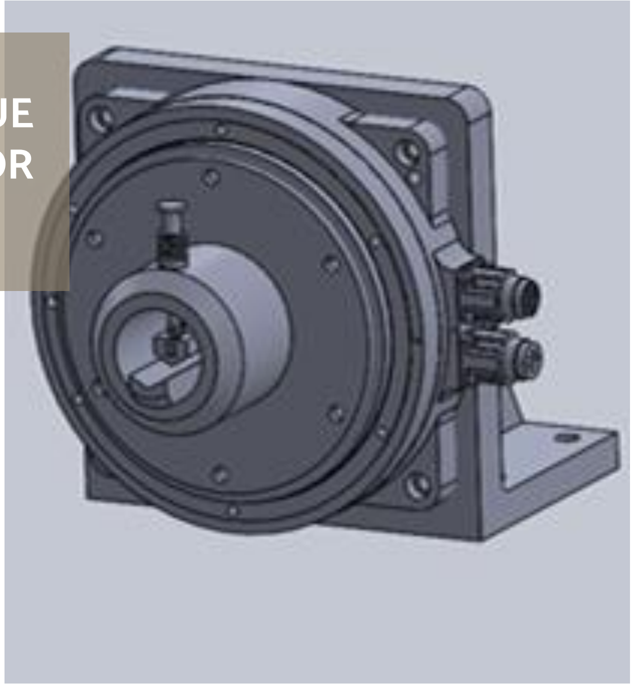


REVISED FINAL DESIGN



ROBOTIC ARM

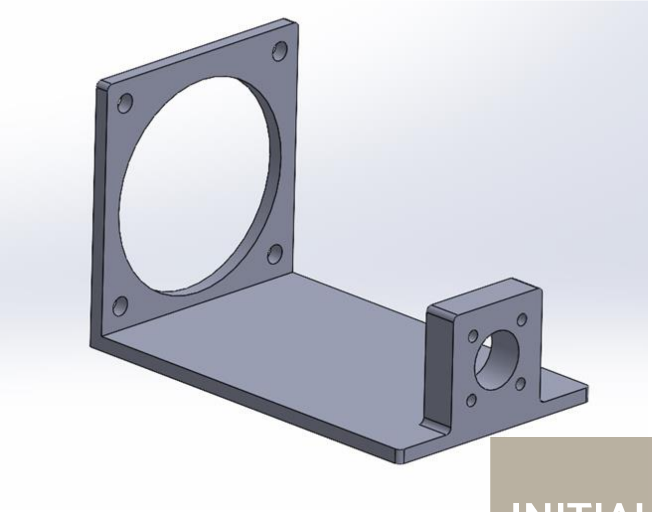
TORQUE MOTOR



DESIGN OF COMPONENTS

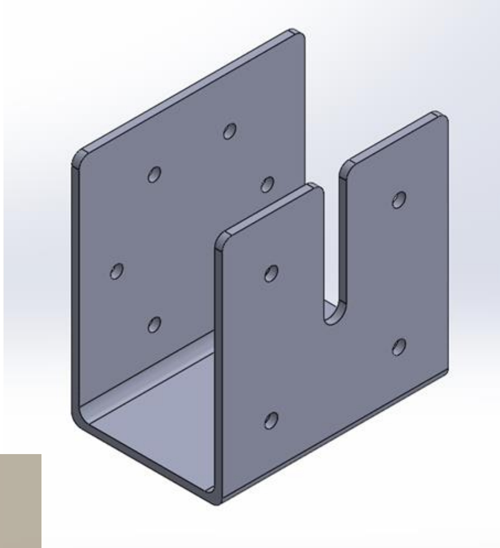
MOTOR BRACKET	- Initial Design + 2 Iterations
GUNDRILL CLAMP	- Initial Design + 1 Iteration
SPINDLE	- Initial Design + 1 Iteration

