Washkewicz College of Engineering

CHANNEL

ELECTRODE ROD BENDER

CHANNEL PRODUCTS

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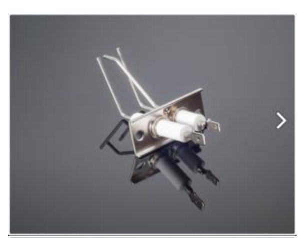
PROJECT STATEMENT

-Create a mechanism to perform precision electrode bending.

-Design and assemble a table with 4 degrees of freedom along with a bending motor that can achieve 2 degrees of freedom

-Utilize stepper motors and slides to achieve linear and rotational motion.

-Control the system using an Arduino controller and EasyDrivers.



PROJECT SCOPE

-Current rod bender was built in the 1980's and uses outdated technology.

-Process relies heavily on human operation.

-Sponsor requires updated technology to stay competitive.

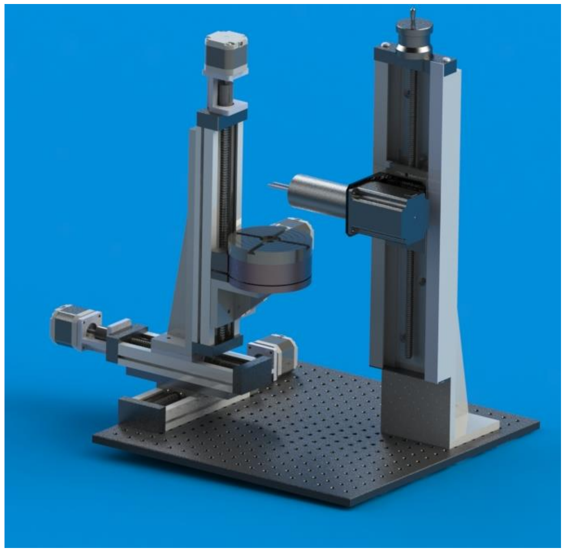
PROJECT BENEFITS

-A new unit will increase reliability and help introduce future innovations.

-System will be durable and perform precision bends to accommodate specific electrode configurations.

- Compact and robust design that can easily be modified and replicated.

PROPOSED SOLUTION



ENGINEERING ANALYSIS

DETERMINING TORQUE FOR BENDING MOTOR:

Materials: Kanthal D & Kanthal A-1

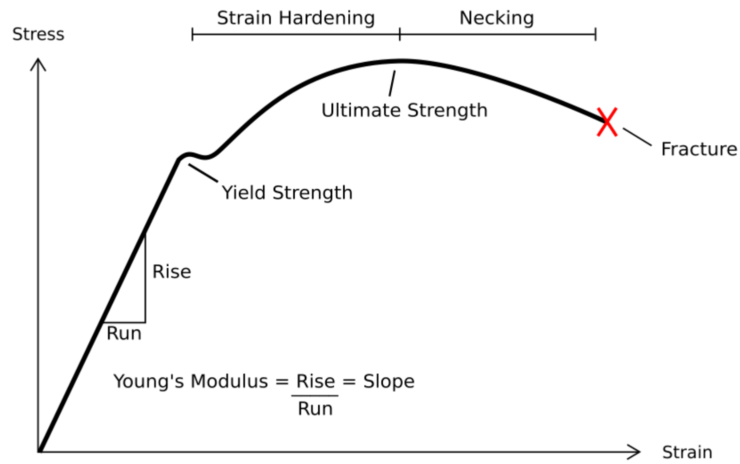
Rod Diameters: 0.052", 0.064", 0.081", 0.091", 0.114"

Mechanical properties

Wire size	Yield strength	Tensile strength	Elongation	Hardness
Ø	$R_{p0.2}$	R_m	A	
mm	MPa	MPa	%	Hv
1.0	545	760	20	240
4.0	475	680	18	230

Bending occurs when Stress is greater than or equal to Yield Strength.

$$\sigma \geq S_y$$



Length between bending pins:	**L**	19.812 mm
Yield Strength:	**Sy**	506.75 MPa
Radius:	**r**	1.448 mm
Bending Moment:	**Mb**	
Stress:	**σ**	
Moment of area about neutral axis:	**Izz**	
Force:	**F**	

$$\sigma = (Mb*r) / I_{zz} \qquad Mb = F*L$$

$$\sigma = (F*L*r) / Izz$$

$$I_{zz} = (\pi*r^{\wedge}(4))/2 = 6.902\ E\ -12$$

$$\sigma = F * (4.156\ E\ 6)$$

$\sigma \geq Sy$

$\sigma = 506.75$ Mpa

$F = (506.75\ E6)/(4.156\ E\ 6)$

$F = 121.930$ N

Torque = F*L

Torque = **2.416 N-m**

STEPPER MOTOR QUALITIES

Pros

-Stepper Motors have very accurate movements that allow very precise controls

-They can operate at lower voltages than other motors with similar torque

-They have high torque when operating at low RPMs

-They are relatively cheap and easy to control

Cons

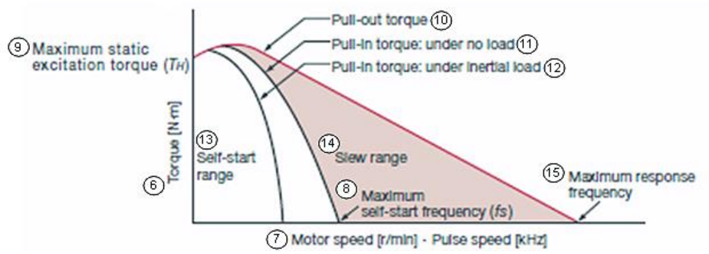
-There is no integrated feedback (Open-loop feedback)

-They require drivers that can be costly.

