DESIGN AND FABRICATION OF SINGLE POINT INCREMENTAL SHEET FORMING MACHINE

by

18-ME-023 SAAD NAEEM BABAR
18-ME-147 ASFAND YAR KHAN
18-ME-191 MUNEEB UL AHSAN
18-ME-195 MUHAMMAD AREEB

Project Supervisor

Dr. ZARAK KHAN (Assistant Professor)

Project Co-Supervisor

ZEESHAN SIDDIQUE (Lecturer)

MECHANICAL ENGINEERING DEPARTMENT
HITEC UNIVERSITY, TAXILA

July 2022

DESIGN AND FABRICATION OF SINGLE POINT INCREMENTAL SHEET FORMING MACHINE

FINAL YEAR PROJECT REPORT

SESSION 2018

THESIS IS SUBMITTED TO THE FACULTY OF THE DEPARTMENT OF MECHANICAL ENGINEERING, HITEC UNIVERSITY, TAXILA IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF BACHELOR’S OF SCIENCE IN MECHANICAL ENGINEERING

DEPARTMENT OF MECHANICAL

ENGINEERING

DESIGN AND FABRICATION OF SINGLE POINT INCREMENTAL SHEET FORMING MACHINE

Submitted by

18-ME-023 SAAD NAEEM BABAR
18-ME-147 ASFAND YAR KHAN
18-ME-191 MUNEEB UL AHSAN
18-ME-195 MUHAMMAD AREEB

Project Co-Supervisor

____

Mr. Zeeshan Siddique (Lecturer)

Project Supervisor

____

Dr. Zarak Khan

(Assistant Professor)

Head of Department

____

Dr. Liaquat Ali

(Professor & Chairman)

Certification

This is to certify that **Muhammad Areeb, 18-ME-195, Muneeb Ul Ahsan, 18-ME-195, Asfand Yar Khan, 18-ME-147 and Saad Naeem Babar, 18-ME-023** have successfully completed the final project **Design and Manufacturing of Single Point Incremental Sheet Forming Machine** at the **HITEC University Taxila**, to fulfil the partial requirement of the degree **BSc Mechanical Engineering.**

Project Supervisor

Dr. Zarak Khan

Assistant Professor

Chairman

Dr. Liaquat Ali

Department of Mechanical Engineering, HITEC University.

DESIGN AND MANUFACTURING OF INCREMENTAL SHEET FORMING MACHINE

Sustainable Development Goals

(Please tick the relevant SDG(s) linked with FYDP)

SDG No	Description of SDG	SDG No	Description of SDG
SDG 1	No Poverty	**SDG 9** ✓	Industry, Innovation, and Infrastructure
SDG 2	Zero Hunger	SDG 10	Reduced Inequalities
SDG 3	Good Health and Well Being	SDG 11	Sustainable Cities and Communities
SDG 4	Quality Education	SDG 12	Responsible Consumption and Production
SDG 5	Gender Equality	SDG 13	Climate Change
SDG 6	Clean Water and Sanitation	SDG 14	Life Below Water
SDG 7	Affordable and Clean Energy	SDG 15	Life on Land
SDG 8	Decent Work and Economic Growth	SDG 16	Peace, Justice and Strong Institutions
		SDG 17	Partnerships for the Goals

DEDICATION:

We dedicate this thesis to Almighty Allah our maker, our wellspring of inspiration, insight, information and understanding. He has the wellspring of motivation all through this undertaking. We likewise commit this venture to our folks who have empowered us all way and their support made us sure to give everything and finish all our work what we have begun and it is conceivable simply because of their prayers and our hard work.

Acknowledgement:

This BS thesis in Mechanical Engineering was finished as a part of the degree program at HITEC University's Department of Mechanical Engineering, Faculty of Engineering and Technology. We want to offer our thanks to Dr. Zarak Khan for permitting us to chip away at this venture under his supervision and direction. We'd likewise prefer to offer our thanks to Engr. Zeeshan Saddique for his help, endeavors, and ceaseless consolation all through the project. We are additionally thankful to Allah and our folks and siblings, who have consistently helped and energized us all through our tasks and studies at HITEC University.

Abstract:

Incremental sheet forming (ISF) processes like single-point incremental forming (SPIF) have been significantly contemplated starting from the start of the 2000s. Other than the applications in the prototyping field, ISF cycles can likewise be utilized in the production of one-of-a-kind parts and little clumps. This ability prompted new business prospects, empowering the advancement of select or custom items. In spite of being a freestyle fabricate process, ISF has a few mathematical limits, essentially because of the shaping mechanics also, formability cutoff of the materials. In this manner, it is essential to lay out distinct rules to give a plausible plan. This paper presents an information premise to plan also, produce ISF parts, primarily by SPIF. The conceivable part arrangements and the plan direction are settled, considering a reasonable part improvement. The equipment to perform gradual shaping activities is framed and the framing process is depicted, introducing elective arrangements. The cycle displaying is finished with a brief depiction of techniques to work on part quality. The ISF process is used to gradually form a sheet to its desired shape and in this process a ball tip tool follows a tool path. The sheet which is to be formed is clamped from the edges and the material is deformed by a localized process. Also, in ISF there is no consequence of state of strain as it is accepted that in this process no pure stretch or pure sheer happens. The tool motion is controlled by computer numerical control (CNC) machines. While this process has gone through reasonable developments in recent years, so manufacturers may benefit themselves from clear design rules to assist the process of designing and to implement single point incremental forming.

Undertaking

I certify that the project **Design and Manufacturing of Single Point Incremental Sheet Forming Machine** is our own work. The work has not, in whole or in part, been presented elsewhere for assessment. Where material has been used from other sources it has been properly acknowledged/ referred.

Muhammad Areeb

18-ME-195

Muneeb Ul Ahsan

18-ME-191

Asfand Yar Khan

18-ME-147

Saad Naeem Babar

18-ME-023

TABLE OF FIGURES

LIST OF TABLES

EQUATION TABLE

Contents

CHAPTER ONE

INTRODUCTION

STATEMENT

Single-point gradual framing (SPIF) is a versatile sheet metal molding procedure wherein parts are formed by the development of a little gadget moving in a progression of passes around the outside edge of the sheet. SPIF is significant for a wide class of sheet metal molding procedures insinuated as veered off consistent sheet forming, which are depicted by Jeswiet et al.1 and Hagan and Jeswiet.2

COMPUTER NUMERICALLY CONTROLLED MACHINE:

A further advantage of SPIF is that the execution inside a PC numerical control (CNC) plant grants standard machining undertakings to be performed on the part despite forming exercises. While there has been a ton of discussion of SPIF as an important custom collecting process, somewhat number of end-client arranged applications have been recorded. A part of the models made by SPIF have consolidated a daylight-based cooker,3 auto components,1 a patient-unequivocal lower leg support4 and a cranial embed. For any collaboration to be for the most part embraced, one ought to be prepared to clearly pass on to the end-clients the abilities and obstructions.

To achieve this, direct arrangement chooses are presented that clearly give the mathematical constraints of SPIF. These standards were then used to make a movement of parts for various clients really. Much investigation has been done to depict the outlining limits of SPIF to choose early in the event that a section can be really outlined. Most often the portrayal of molding endpoints is done by making shaping cutoff curves,6-8 which can then be used in restricted part diversions to choose prior to outlining in the event that a section outperforms the most outrageous permissible strain. For a really long time, it has been realized that significantly greater strains can be achieved than in conventional sheet forming.9-14 For this clarification, it has been recommended that SPIF uses the crack shaping breaking point bend (FFLC) to address outlining limits rather than a customary outlining limit twist. The justification for this development in formability is the issue of some conversation, for specific makers stating it is a result of through-thickness shear,15,16 while others ensure that it is a direct result of constraint of strain around the outlining locale, achieving covering of neck game plan and lower totaled damage.11,17 In a prototyping environment, nevertheless, a more straightforward procedure for deciding part shape hindrances is attractive, as restricted part entertainment can be exorbitant, dreary and requires critical fitness.

INSPIRATION:

Regardless of its noteworthy roots, it's miles handiest in the last numerous years that the use and abilities of ISF have developed eminently. This can be ascribed to two essential components. Propels in assembling age, particularly the improvement of PC mathematically, right off the bat, controlled (CNC) hardware, has empowered what is generally an expert specialty to be done with some degree of mechanization. Furthermore, a developing side interest in customization has achieved an inspiration for developing framing strategies which don't need specific tooling. Tooling can be restrictively exorbitant while considering little bunch sizes or unique cases.

FLEXIBILITY:

The need for adaptability of the strategy to permit the largest reasonable scope of items to be molded enjoys set off a developing leisure activity in one exact variety of ISF: lopsided gradual sheet framing. As such a pc mathematically made due (CNC) indenter activities over the floor of a sheet of metallic along a lopsided course, for the most part of shapes or a twisting of plummeting profundity, characterizing the type of the item. Thus a different assortment of topsy-turvy product might be molded without specific tooling by moving the gadget close by a suitably planned way. The expression 'gradual sheet shaping' has thus as of now come to be generally emphatically connected with uneven CNC steady sheet framing procedures, and will take this importance throughout the unwinding of this postulation.

Scholarly and business interest in ISF has developed eminently during the last ten years, with specific leisure activity in Japan, Europe and Canada. Research has zeroed in on 3 principal locales: improvement of tooling and techniques for device way plan to permit a lot more extensive scope of product to be molded to a higher excellent; aspect of the effect of cycle plan factors on framework capacities; and examination of the cycle mechanics through mathematical recreation and size of gadget powers. A data of the misshapen Ing system is major to permitting right mathematical models of the technique to be progressed for apparatus course plan and way control, and to grow a comprehension of the raised shaping cutoff points found in ISF in contrast with squeezing. In spite of boundless examinations, the mechanics of the way aren't well perceived; results are compelled and have now not been totally upheld with the guide of trial confirmation. Moreover, research at the mechanics of ISF has zeroed in on least complex one association of substances: sheet metals. The pertinence of the framework to elective enterprises of substances, comprehensive of composite sandwich boards, and the connected deformity mechanics, isn't as expected comprehended 100% of the time.

CHAPTER 2

LITERATURE REVIEW

TECHNIQUE

The least difficult state of ISF is single-point gradual shaping (SPIF) (Fig. 1a), where a sheet of steel is braced unbendingly around its edges and framed on one surface by a solitary indenter. This can be in contrast with a customary profound drawing strategy wherein a spotless holder allows in a sheet of steel to be drawn between a male and female pass on set which frame the whole state of the item, as represented in Fig

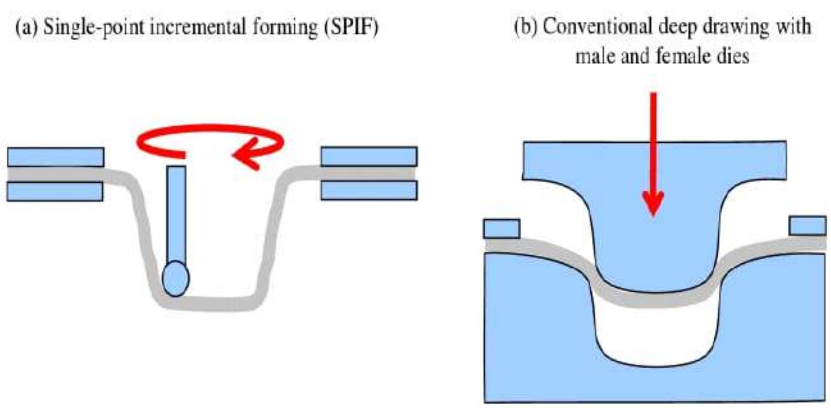


Figure 1 comparison of SPIF and Deep

RESEARCH ON ISF:

Scholarly and business leisure activity in ISF has developed definitely during the last ten years, with exact side interest in Japan, Europe and Canada. Research has zeroed in on 3 most significant regions: improvement of tooling and strategies for device heading design to empower a lot more extensive scope of product to be framed to a higher phenomenal; size of the impact of strategy format factors on way capacities; and examination of the way mechanics through mathematical reproduction and size of hardware powers. A skill of the misshapening component is fundamental to permitting right mathematical models of the cycle to be produced for gadget course plan and strategy control, and to extend a mastery of the raised shaping cutoff points found in ISF in assessment to critical. Regardless of broad exploration, the mechanics of the technique aren't as expected comprehended; impacts are confined and highlight not been totally upheld by utilizing exploratory check. Besides, research at the mechanics of ISF has zeroed in on best one gathering of substances: sheet metals. The pertinence of the method to elective organizations of materials, which incorporate composite sandwich boards, and the related disfigurement mechanics, isn't as expected comprehended. The expectation of this postulation is subsequently to give new experiences into the disfigurement mechanics of ISF did to 2 organizations of substances: sheet metals and sandwich boards.

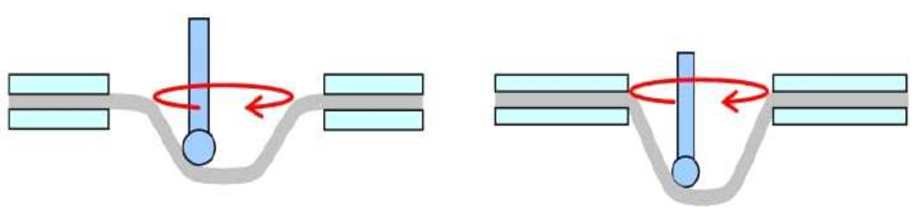
Research in ISF has been planned in 4 past audits throughout the course of recent years. Shima completed the essential audit of the country of the specialty of ISF in 2001, which depicts the central adaptations in framework and exploratory set-up alongside surprising advancements which incorporate steady miniature shaping. A second survey of the field changed into given through Hagan and Jeswiet in 2003. This outline covers a few fundamental outcomes for turning and shear framing, notwithstanding stylish lopsided ISF techniques. In 2005 a more extensive evaluation of ISF was provided through Jeswiet , which got commitments from the heads of the key European and Canadian examinations organizations. This covered framework arrangements, gadget way format systems and the essential outcomes in expressions of exactness, shaping cutoff points and surface completion. Be that as it may, the outline especially centered around advancement in Europe and Canada; numerous original upgrades of ISF created in Japan have been presently not surveyed, plausible because of the reality Japanese work is much of the time distributed in the Japanese language. In 2006, Allwood and Autonomy gave the principal survey of bendy metallic framing upgrades in Japan, beginning from expulsion of bar, shaping of cylinders, bendy rolling and revolving sheet framing techniques. In a connected field, an outline of turning, shear framing and float shaping techniques through Wong transformed into written in 2003. This gives a top to bottom record of the advancement and key results of revolving sheet framing draws near, some of which, alongside the improvement of the 'sine guideline', is immediately material to explore in ISF. The evaluation provided on this part will build on the first surveys through providing a spic and span examination of cutting-edge writing from around the globe

GEAR AND METHODS OF IMPLEMENTATION OF ISF:

The framework utilized for ISF incorporates 3 principal parts: the workpiece help and setup of indenters; the apparatus for utilizing the indenter; and the plan of the indenter itself. A various scope of plans of each of the three of those parts have been investigated with the last goal of making an interaction that is completely bendy and ready to shaping the most extensive suitable assortment of calculations. The manner by which this framework is utilized might be characterized by utilizing the way execution framework, from item format to finished item.

WORK PIECE SUPPORT AND INTENDER CONFIGURATION:

The most to be expected kinds of ISF are called unmarried element gradual shaping (SPIF) and two-factor steady framing (TPIF), as characterized through Jeswiet et Inolves framing a braced workpiece with a solitary versatile indenter. The brace can both be a standard structure this is enormous than the edge of the molded component (Fig. 2a) or can uphold the border of the formed component (Fig. 2b). The principal design enjoys the benefit of being the least complex totally bendy technique for ISF requiring no item specific tooling, but the downside of considering gigantic mathematical mix-ups in light of the workpiece being to a great extent unsupported. This procedure is regularly utilized for items with surprising or interestingly framed edges, for example a lower leg guide via Ambrogio and a cranial embed through Duflou et . The second arrangement (Fig. 2b) has the advantage of compelling misshaping out of entryways the border of the gadget way anyway the downside of requiring a clasp this is remarkable to the edge of the item. This is more noteworthy typically utilized wherein the edge of the item is a simple shape. For example, Duflou et utilized a round edge to help cones that have been shaped by means of SPIF, while Jeswiet et utilized a rectangular casing to help the edge of a sun cooker molded by utilizing SPIF. In each SPIF setups, it's miles least complex feasible to shape curved calculations with no re-contestant highlights.



a) Clamp larger than perimeter of tool path   b) Clamp supports perimeter of tool path

Figure 2 . Single point Incremental sheet forming (SPIF)

A scope of chance and less typical plans of ISF have been developed for specific projects. A strategy uniquely for framing spines, alluded to as kick the bucket less rib shaping, was created through Powell and Andrew on the University of Cambridge in 1992. This includes making rehashed passes among rollers to make a rib around the edge of a sheet of metal. Potential applications were perceived as airframes, structural parts and concentrated vehicle parts. Adaptable strategies have been progressed for shaping sheets with gentle bend without specific tooling.

In 1999 Tanaka fostered a cycle where a sheet of metal is bended by more than once squeezing among upper and lower versatile devices while deciphering sideways between punches. A comparative cycle for bending sheet metal in two headings was created by Yoon and Yang in 2001 ,where the flexible device was supplanted with a punch set comprising of four unbending lower support punches and one upper focal punch. In 2003 Yoon and Yang created steady roll shaping for bending unsupported sheets in two headings, where the unbending punch set was supplanted by a bunch of rollers which permitted the sheet to stay in consistent contact with the device, in this manner diminishing the cycle time. A further particular improvement of ISF is gradual shaping of foils for a tiny scope, showed by Saotome and Okamoto in 2001. Potential applications incorporate miniature electro-mechanical framework parts and miniature gadgets. For trial assessment of 2D improved on FE models, Muresan fostered an instrument and clear holder which permits roughly plane strain framing. A flat round and hollow device shape the workpiece by moving in reverse and advances against a positive pass on.

Cinching of the workpiece in each SPIF and TPIF has quite often concerned the use of a ceaseless casing to brace round the edge of the workpiece unbendingly.