MOTOR BRACKET

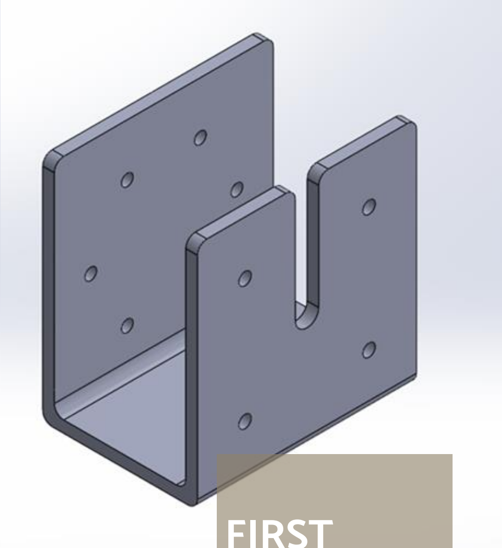


INITIAL DESIGN

5mm thickness



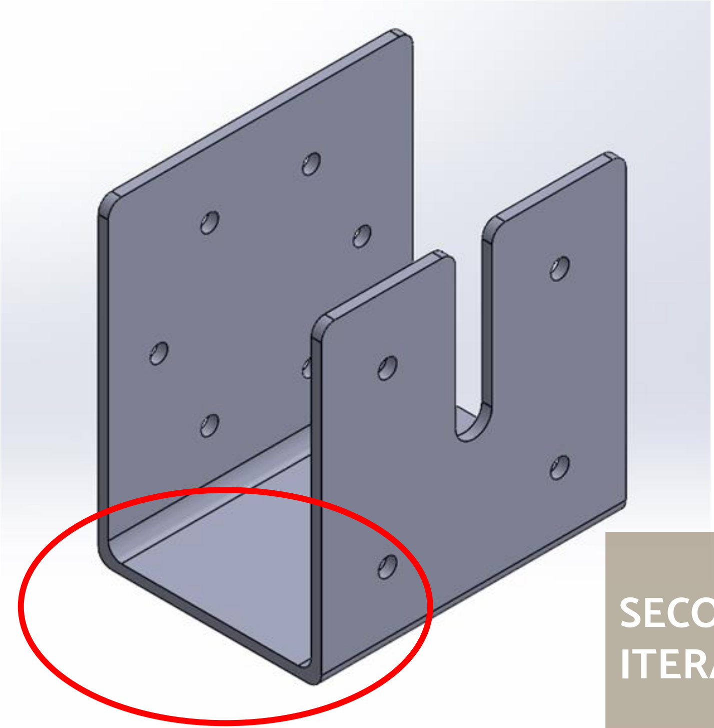
8mm thickness



FIRST ITERATION

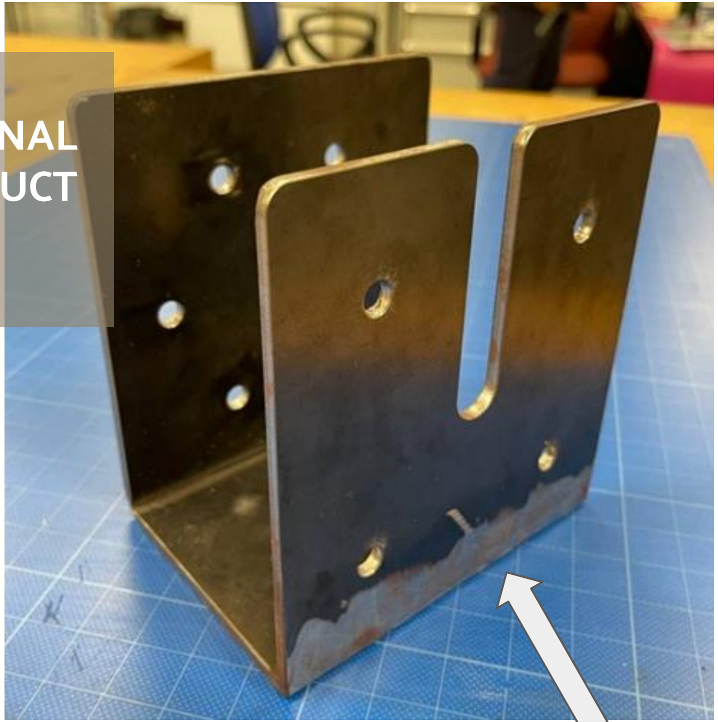
MOTOR BRACKET

5mm thickness



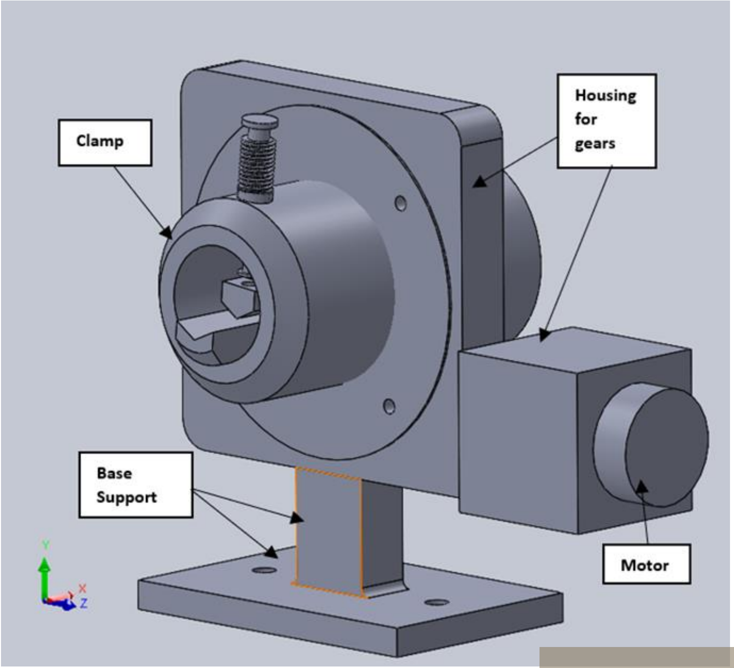
SECOND ITERATION

FINAL PRODUCT



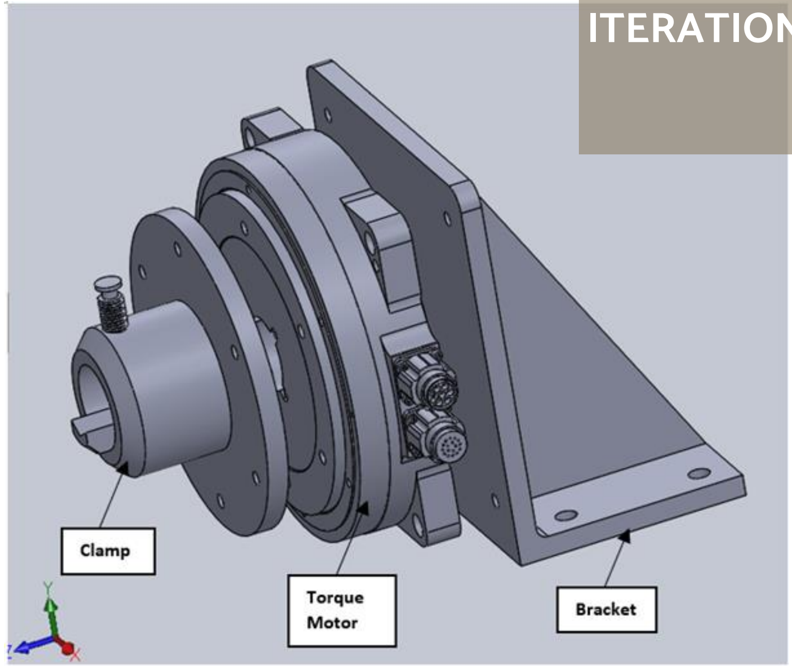
Welded Joint

GUNDRILL CLAMP



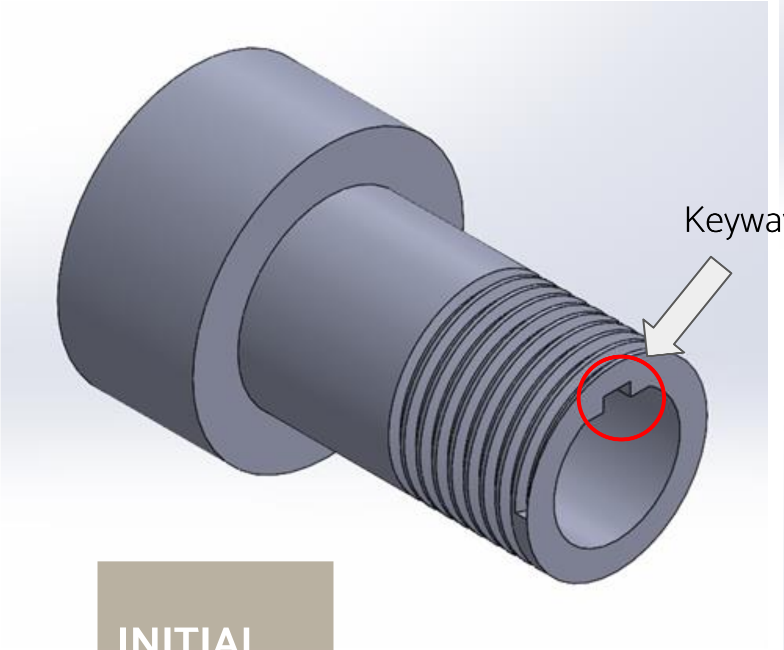
INITIAL DESIGN

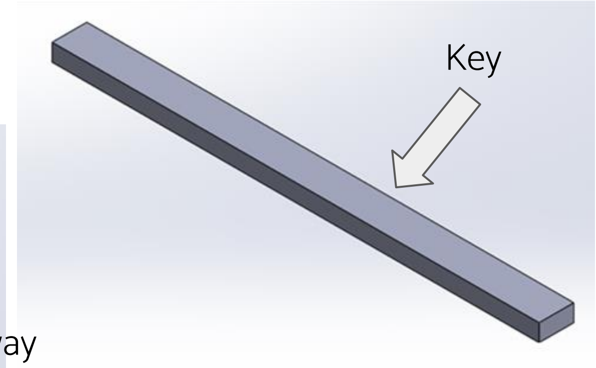
FIRST ITERATION

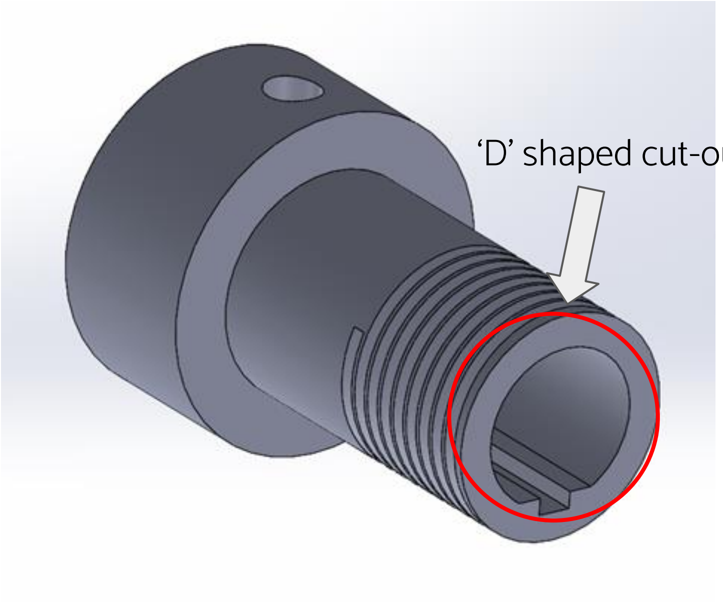


SPINDLE

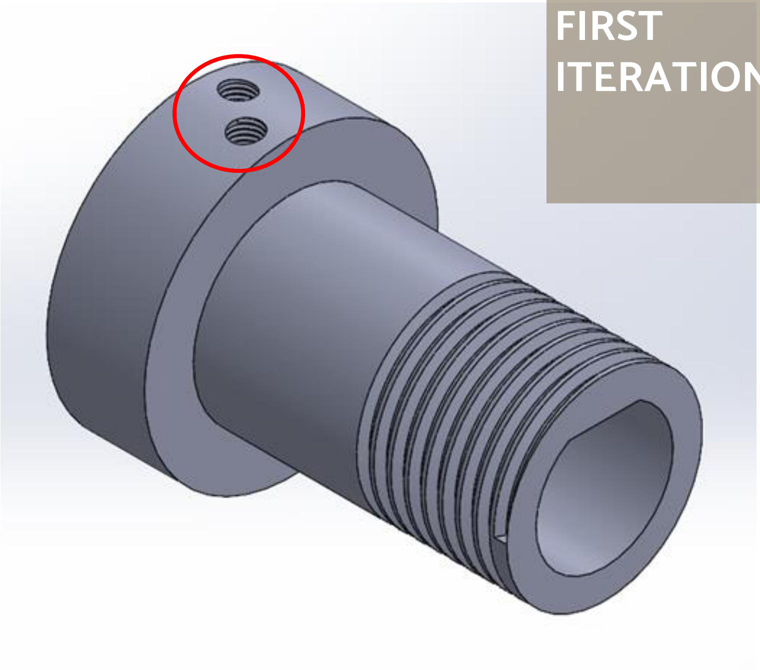
INITIAL DESIGN







SPINDLE



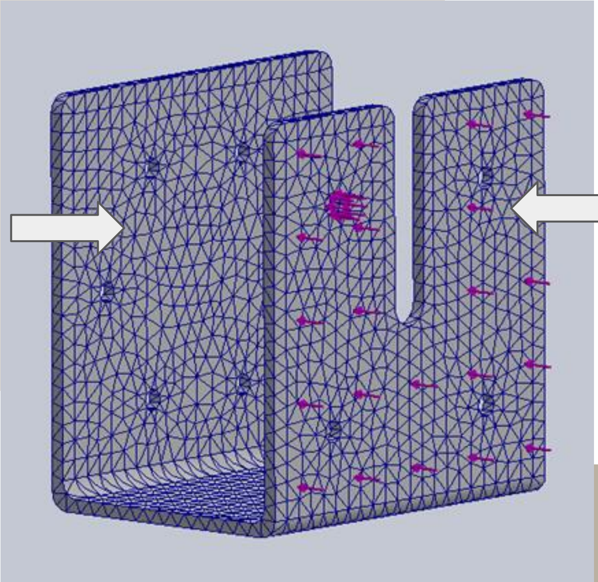
FIRST ITERATION

FINAL PRODUCT

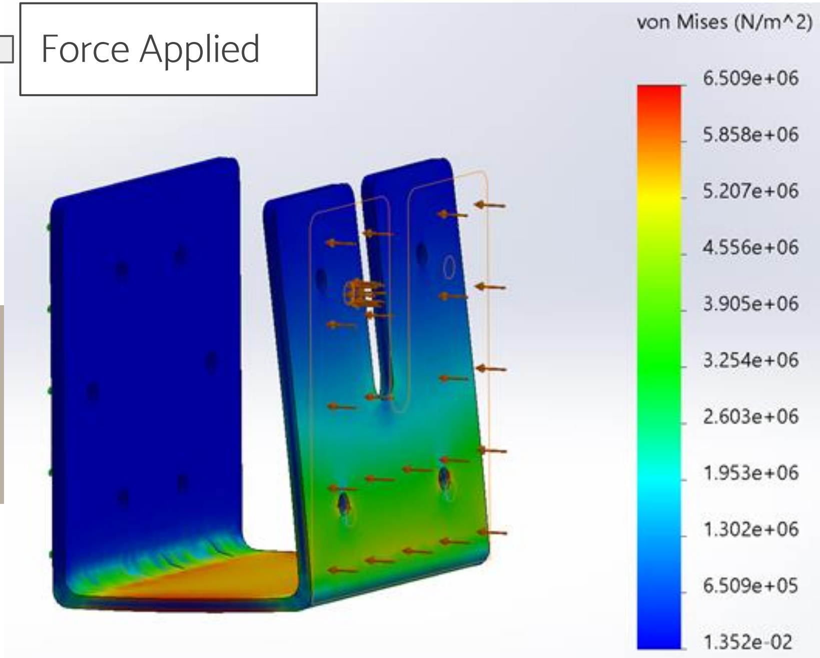
MOTOR BRACKET

SIMULATION

Fixed Geometry



Force Applied

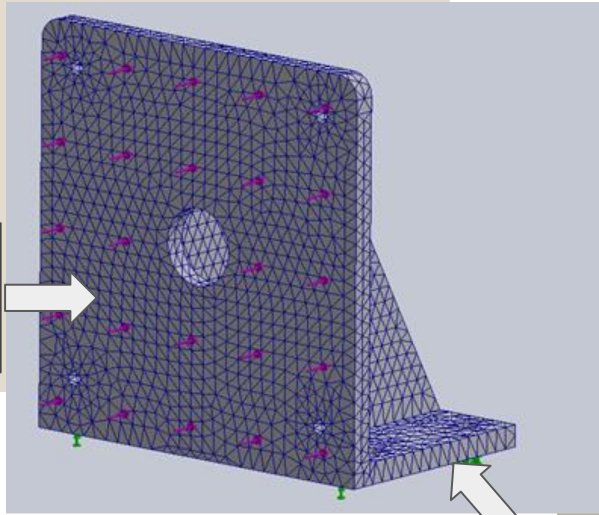


Yield Strength of Mild Steel = 250e+06 N/m^2

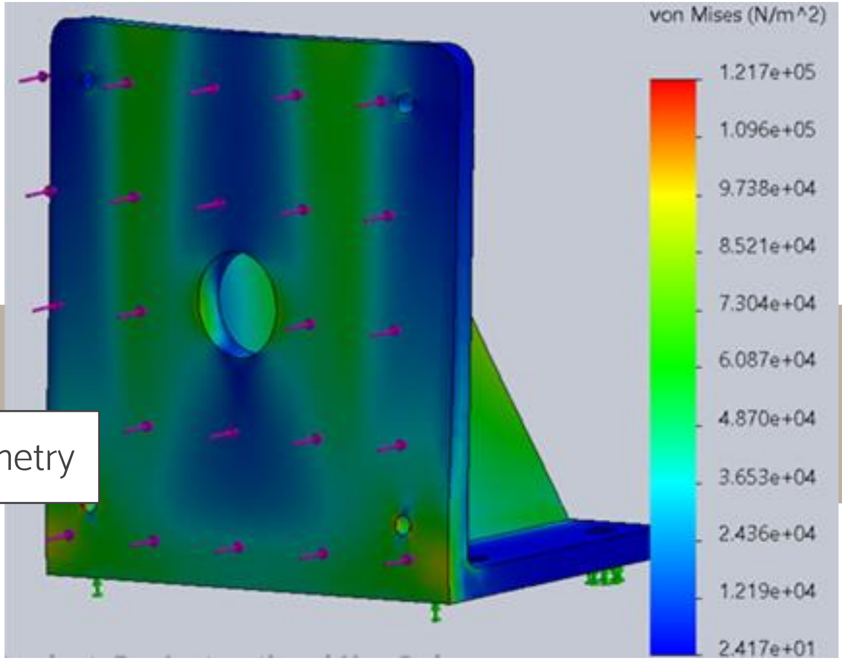
L-BRACKET

SIMULATION

Force Applied



