International Journal of Aquatic Science
ISSN: 2008-8019
Vol 12, Issue 03, 2021

Design And Fabrication Of Arduino Controlled Cnc Foam Cutting Machine

S. K. Dhinesh[1], K. L. Senthil Kumar[2], K.S. Prasad[3], M. Raghunath[4], S. Madheshwaran[5], A. P. Gokulraj[6], Saravanan M[7]

[1,2,3,4,5,6,7] *Department Of Mechatronics, Bannari Amman Institute Of Technology, Sathyamangalam, Tamil Nadu, India*

Dhineshsk@Bitsathy.Ac.İn[1]

Abstract: ***The Foam Cutting Machine Utilized In To Develop Prototypes For Clear Vision In Their Model This Improvement Is Executed Through CAD/CAM Software, So It Will Increase The Demand For Personalization Has Made The Rapid Prototyping Companies Develop In Recent Decades. Rapid Prototyping Technology Is Persevering With To Enhance In Speed And Accuracy, The Cap Potential To Deliver > 1 M. The Foam Cutting Process Uses Experimental Cutting Trials And Finite Element Analysis. The Cutting Pressure Speed, Wire Temperature And Kerf Width Were Measured. This Study Is Executed To Discover The Distinction And Reliance Of Cutting Boundaries. Foam Cutting, Rapid Prototyping And Production Machines Are Quite Used Because Of Their Excessive Velocity, Massive Operating Volumes And Low Price In Preliminary Investment. The Effects Of This Study Resource To Enhance The Recent Twine Foam Reduction Through Fixing The Constraints And Disadvantages To Choosing High-Quality Reducing Parameters Of The Computer Numerically Controlled Gadget. The Essential Matters For The Aerodynamic Studies For Cutting Foam For Some Mm Thickness. Research Is Suggested By Selecting The Cutting Parameter Function Curves Of Various Foam Types.***

Keywords: Additive Manufacturing, Foam Cutter Machine, Hot Wire Cutter.

1. INTRODUCTION

Most Foam Cutter Machines Are Likely CNC Machines. In The CNC Machine Cutting Process Done By A Hard Tool, Another Hand Laser Is Used. For Very Thin Material, There Was No Need For Hard Tool Bits And Lasers. Instead Of Tool Bits And Lasers, The Special Type Of Cutting Used In The Machine Is Named Hot Wire, Or A Special Type Of Resistance Wire (Nickel-Chromium Wire) Which Gets Heated When Electric Current(I) Passes Through It. The Nickel-Chromium Wire Vaporizes And Melts The Foam When Electric Current Passes Through It. By Using This Technology, We Can Get Our Designated Shape And Size. Very Fine Thickness Can Be Achieved By This Technology For This Purpose It Is Employed In The Aerodynamic Events.

2. DESIGN OF FOAM CUTTER

2.1 Mechanical Cad Design

The Designing Is One Of The Most Important Phases Of The Production, Wherein Many Adjustments Are Made To Produce A Design And Its Miles Selected As A Model. The CAD Designs Are Made By Using Solid Works Software.

Fig. 1. Design Of Foam Cutting Machine.

2.2 Selection Of Components

Aluminium Profiles. In This Project We Have Used 20x20mm And 30x60mm Aluminium Profiles. These Dimensions Of The Profile Are In Standards. These Profiles Are Made Of High Strength Tempered Al Alloy 6063 - T5[1]. The 20x20 Profile Weighs Approximately 0.74 Kg Per Meter. The Diagonal Section Thickness Is 1.5 Mm[2].

L-Clamp. These L-Clamps Are Durable And Versatile. They Are Made Up Of High-Quality Aluminium. The Dimensions Of The L-Clamp Are 30 X 30 Mm And Can Be Utilized For Locking The Aluminium Profile Of 30 X 30 Mm. These Are Straight Angle Corner Stands With Two 8.8 X 5.9 Mm Oval Holes (+/- 0.05% Accuracy).

Nema Stepper Motors. The Stepper Motors Used In This Project Are NEMA 17 (4.2 Kg-Cm Torque) And NEMA 23 (180 Kg-Cm Torque) Stepper Motors Respectively. In This Binder Jetting 3D Printer, We Have Used Two Planetary Geared NEMA 23 Stepper Motors. It Also Has A Step Angle Of 1.8°. The Number Of Phases In This Motor Is 2. The Rated Voltage Of This Motor Is 3.2V And The Rated Current Is 1.4A. The Resistance Per Phase Is 2 Ohm And The Inductance Per Phase Is 2.8mh. The Holding Torque Of This Stepper Motor Is 4.2 Kg-Cm. The Total Weight Of This Stepper Motor Is 300 Grams. The Width And The Length Are 42.3 And 24mm.