Fig. 3 ISF hardware.
a Clamping system.
b Forming tools

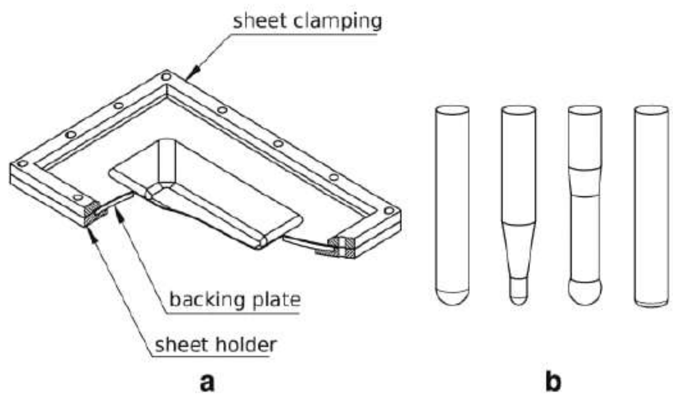


Figure 3 Clamping of the workpiece and different forming tools

ISF PART DESIGN:

One of the proposed utilizes for ISF is the assembling of specific components or little cluster producing. Concerning each and every other creation way, it's miles critical to design the parts in accordance with the technique limits, giving the part attainability. Studies were looking at outstanding materials and calculations, with genuinely instructive pyramids and frustums (consistent different wall point parts) and with a couple of cases concentrate on errands to approve the thought. One of the essential strides inside the part design is the fabric determination, as well as the meaning of the underlying thickness. The determination of material and thickness should consider the ideal mechanical way of behaving for the molded part as well as the resulting limitations concerning the mathematical capacities deterrents. Despite the fact that ISF techniques are better ideally suited for exorbitant formability materials, SPIF works with the two metals and plastics sheet substances. Table 1 synopses some of the most utilized materials and thicknesses. In what concerns the part calculation, a couple of contemplations should be followed inside the plan. While outstanding part setups are feasible, permitting noteworthy adaptability to a given shape, the procedure is described by a small bunch of obliges that should be followed while planning a component. It is critical to take note of that the ISF parts are done with various emphasize systems as managing, surface finishing, welding and others. Hence, the proposed tips for ISF should be viewed as joined to emphasize techniques limitations. One of the most basic issues connects with the shaping disposition. A few creators have tried most shaping plots for uncommon substances and thicknesses, with unmistakable working boundaries. Allwood have summed up a portion of the accomplishments. Regular blend plots for aluminum allows in fluctuate round 70 ∘ , for steel combinations round 60 ∘ and for a couple of thermoplastics round eighty ∘ . This charge increments with thicker sheets and is additionally supported with the guide of the framing boundaries. Table 2 sums up a few standard points reachable in a solitary stage framing activity.

Table 1 Materials and thickness used in ISF operation

Material	Alloy	Thickness
Aluminium	1xxx	0.5 to 3.0 mm
	3xxx	0.5 to 3.0 mm
	5xxx	0.5 to 3.0 mm
Steel	low carbon	0.5 to 2.0 mm
	DPxxxx	0.5 to 1.5 mm
Brass	–	0.5 to 1.5 mm
Cooper	–	0.5 to 1.5 mm
Titanium	grade 2	0.5 to 1.5 mm
PE	–	1.0 to 5.0 mm
PA	–	1.0 to 5.0 mm

Table 1 material and thickness used in ISF operation

Table 2 Maximum forming angles in a single-stage SPIF operation

Alloy	Thickness	α_{max}
AA 1050-O	1.5 mm	76°
AA 3003-O	1.2 mm	71°
AA 3003-O	2.1 mm	78°
DP600 steel	1.0 mm	68°
Polyethylene	3.0 mm	81°

Table 2 Maximum forming angle sin SPIF

PART CONFIGURATION:

As alluded to, various shape arrangements are doable to frame utilizing SPIF and other ISF procedures. Figure 4 addresses some of the most applicable conceivable part designs. Most parts fabricated through SPIF comprise on an unmarried or two or three field type shapes. The part calculation emerges from a level plate with a wall point among 0 ∘ and αmax from the edge to the middle (Fig. 4a). A crate shape can both characterize a full wanted shape or can be the outcome of the floor expansion however much the level clear plane or the expansion of addendum surfaces. The crate type part arrangement closes in the most extreme expense strong split the difference among part good and way time and inconvenience in greatest cases. In spite of the suggestion to configuration parts without changes in arch, the ISF techniques license to obtain better muddled parts, with two or more noteworthy changes in curve (Fig. 4b). A turn of the formed part is needed all through the SPIF framework, requiring another set up. Different varieties of ISF procedure like TPIF or DPIF might be better ideally suited for this component setup. At times, a utilization of a simple fractional bite the dust, very much like a sponsorship plate is sufficient to allow a generally excellent assembling of part with more than one changes in bend. One more option of ISF approaches is to shape free shape spines close by components (Fig. 4c). Both inward and external ribs might be formed. ISF is pleasantly relevant for bend ribs, as other regular procedures are higher proper for straightforwardly line spines. The standard most extreme shaping viewpoint for a rib is more noteworthy than in field kind parts. Aside from the introduced designs, it's far conceivable to do ISF tasks without a full brace of the clear sheet. By leaving a couple of free perspectives, it is practical to accomplish passage and semi-burrow kind parts (Fig. 4d, e). The decide outlines a basic quickly line bowed anyway the framework allows in to give freestyle components. Passage and semi-burrow parts are broadly utilized in unmistakable product and applications. The utilization of passage or semi-burrow part design helps the valuable region of the part, bringing down how much piece and permitting the creation of bigger parts. In huge parts, this setup moreover endowments framework time. A mishap on shaping passage like components is the diminished most framing viewpoint in light of untimely disappointment by utilizing tearing.

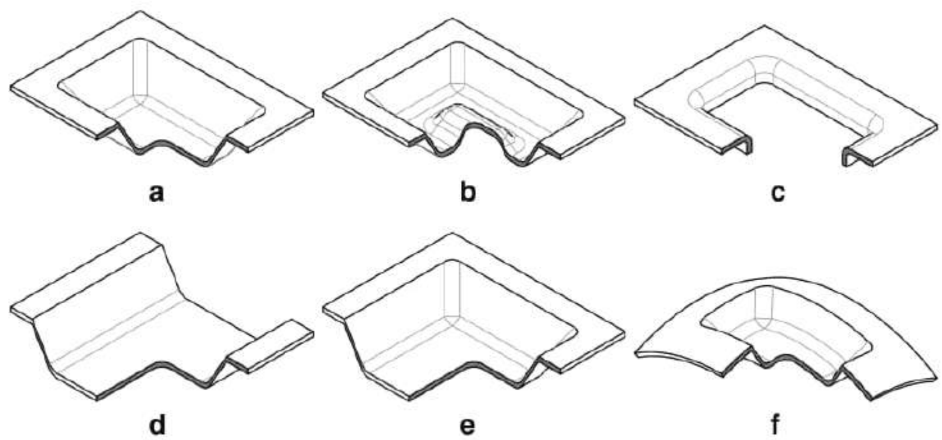


Figure 4 Possible SPIF part configuration: A: container part, B: island type part, C: flanged part, D: tunnel part, E: semi-tunnel part, F: pre-formed part.

RAPID PROTOTYPING AND SMALL BATCHES MANUFACTURING

An overwhelming area of programming for the SPIF interaction is the improvement of models to assist the modern item design and improvement with handling. As the mechanical places of SPIF parts permit the improvement of absolute last pragmatic models for every evaluation and giving an item. Plus, SPIF offers a staggering chance of planning free-shape steel shapes for exceptional or low amount producing series, generally inconceivable or extremely expensive.

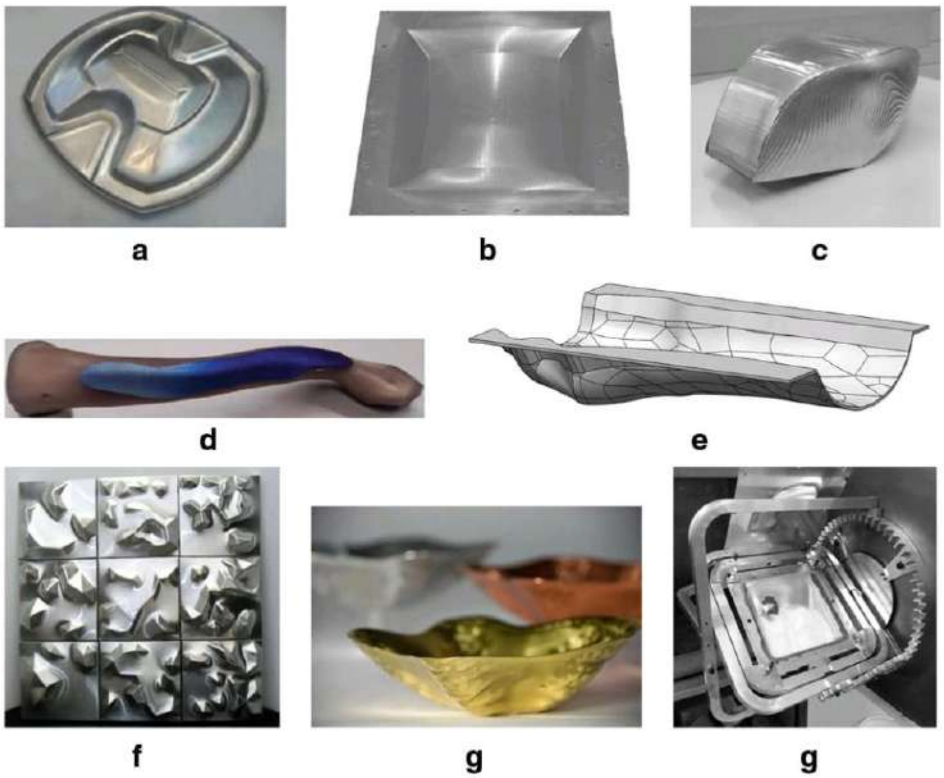


Figure 5 Different ISF parts manufacturing.

DEFORMATION MECHANICS:

The disfigurement mechanics is one of the most extreme principal districts of exploration of ISF, depicting how the sheet moves under the indenter and the follows related with it. A comprehension of the deformity component is fundamental for grant precise mathematical styles of the strategy to be progressed for gadget heading design and procedure make due, and to build a comprehension of the extended framing cutoff points of ISF in contrast with dire. Past investigation into the disfigurement mechanics has fixated on two methodologies: trial estimation of lines and relocations of the surfaces of sheets; and utilizing the limited component (FE) strategy for expectation of lines through the thickness. Albeit this work has given prized bits of knowledge, the work is obliged and every once in a while, problematic, and thus the deformity isn't completely perceived. Estimations and mathematical reenactments of both SPIF and TPIF have demonstrated that, for a conventional twisting device bearing along straight or daintily bended sides, material doesn't pass extensively inside the heading lined up with the airplane of the undeformed sheet, yet activities specifically consistently to this plane. Thus, stresses on the outer layer of the sheet are zero or irrelevant lined up with the gadget course and brilliant opposite to the device course, and those rules relate to the minor and fundamental guidelines of surface strain individually. This transformed into first estimated for SPIF of round and curved frustums by involving Iseki in 1993 [75]. Shim and Park [53] later utilized a FE assessment to foresee that strains are about uniaxial along promptly sides shaped by SPIF, and Kim and Park [38] anticipated a comparable outcome for an indenter moving forward and backward along a straightforwardly line. Albeit close to uniaxial floor follows were most regularly situated in ISF, non-zero minor surface follows can be done underneath certain circumstances, and this has been of extraordinary interest for plotting framing limitation charts over a lot proportions of essential to minor floor pressure Iseki [75] first utilized a go-structure and a straightforwardly line to produce in excess of a couple of strain states from uniaxial to biaxial in 1993.

Shim and Park [53] found that near to equi-biaxial follows occurred at the sides of shapes with different points, even as uniaxial strains came to fruition along the level perspectives. Kim and Park [38] utilized a quickly line investigate produce different proportions of generally critical to minor strain, and expressed that the tension state at the start and end variables of the street become biaxial, while the strain inside the middle become uniaxial. Filice et al [45] revealed that decreasing the span of shape of the instrument course builds the minor pressure, and that near to biaxial lines might be achieved with a width of the device way of 24 mm. A pass structure transformed into utilized by the indistinguishable creators to make biaxial strain conditions on the convergence of opposite lines. A vault, hyperbola, cone, pyramid and 5-curve shape had been utilized by Jeswiet et al [46] to make non-zero minor follows on framing limitation outlines for SPIF. Nonetheless, the minor strains accomplished on those shapes had been little in assessment to the fundamental follows, and in this way lines had been close uniaxial. Following from the above outcome that strains along quickly viewpoints are uniaxial and that texture explicitly uproots common to the airplane of the undeformed sheet, follows at the sheet surface opposite to the gadget course (for example Close by the course of steepest drop at the sheet floor) blast with expanding wall viewpoint. Because of preservation of degree, the outcome brings roughly a dating between the wall thickness subsequent to framing ($t1$) with the wall mentality (α) and the remarkable wall thickness ($t0$) known as the sine guideline (2.1).

$$T1 = t0 \sin \alpha$$

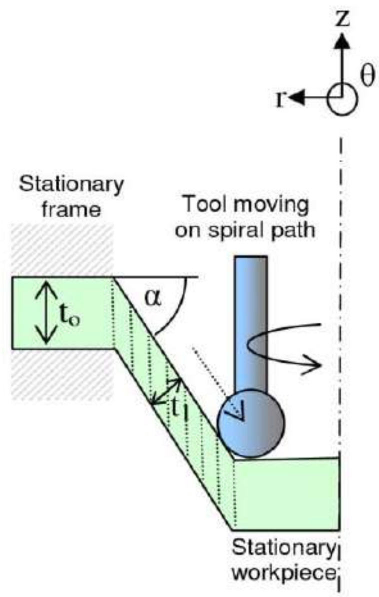


Figure 6 Idealized deformation mechanism for pure sheer.

Besides, the glorified instrument for shear turning changed into got from two approximations made to the genuine misshaping estimated with the guide of Kalpakcioglu [81]. Bending of the plate close to the mandrel, right off the bat, floor become overlooked to such an extent that hub gridlines were approximated as outstanding completely hub, on the possibility that the mutilated area turned out to be little in contrast with the thickness of the sheet. Besides, circumferential stream that passed off throughout the curling iron become approximated as airplane pressure. The exceptional misshaping system estimated with the guide of Kalpakcioglu [81] for shear turning.

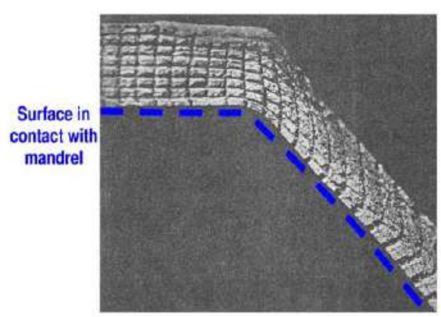


Figure 7 . Deformed grid on cross-section.

CHAPTER 3

PROBLEM STATEMENT

There are many sheet metals forming processes such as stamping, punching, bending, deep drawing, stretching and many more. These processes required a lot of heat treatment processes which cause time delay, cost of production increase. The ISF process is intended for batched production which is small in number. SPISF technique use no die for production it has a forming tool which moves over a surface of metal sheet and form required shape, there is no change in any of the equipment of machine is required only program changes are required for different forming shape.

METHODOLOGY

BASIC KNOWLEDGE

The basic knowledge about the 3-axis CNC machine their working parameters are studies in research papers the knowledge forming process is also studies. We design our machine according to our literature review our market analysis. We search for different types of material which we can use to build our machine to achieve our desire working conditions.

IMPLEMENTATION EQUIPMENT FOR ISF

The sheet forming equipment consist of three main components: the support for the workpiece also known as clamping of work piece, the indenter that moves over the work piece and its configuration system, the machinery that is used by the indenter to perform required job. There are many type of designs are used for the router(bed) of CNC machine, all these different design are for achieving the flexibility in the process the type of equipment we use to build our machine is explained below we have divided our project in different phases that we will discuss later

SUPPORT FOR WORK PIECE INDENTER CONFIGURATION

The basic method uses for supporting the work piece in SPIF is basically a clamping method with a single forming tool. The clamp can either larger then perimeter of formed path, it depends upon the size of router we use and the size of forming shape we are making on sheet metal, as in our case we design the clamping system larger then perimeter of formed path it is benefit for complex shapes were tool is required to move freely as compare to simple shape. Clamping method in SPIF always involve a frame using nuts and bolts to rigidly fixed the work piece form its outer edges. However clamping process which involve clamping process like, frame with support the work piece with balls which make the material to move in to deforming area. Another process of clamping the work piece involve using four opposite spring to hold the workpiece that revolve around the tool of two axis of ISF. The main advantages of using those clamping design instead of using clamping with rigid frame. Less waste product is formed as compare to the edges cut off. Any type of design can be formed.

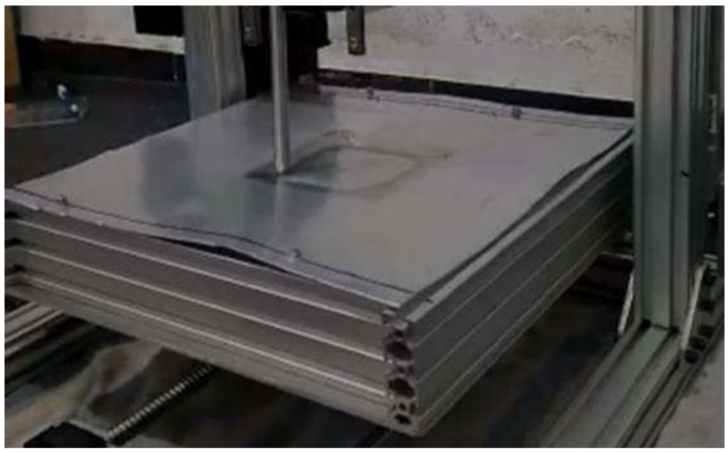


Figure 2 clapping method of sheet

MACHINARY USE FOR TOOL COUNTORING

The machinery uses to support and help to move the indenter on the surface of sheet has a great influence on the significance of process and its flexibility. The degree of freedom of tool its path, allowable speed and accuracy depends upon the process capability of ISF. SPIF machines are very expensive because of its degree of freedom are high. We developed 3 axis CNC machine for our forming process our design is convenient and flexible which can be converted to milling or 3D printer. Most of industries use milling machines that are readily available in the workshop and perform forming process using forming tool.