Fixed Geometry



Yield Strength of Mild Steel = 250e+06 N/m^2

TESTING BOM

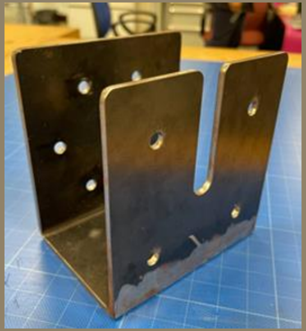
BLV640NA-3

Supplier: Oriental Motor
Quotation: $802.50
Lead time: 6 Weeks

48V DC Power Supply

Supplier: Kaichin Computer Systems Pte Ltd
Quotation: $433.33
Lead time: -

Motor Bracket



Supplier: Fujitson
Quotation: $95
Lead time: 2-3 Weeks

Spindle

Supplier: Fabricated in NUS
Quotation: -
Lead time: -

TESTING BOM

Tachometer

Supplier: Loaned from NUS
Quotation: -
Lead time: -

Fume Extractor (Vacuum)

Supplier: Loaned from NUS
Quotation: -
Lead time: -

M14 Clamping Kit

Supplier: Loaned from NUS
Quotation: -
Lead time: -

CC05IF-USB Communication Cable

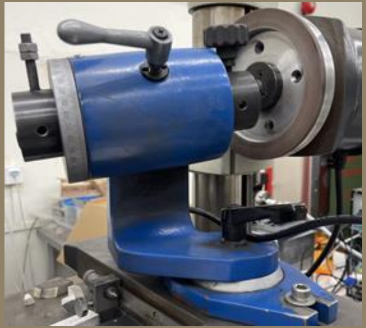
Supplier: Loaned from Oriental Motor
Quotation: -
Lead time: -

TESTING BOM

KUKA KR60 Robotic Arm

Supplier: Loaned from SimTech
Quotation: -
Lead time: -

Gundrill Clamp



Supplier: Loaned from SimTech
Quotation: -
Lead time: -

Gundrill (6.35mm)