Stepper Motor Driver. In This Foam Cutting Machine, We Have Used Motor Drivers For The Dynamic Control NEMA 17 Stepper Motors. The Stepper Motor Driver Used Is A4988, It Is Used To Drive NEMA17 Stepper Motors. The Power Input Of This Motor Is Of Range 9 ~ 40 V DC. The Normal Output Current Is 3.5 A. The Peak Output Current Is 4A And The Micro Steps Are 1, 2/A, 2/B, 4, 8, 16, 32. The Stepper Drivers Are Used To Control Direction And Speed.

Hot Wire. The Foam Can Be Cut Using Different Cutting Situations. The Different Criteria For The Cutting Of Foam Are Dependent On The Nickel-Chromium Wire Material, Wire Dimensions, Wire Cutter Temperature, Wire Cutter Speed And The Kerf Width. Mostly Two Types Of Nickel-Chromium Wire Foam Cuttings Are Available Such As Heat Mechanical Shearing And Unique Heat Cutting Method. We Use Heat Mechanical Shearing. By Using Different Diameters Such As 0.6 And 0.32 The Temperature[3].

Arduino Uno. The Micro-Controller Used In Arduino Uno Is Atmega328p. The Working Voltage Is 5V. The Working Voltage Is Of Range 7-12V. It Has 14 Digital IP And OP (Output) Pins. It Has Six Analog Input Pins. It Uses A Primary Control Board To The Powder Levelling Motor. It Has A Memory Of 32 Kb. It Belongs To The AVR Family Controller. This Controller Has 14 Digital Input Output Pins Out Of Which 6 Provide Pulse Width Modulation Output. SRAM Of Arduino Was 2 KB And EEPROM Of 1 Kb. Arduino Uno Works With A Clock Speed Of 16 MHZ. It Has One USB Port And One Power Adapter Port. The Board Gets Power Through Both Ports .Using The USB Port Program Gets Uploaded[4].

CNC Shield. Basically, A CNC Shield Controller Used To Control The 3-Axis Machine. The CNC Controller Has A Stepper Motor Driver Slot. It Consists Of One X Axis, One Y Axis, One Z Axis And One A Head Connection (Extruder)[5]. The CNC Shield Works On 12 V DC Supply. It Also Consists Of Reset Button, Driver Enable Pin, Set Xyz Drive Module Step And Direction Pins, A-Drive Module Step And Direction And Power Supply Pin. The CNC Shield Connects To The Arduino, Data Comes From The Arduino. Complete Control Of The Stepper Done Using This CNC Shield[6].

Limit Switch. Limit Switch Is An Electromechanical Device. When It Gets Triggered By Any Physical Force It Switches. The Limit Switch Consists Of NC, NO, COM. In This Project The Limit Switches Are Used To Limit The Movement Of The Axis And Also Used For Homing. The Limit Switch Is Connected With A CNC Shield. When The Motor Runs And The Axis Once Presses The Limit Switch, The Circuit Becomes Open, The Motor Stops.

Dc-Dc Converter. DC To DC Converter Isan Electromechanical Device The Converts One Voltage(V) Level Input Of Direct Current (DC) Of Another Voltage Level Of Direct Current. There Are Two Types Of DC-To-DC Converter Are Isolated And Non-Isolated Types. Non-Isolated Types DC To DC Converter Is Consists Of One Coil, Capacity Coupling, SEPIC And Zeta. Isolated Types DC To DC Converter Consists Of Transformer Coupling Type, Forward Transformer Type, FLY-Back Transformer Type. DC To DC Converter Is Connected With Hot Wire. The Input Voltage Of Converter In This Project 12 V.

Smps Power Supply. The Entire Power Supply For This Foam Cutting Machine Is Given By SMPS Power Supply 24V 20A. It Rectifies The AC Voltage To DC Voltage And Provides A Constant Power Supply. It Also Includes A Wired Power Switch. A Power Cable Is Included.

Timing Belt. The Material With The Bet Neoprene Rubber With Fiberglass Core. The Core Wire Material Of This Timing Belt Is Glass Fiber. The Itch Of This Is 2mm. The Width Of The Belt Is 6mm. The Total Length Of This Belt 10m. The Shape Of This Timing Belt Is An Open Loop.

2.3 Software Requirements

Arduino IDE. It Is A Multipurpose Application That Can Be Used For Multiple Operating Software Like Windows, Macos, Linux And Operating Systems Which Is Programmed In From C And C++. It Is Helpful To Code The Required Commands And Can Be Written To Any Compatible Arduino Boards[6].

Solidworks. For The CAD Designing Of The Mechanical Structure And For The Analysis Of The Binder Jetting 3D Printer, We Have Used Solidworks 18.0 Which Is A Licensed Version.