Our design details will be explained later in the paper, we develop a system which has three axis movement X, Y and Z, indenter is fixed on the z axis without spindle so there is no rotation of tool in our machine. Our machine is easily programmable which can achieve high level of automation which can support industrial environment.

INDENTER DESIGN

There are two parts of indenter design one is indenter head which is mostly use in spherical shape, because it can easily access the corner of forming material while maintain forming at larger angle can be done by smooth tool contact with the surface of work piece. The indenter head applies a localized force to deform the material. Other part is the shaft of indenter which separate the head, and end of the shaft is use to mount on the machine with the help of an interface. And cone type of head is use to achieve greater stiffness then a straight shaft with the external angle of 67^0 (Jackson, February 2008). Common material use for indenter is HSS in order to withstand abrasive wear.

Spherical head tool is used to minimize the sliding contact and to achieve the good surface finish. Rotating tool also increase the formability as compare to rotating tool but for rotation a spindle is required which can be expensive. Rotating speed of tool can be control with programing. The tool radius for any ISF process can be between 5mm to 15mm however ever it degree of elements not affect the process perimeters or process capabilities., the optimum diameter is of 10mm according to literature review, according to research galling can occur due to the tool small diameter. The thickness of the tool must be larger than the sheet thickness about 5 times.

Lubrication is also required between the surface of indenter and sheet metal to have friction less surface finish and less wearing of tool tip. The surface finish of the process is improved by lubrication but the process formability is increase with no lubrication.

Figure 3 indenter design

PROCEDURE FOR FORMING PROCESS IMPLEMENTATION

The implementation process describes how the product is made using different perimeters which should be taken under consideration for achieving better results. The main aim of any process is to minimize the cost its development time and maximize the process capabilities to achieve high production results. There are many process perimeters which are required for the processing of ISF. In ISF process first aim is to obtain part of desire quality without fracture. To achieve the desire result the process perimeters like **step-down, feed rate, tool diameter, wall angle, type of material, sheet thickness, tool force** should be adjusted before starting the forming process. The failure in any of the perimeter can cause acceleration in part design and geometry. After a lot of research in this field, the optimum condition for performing this process is obtained, uniform plastic deformation and thickness distribution can be achieved by increasing the wall angle and tool diameter and reducing the step down. Incremental step dept is another perimeter which is denoted by ΔZ when conventional path of tool is define for minimum thickness. To reduce the stress in the interface region of sheet and tool step-down should be decrease.

PHASE 1: CAD MODELING

The ISF process start with CAD modeling of the desired part design and its geometry. Which can be designed on any CAD software like solid works for conventional design part we can also use laser technology for medical application where laser scan the object to get the perfect geometry. The CAD modeling process is the initial yet an important step for implementing the ISF the perimeters values are being given at optimum condition at that stage.

PHASE 2: TOOL PATH

Tool path produces an approximation of required geometry mostly used tool path design is spiral contour with fixed perimeter generated by CAD/CAM software. Pre-defined path is generated by the software is commonly inward and downward concave profile. The conical shape components can be formed by smaller opening and the larger wall angle. This will reduce the bending near component opening. Slices of the CAD geometry are used to create the contour touch path, spiral contour path, and tool adjustment, which together produce the desired spiral contoured path.

PHASE 3: SELECTION OF PROCESS VARIABLE

The next phase before implementing the ISF process is to select the process variable that are likely to affect the optimum condition of the design. Tool force, lubrication, linear speed, tool radius are the different types of variables.

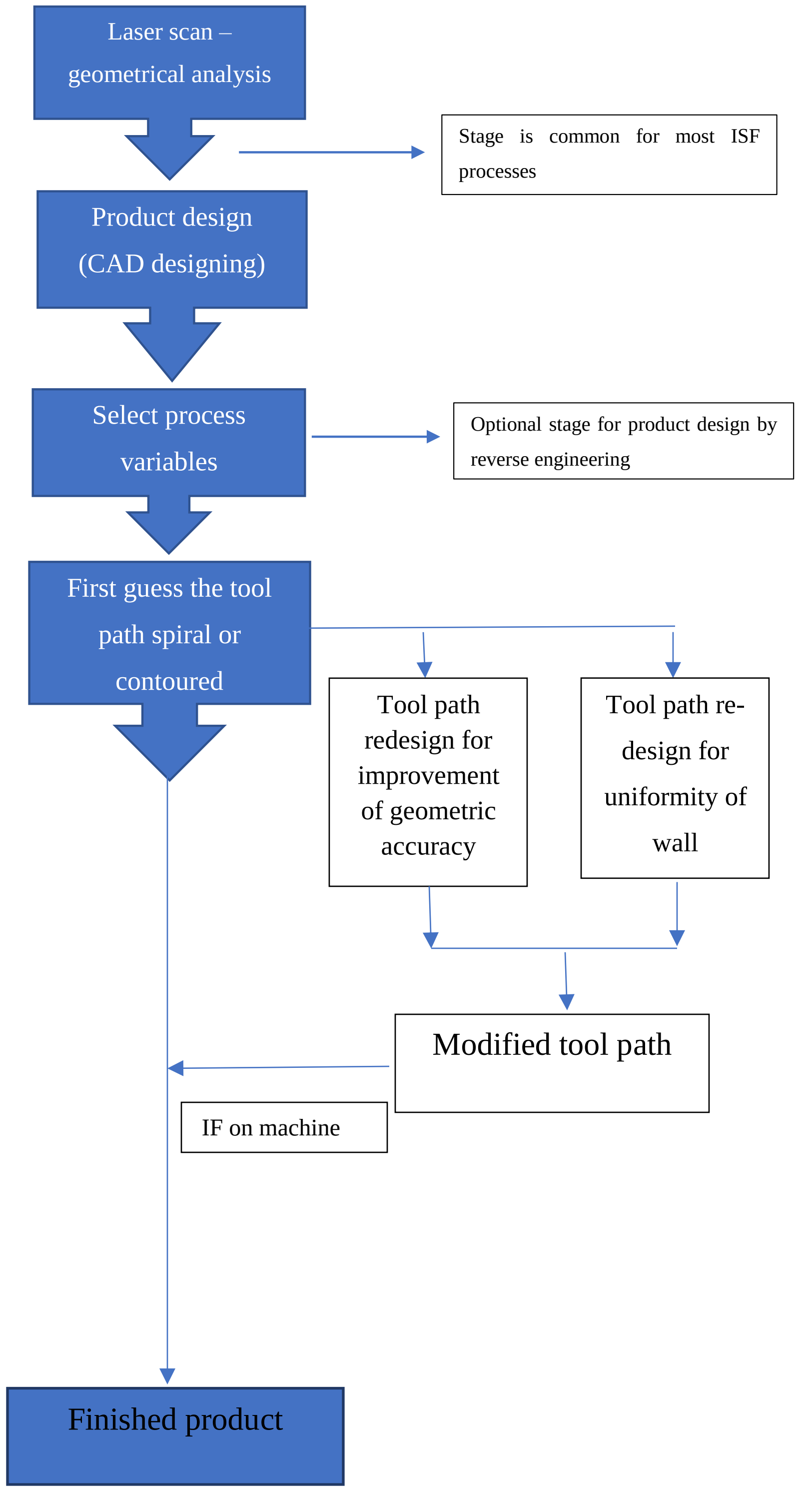


Figure 4Process flow chart for processes that take place while forming

DESIGN AND FABRICATION OF ISF MACHINE

Designing and fabrication of ISF is based on the regular CNC machine development, the main differences are the process perimeter are changed. We have developed a flexible model for SPIF machine where there is 3-axis router and an indenter which is computer controlled, the linear speed of the tool is also control using the optimum perimeter condition. The model which is to be forms is first designed on solid works then the file is converted to required format for a software which is ULTIMAKER the details will be provides later in the paper. The software then slices the model in to spiral contour path which can be CW or CCW and the process time is calculated. The designing and fabrication processes are divided in to different phases which we are going to discuss in detail, each and every part of the machine will be discuss along their design perimeters and geometry.

1. Modeling phase.
2. Mechanical components.
3. Electrical components.
4. Programing of machine.
5. Software use for ISF.
6. Sheet material and its deforming perimeters.

CAD MODELING AND DESIGNING

Due to competitive market now, days customer demands high quality product at low cost, identify the product function and its importance is essential to achieve high quality product at low cost. Assessing the function of product and compare it with the manufacturability of the designed product is the main aspect of reducing cost. Every industry who develops any type of product must apply different technique like concurrent engineering, DFA techniques, value engineering and product integrated development processes. Our machine is design according to two phases of IPDP which are conceptual design and the other is preliminary design. The product development requires a series of tasks and objectives which are needed to achieve in order to have high quality product.

ISF MACHINE MODELING

CONCEPTUAL DESIGN

At the start of new design phase, the main aim is to identify the product conceptualization that, for what the product is going to be use for what are working perimeters, parts availability in market. The products functions must be defined for what this product is going to be used for? In case of our concept designing phase, we made a conceptual model which show in fig. in the concept design we define the axis of machine, the workpiece holding frame and configuration, movement of X, Y and Z axis, tool rotation mechanism where we use a pully to drive the spindle, number of motors used and its types, pitch and diameter of lead screw, frame of machine and types of beam use for the development off machine frame, types of bearing use for smooth movement of leadscrew.

PARTS	**DIMENSIONS**	**QUANTITY**
EXTRUSION FOR FRAM	60/60 BEAMS different lengths of 600mm, 350mm, 300mm, 250mm are used in frame	9 extrusions are used of different lengths
MOTORS	NEMA 22 stepper motor is used	4
LEAD SCEW X	Length 406mm and diameter 12mm.	1
LEAD SCREW FOR Y AXIS	Length 540mm and diameter of 12mm	1
LEAD SCREW FOR Z AXIS	Length 160mm and diameter 12mm	1
BELT LENGTH	104mm of belt length is use for the movement of spindle	1
LINEAR MOTION X, Y, Z	X axis travel 260mm Y axis travel 80mm Z axis travel 80mm	3 sets of linear rails
BED	216mm I X direction	4 C beams

	240 in Y direction and the thickness is according to the type of C beam	
Z AXIS MACHINED PART	Machine part for motor fixing aluminum material of length 135mm and width 80mm	1
SMOOTH ROD	Smooth rods of 485mm	4

TABLE 1; PARTS AND DIMENSION OF USED IN CONCEPTUAL DESIGN

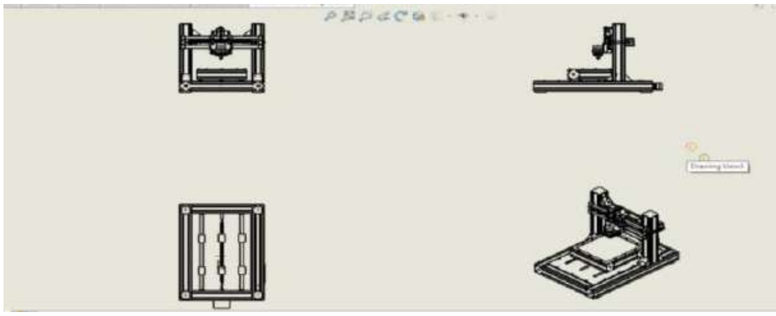


Figure 5 drawing views of conceptual ISF

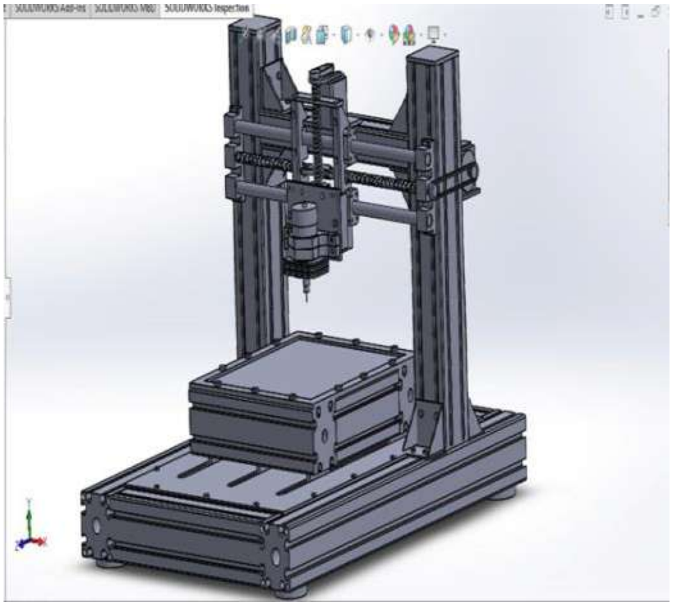


Figure 6 isometric view

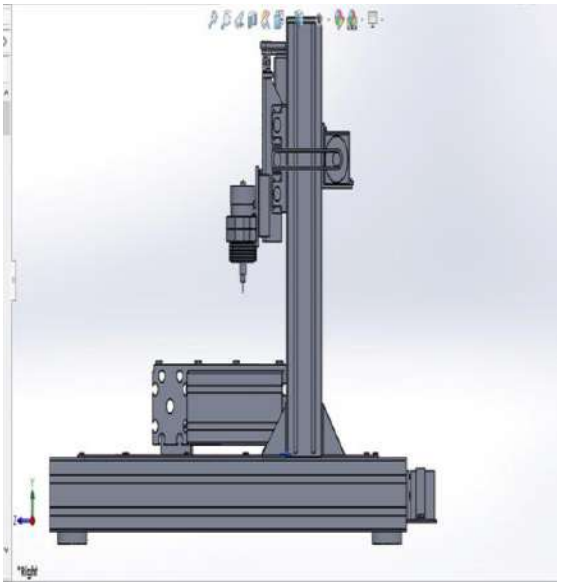


Figure 7 Side view

PRELIMINARY DESIGN

Preliminary design means using all possible creativity in the decision making but thoughtfully and rationally where we unfolded all the possible function of the product which to be designed and several solutions are to be listed. After the conceptual stage all the function of the product are in front of us and we are able to modify our model according to our needs and market analysis. We remove our spindle mechanism and reduce our cost because incremental forming can be done without tool rotation instead, we use tool holder. Lead crew are change with ball screw because they work more efficiently than the lead screw. NEMA 24 stepper motor is use in place of NEMA 22, T slot beams are used for the bead, for frame 440 extrusions are used in place of C beam. All the changes were made to improve the functionality of machine and reduce the manufacturing cost of the machine.

PARTS	DIMENSIONS	QUANTITY
100×100 EXTRUSIONS	In Y axis direction frame extrusion length is 430mm, in X axis 475mm, 395mm in Z axis direction 380mm	7
T SLOT BEAMS	$20\times 40\ extrusion$ and length 315mm in X direction 350mm in Y direction	4
MOTORS	Stepper motor NEMA 24	3
LINEAR RAILS	225mm in length 110mm in width	1 pair
LINEAR MOVEMENT OF X AXIS	Tool move 195mm in x direction	1
LINEAR MOVEMT OF Y-AXIS	190 mm tool movement in Y axis	1
LINEAR MOVE MENT OF Z -AXIS	135mm linear movement in z axis	1
BALL SCREW	X and Y axis 470mm with pitch 4mm and diameter of 12mm Z axis 240mm length pitch 5mm	3
SMOOTH RODS	440 mm in y axis with 12mm diameter, 470mm	4

TOOL Diameter and size	10mm diameter tool is use hemispherical type	1

Table 2 PARTS USED IN ACTUAL MACHINE DESIGN AND DIMENSIONS

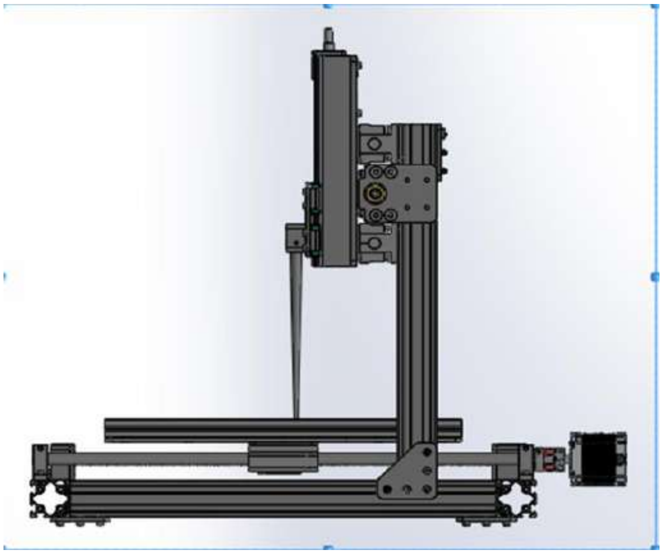


Figure 8 SIDE VIEW

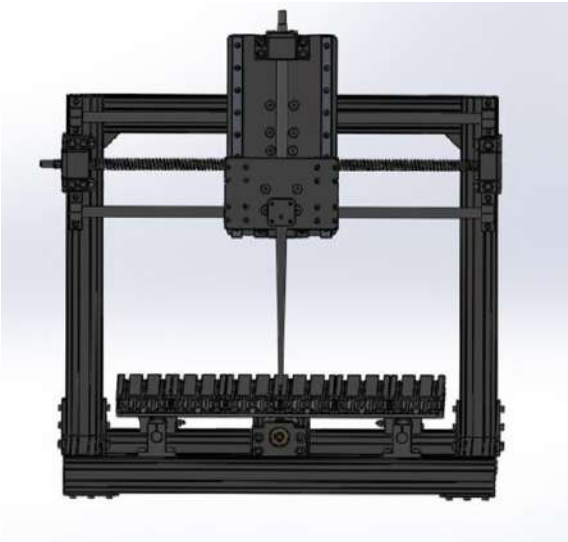


Figure 9 FRONT VIEW

Figure 10 ISOMETRIC VIEW OF ISF MACHINE

ANALYSIN OF CAD MODELING

In order to know the proper working of our machine we should analysis our design, degree of elements our design is feasible according to our perimeter. The tool force which is generated by motor or ball screw also known as mechanical advantage. We have done our analysis of amount of force tool has apply to do forming on sheet. Design analysis can be done on any software like ansys software, solid works, fusion 360. The result of our tests is given below