Supplier: Loaned from Halliburton
Quotation: -
Lead time: -

TBT No 851248

Supplier: Loaned from Halliburton
Quotation: -
Lead time: -

TESTING CRITERIA

TIME

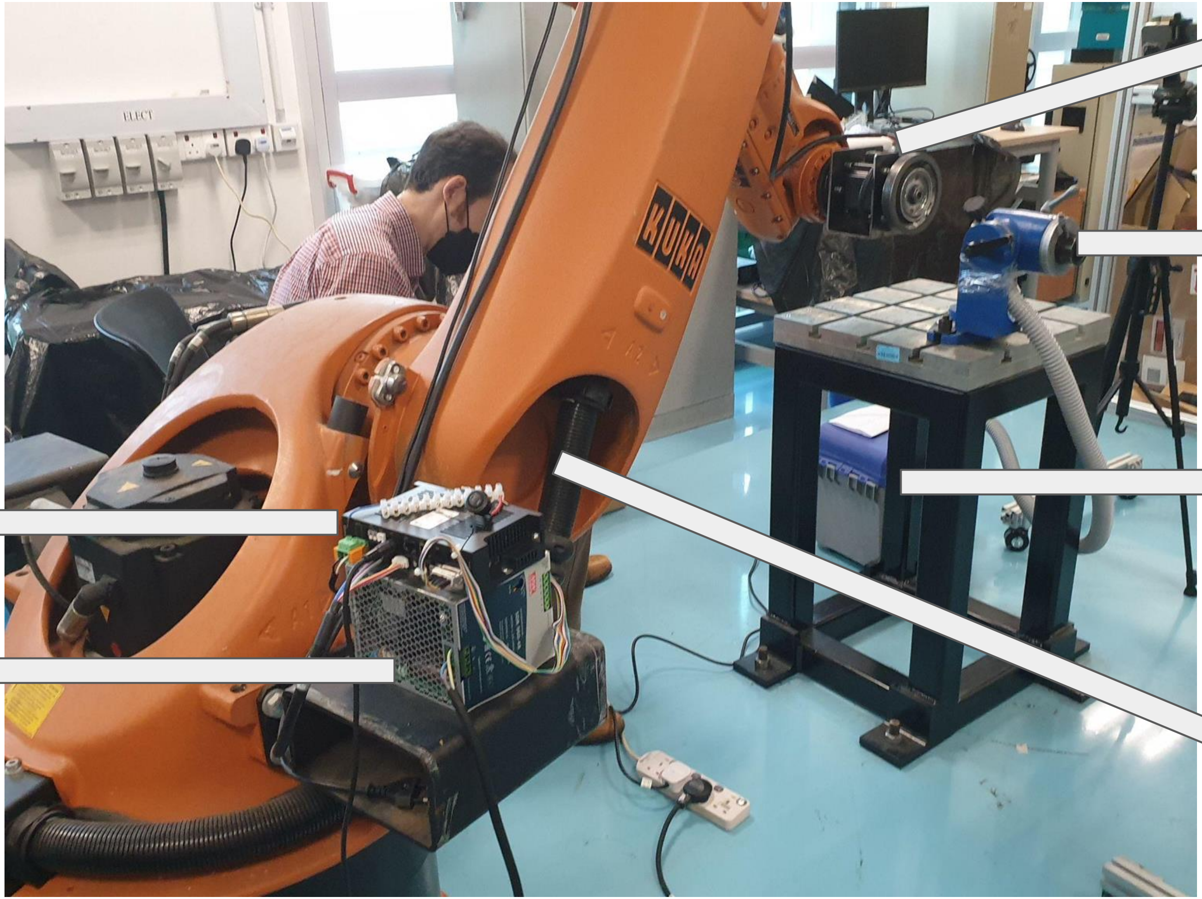
Time taken (manual grinding process) : 10 -15 minutes

ACCURACY

Measurement of ¼ diameter

Comparison of theoretical, manual grinding & automated grinding

FULL ASSEMBLY



Motor & Bracket

Gundrill Clamp

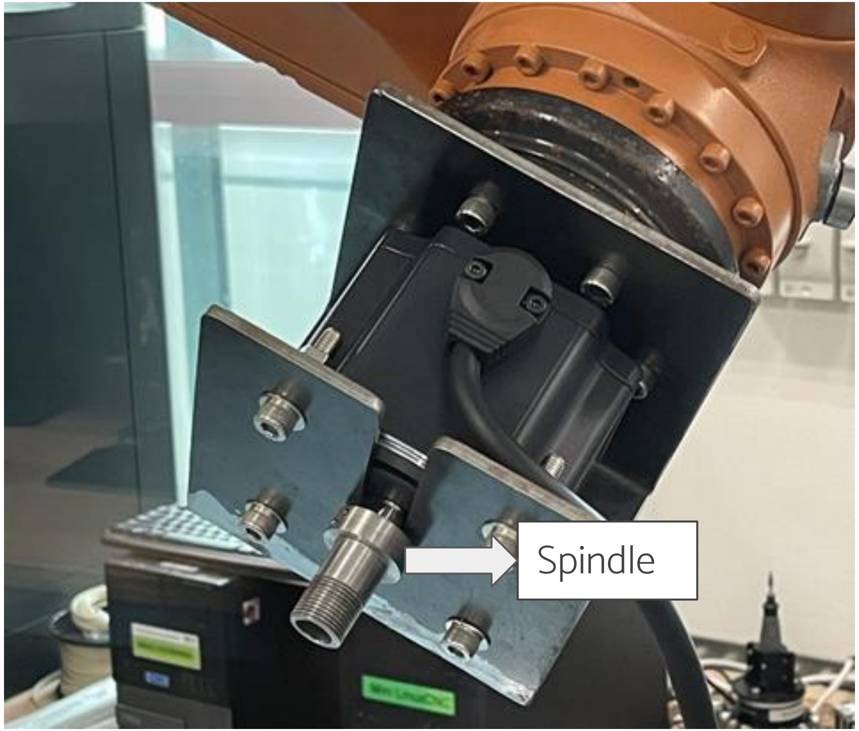
Fume Extractor (Vacuum)