GRBL Firmware. GRBL Firmware Is Open Source. GRBL Firmware Is Used To Control The Motion Of The Motors. Our Micro- Controller Arduino Is Connected With A CNC Shield And Motors Are Connected With A CNC Shield. When The Grbl Firmware Is Uploaded In Arduino. Then Arduino Knows How To Read The G-Code And How To Control The Motors. GRBL Firmware Contains The Source Code Of The Machine[7].

Universal G-Code Sender. All The Things Are Settled, Now We Want A User Interface For Initial Motor Setting, Whether To Check Motion Of Motor. Manual Movement Done By Using Universal G-Code Sender. It Acts Like The User Interface Of A Foam Cutting Machine. Universal G-Code Sender Is Basically A Java Runtime Environment. The Arduino Gets Connected With Universal G-Code Sender Step Calibration Is Also Done Using This Universal G-Code Sender. And Also The Bed Ratio Is Done Here.

Inkscape. Inkscape Is A Software Which Is Used To Produce The G-Code. Firstly, We Design Required In Solid Works, After That Design Obtained From The Solid Works Is Kept In Inkscape For Generating G-Code. The STL Format Files Are Only Allowed In Inkscape.

Micro Stepping Calculation. The General Resolution For Stepper Motors Is 200 Steps Per Revolution. For Each Step It Moves To 1.8 Degree For A Circular.

Formulae

Step Per Rev* Fm /Pitch * N

Fm- Micro Stepping Factor

N- Number Of Teeth On Pulley

3. WORKING PRINCIPLE

To Discover The Cutter Criteria And Situations Is Needed To Test. Here Part Clarifies This Distinguished Cutter Criteria And Examination Arrangement That Was Utilized In This Examination. We Selected A Cutting Process Accessible Unique Heat Cutter Was Chosen To Direct The Experiment.

3.1 Cutting Criterias Of Hotwire Cut

Foam Are Cut On Various Cutter Situations To Discover Suitable Cutter Situations And The Variety Properties Of Cutter In Convincing Criterias. The Cutter Criterias Is A Heat Wire Foam Cutter Is The Hot Wire Of Material With Its Measurement, Cutter Rate, Cutter Temperature Of The Kerf Width. Kerf Width On Hole In The Middle Of Foam Parts Where They Isolated Through Cuts. Cutter Situations Are Changed By Fluctuating The Pre Flexible Cutter Criteria; Cutter Temperature, Cutter Rate And Wire Are Measured[5].

Fundamentally It Has Two Kinds Of Hot Wire Foam Cutter Steps And A Heat Mechanical Shearing Technique. In Heat Mechanical Shearing And The Hot Wire Contacts The Foam, Applying Power To Shear Away Foam Material. In A Warm Cutter, Hot Wire Doesn't Contact Foam Material, The Foam Disintegrates Because Of Heat And Forming The Cuts[8].

3.2 Foam Cutting Build

The Analysis Set Utilized In Investigation Is Portrayed As Shown In (See Fig. 1). This Essentially Comprises A Nickel-Chromium Wire Tightness Instrument, The Feed Rate Control System With The Current Control Equipment. Foam Placed On A Stage With Feed Off Into Heat Wire At A Consistent Speed. Warming On Wire Is Done Through Current Which Is Provided Through Associating Both Hot Wires Ends Of An Electric Supply. Foam Built With 30% Of Material Is Made Up Of 3D Print.

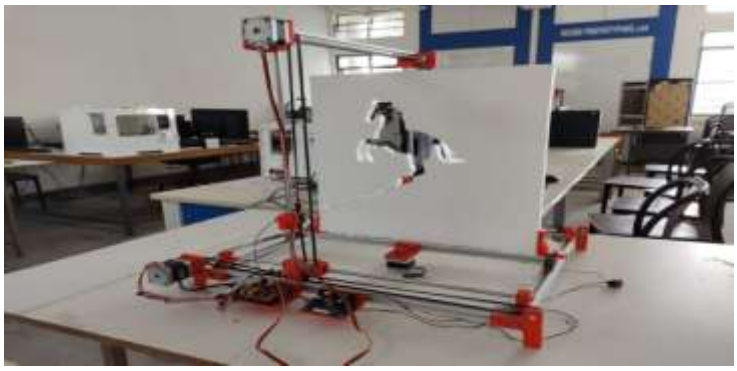

Fig. 2. Foam Cutting Build.