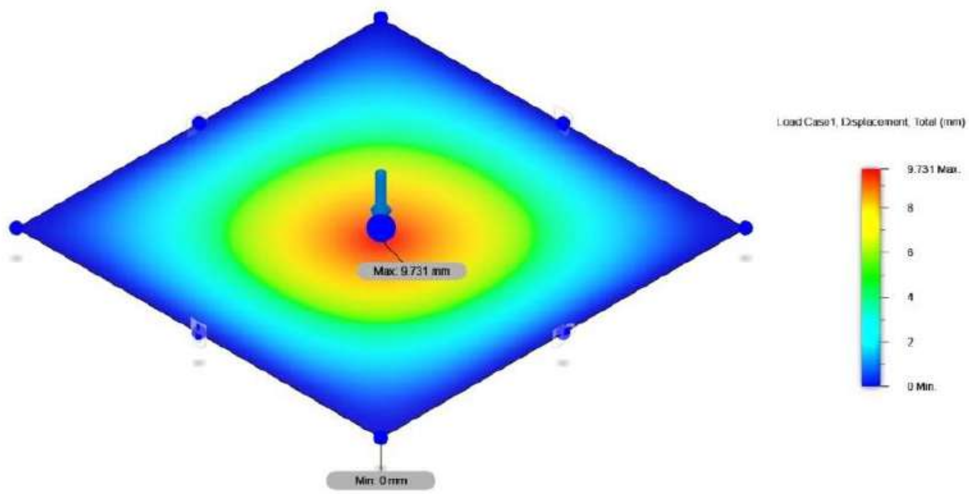


Figure 11 displacement of sheet due to tool force

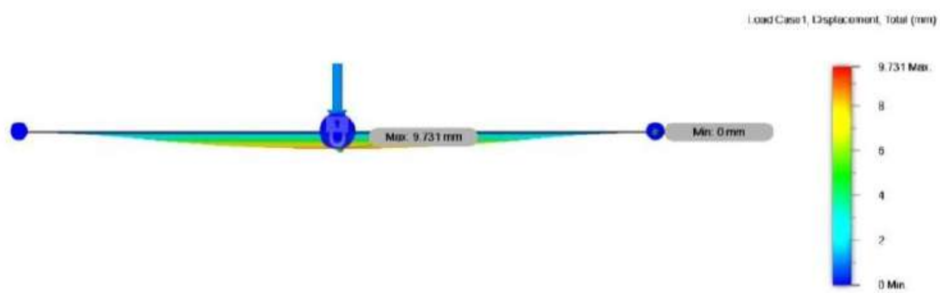


Figure 12 deforming of sheet due to maximum force

MECHANICAL COMPONTS

The mechanical system in incremental sheet forming machine is essential for the proper working of the machine. The mechanical components play integral part of the performance of the system, a lot of process are uses in making of these mechanical components. We will discuss each and every component use in our system its size and its material and where it is used.

40 SERIES T-SLOT ALUMINUM EXTRUSION

SPECIFICATION:

CODE	S8- 40×40-1N
SLOT WIDTH	8.2mm
MASS OF INERTIA	lx: 447.20cm^4 ly: 447.20cm^4
SECTION MODULUS	zx: 89.45 cm^3 zy: 89.45cm^3
T-SLOT HEIGHT	12.3 mm
T-SLOT WIDTH	8.2mm
HOLE	Φ12mm
WALL THICKNESS	6.3mm.

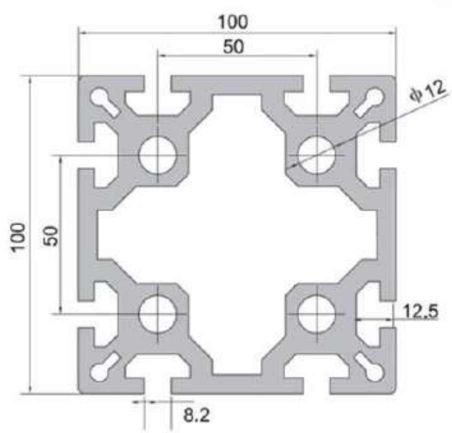


Figure 13 drawing view of extrusion

USE OF EXTRUSIONS IN ISF MACHINE

The main purpose for building those 100 x 100 aluminum extrusions is because they can be very beneficial in building frame of CNC routers. We use high quality product in our design because and fault in those beams can cause our tool movement to differ which can cause geometric faults in our final product. We use 7 beams of 100x100 extrusion of length

Figure 14 frame of ISF machine

BALL SCREW

A ball screw is a type of mechanical linear actuator that smoothly converts rotational motion to linear motion. Ball bearings that function as a highly precise screw have a helical raceway given by a threaded shaft. High thrust loads can be applied or absorbed, and they can do so with little internal friction. Due to extremely high tolerance design, they can be used in applications requiring a high degree of precision. The threaded shaft acts as the screw, while the ball assembly serves as the nut. Ball screws are usually bulkier than traditional leadscrews since they require a device to recirculate the balls.

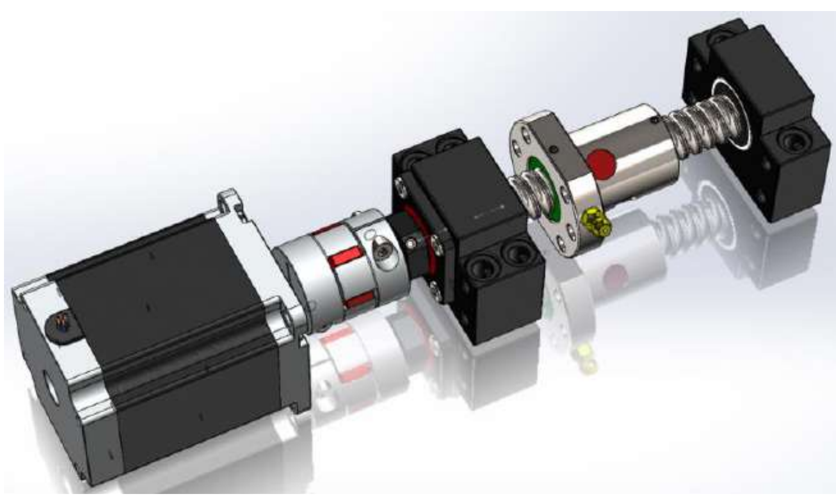


Figure 15 ball screw assembly

PARTS IN BALL SCREW ASSEMBLY

BALL NUT

- The ball nut is made of 316L Steel internals with Aluminum casing around it.

- The Ball nut is the primary component in the assembly.
- It is used to house the 'Balls' used in ball screws and acts as the center of ball recirculation.
- It acts as an interface between the screw and the steel balls.
- It is responsible for the conversion of rotary motion into linear motion.
- It is also responsible for the lubrication of the system with supplied grease port.

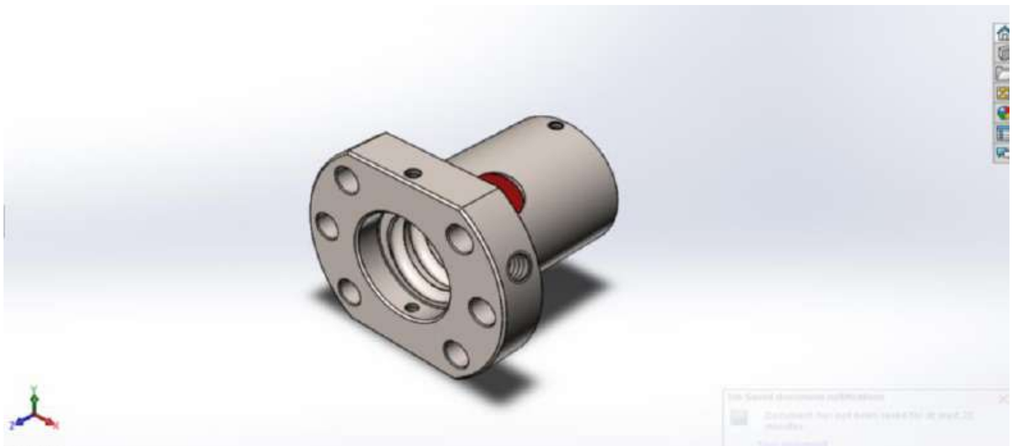


Figure 16 ball nut drawing

Steps for CAD model ball screw

- Revolve
- Extruded Cut
- Fillet
- Chamfer
- Hole Wizard
- Helical Thread
- Sweep Cut

SCREW

The screw is the part of assembly that provides stroke and path to the ball nut for linear motion. Balls are allowed to run on the helical pathways cut into the screw. The precise turning of screws allows it to achieve accuracies of up to microns. It is usually manufactured either by Rolling or Grinding.

FEATURES USED

- Extrude
- Helical Thread
- Sweep Cut
- Extrude Cut
- Chamfer
- Fillet
- Thread

Figure 17 BALL SCREW

Figure 18 CAD model of screw

BF-XX SHAFT END SEAT

At the front end of the ball screw, a shaft end seat is used which provides the screw with the following functions,

- Rotational Concentricity
- Stroke End
- Constraint

This is part is produced through die casting of Aluminum.

FEATURES USED

- Extrude
- Extrude Cut
- Chamfer
- Fillet
- Hole Wizard

Figure 19BF-XX SHAFT END SEAT

BK-XX SHAFT END SEAT

The BK seat performs all the task that BF seat performs while adding some more features, A nut at the opposite end is used to provide tensioning to the system and securing the seat post. This is also manufactured by Die Casting of Aluminum.

FEATURES USED

- Extrude
- Extrude Cut
- Chamfer
- Fillet
- Hole Wizard

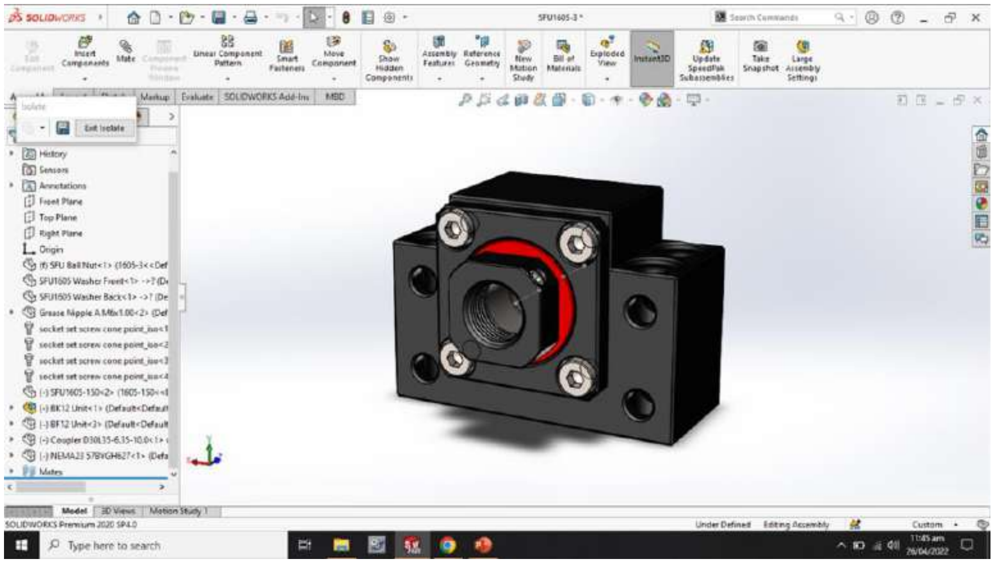


Figure 20 BK-XX SHAFT END SEAT

FELXIBLE COUPLING

A flexible coupling is used to couple the screw shaft to the motor. Such couplings have the capability to remove the axial plays via their ability to 'flex'. Majority of manufacturing and assembly error can be rectified via these couplings. This part is made with a combination of die casting of Aluminum and injection molding of polymers. Flexible coupling reduces the wear and tear of the machine, or it can fix them to certain extend. Any type of misalignment deflection in the angle of the shaft can be reduced through those couplings they are perfect fit for our modeled machine.

FEATURES USED

- Revolve
- Extrude Cut
- Chamfer
- Fillet
- Part Import

LINEAR RAILS AND LINEAR RODS

While designing any CNC machine or 3D printer the main problem we face is to choose between linear rails or linear rods. There many factors that involve in choosing between those two. Firstly, is the cost being not an issue we can use the linear rails but these rails are expensive can with stands high load, high rotating speed, and occupy les space. In our design we use three-degree movement where in X and Y axis movement we use linear rods and in Z axis because of excessive force or load we use linear rails which allow smooth movement whine working. The linear rods are easy to install and can be cheap and use in structural beams.

DESIGN CONSIDERATION

For compact design linear rails are considered where they required support material like aluminum extrusion which act as whole body. Pairs of linear rods must be selected to achieve one dimension movement. Our main goal is to do incremental forming on sheet which is mainly depend upon the movement of Z axis and tool force that's why we used linear rails in z axis instead of linear rods.

LINEAR RAILS AND RODS LOADING CRITERIA 1030837

Linear bearing loading capacity is difficult to analyze that's why we are going to work on dynamic loading capacity of linear bearing carriage. Linear bearing carriage is a part that moves with the rails or the rod mostly we use 20% more dynamic loading then intended in design. linear rail can carry higher dynamic loads compared to a pair of linear bar carriages of the same rail width diameter.

ACCURACY AND PRECISON OF LINEAR RAILS

The rails can only go in one direction because to the construction of linear rails. On the other hand, linear rails enable the carriage to travel on and revolve around the bar. The precision of linear rods is less accurate than that of linear rails due to this additional degree of freedom. Additionally, to enable the carriage to glide smoothly along the rail, linear rail carriages are frequently built with rolling ball bearings. Normal linear rod carriages lack rolling ball bearings, which increases friction and causes binding. An important factor in determining how accurate a linear bearing assembly is is parallelism. This only matters when linear rails are used in pairs though. The carriages will go in the other direction if the distance between the two rails changes will lock, increasing friction and decreasing accuracy.

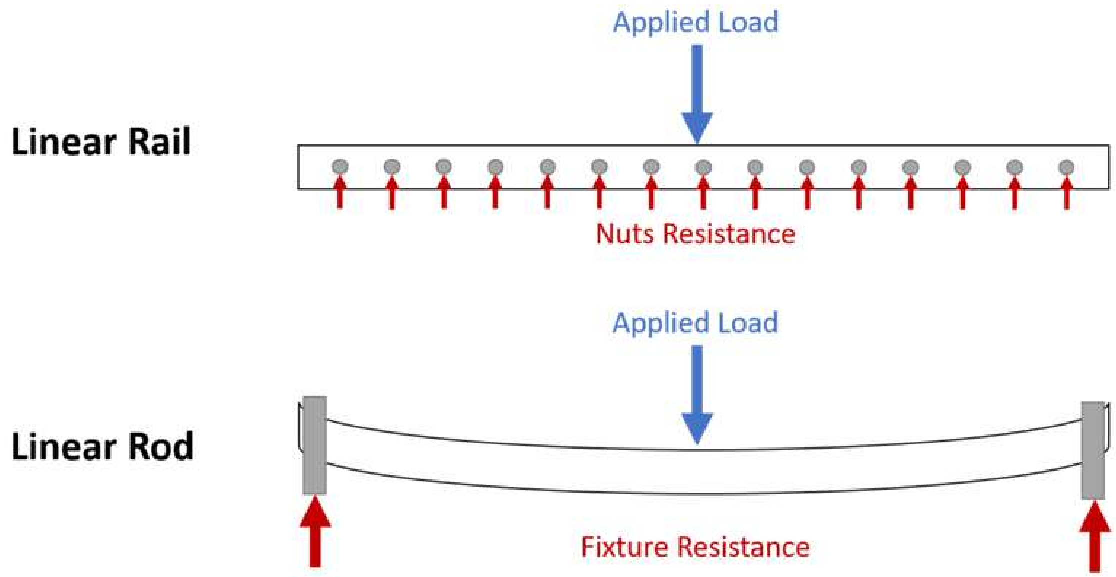


Figure 21 loading and deformation on linear rails and linear rods

ELECTRICAL COMPONENTS

The one of the main parts of CNC machine involve electrical components, apart from motor or CNC controller there are many different parts that are involve in the machine. CNC digital systems discovered on a CNC bed with other components to create a completely running device. there are numerous digital phases of factors like limit and proximity switches, motor wiring, appropriate cable sizing and selection, and many other things are crucial to a CNC's functionality. These characteristics, in my opinion, are essential to creating a dependable device. Additionally, a few CNC electrical features, such as manual pulse turbines, home and e-forestall buttons, contact-off device sensors, and many others, aren't always necessary. Depending on the user, these features may or may not be necessary for the system, but they do improve usability no longer to mention, improving the system's overall look and feel We also develop a system which not have home button or tool stop button but we can control it numerically through computer software, software detail will be discussed in below topics.

NEMA 24

STEPPER MOTOR

The stepper motor is an electrical motor which moves or rotate shaft in fixed steps at fixed angle at a fixed number of degrees. All these functions are obtained because of the geometry of motor, this allows the recognize the fixed position of shafts by counting the steps without any sensor.

WORKING PRINCIPAL OF STEPPER MOTOR

Like all motors, stepper motors have stationary (the stator) and rotatory (the rotor) elements (rotor). The stator has wired teeth, while the rotor either has a permanent magnet or an adjustable reluctant iron core. The rotor aligns with the magnetic field created by the current flowing in the coil, which is the fundamental working principle that powers the stator phases.