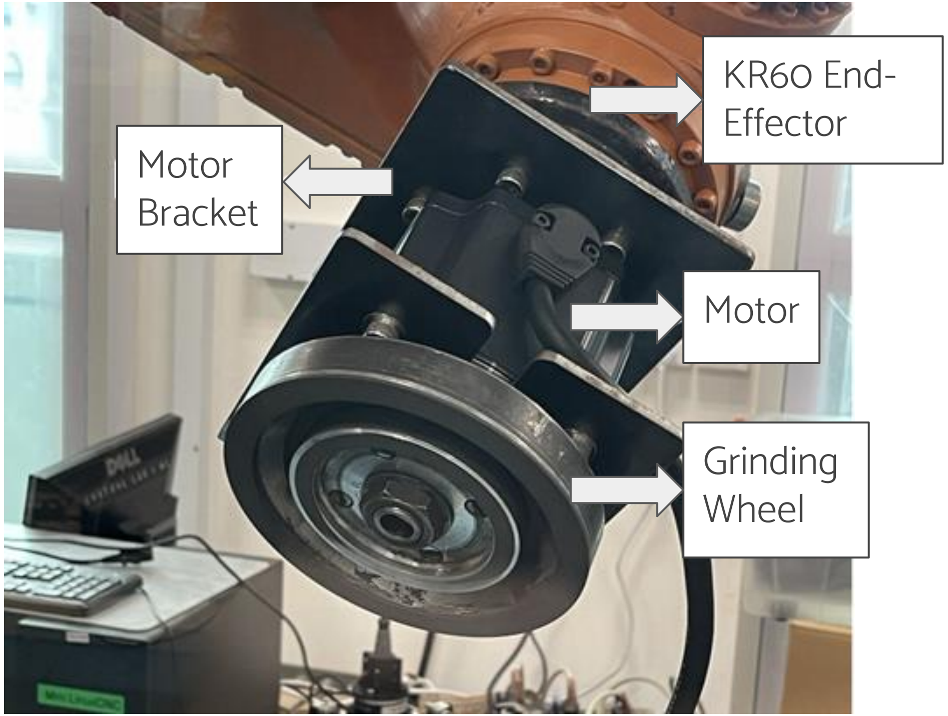
KUKA KR60

Motor Driver

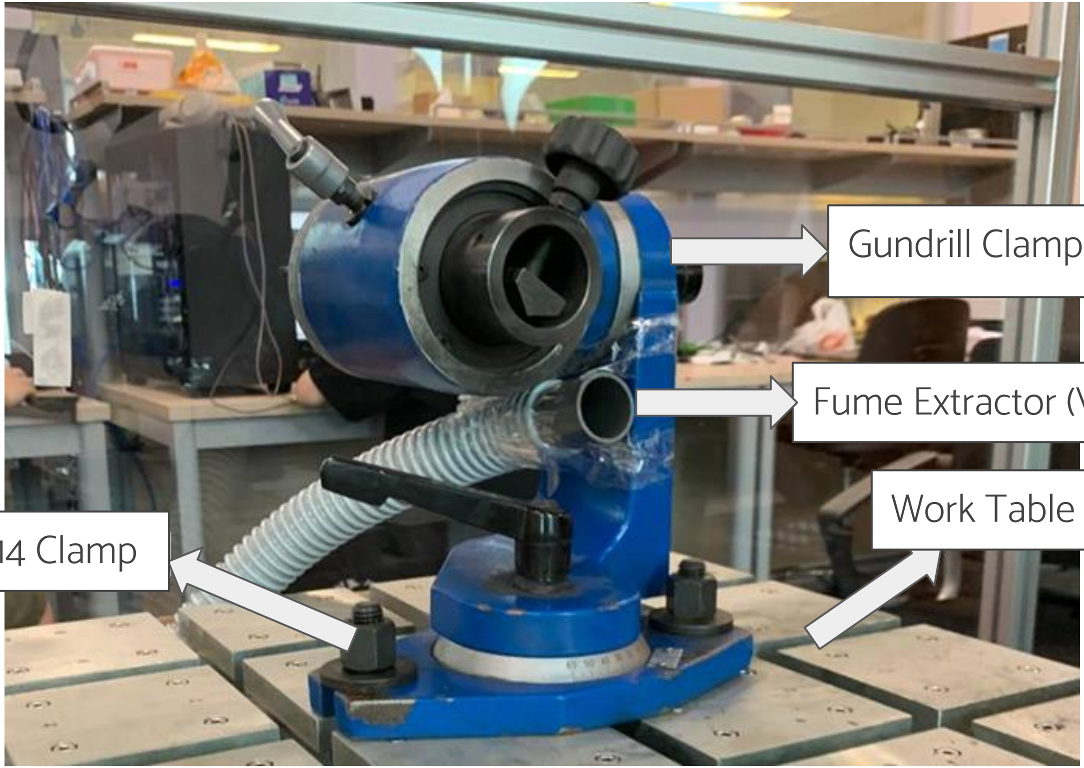
Power Supply

MOTOR ASSEMBLY

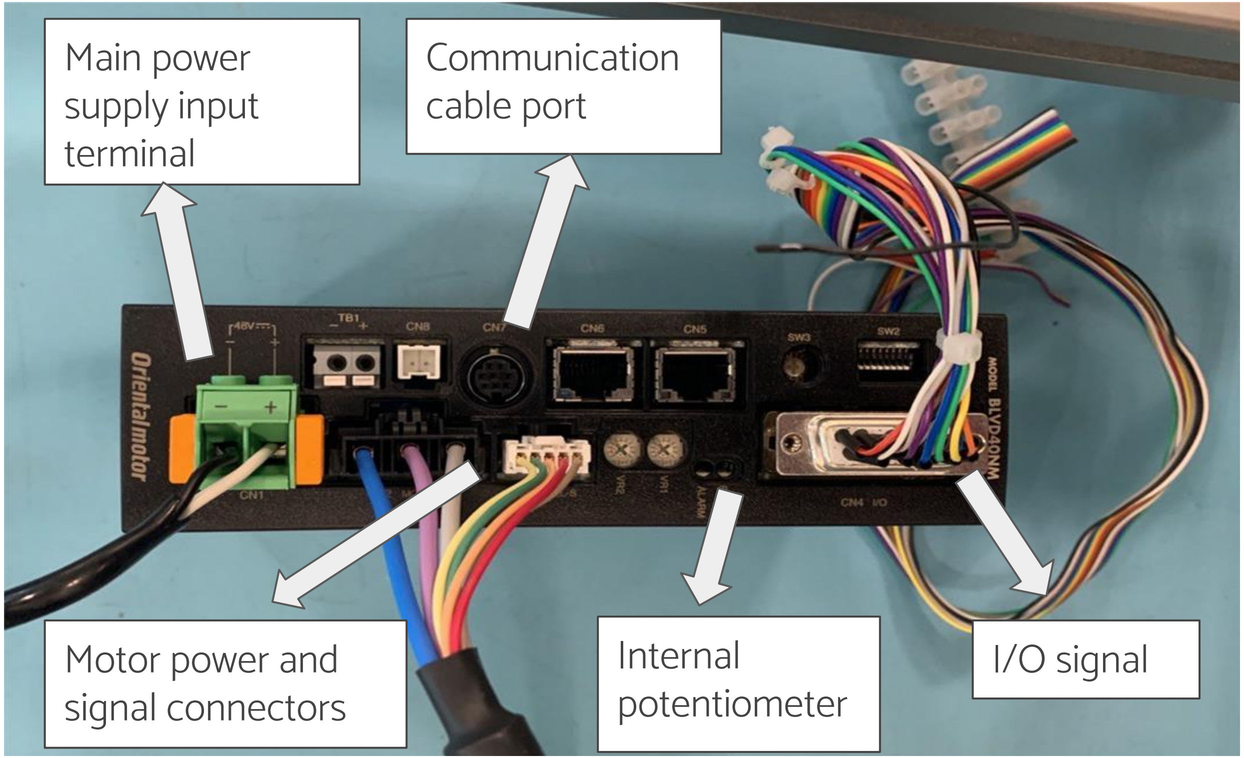


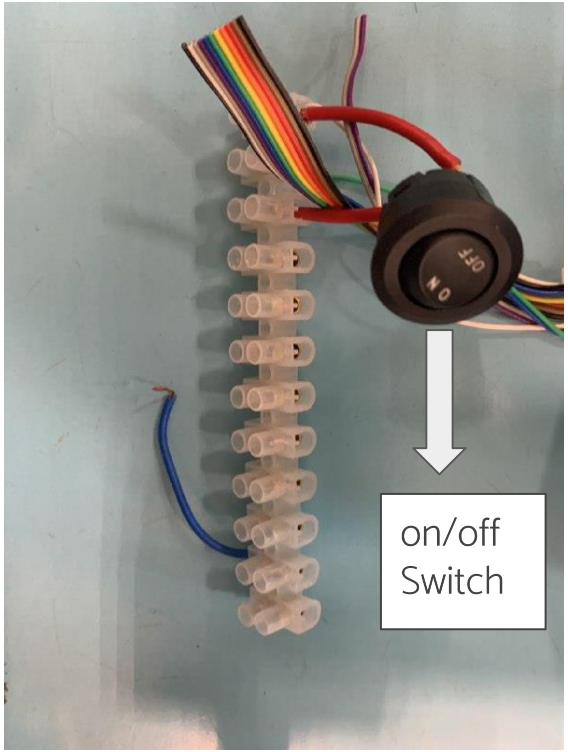


TABLETOP SET-UP

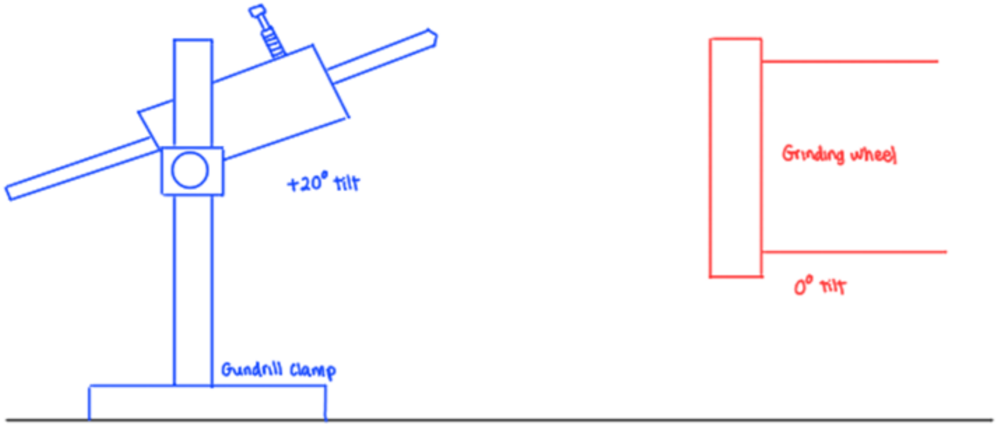


MOTOR ELECTRICAL CONNECTION



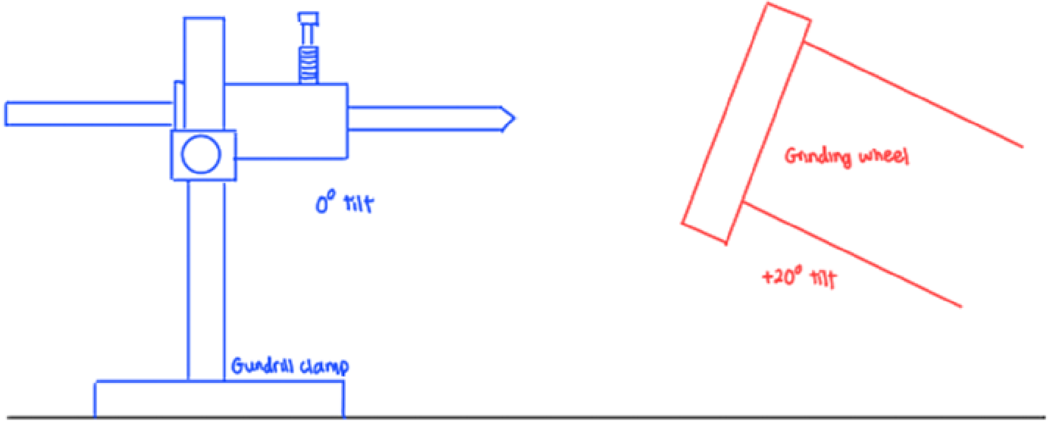


TRANSLATION OF ANGLES (TILT)