The Wire Tensioning System Consists Of A Nickel-Chromium Wire Tensioned Through Loads Dropped Toward The Single Side Of Wires. The Principle Loads Of 500g Are Utilized To Pressure The Wire Side. The Foam Taking Care Of Part Comprised Of A Square Thread Screw Of 6 Mm Pitch Has Combined With Stepper Motor Of Nema 23 Modal Is Driven Through An Embedded System By Arduino Mega Model 2560 Placed Pulse Width Modulation Signals Helped On A Stepper Motor Regulator 12-Volt Force Supply. Foam Parts Placed On Stage Are Associated With A Rotating Threaded Screw. Current Is Provided Wire Through Double Direct Current Supply. A Computerized Thermocouple Thermometer Was Utilized To Quantify The Temperature Of Wires. As Cutter Temperature Is Required To Estimated The Thermal Element, The Hub Is Placed At A Wire 5 Mm Off Cutter[5].

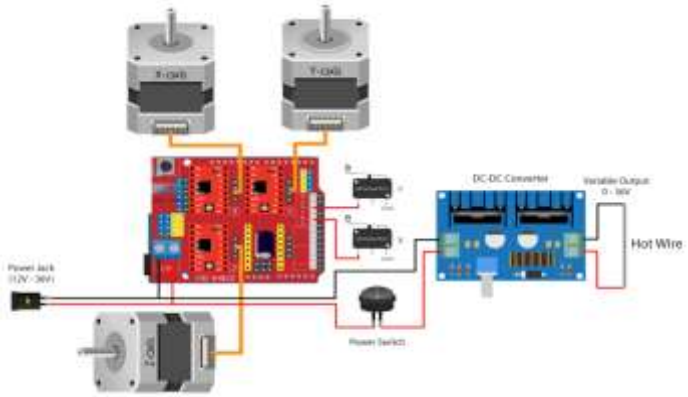

Fig. 3. Working Diagram.

The Stress On The Wire Is Dictated To The Quantity Of Grade Loads Utilized. Seat High Force Supply Is Utilized To Quantify, Manage A Current Inventory And Hot Wire. Feed Rate Is Calculated By The Step Counts On Motors And Screw Drives Pitch. Analysis Completed Utilizing Double Nickel-Chromium Wires On The Widths 0.6 Mm And 0.32 Mm. Commonly, Wire Widths 0.2 Mm To 0.5 Mm Is Advantageous On Hot Wire Foam Cutters[9].

3.3 Foam Cutter Sample

The Analysis Was Utilizing Foam, From The Utilized In Art Work. The Density Of An Example Is 1.04 G/Cm3. Melting Point Is 239^{o}c, Warm Conductivity Is 0.0334 W/ (M K).

3.4 Difference Of Temperature Through Current

At A Point When Current Is Tried On Wire And This Warms Up, It Goes On Steady Temperature Following The Specific Measure Of A Times. The Steady Temperature Is Estimated As Various Current Capacities. This Is Complete Before Removing Interaction To Discover A Current Worth Of Obtaining A Specific Temperature Value. That Examination Is Done Through Nickel-Chromium Wire With Diameter Across 0.6 Mm And 0.32 Mm. The Wire Is Frequently Accessible. The Diameter Of Wire Ranges 0.2 Mm To 0.5 Mm Are Advantageous To Hot Wire Foam Cutters. 0.6 Mm Distance Across Wire Would Stand With Higherpressures Than Reach To 0.32 Mm Wire Also, 0.6 Mm Wire Is Utilized For The Test Since Wire Listing Would Be Effortlessly Kept Away From With That[10].

Table1. Difference Between Wire Temperature And Current On 0.32 Mm.

Current In Amps	Wire Temperature In ^{0}C
0.5	41
1.0	86
1.4	172
2.0	253
2.2	251
2.4	351
2.6	332
2.8	372
3.0	425

Table 2. Difference Between Wire Temperature And Current On 0.6 Mm Wire.

Current In Amps	Wire Temperature In ^{0}C
0.5	28
1.0	45
1.5	65
2.0	98
2.5	125
2.6	137
2.8	148
3.0	158

(See Fig. 4). Represents The Variety On Wire Temperature On Double Wire, When It Provides Current Changes. Wire Temperature Parallel Increases The Time. Temperature Of 0.32 Mm Wire Increases Quicker Than 0.6 Mm Wire. This Unique Warm Cutter, The Wire Has To Be Warmed Above 300^{0}C. (See Fig. 4). Portrays The 0.32 Mm Distance Across Wire Would Reach The Temperature Through Less Measure Of A Current[10].