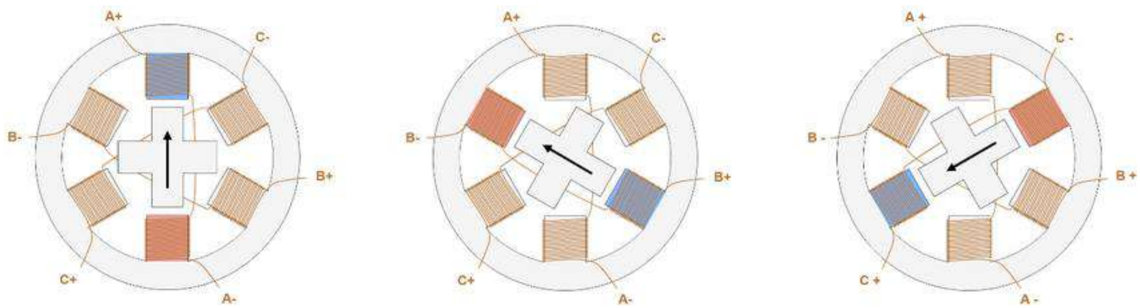


Figure 22 STEPPER MOTOR STEPS

WHY NEMA 24

They're large than the same old 23 body motor, but have the equal mounting and shaft dimensions, plus higher torque. A wide variety of motor windings and stack lengths are comfortably to be had. we've eight-cord automobiles that may be linked in all viable configurations: collection, unipolar or parallel to maximize flexibility for your utility. We can also customize the windings to flawlessly suit your voltage, modern and maximum torque at working. NEMA stepper motor sizes rely on the frame length of the stepper motor. NEMA method the standards set through “country wide electric manufacturers association”, that's constructed from 560 major electrical producers generally inclusive of manufacturers of device and devices for energy generation, transmission, distribution, and power programs. The motive of well-known placing is to dispose of misunderstandings among electric product producers and customers and to specify the safety of these product programs.

MOTOR SPECIFICATIONS

SPECIFICATION	24-P-6
Max speed (rpm)	1500.7
48 V (rpm)	60
Optimum torque	223.5 0.22
Peak power (w)	100
Rotor inertia (oz-in^2 / kg-m^2)	4.6 $8.4e^{-5}$
Weight (pounds / kg)	3.1 1.4
Maximum deliver input current	3.54
Shaft *dia* in / mm	0.315 / 8.0
Max axial force (lbs.)	4.530
Max radial force(lbs.)	16.50
Max axial force (lbs.)	4.568

TORQUE CURVES

The motor torque at a given voltage when a 100% command is set is represented by torque curves. These graphs show the torque at a 100% duty cycle. The highest power is accessible at "100 percent" torque setting at "Optimal Speed" point.

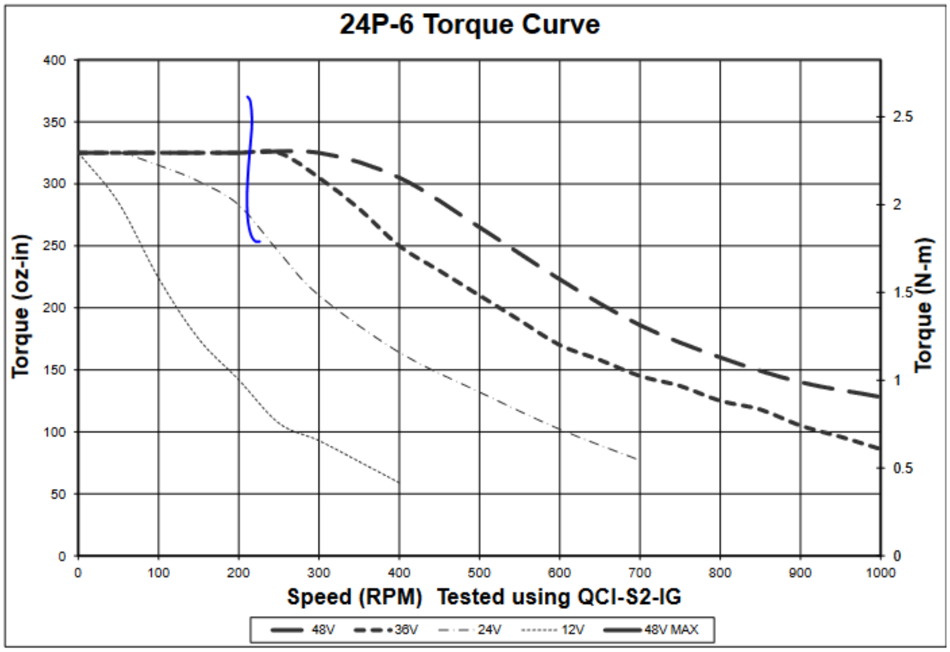


Figure 23 torque curve

MOTOR DRIVER (TB6600)

A two-phase stepper motor can be controlled using the user-friendly, professional TB6600 Arduino Stepper Motor Driver. It can emit a 5V digital pulse signal, therefore it works with Arduino and other microcontrollers that can. The 9–42VDC power supply of the TB6600 Arduino stepper motor driver allows for a wide power input range. Additionally, output 4.1 Ampere, which is adequate, the majority of step size motors. Speed and direction control are supported via the stepper controller. Six DIP switches are used to control the micro step and output current. There are a total of 8 different types of current control and 7 different steps. Additionally, high-speed optocoupler isolation is used at all signal terminals, enhancing the signal's resistance to high-frequency interference. It can drive 57, 42-type 2 different, five different, and hybrid stepper motors as a professional device.

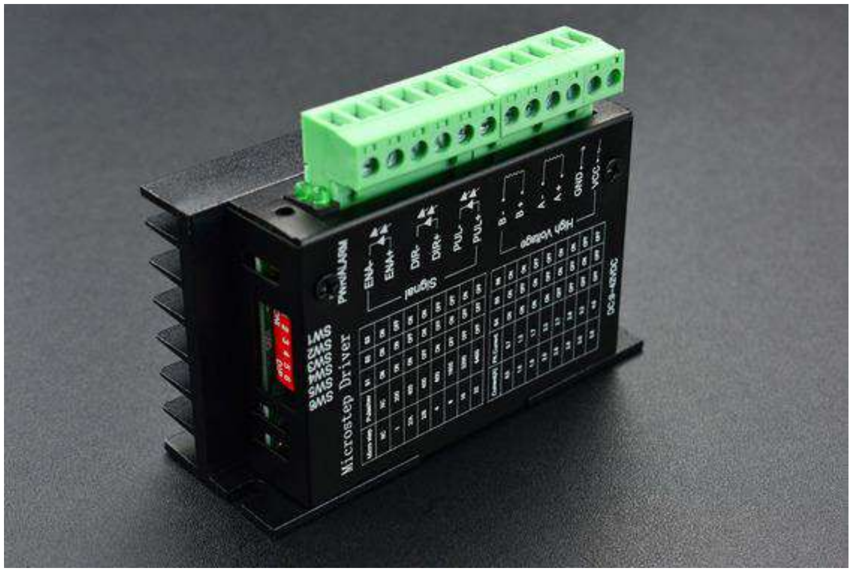
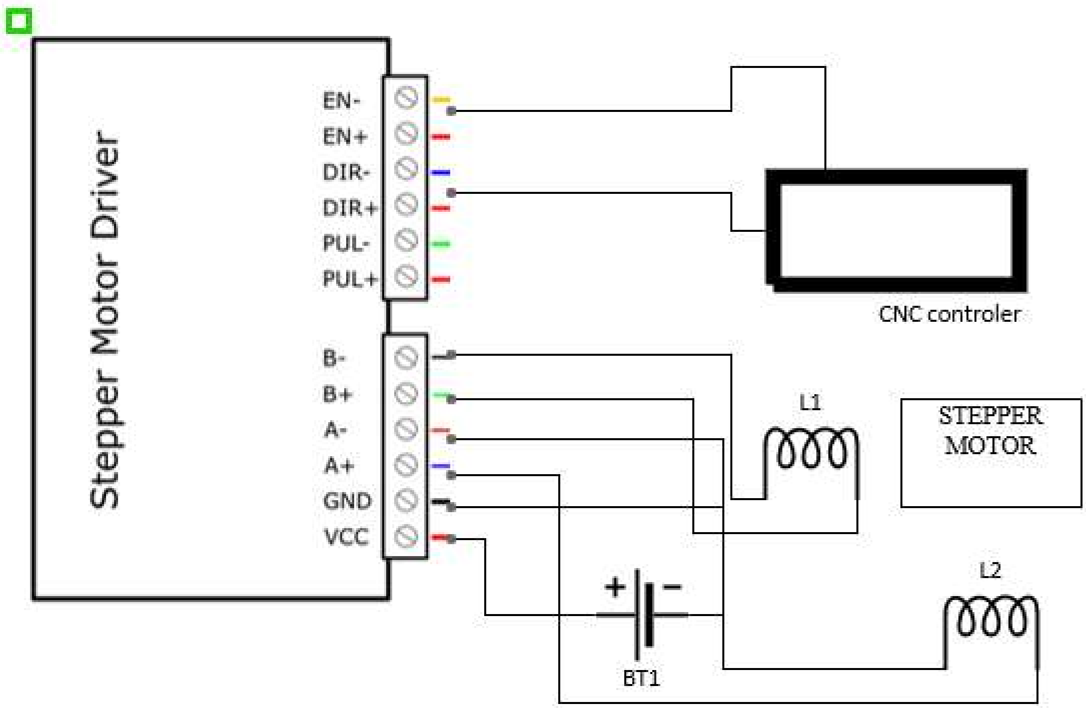


Figure 24 MOTOR DRIVE TB6600

LAYOUT OF MOTOR DRIVER

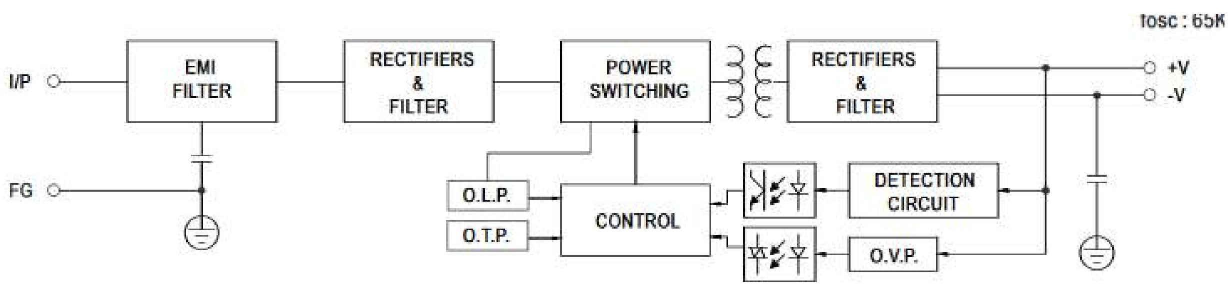


LRS-150 POWER SUPPLY

Meanwell power supply is used to power the system with output voltage of 12V and power of 150W it has the efficiency of 87.5% that why we are using it for the powering our machine. The design has a metallic mash case that enhance the heat dissipation it can operate from -30^{0}C to 70^{o}C without fan.

Figure 25 LRS 150 power supply

LAYOUT



CNC CONTROLLER SKR 1.3

SKR 1.3 act as the motherboard of the machine which control all the function of the machine such as motor RPM, linear motion of the X, Y and Z axis. It uses the ARM level Cortex-M4 series with 32bit and 170Hz frequency. Marlin2.0. Visual Studio Code is a powerful development tool for Marlin2.0., Its integrated development environment has the following advantages: it supports online debugging, which is more useful product development and performance optimization and uses C a development language that is easy to get started with. It can support 12-24V input, output current 3A. it also contain SD card support from where a firmware can be installed.

MAINBOARD POWER WIRING METHOD

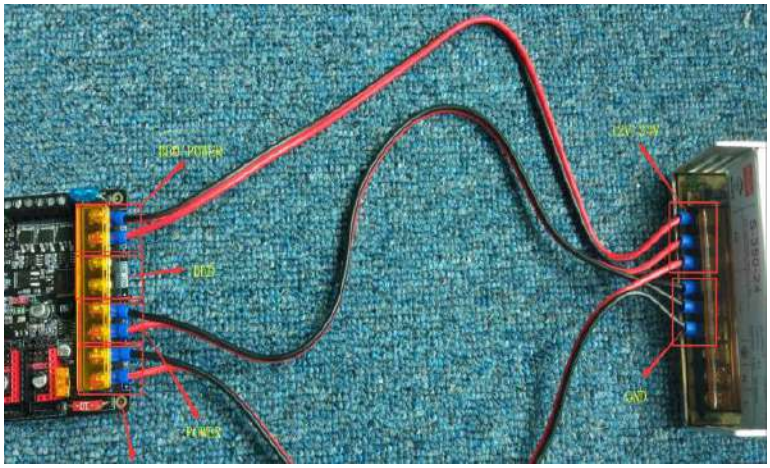


Figure 26 THREE POWER SUPPLT METHOD

Three types of power lines needed to connect the motherboard

- Hot bed power supply
- Motherboard power supply
- Motor power supply

MOTHER BOARD SIZE DIAGRAM

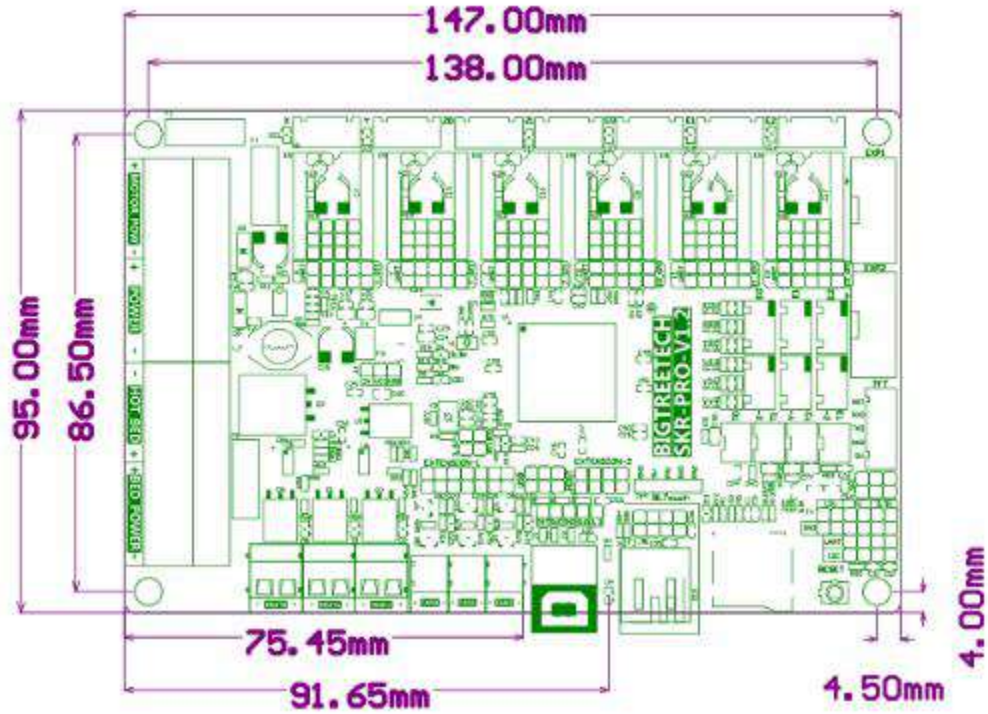


Figure 27 MOTHER BOARD DIMENSION

MOTHER BOARD WIRING DIAGRAM

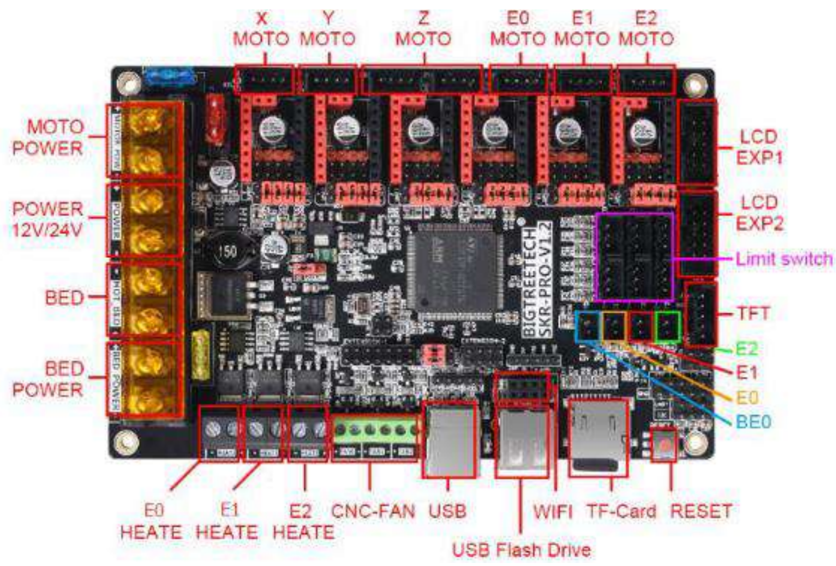


Figure 28 MOTHER BOARD WIRING MANNUAL

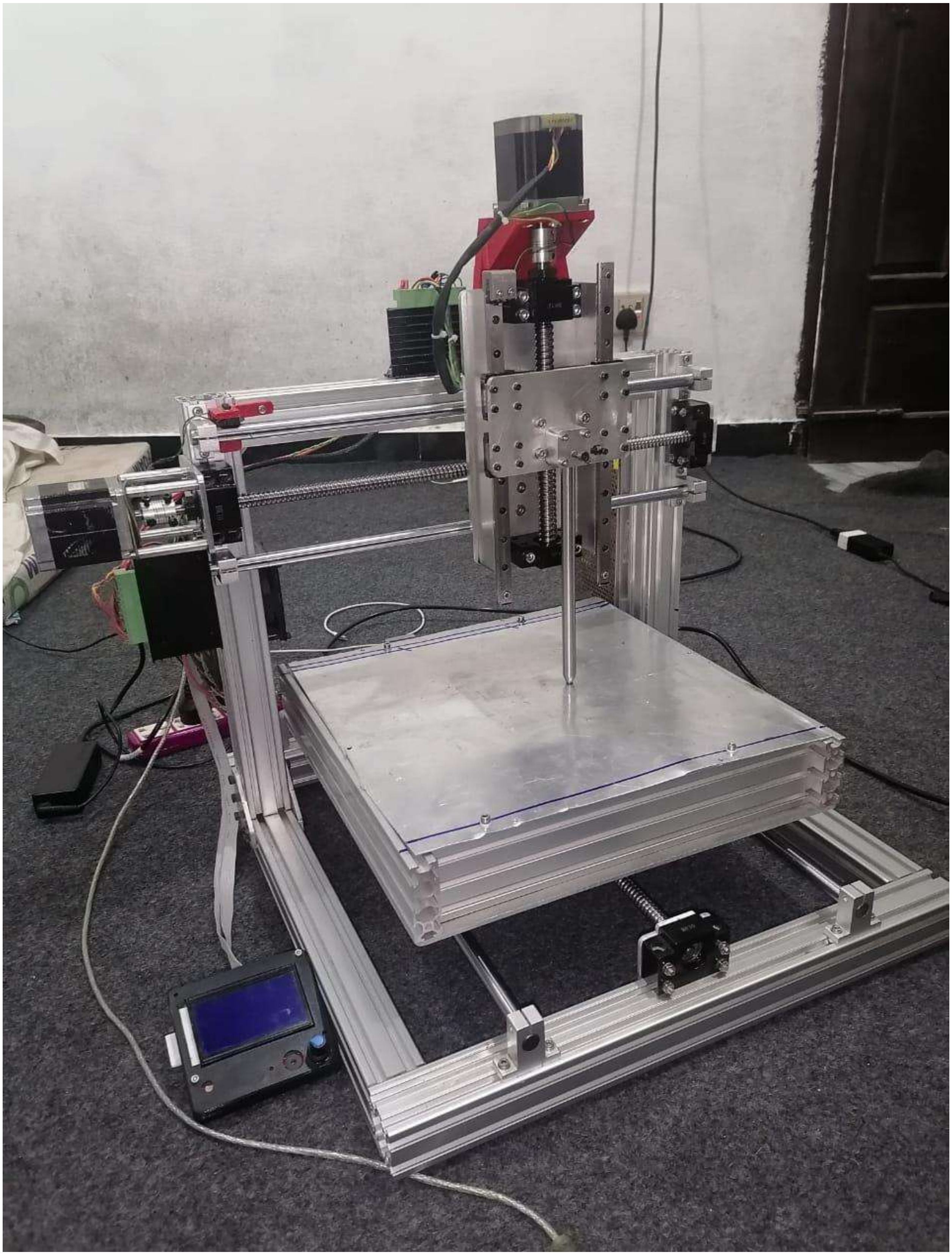


Figure 29 Final machine fabrication

SOFTWARE USE FOR GENERATION OF TOOL PATH AND G-CODE

Every CNC machine has a post processor of its own which is used to preform its work easily as post processors are expensive and, on our project, we cannot purchase its own postprocessor so we use 3D printer software ULTIMAKER CURA. Which uses STL file and slice it to generate the G-code of the required design.