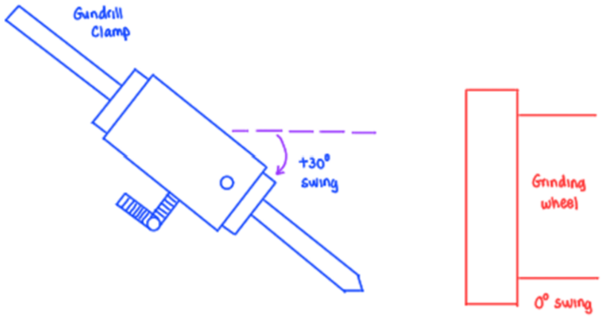
GUNDRILL CLAMP ANGLE (MANUAL)

GRINDING WHEEL ANGLE (AUTOMATED)

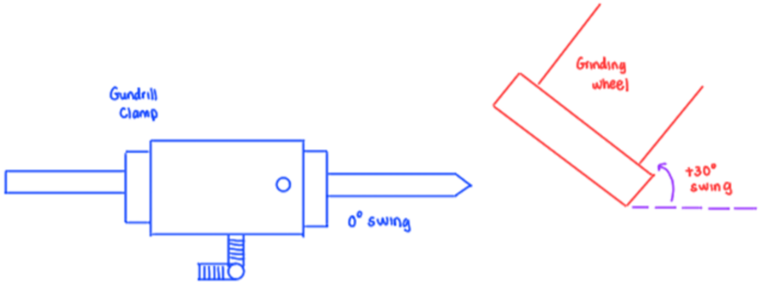


TRANSLATION OF ANGLES (SWING)

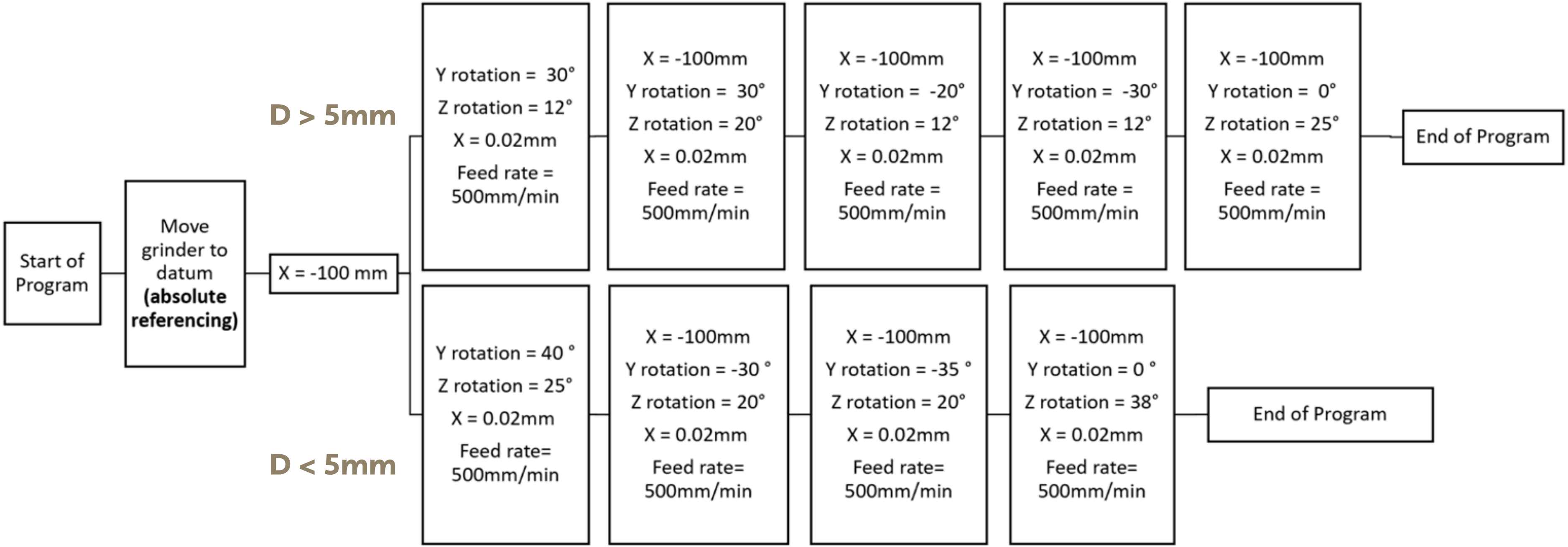
GUNDRILL CLAMP ANGLE (MANUAL)



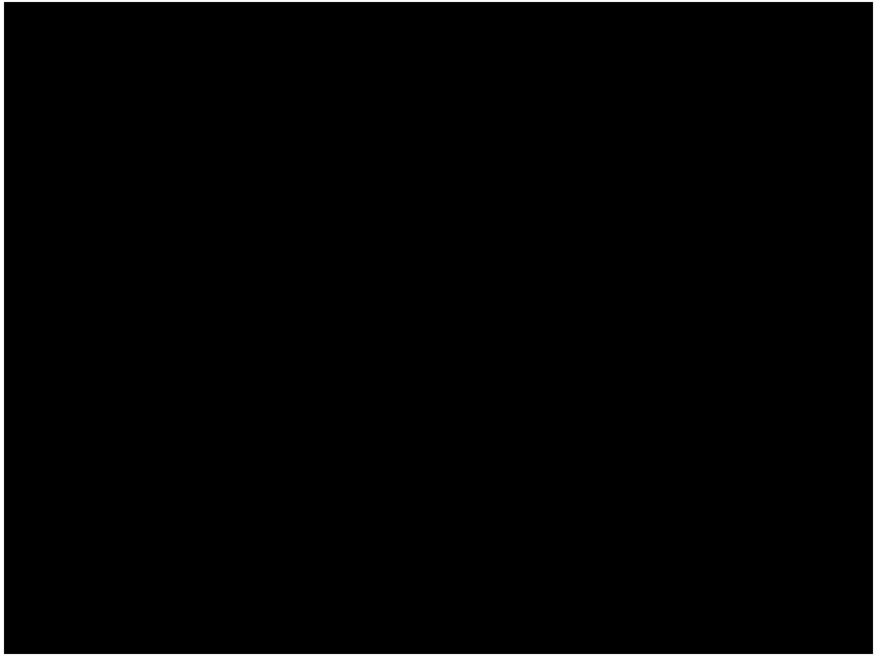
GRINDING WHEEL ANGLE (AUTOMATED)

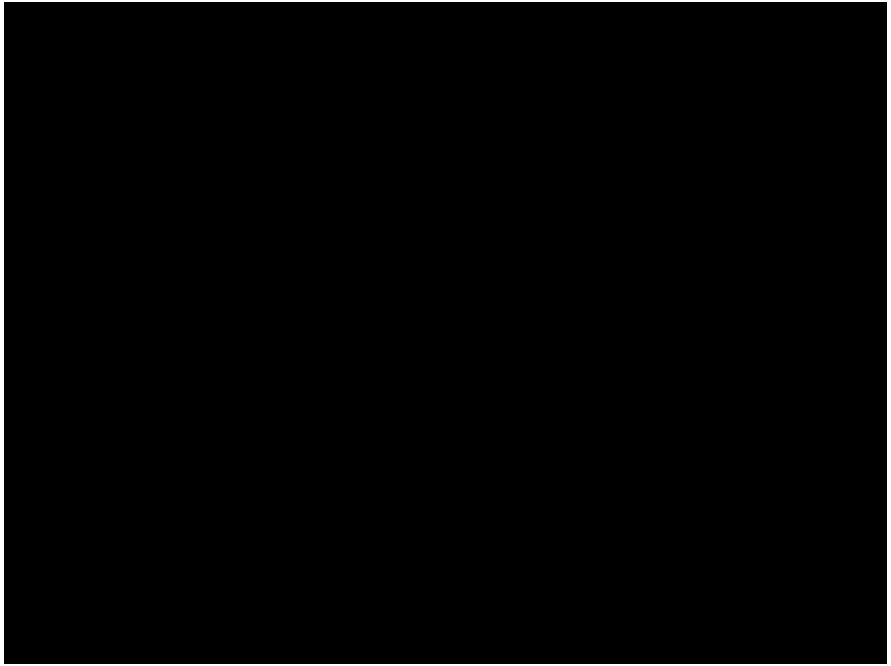


PROGRAM FLOW



PROGRAM FLOW





TROUBLESHOOTING

Reference Axis

Setting the reference axis at grinding wheel does not work well with the program.