-Bipolar or Unipolar drive (allows power to be delivered to one or two sets of windings)

-Resonance between the motors can cause instability in the system

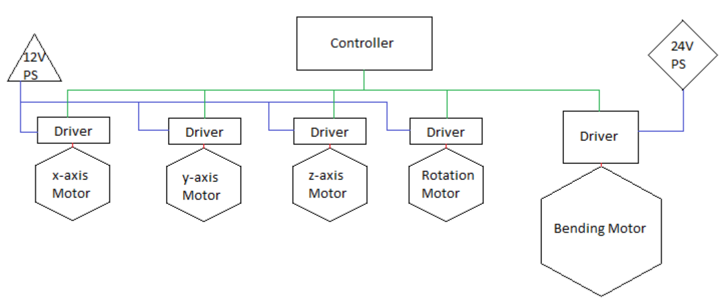
STEPPER MOTOR TORQUE CHART



Speed - Torque Chart

STEPPER MOTOR CONNECTION

How we will control the stepper motors:



The controller will be connected to the drivers and the drivers will be connected to the positioning motors. The Bending motor will have a higher torque and require a larger power supply to power the driver controlling it.

STEPPER MOTOR CONNECTION

How the stepper motors work:

-Each 'step' rotates the motor a set amount.

-The driver can operate in micro-steps allowing more accurate control

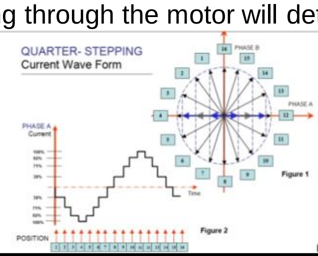
-Our motors are 200 steps/revolution (1.8 degrees per step)

-Our drivers can break a step into 8 microsteps

  -This allows us to have a functional 1600 steps/revolution (0.225 degrees per step).

-Bipolar windings allows us to deliver more torque from the motor with the same driver (if needed)

-The sign of the current going through the motor will determine the direction the motor spins



BILL OF MATERIAL

Quantity	Item	Supplier	Catalog	Unit Price	Total
2	NEMA 17 Motor-Mount Slide | XY 0.125"	McMaster-Carr	6734K1	$ 889.60	$ 1,779.20
1	NEMA 17 Motor-Mount Slide | Z 0.125"	McMaster-Carr	6734K2	$ 996.71	$ 996.71
1	Ultra-Precision Slide | Bender	McMaster-Carr	5242A34	$ 895.00	$ 895.00
1	Sherline 4" Rotary Table	Amazon/Sherline		$ 336.00	$ 336.00
4	NEMA 17 Stepper Motor	McMaster-Carr	6627T66	$ 56.10	$ 224.40
1	NEMA 23 Stepper Motor (3Nm)	StepperOnline	127	$ 30.54	$ 30.54
1	Multipurpose 6061 Aluminum Bar 3" X 3" X 36"	McMaster-Carr	9872T236	$ 146.75	$ 146.75
1	Multipurpose 6061 Aluminum Sheet (Brushed) 12" X 12" X 3/8"	McMaster-Carr	1651T917	$ 148.82	$ 148.82
1	Arduino UNO Rev 3	Amazon/Arduino		$ 19.95	$ 19.95
4	NEMA 17 EasyDriver Stepper Motor Driver	Amazon/SparkFun		$ 9.80	$ 39.20
1	NEMA 17 Power Supply 50W 12V 4.2A	StepperOnline	311	$ 8.42	$ 8.42
1	NEMA 23 Stepper Motor Driver Max 80VAC or 110VDC with 2.4-7	StepperOnline	MA860H	$ 54.88	$ 54.88
1	NEMA 23 Power Supply 350W 24V 14.6A	StepperOnline	177	$ 26.80	$ 26.80
1	In-house Machining	Cleveland State		$ -	$ -
1	Various Hardware Budget	Misc.		$ 1,000.00	$ 1,000.00
				TOTAL	**$ 5,706.67**

MARKET POTENTIAL

Optimization of rod bender can lead to increase in production for sponsor.

- Increases in speed
  - Motors speed will be increased, affecting overall production rate
- Less human interface
  - Employee only has to place electrode then initiate program

Design allows for easy modifcations that can lead to more complex electrode assemblies.

PROJECT TIMELINE

January - Finalize all adjustments to design and begin ordering components.

February - Begin machining and assembling rod bender.

March - Start assembling the controller scheme and troubleshoot issues related to design.

April - Finalize controller scheme and troubleshoot.

May - Finished product.