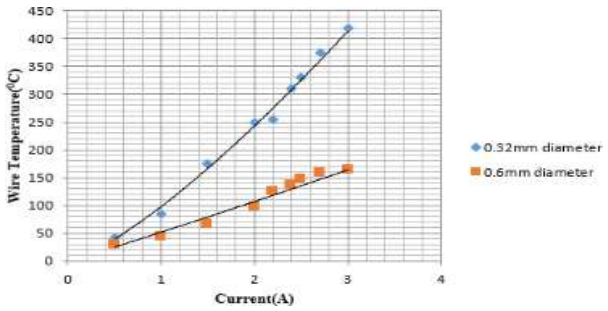

Fig. 4. Wire Temperature Vs Current.

3.5 Difference Of Temperature With Time

0.32 Mm Wire Diameter As Utilized In This Test. Current Is Provided By The Wire And Temperature Is Estimated Until The Goes On Steady Temperature Esteem. No Cutter Would Be Performed When Taking Its Readings Appeared On (See Table 3).

Table 3. Wire Temperature Vs Time.

Time(S)	Wire Tempera-ture(^{O}c)	Time(S)	Wire Temperature(^{O}c)
0	25	11	284
1	29	12	292
2	43	13	298
3	68	14	303
4	112	15	305
5	161	16	309
6	185	17	312
7	204	18	313
8	230	19	314
9	254	20	311
10	278		

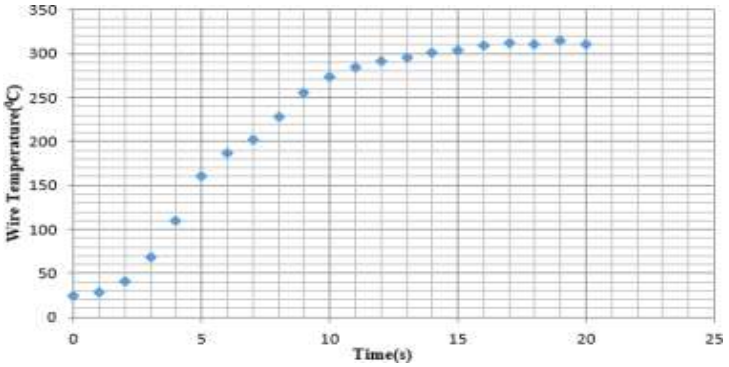

Fig. 5. Difference Between Temperature In Wire And Time Taken No.Of. Cutter Is Carried Out.

(See Fig. 5) Shows A Variety Of Wire Temperature And The Time When The Cutter Isn't Finished. Fist The Wire Temperature Increases Progressively. At That Point It Spans To A

Steady Value

3.6 Difference Between Temperature And During Cutting Process Time

Part Of Analysis Is Carried Out By A Distinctly Unique Thermal Cutter. To Accomplish A Unique Thermal Cutter, The Wire Needs To Be Warmed More Than 300^0 C. Along These Lines Above 2.5Amps Current Needs To Be Put On Wire Need Get Temperature As Indicated By The Result Is Part A Of Analysis. 2.5Amps Current Is Put On Wire And The Cutter Is Begun Then Wires Have Gone To Steady Temperature. Temperatures Between The Time In (See Table 4) Are Recorded While The Cutter Is Finished[10].

Table 4. Difference Between Temperature In Wire Versus During Cutting Process Time.

Time(S)	Wire Temperature(^{O}c)	Time(S)	Wire Temperature(^{O}c)
0	315	11	284
1	318	12	286
2	305	13	281
3	304	14	293
4	307	15	291
5	301	16	268
6	298	17	274
7	294	18	272
8	287	19	270
9	281	20	274
10	277	21	278

(See Fig. 6) Shows The Variety On Wire Temperature And Time When Cutter Is Carried Out. Toward Starting Wire Temperature Is Greatest, There Is No Heat Transfer[8]. It Burns-Through The Brief Period Of The Temperature Of Wire To Arrive At A Consistent State. To Get Similar Properties, The Exactness In The Item Needs To Be Cut Than The Stable Cutter Situations And Steady Temperature Is Shown Below[11].

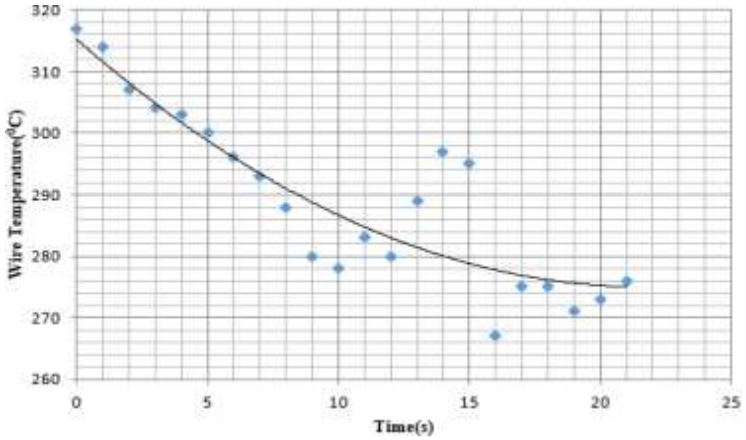

Fig. 6. Temperature On Wire Versus During Cutting Process Time.