Parallelism Of Wheel

Parallel wheel is essential for more accurate result.

Reference Point

Reference point is set at the tip of the gundrill.

TROUBLESHOOTING - SETTING REFERENCE AXIS

Setting Reference Axis:

- A pointed tool is used.
- Grinding wheel is contact with the pointed tool from 4 position.
- Reference axis is set.

TROUBLESHOOTING - REFERENCE AXIS

CHALLENGES OF REFERENCE AXIS AT WHEEL

- Constant change in reference axis makes programming difficult.
  - Reference Axis rotates when the grinding wheel rotates.

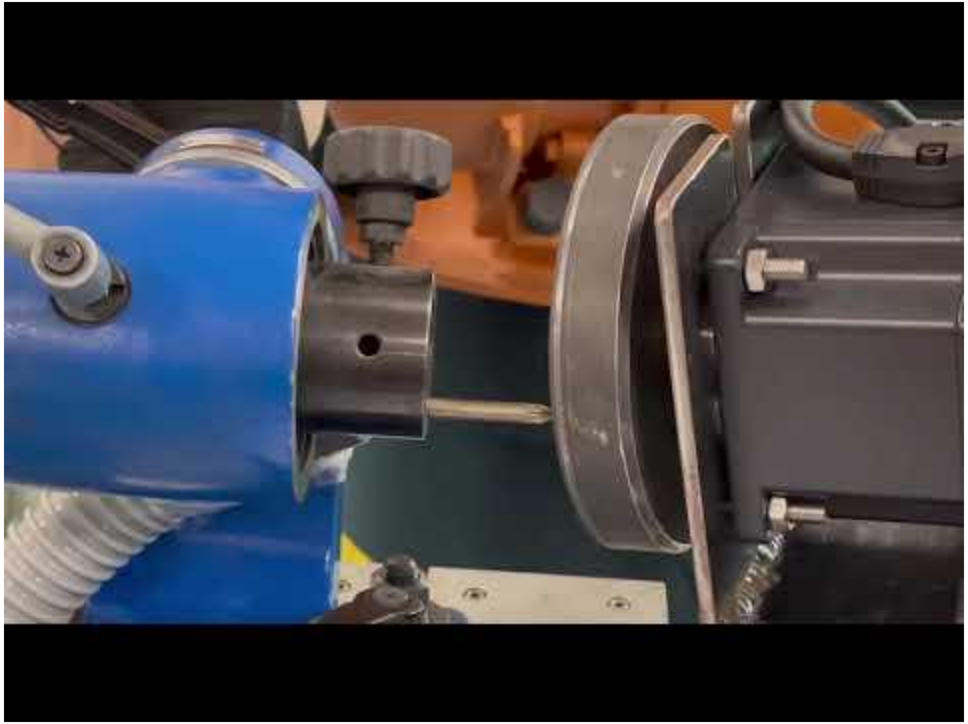
SOLUTION

- Re-calibrate reference axis to be located at the gun drill tip (stationary object).

TROUBLESHOOTING - SETTING REFERENCE AXIS

Setting Reference Axis At Gundrill

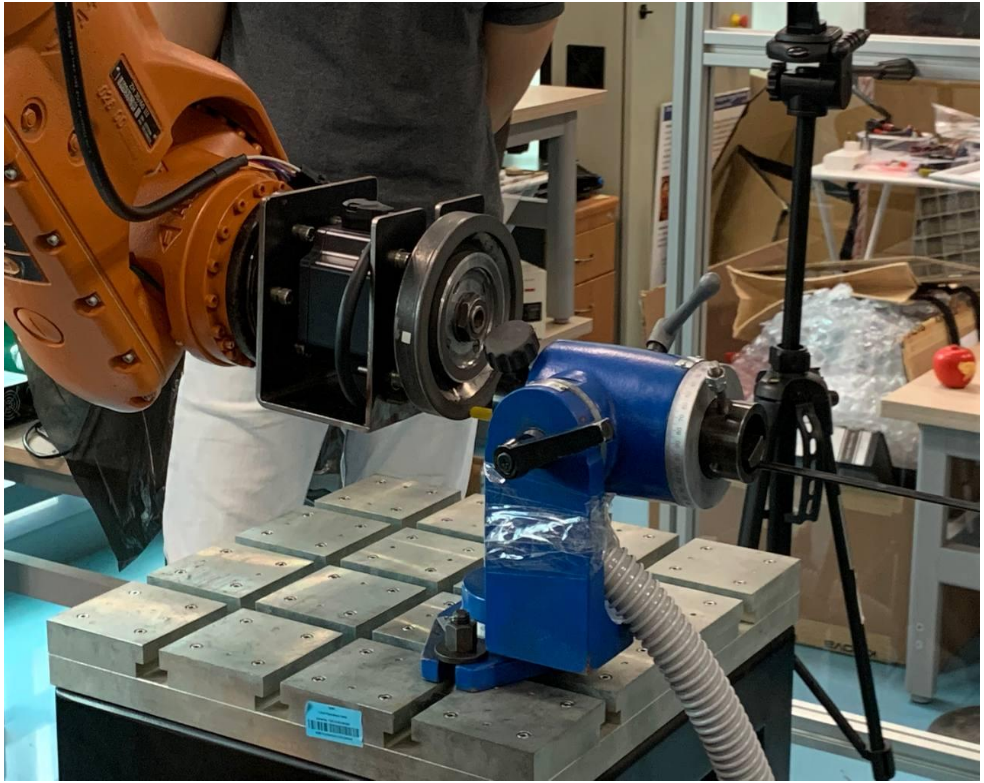
- Pointed tool (drill bit) is fixed.
- Grinding wheel move towards drill bit.
- Once the grinding wheel is contacted with drill bit.
- Reference point is set.



TROUBLESHOOTING - PARALLELISM OF GRINDING WHEEL

To ensure parallelism of grinding wheel:

- Both ends of the grinding wheel are measured.
- Measured values at both ends must be similar.



TROUBLESHOOTING - PARALLELISM OF GRINDING WHEEL

CHALLENGES

- Grinding wheel is found to be unparallel (surface is not flat).

SOLUTION

- Re-calibrate to ensure:
  - Highest point of the wheel is used when setting reference point.
  - Highest point refers to the point where grinding wheel sticks out of its plane most.

TROUBLESHOOTING - SETTING REFERENCE POINT

Setting Reference Point

- Grinding wheel is set to a fixed point.
- Gundrill is inserted into the clamp
- Lock the gundrill once it touches the stationary grinding wheel.
- A paper is used as an indicator to ensure there is a contact.
- Reference point is set.

TROUBLESHOOTING - REFERENCE POINT

CHALLENGES

- As all steps are programmed based one reference point(starting):
  - Unable to cut 4th and 5th steps.

SOLUTION

- Reference point for each individual steps.
  - Wheel is rotated to ensure it is in contact with the gundrill.

TROUBLESHOOTING - SETTING REFERENCE POINT (USING FRICTION)

FULL TESTING

TESTING CRITERIA

ACCURACY OF REGRIND

- Determined by the <u>closeness</u> of the experimental ¼ diameter value to the theoretical ¼ diameter of the gundrill.
- The <u>closer</u> the experimental ¼ diameter value is to the theoretical ¼ diameter, the <u>higher the accuracy</u> achieved.

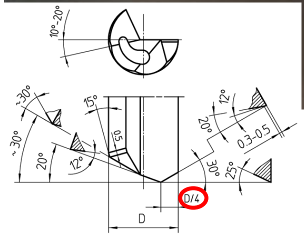
EFFICIENCY OF PROCEDURE

- Measured by the <u>total time taken</u> for the automated regrinding procedure.
- The <u>lesser</u> the total time taken for the procedure, the <u>higher the efficiency</u> of the process.