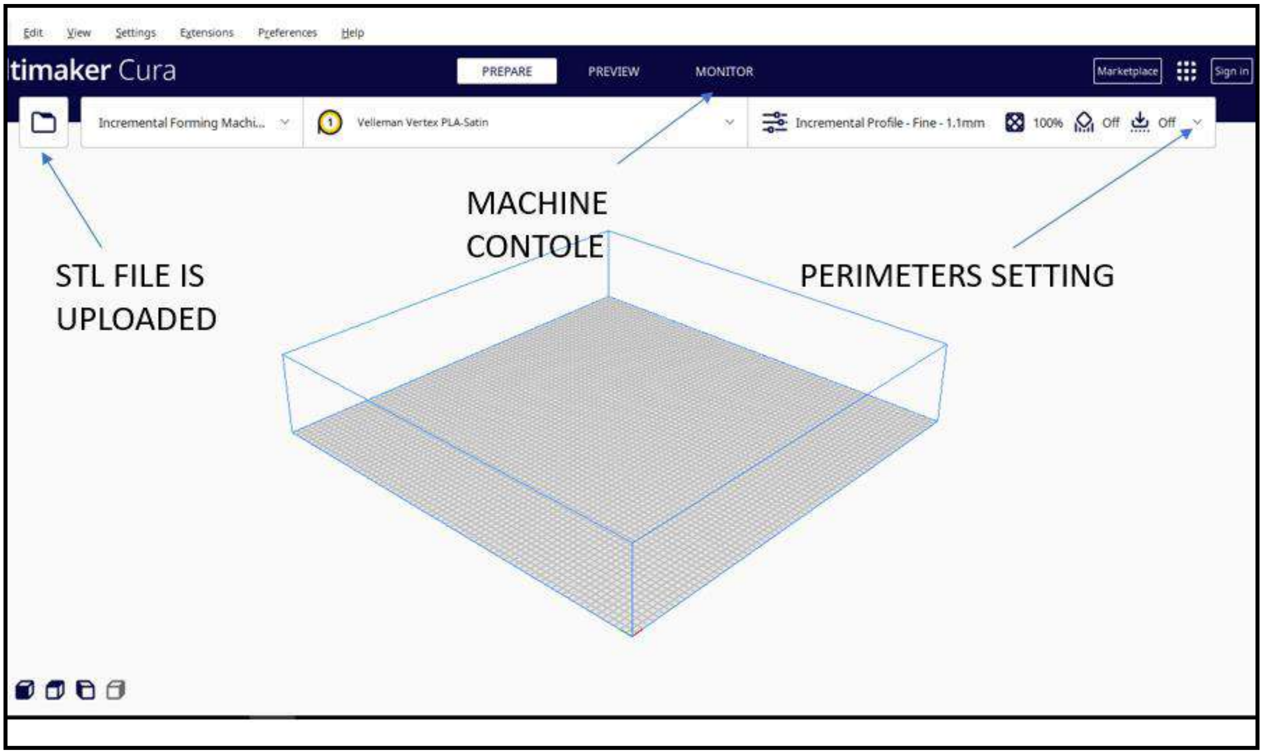


Figure 30 ULTIMAKERCURA INTERFACE

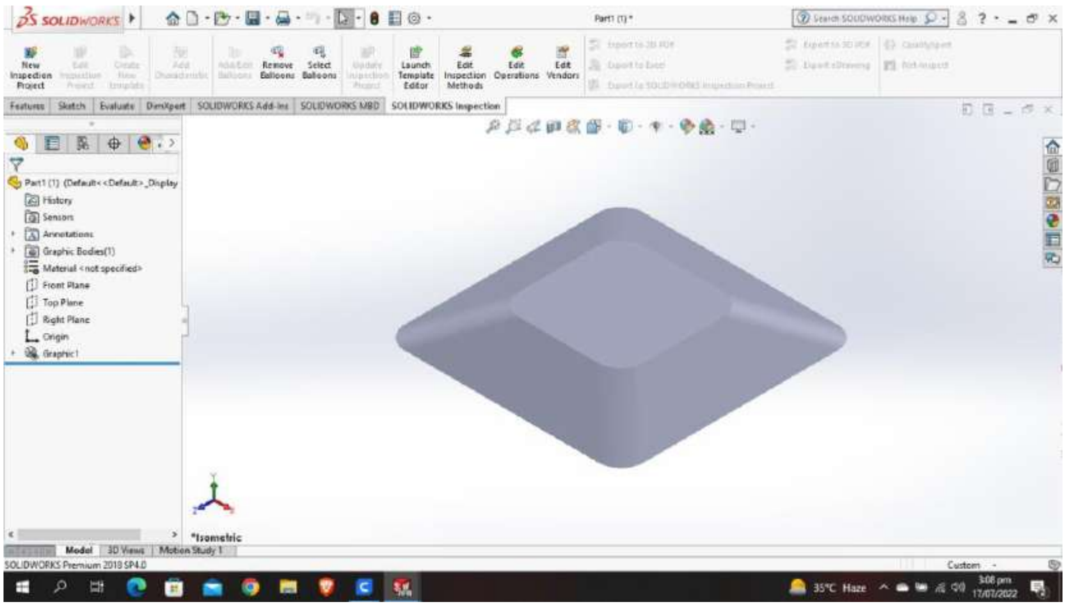


Figure 31 SOLID WORK PART WHICH IS TO BE DESIGNED

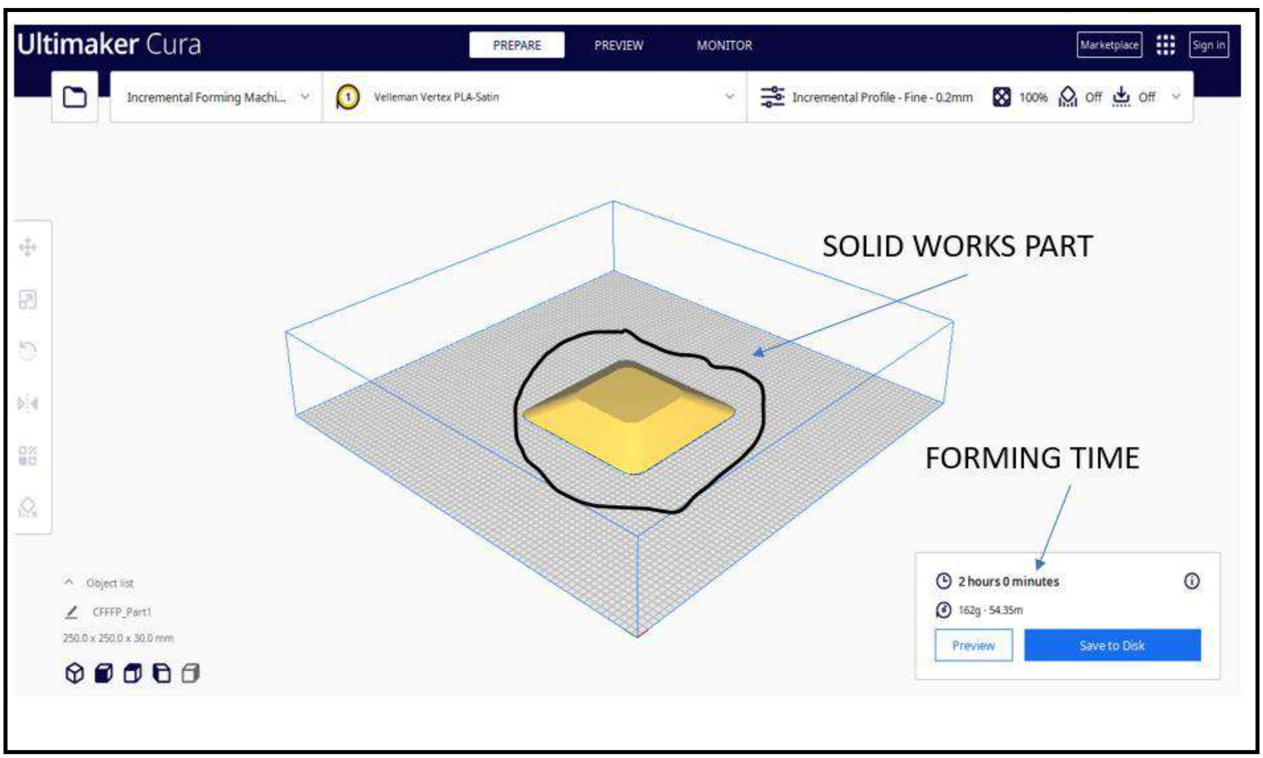


Figure 32 STL PARTS AND SLICED TO GET FORMING TIME

EXPERIMENTATION

ISF process applied to singular type of sheet however the main and economic advantage for customize production can be applied to materials which required die for their production of things. The different materials like sandwich panels, which increase the stiffness and offer weight savings as compare to singular sheet metal. Our experimentation is based on singular aluminum sheets with the thickness of 0.8mm-1mm. First, we investigate the working perimeters of ISF for different type of geometry on sheet material.

EXPERIMENT OBSERVATION

Experimental trying out has also been carried out by means of unmarried factor forming of a cone design geometry with a regular drawing perspective for analyzing the deformed part to study and analyze the fracture behavior, unique thickness of sheets is deformed to inspect the bending criteria and aspects, after the process cone design with variable wall angles is produced to observe the written fracture profile. The certain experiments are defined in the subsequent parts.

EXPERIMENT SETUP

The SPIF testing's procedure setup and measurement configuration. For both the deformation and fracture experiments in the experiment, aluminum alloy AA1100 with a thickness of one metric linear unit is used. The same frustum form as in the iron simulation has been created to observe the deformation of the material using the SPIF approach, and the deformation process is being tracked by a Digital Image Correlation to live the strain in both meridional and directions. In the shaping process, a spiral tool path with a step-down value of 0.2 mm—the same as in the iron simulation—was used. To lessen the friction, a hemispherical tool with a 10mm diameter is utilized with WD40 as lubricant

DESIGN EXPERIMENT 1

The main objective of this experiment is to identify the main forming perimeter of the process. The experimental perimeters that are varied are step size or depth formed, diameter of indenter, feed rate and forming angle. The experiment is done practically which are used are high and low + AND –

RUN #	Step size	Forming angle	Depth	Feed rate
1	-	-	-	+
2	+	-	-	+
3	-	+	-	-
4	+	+	-	-
5	-	-	+	-
6	+	-	+	-

PROCESS PERIMETERS HIGH AND LOW

	Low	high
Forming angle (degree)	65	80
Depth (mm)	100	158
Feed rate (mm/min)	3.57	60
Base dia (mm)	1000	1400

EXPERIMENT

The selection DEGREE OF ELEMENT is employed to get attribute information, where every sequence is given above on Table one is run and also the final information is either a vry low (-) or strength (+). As in this case, a variety DEGREE OF ELEMENT is usually wont to verify the important measures in a very method, in order that the crucial factors can be wont to analyses alternative DEGREE OF ELEMENTs to induce a lot of careful information and a lot of results. The value of the choice DEGREE OF ELEMENT area unit a very normal factor plot; see Figure a pair of. The issue plot shows step size, spindle rotation speed, federate and forming angle all have a bearing upon formability. the flexibility to sheet incrementation is a lot of possible small size steps, federate and forming angle area unit used. All of the elements fashioned within the experiment area unit cone formed, as suggested within the CIRP keynote paper [1]; during this experiment, the depth and diameter of the fashioned half have no result upon the whether or not the half is with success formed. The diameter of the half isn't expected to possess an effect on forming. In choice style of experiment measure to misshapen elements with an area of the surface undeformed a lot of larger than a square measure. In contrast to deep drawing process, where the projection material's degree of element flow into the distortion space is changed, the projections of the manufactured half stay unchanged. The material must become thinner inside the deformation zone in order to maintain a constant volume. This has been supported by prior research. Based on the fabric's initial thickness at a certain forming orientation, the sin law was used to calculate the fabric's ending thickness. The answer of diameter is explained and depth of the half don't have an effect on the probability of deforming a part. so smaller a diameter and shallower elements area unit used to cut back machine time.

RESULTS

After experimentation of different sizes and shapes of the design the perimeter that effect the design geometry is STEP SIZE the forming time also depend on the complexity of the designed part and also on the step size while other perimeters also have some effect on the final product. If we increase the step size of the forming parts the forming time will decrease and the surface finish is also not good while if we decrease the step size the time of the forming will be increase and the surface finish will be good.

CHAPTER 4

PREDECTION OF FORMING FORCES

The method to measure the thickness and area of contact between the tool and workpiece are as follow, the thickness of the work piece is investigated by overlap method. As the in ISF localized deformation take place in the plain at 90 degrees to the direction where the tool is move. For the experiment the hemispherical tool is used for the forming process in spiral tool path and the tool move incrementally ΔZ. Let $\alpha\ and\ \alpha + 1$ will be the two tool paths with the profile $O^{\alpha} and\ O^{\alpha+1}$ center of forming tool. The profile can be divided in to 3 parts Type equation here.

- deform wall region $S_e A^{\alpha}$
- tool in contact with sheet $A^{\alpha} C^{\alpha}$
- undeformed region $C^{\alpha} D^{\alpha}$

The $A^{\alpha} B^{\alpha} C^{\alpha} D^{\alpha}$region advances to $A^{\alpha} A^{\alpha+1} B^{\alpha+1} C^{\alpha+1}$when the tool descends to the (α+1)th position from the ith position. The material in area $D^{\alpha} E^{\alpha}$firmly descends to $C^{\alpha+1} D^{\alpha+1} E^{\alpha+1}$ and degree of elements not distort. Here, it is anticipated that material flow will follow a normal to the previously produced profile and the tool-sheet contact region will switch from $A^{\alpha} B^{\alpha} C^{\alpha}toA^{\alpha+1} B^{\alpha+1} C^{\alpha+1}$. While region $C^{\alpha} D^{\alpha}$ joins the additional deformation, region $A^{\alpha} B^{\alpha}$exits the plastic deformation zone. Using the process outlined above, the material in the undamaged sheet is separated into a number of little parts, and their movement is monitored. By using constant space among the elements' starting and ending location, the thickness of every part is computed after the process is ended. In doing so, it is assumed that each element's thickness is constant.