3.7 Difference Between Temperature And Cutting Distance

Part Of Analysis Is Performed Distinctly To Unique Thermal Cutters. In This Way 2.5Amps

Current Is Put In To Wire, Cutter Begins After Wire Has To Come On At Steady Temperature. Temperatures On Various Places Of The Cutter Way Are Stored.

Table 5. Difference Between Wire Temperature And Cutting Distance.

Cutting Distance In Cm	Wire Temperature In ^{0}C
0	312
1	310
2	304
3	296
4	296
5	281
6	283
7	292
8	275
9	265
10	278

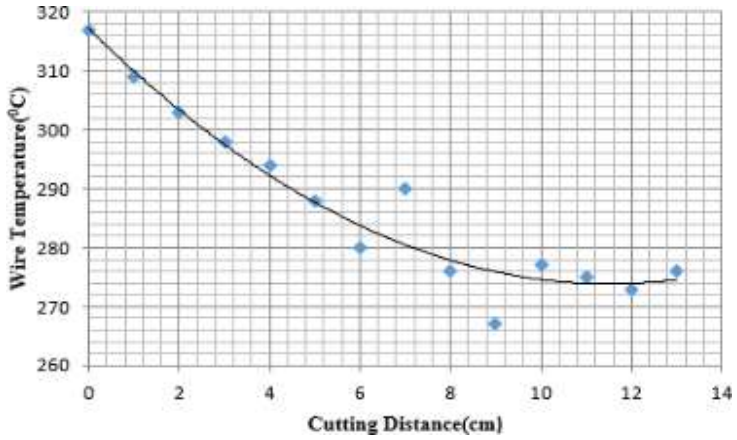

Fig. 7. Difference Between Wire Temperature And Cutting Distance.

(See Fig. 7), A Variety Of Wire Temperatures With Cutter Distance Has Appeared. The Higher Value Cutter Temperature Is Toward The Start Of Cutter Interaction. The Cutter Distance Of Temperature Lessens And Goes To A Steady Value. To Get Similar Properties, The Exactness In An Item Needs To Be Cut After Stable Cutter Situations. In This Manner Several Pieces Of Foam Material Must Be Cut Before Cutter Interaction Of Necessary Parts[11].

3.8 Difference Between On Kerf Width And Current

Kerf Width On Hole Between Foam, That Is Isolated Through Cut. At Point When Temperature In Wire Shifts, Kerf Width Of Cut Fluctuates. The Tests Are Cutter Utilizing Diverse Current Qualities. The Feed Rate Is Kept Steady At The Speed Of 21.10mm/S. At That Point Kerf Widths Of Examples Are Measured.

Table 6. Difference Between Kerf Width Versus Current.

Current In Amps	Initial Temperature In ^{0}C	Kerf Width In Mm
1.5	178	0.320
1.8	215	0.335
2.0	249	0.415
2.2	253	0.669
2.4	305	1.195
2.6	329	1.535
2.8	370	1.590
3.0	415	1.802

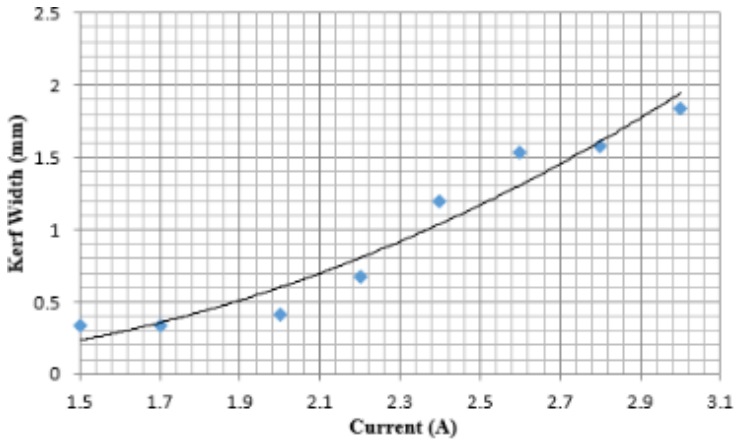

Fig. 8. Difference Between Kerf Width Versus Current.

As Indicated By The Chart Appearing In (See Fig. 8). Kerf Width Increases On Current. At Point Current Expands, That Heat Produced From Hot Wire Increments, More Material From Foam Disintegrates Making More Extensive Kerfs.