TESTING RESULTS - ACCURACY

IMPORTANT POINTERS

- The ¼ diameter values were measured using the Keyence Microscope at NUS Advanced Manufacturing Lab (AML).
- The theoretical ¼ diameter of the gundrills used is 6.35mm/4 = 1.59mm.
- A total of three gundrills were borrowed from Halliburton and measured, to determine the average inaccuracy of manual regrind.



TESTING RESULTS - ACCURACY

Measurements of the three gundrills manually re-grinded at Halliburton

Theoretical ¼ diameter of gundrill = 1.59mm.

	First Reading (mm)	Second Reading (mm)	Third Reading (mm)	Average Reading (mm)	Inaccuracy (Absolute Value)
Gundrill 1	1.62	1.64	1.62	1.63	0.04
Gundrill 2	1.64	1.65	1.65	1.65	0.06
Gundrill 3	1.65	1.64	1.66	1.65	0.06
				Average Inaccuracy	0.05

TESTING RESULTS - ACCURACY

Measurements of the gundrill re-grinded by KR60

Theoretical ¼ diameter of gundrill = 1.59mm.

	First Reading (mm)	Second Reading (mm)	Third Reading (mm)	Average Reading (mm)	Inaccuracy (Absolute Value)
Trial Test 1	1.57	1.58	1.57	1.57	0.02
Trial Test 2	1.60	1.58	1.59	1.59	0.00
Trial Test 3	1.61	1.63	1.63	1.62	0.03
				Average Inaccuracy	0.02

More accurate compared to manual regrind, as the average inaccuracy is lower than 0.05mm.

TESTING RESULTS - EFFICIENCY

IMPORTANT POINTERS

- For the testing procedure, the time recorded includes the time required for manual rotation of the gundrill in the x-axis, using the gundrill clamp.

Time taken for testing	
Trial Test 1	6 min 20 sec
Trial Test 2	6 min 08 sec
Trial Test 3	6 min 11 sec
Average Time Taken	6 min 13 sec

EVALUATION - ACCURACY

Average Inaccuracy of Manual Regrind (mm)	0.05
Average Inaccuracy of KR60 Regrind (mm)	0.02

OBSERVATIONS

- The average inaccuracy for the gundrill re-grinded on the KR60 (0.02mm) is significantly lower than that of the manually re-grinded gundrills (0.05mm).

	First Reading (mm)	Second Reading (mm)	Third Reading (mm)	Average Reading (mm)
Trial Test 1	1.57	1.58	1.57	1.57
Trial Test 2	1.60	1.58	1.59	1.59
Trial Test 3	1.61	1.63	1.63	1.62

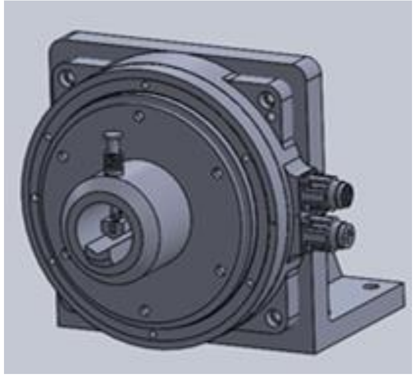
- As more trials were performed, the inaccuracy of gundrills increased.
- This could be due to calibration and the condition of the reference gundrill used.
- Initial inaccuracy in the reference gundrill causes deviation in the final results of the re-grinding. The inaccuracy worsens as more trials are performed.

EVALUATION - EFFICIENCY

Average Time taken for Manual Regrind	10 - 15 minutes
Average Time taken for KR60 Regrind	6 minutes 13 seconds

OBSERVATIONS

- The average time taken for the KR60 automated regrind (6 mins 13 sec) is significantly lower than that for the manual regrind (10-15 minutes depending on experience level).

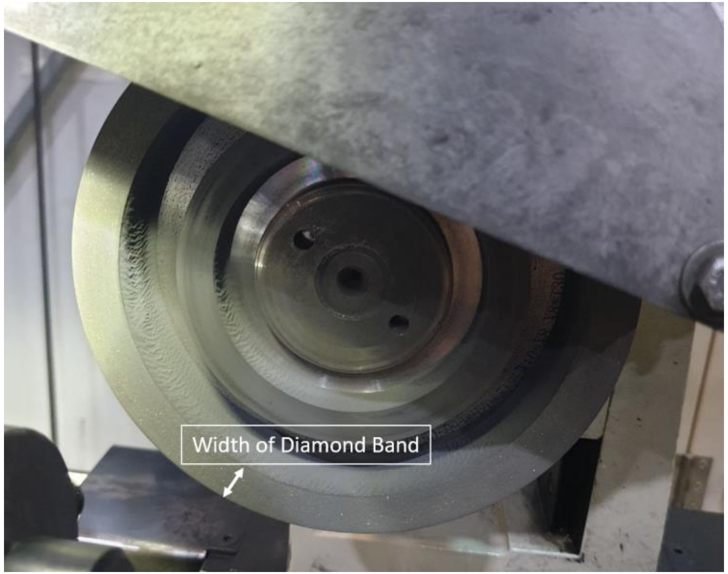


- The time taken for the KR60 regrind includes the time needed for manual rotation of the x-axis (torsion angle on the gundrill clamp), as system is not fully automated.
- With the implementation of the torque motor, the time taken for the automated process is expected to reduce further.
- During testing, the robotic arm movements were slowed down for safety purposes. These can be sped up during actual implementation.

DESIGN LIMITATIONS

DIAMOND BAND ON GRINDING WHEEL

- The automated design is applicable only to gundrills with diameters smaller than the width of the diamond band on the grinding wheel.
- For gundrills with diameters larger than the diamond band width, some edges on the gundrill will not be grinded off.
- Dimensional accuracy will be compromised.



Width of Diamond Band = 15.06mm

DESIGN LIMITATIONS

INITIAL CALIBRATION REQUIRED

- Initial calibration is required for gundrills of each diameter (e.g., calibration for 6mm gundrill cannot be used for 8mm gundrill).
- Reference points where the gundrill contacts the grinding wheel are slightly different.
- Time-consuming for Halliburton due to the wide range of gundrill sizes owned by the company.

SOFTWARE NOT USER-FRIENDLY

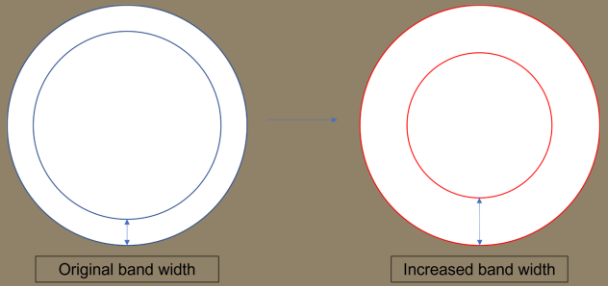
- Programming software for the KR60 may not be flexible for making minor changes to the program.
- Software does not allow for certain steps in the program to be executed separately.

RECOMMENDATIONS

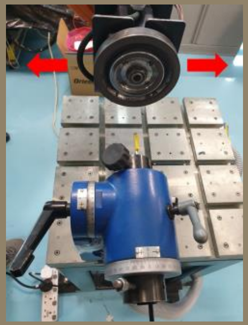
LIMITATIO N

Design not suitable for gundrills with diameters larger than grinding wheel diamond band width.

- Change the grinding wheel design by increasing its diamond band width, to accommodate a wider range of gundrill sizes.



- Program the robotic arm to translate along z-axis, so that the gundrill surface can be evenly grinded even if its diameter is exceeds diamond band width.



RECOMMENDATIONS

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Calibration process of robotic arm might be inaccurate and too time-consuming.

- Install force sensors on the robotic arm to improve accuracy and speed of calibration process.
- Closed-loop feedback system can significantly improve accuracy of regrind, but costs will increase accordingly.

- For calibration, a ‘Golden Standard’ gundrill should be used as a reference gundrill.
- A ‘Golden Standard’ gundrill is one with the ideal dimensions and angles grinded off its tip.
- Calibration process will increase in accuracy and subsequent regrinding of gundrills will be optimal.

CONCLUSION

OBJECTIVES

- The automated regrinding system can perform regrinding of gundrills safely, efficiently and accurately.

- The system can withstand the grinding loads and high stress conditions.

EXPERIMENTAL RESULTS

- Results have shown an improvement in accuracy of 0.03mm (60%) and a decrease in regrinding time by 8 minutes 47 seconds (59%).

DESIGN COSTS

- Estimated costs of design stands at approximately SGD$50,000 (including robotic arm).

- Cost is reasonable, based on the experimental results.

POSSIBLE IMPROVEMENTS

- Force sensors can be installed to aid with the calibration process.

- Grinding wheel design should be modified to suit a wider range of gundrill diameters.

THANK YOU

We have come to the end of the presentation.