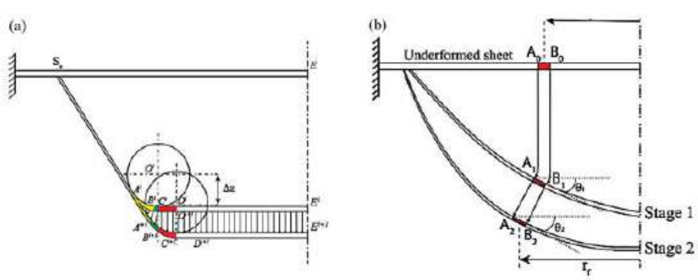


Figure 33 . single and multistage Incremental forming

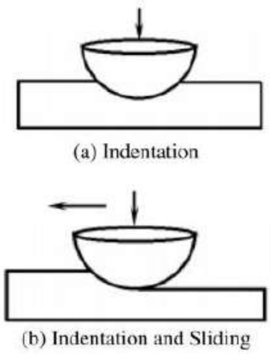


Figure 34 indentation performed on flat surface

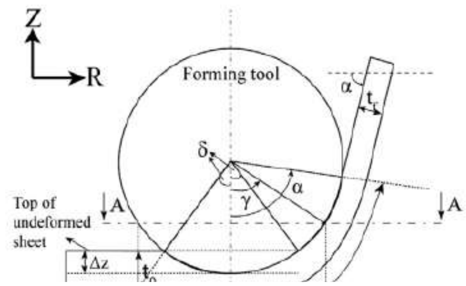
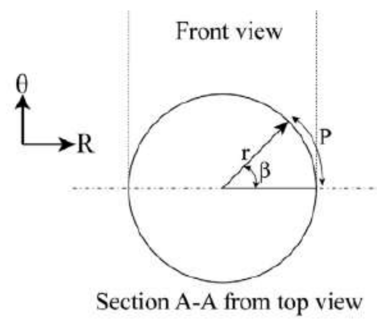


Figure 35 Area of contact in SPIF



The methodology is used to determine component thickness in multi-stage forming strategies. The first stage's thickness is determined by taking into account the previously mentioned overlap in the deformation zone. After the first stage is finished, it is believed that the material will travel normal to the geometry and move on to the second stage (Fig. 1(b)). For instance, movement from element A_0B_0 to element A_1B_1 in Fig, tracked with the overlap methodology, and movement from A_0B_0 to A_2B_2 is regarded as normal to A_1B_1.By using volume constancy between A_0B_0 and A_2B_2, thickness is computed. The projected thickness is used to compute the strain components under the assumption of plane-strain deformation. The stress-strain relationship of the material being deformed is used to calculate equivalent stress, or σ_{eq}. Using the following formulas, stress components in the thickness σ_t, meridian (σ_φ), and circumferential (σ_θ) directions are determined.

$$\sigma_t = -\frac{2\sigma_{eq}}{\sqrt{3}}\left(\frac{t}{R+t}\right); \sigma_\phi = \frac{2\sigma_{eq}}{\sqrt{3}}\left(\frac{R}{R+t}\right); \sigma_\theta = \frac{\sigma_{eq}}{\sqrt{3}}\left(\frac{R-t}{R+t}\right)$$

Equation 1 strain component calculation equation where t is the rate of thickness determined using the overlap-based algorithm, and R is the forming tool radius.

The crucial elements needed to forecast incrementing forces in the ISF process is the calculation of area of contact between the tool and work piece(sheet). By looking at the contact area for various process parameters in the CAD models, they were able to construct an expression for it. t is expected that as the tool advances, it will lose contact in the tangent direction with the sheet in a circum-direction. Two distinct portions of the contact area are identified: under the surface plain and the top and above of not deformed area. Area of contact is computed using depth of incrementation Z and indenter radius R in the area beneath the top of the undeformed sheet.

$$A_1 = \pi R \Delta z$$

Equation 2 Area of contact

Calculating the area of contact on the work piece(sheet) involves the perimeter P which are integrated of the contact of tool and sheet the at a simple angle from the forming tool's axis. As seen in Fig. let β will be the area of contact between the angle in top view. β fluctuates from 90 to 0 as γ fluctuates from $\sigma\ to\ \alpha$. The perimeter of the tool-sheet intersection is determined by making the calculation under the supposition that β varies linearly with respect to γ:

$$A_2 = \int_{\delta}^{\alpha} PRd\gamma$$

Equation 3 contact area under deformation

where $\delta = \cos^{-1}(1 - (\Delta z/R)$, $\beta = \pi(\gamma - \alpha)/2(\delta - \alpha)$, $P = \beta r$, $r = R\sin\gamma$.

$$A = A_1 + A_2 = \frac{\pi R}{2}(R + \Delta z) + \frac{\pi R^2}{2(\delta - \alpha)}(\sin\alpha - \sin\delta)$$

Equation 4 area of contact calculation and analysis

It was determined by the IF procedure, which used finite analysis, that the contact of the tool and sheet shape roughly compared to a design. Our team makes a comparable finding by examining the contact pressure.

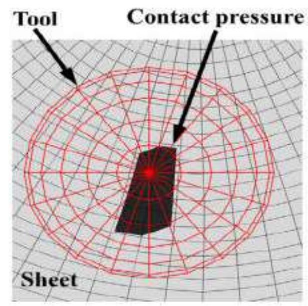


Figure 36 localized pressure observation

RESULTS

Conical shaped components are created utilizing a variety of process parameters which are discussed before, to evaluate the devised method for calculation of ISF forces. ISF forces supposed by an experimental model are verified using data from experiments. Using Al5052 material, a series of tests are carried out in the current study to carefully review the given method. However, Al3003 material attributes, to contrast experimental data with analytical conclusions obtained using the current force prediction model.

$$F_z = 0.0716\sigma_y t_0^{1.57} d^{0.41} \Delta h^{0.09} \alpha \cos\alpha$$

Equation 5 CURRENT FORCE PRIDICTION FORMULA

For two materials, the effects of every parameter are examined while maintaining other parameters at their default settings. Al5052-O materials were employed in the trials, and the standard values were: diameter of indenter (d), 9.5 mm, depth (z), 0.33mm, initial thickness of sheet(t_0), 0.88 mm, and wall angle (α), 50^0.While the Al3003-O material was employed, the following standard parameters were used to validate the model (d) of 10 mm, (Z) of 0.5 mm, (t_0) 1.2 mm, and α of 50^0. Stress-strain relationship for Al5052-O is σ =$332\in^{0.12}$MPa, and yield strength is σ_Y= 203 MPa. Relation of stress and strain for Al3003-O $\sigma = 184\epsilon^{0.224}MPa$ and yield strength $\sigma_y = 103MPa$.

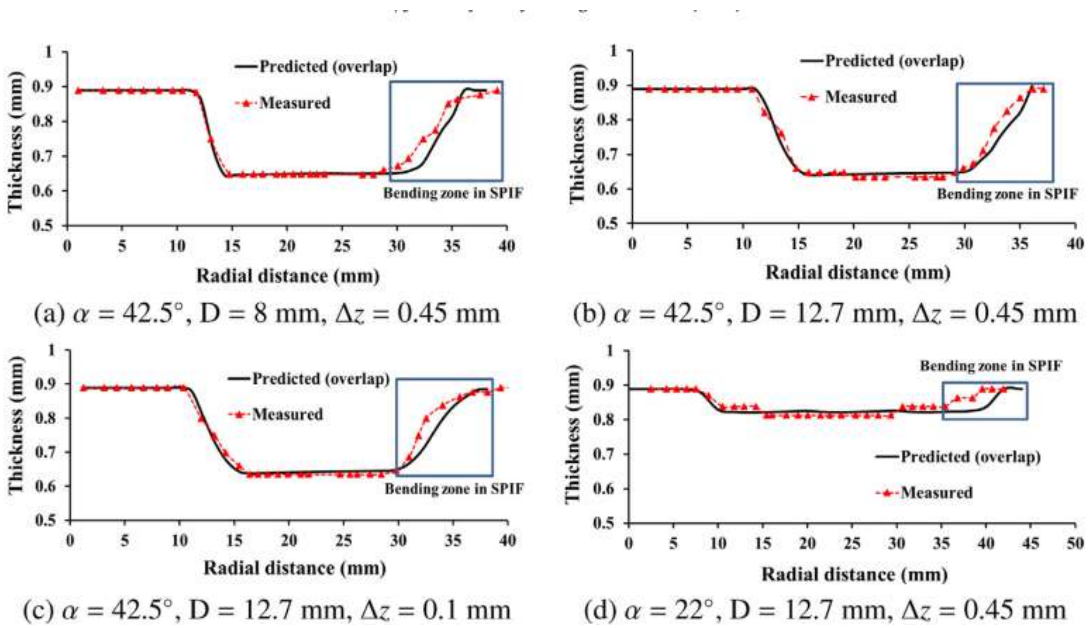


Figure 37 Comparison of theoretical predicted and experimental thickness.

ACTUAL THICKNESS VALIDATTION

Al5052 is used to create truncated conical components, which are then used to validate the model for précised thickness. For a 22-degree angle cone, its nominal diameter is 80 mm, and for a 42.5-degree cone, it is 70 mm. In order to conduct the studies, 0.87 mm of initial value of thickness of sheet is used. As illustrated in Fig. The manufactured part thickness is (22.2 and 44.5 wall angles) is calculated and the actual measurement is compared. The comparison shows that the projected thickness values and the experimentally discovered thickness distribution agree well. The largest deviation in thickness distribution between the supposed and calculated values is 3 percent at the end wall area and the open area of component is 10 percent. Since the prediction model degree of elements not account for the bending effect at the open area of part, the more percent of error can be caused due to this impact. Diameter of the tool (D) of 9.53 mm and steps depth (z) of 0.23 mm are used to create this geometry. Both SPIF and DSIF are used to build this component. Figure displays an error plot and a comparison of the observed and projected thickness along the cross-section A-A. It is evident that the suggested model accurately predicts thickness. Maximum discrepancy between thickness distribution anticipated and measured in the wall. The largest difference between the anticipated and measured thickness distribution for a component manufactured using the DSIF process is less than 3%. This methodology has also been shown to be quite effective for DSIF.

FORCE VALIDATION

Al5052 and Al30030, the force prediction methodology is confirmed. By adjusting the process variables for Al5052-O, cone shaped part are created. The experimental data collected during the current work and the forces anticipated using the current methodology are compared with the prediction made using the aforementioned empirical equation. Addition of D = 9.53 mm, z = 0.33 mm, and t_0 = 0.88 mm are used as process parameters. The graph below compares the axial force for the material Al5052-O that was anticipated and measured. The maximum difference between axial force that has been measured and projected is 7.88 percent. Figure below compares the axial force for the Al3003-O material that was anticipated and measured. The high value of difference between forces predicted and measured in this situation is 19.58 percent. The inaccuracy shown in cones with walls less than 50 degrees is, however, less than 7%. Increasing depth's effect the coned shaped parts are formed by using these perimeters depths of 0.22 mm, 0.334 mm, and 0.54 mm are used to study the variation of axial force with incremental depth. Other process variables include the material Al5052-O, D = 9.5 mm, α = 50, and t_0 = 0.88 mm. Figure compares the axial force for the material Al5052-O that was anticipated and measured the supposed value of forces which are in axial direction and the experimental results correlate fairly well. The maximum difference between the expected and actual axial forces is observed to be 7%.the data values which are available, the variation of axial force for Al3003-O is investigated at depths of 0.25 mm, 0.38 mm, and 0.5 mm. Figure displays a comparison of the force in the axial direction for the Al3003-O material that was predicted and measured. The maximum observed difference between the forces anticipated and measured is 12.13 percent.