3.9 Difference Between Kerf Width And Feed Rate

At The Point The Feed Rate Changes, Measure Of Hot Disseminated To Foam Element Fluctuates. Changes In Measure Of Element Vaporization On Foam Making Distinctive Kerf Width. Analysis Is Done By Applying A Steady Current On 2.1Amps On Cutter Wire. Foam Is Cut Utilizing Diverse Feed Rate, The Kerf Width Is Estimated. It May Very Well Be Presumed In Low Feed Rate, Kerf Width Is Enormous. Kerf Width Diminishes When Feed Raterises.In Low Cutter Rates, And A Lot Of Time To Disperse Heat To Disintegrate Foam. (See Fig. 9). Illustrates Variations Of Kerf Width On Feed Rate.

Table 7. Difference Between Kerf Width Versus Feed Rate.

Feed Rate In Mm/S	Kerf Width In Mm
7.24	2.51
9.31	1.59
11.39	1.59
12.54	1.25
13.52	0.99
15.61	0.95
18.55	0.90
20.47	0.82

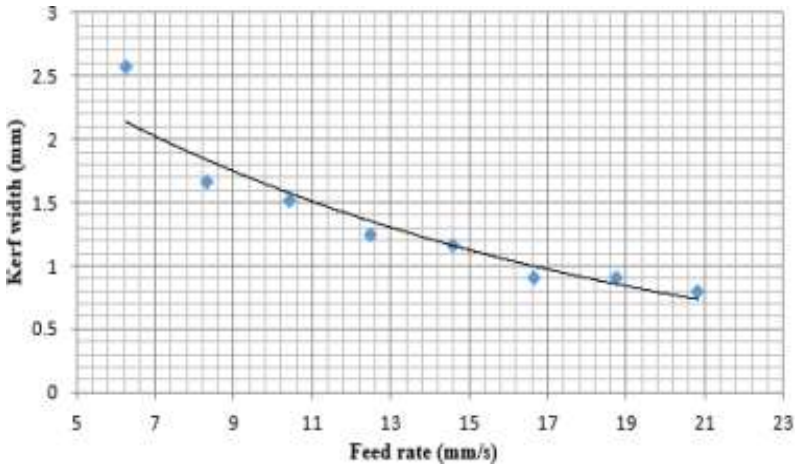

Fig. 9. Difference Between Kerf Width Versus Feed Rate.

The Examination Demonstrated Of Higher Temperatures Would Be Accomplished Proficiently Utilizing Wires Of More Modest Distances Across. 0.6 Mm Diameter Of Wire Necessary To Higher Current That Achieves Higher Temperature. Wires With A Less Diameter Are Highly Appropriate To Unique Thermal Cutters[5].

The Cutter Temperature Versus Time Chart Appear That How Much Time Has Taken To Arrive At A Consistent Temperature On Wire Before Cutter Begins. Base Opportunity To Arrive At A Stable Temperature Would Be Distinguished. Similar Measures Of Foam Must Be Cut Prior To Going To The Necessary Parts To Get Steady Cuts With Uniform Properties. The 3D Chart Of Kerf Width For Cutter Temperature And Feed Rate Are Plotted On Investigate These Connections Between Feed Rate Versus Temperature Acquire 1 Mm Kerf. That Appears In (See Fig. 10).

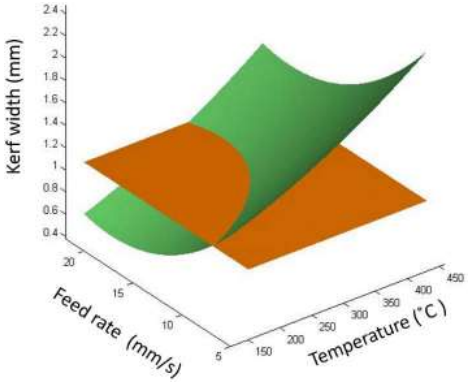

Fig. 10. Difference Between Of Kerf Width Versus Respect To Temperature On Feed Rate.

That Convergence Of Plot Through 1 Mm Kerf Width On Plane Is Projected On XY Plane On Track Down A Controlling Form On Wire Cutter.

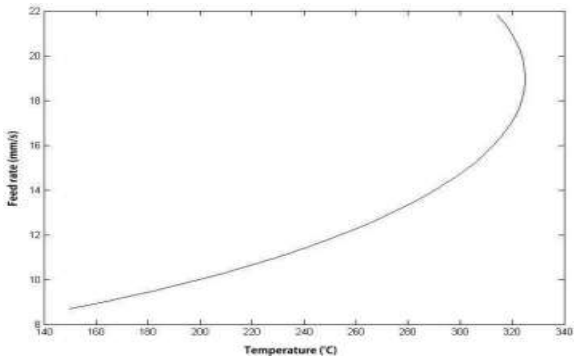

Fig.11. It Shows On Temperature Of Projected Contour Versus Feed Rate Plane Of 1mm On Kerfwidth.

This Projected Shape Appeared In (See Fig.11), Feed Rate Control By Capacity To Earn A 1mm Kerf Width Is Distinguished,

F(X)=0.00056 X2 - 0.1617x + 23.7694 (X = Temperature, Then F (X) = Feed Rate)

The Control Situation Necessary Feed Rates Are Directly Relative To Temperatures Below 200^{o}c. Past Outcomes Upgraded The Unadulterated Warm Cutter Isn't Apply On Higher Temperature Range With An Undeniable Degree Of Dynamic Control Of The Boundaries Are Required. Interestingly, The Temperature Ranges Between 300^{o}c-320^{o}c Gives A High Adaptable Scope On Feed Rates (14-26 Mm/S). The Plan Of Mathematically Controlling Machines Ought To Be Viable To The Above Cutter Attributes.

4. CONCLUSION

The Arduino CNC Foam Cutter Machine Is An Effective Method To Prepare Foam Moulds Of Multiple Shapes. It Is Seen That The Hot Wire Is Thin And Has High Durability. By Using The Computer Numerical Method, We Can Adjust The Speed Of The Machine With Different Feed Rates As Per The Industry. The Drive Mechanism For Controlling The Axis Can Be Selected By Selecting The Motors For Providing Appropriate Feed. For Completing The Project Preliminary Study Plays A Major Role In Controlling High Reliability With Accuracy.

Acknowledgment
The Work Was Supported In Part By The Bannari Amman Institute Of Technology. Authors Are Thankful To Micro Prototyping Special Lab For Providing The Commercial Software And Hardware For This Study.

5. REFERENCES

[1] A. Toktaş And G. Toktaş, "Effect Of Welding Parameters And Aging Process On The Mechanical Properties Of Friction Stir-Welded 6063-T4 Al Alloy," J. Mater. Eng. Perform., Vol. 21, No. 6, Pp. 936–945, 2012)
[2] J. Røyset, U. Tundal, And O. Reiso, "Comparison Of Properties Of Extruded 6xxx Alloys In T5 Temper Versus T6 Temper," Mater. Forum, Vol. 28, Pp. 300–304,

(2004).
[3] M. Jouaneh, A. Hammad, And P. Datseris, "A Flexible Automated Foam Cutting System," Int. J. Mach. Tools Manuf., Vol. 37, No. 4, Pp. 437–449, (1997).
[4] Louis, "Working Principle Of Arduino And Using It As A Tool For Study And Research," Int. J. Control. Autom. Commun. Syst., Vol. 1, No. 2, Pp. 21–29, (2016).
[5] S. H. Lee, D. G. Ahn, And D. Y. Yang, "Calculation And Verification Of Rotation Angle Of A Four-Axis Hotwire Cutter For Transfer-Type Variable Lamination Manufacturing Using Expandable Polystyrene Foam," Int. J. Adv. Manuf. Technol., Vol. 22, No. 3–4, Pp. 175–183, (2003).
[6] B. Ahmed, "Design And Analysis Mini CNC Plotter Machine," (2018).
[7] S. S. Sarguroh And A. B. Rane, "Using GRBL-Arduino-Based Controller To Run A Two-Axis Computerized Numerical Control Machine," 2018 Int. Conf. Smart City Emerg. Technol. ICSCET (2018).
[8] H. Brooks And D. Aitchison, "Foam Cutting Mechanics For Rapid Prototyping And Manufacturing Purposes," 9th Natl. Conf. Rapid Des. Prototyp. Manuf., No. March, 2008.
[9] D. Aitchison, H. Brooks, J. Bain, And D. Pons, "An Investigation Into The Prediction Of Optimal Machining Conditions For Polystyrene Foam Cut With A Taut Hot-Wire," Newtech 2009, Galati, No. September, Pp. 19–24, (2009).
[10] A. Abeysinghe, S. Abeysiriwardena, R. Nanayakkarawasam, W. Wimalsiri, T. D. Lalitharatne, And S. Tennakoon, "Development Of A Numerically Controlled Hot Wire Foam Cutting Machine For Wing Mould Construction," 2nd Int. Moratuwa Eng. Res. Conf. Mercon 2016, Pp. 60–65, (2016).
[11] H. L. Brooks And D. R. Aitchison, "Force Feedback Temperature Control For Hot-Tool Plastic Foam Cutting," Proc. Inst. Mech. Eng. Part B J. Eng. Manuf., Vol. 224, No. 5, Pp. 709–719, (2010).