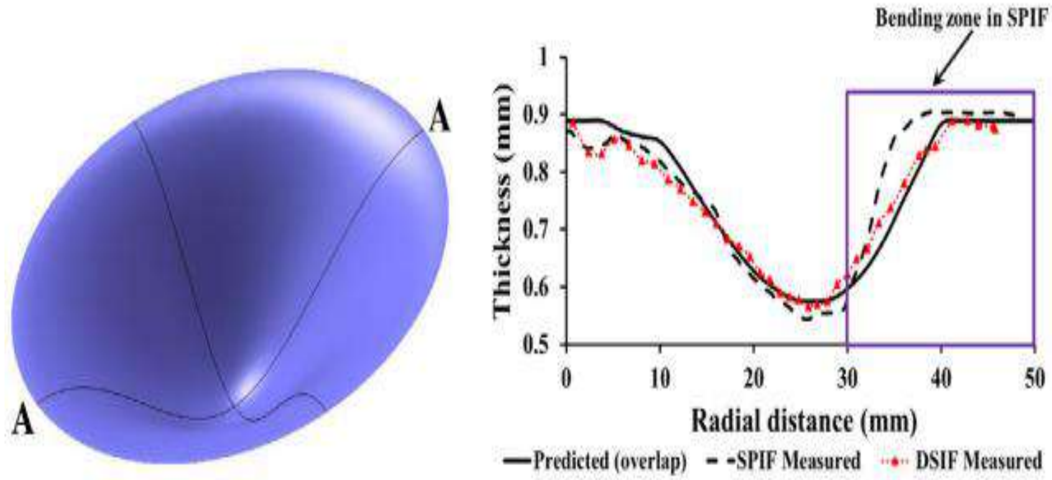


Figure 38 Ellipsoidal and thickness comparison along section geometry A-A

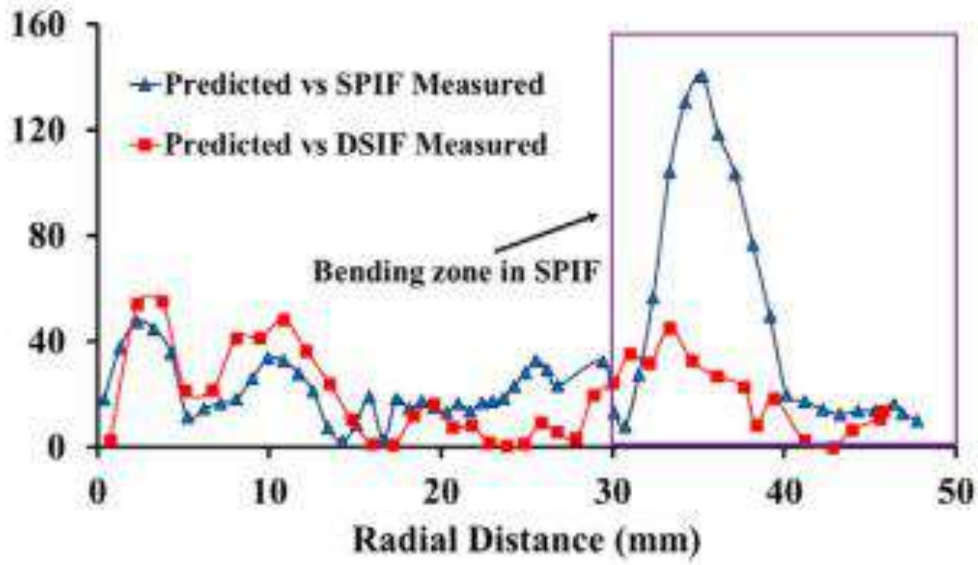


Figure 39 Error in thickness along section A-A

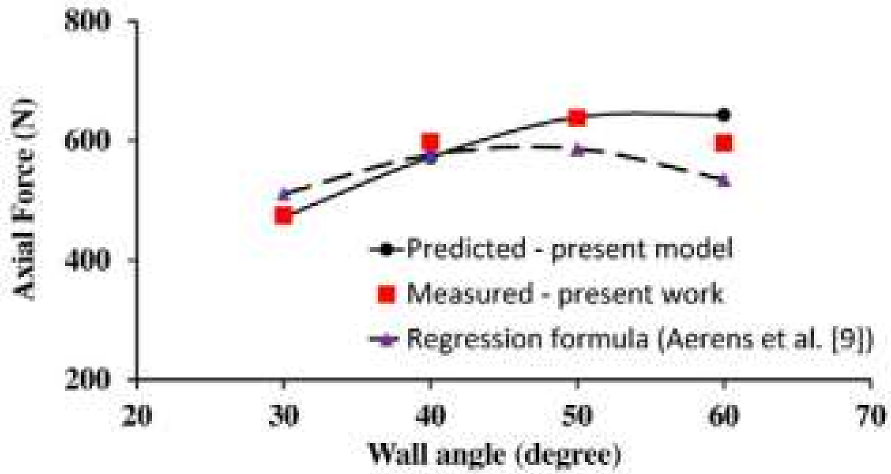


Figure 40 Variation with wall angle A15052-O

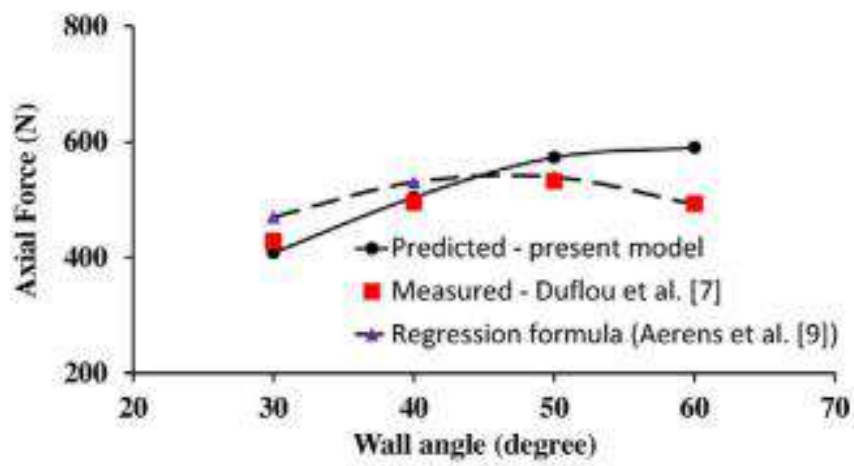


Figure 41 Variation with wall angle A13003-O

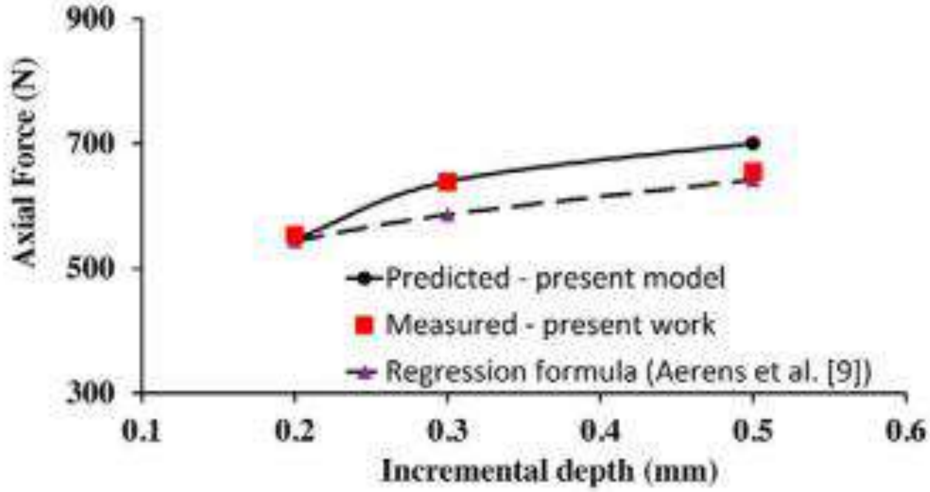


Figure 42 variation with incremental depth A12052-O

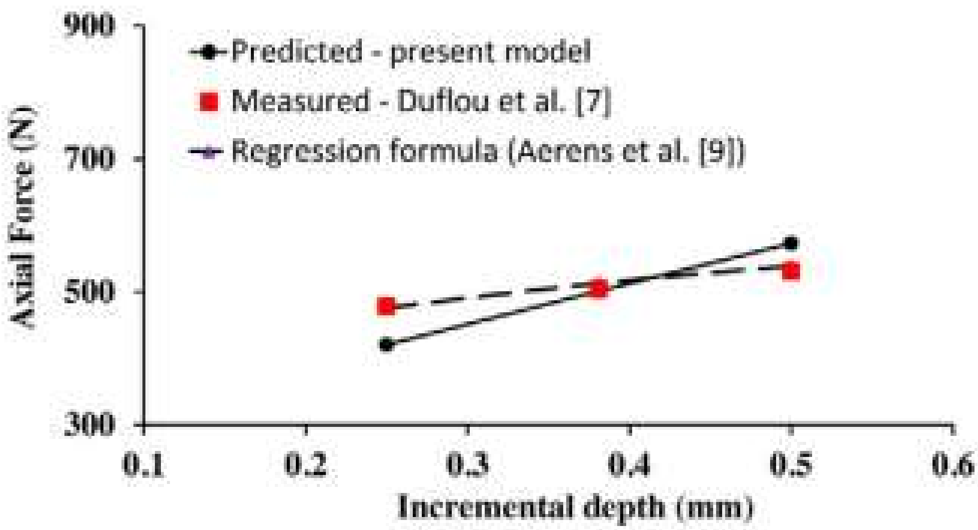


Figure 43 Variation with incremental depth A13003-0

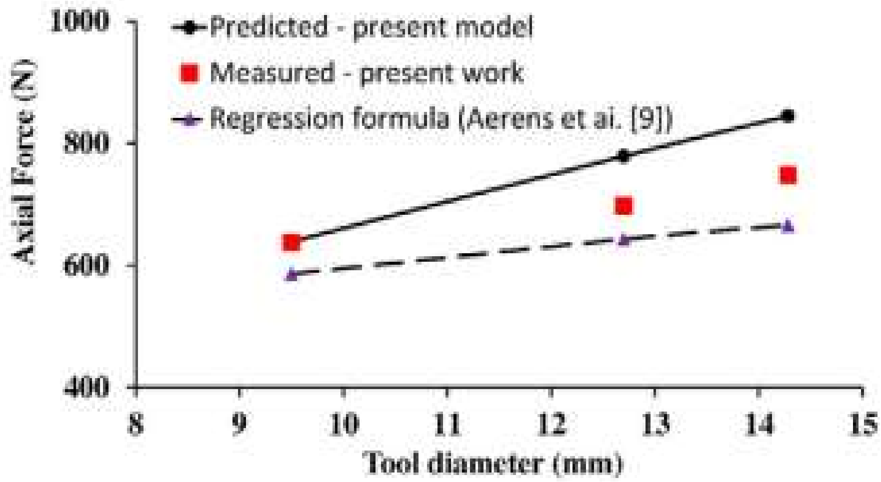


Figure 44 Variation in tool diameter A15052-0

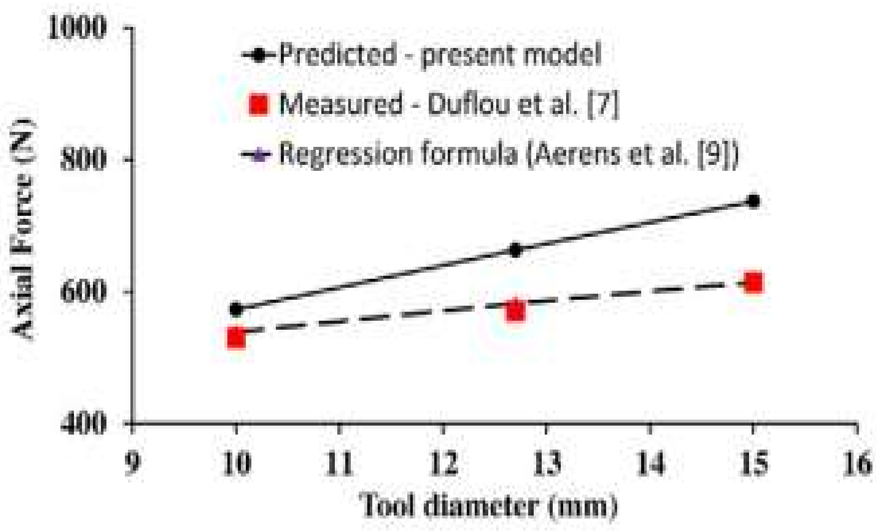


Figure 45 Variation inn tool diameter A13003-0

Influence of tool diameter: Utilizing Al5052-O material, a series of studies are conducted using tools with diameters of 9.58 mm, 12.70 mm, and 14.280 mm. Different parameters include t0 = 0.88 mm, z = 0.3 mm, and = 50. Figure compares the axial force for the material Al5052-O that was anticipated and measured. The predicted forces in the axial direction values and the experimental results correlate fairly well. The maximum difference in axial forces between predicted and measured is 13.02 percent. Based on the available measured data, the difference axial force for Al3003-O is investigated with tools with diameters of 10mm, 12.7mm, and 15mm. For the material Al3003-O, a comparison of axial force measurements and predictions is shown. When the tool diameter is 15 mm, the largest recorded difference between the expected and actual forces is 20.03 percent impact of the initial sheet thickness Al5052-O material is used in experiments with two sheet thicknesses of 0.5 and 0.88 mm to examine the impact on axial forming force. Z =0.3mm, α= 50, and D = 9.5 mm are additional process parameters that are employed. Al5052-O material's anticipated and measured axial force are compared.

COMPARISON OF PREDICTION MODEL

The forces in free-form-geometry components: The ability of defining the forces is shown using the free-form parts (ellipsoid). The ellipsoidal parts major and minor diameters are set at 85mm and 65mm, with part depth of 25mm. Al5052-O sheets are used to fabricate the components in order to show how reliable the force prediction model is. Tool diameter D = 12.7 mm, incremental depth z = 0.5 mm, and sheet thickness t0 = 0.88 mm are the process variables used to manufacture the components. As illustrated the the median of forces in axial direction is contrasted with the expected values. Due to the bending effect, the difference between the expected and measured axial force in the component opening region is larger.

(c) Formed component

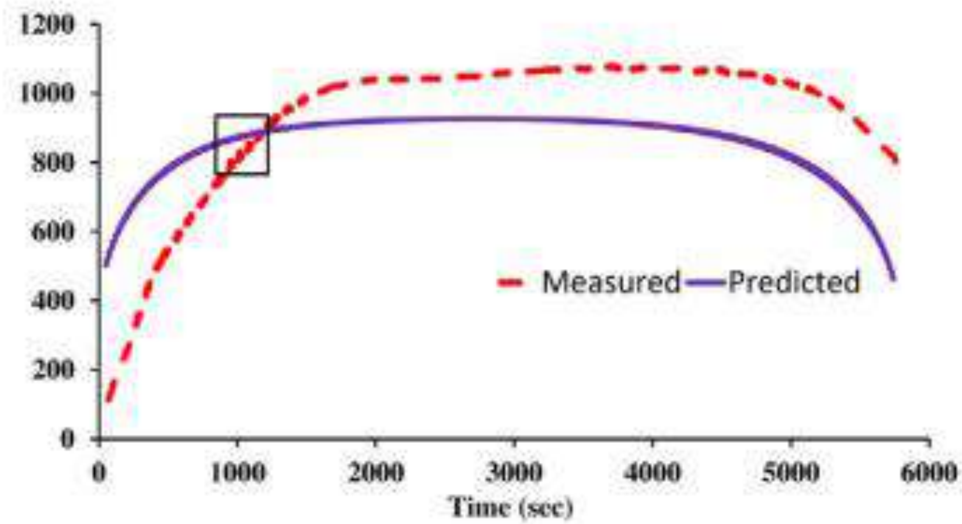


Figure 46 comparison of average axial forces

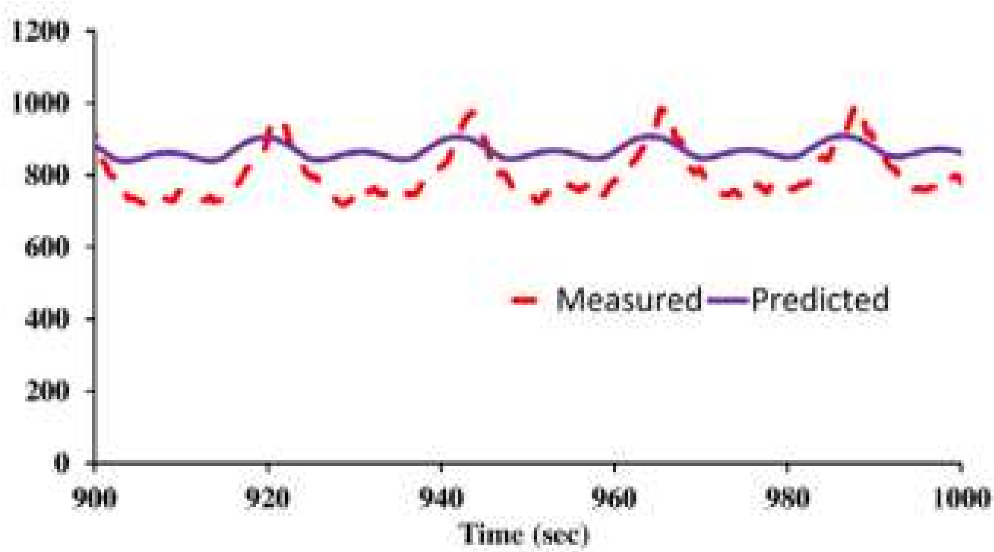


Figure 47 Comparison of actual axial forces

Modelling method was used to determine the area of the contact or the meeting area of the tool and the sheet in the comparison of prediction models. They used CAD software to simulate the mating of the indenter and the work piece, and the software was used to determine the mating between the indenter and work piece is relay on the analogy of indentation and slicing. They separated the space into two sections: one below the unformed sheet, and the other above it.

$$A = \frac{\pi}{4}R^2(1 - \cos(\alpha)) + \frac{3\pi}{4}R\Delta Z$$

Equation 6 expression for contact area

Predictions made with the model and the current part is differentiated to show the improvement in the current work. As can be observed in Figure the prior model overpredicts the contact area, leading to large expected formation forces. As illustrated in Fig. The current model outperforms the prior model in its ability to forecast the forming forces.

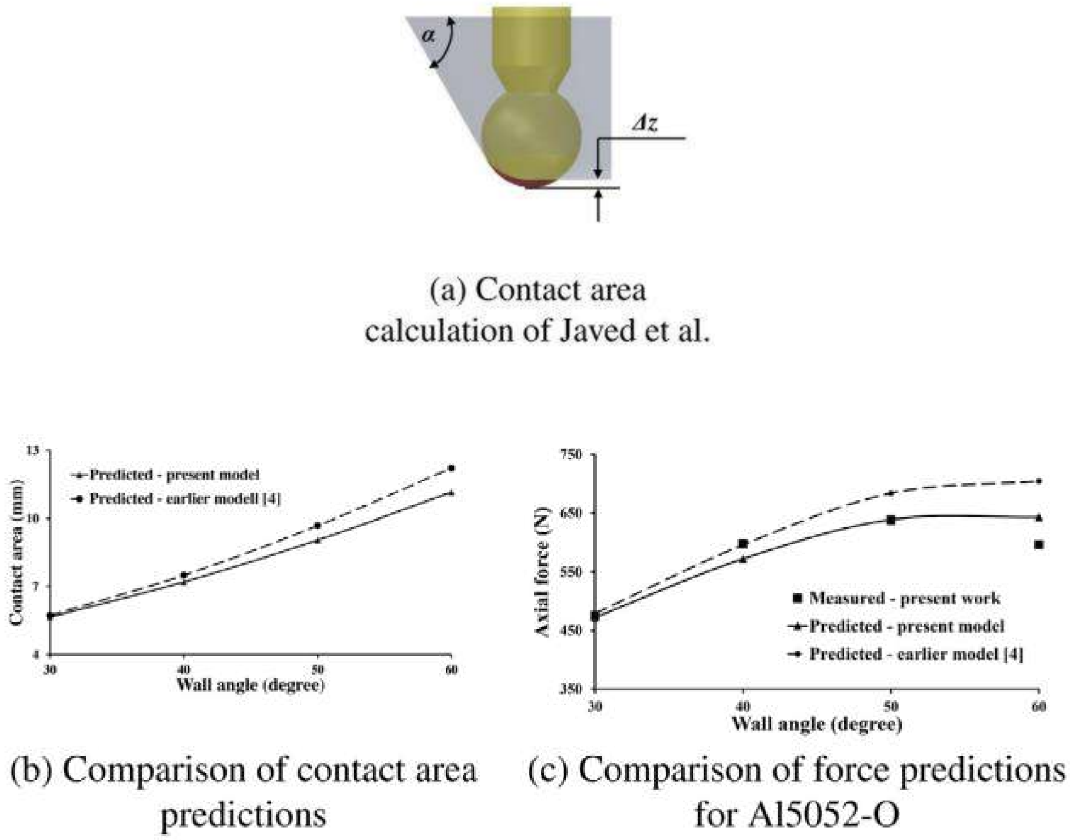


Figure 48 . Comparison of prediction models

Chapter 5:

Analysis of Results

5.1 Procedure of experiment

5.1.1 Plan of experiments:

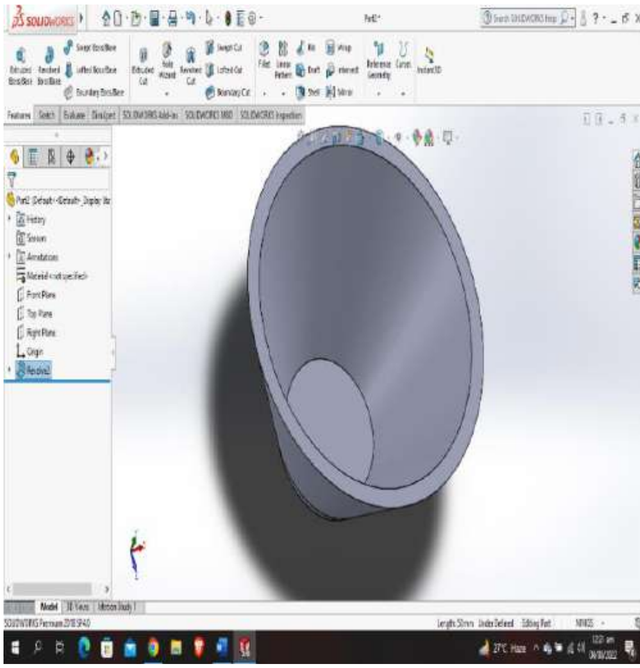
We performed different experimentations to analyze the effect of tool diameter, steps size, & wall angle on the formability of commercially used Al5052. The settings of Ultimaker Cura were same for all experimental tests. All parts were designed into conic shape with a 94 mm diameter and a 50 mm depth. The material's formability was evaluated using constant angle tests at angles of 55 and 65 degrees. We used multi-angles testing to identify the depth accomplishments and maxi-mum forming angle of the given materials. Angles were continuously changing along the conical profile, ranging from 35˚ to 90˚.

Table 5.1 Experimental plan

Fixed Angle Test			**Multi Angle Test**		
Tool dia	Angle˚	Steps size (mm)	Tool dia	Angle˚	Steps size (mm)
6mm	55	0.5	6mm	35-90	0.5
	65˚	0.5			
10mm	55˚	0.5			
	65˚	0.5			

5.1.2 CAD design development:

We designed conical shapes and created it into a single operation to understand the Incremental Sheet Forming mechanism. We created contour tool paths and CAD geometries with the help of UGNX CAD and CAM. G and M codes were generated from SolidWorks. In Ultimaker Cura we slice the conical shape parts.



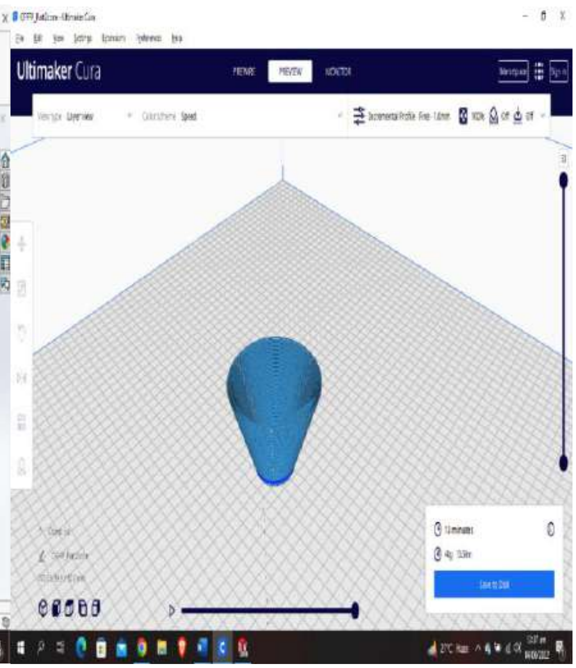


Fig. 5.1 CAD profile

Fig. 5.2 CAM tool path

5.1.3 Process description:

We fitted the metal sheet forming-tool with a smooth hemi-spherical headed into the machine. This forming tool was composed of high-speed steel, which allows for formation of stainless steel and aluminum material. Metal sheet was fixed and positioned with the help of nuts into the bed and pressed down. The sheet started deformation when the z-axis value increases downward. When the z-axis increases the forming tool will apply force to deform the metal sheet in steps. Z will increase when the machine completes its one loop. The forming tool will move in a predetermined manner. The step size was 0.5 for all experiments.

5.1.4 Material:

We used easy cone-shaped specimens to evaluate the material's formability. Commercially used Al 5052 was selected as sample material because it was often used in the sheet metal forming industries. The following list of material parameters: Young's modulus was 72GPa, density was 2.71 g/cm3, Poisson's ratio was 0.27, UTS was 150MPa, and the maximum elongation at fracture was between 50 and 60 percent.

5.2 Results

5.2.1 Effect of wall angle:

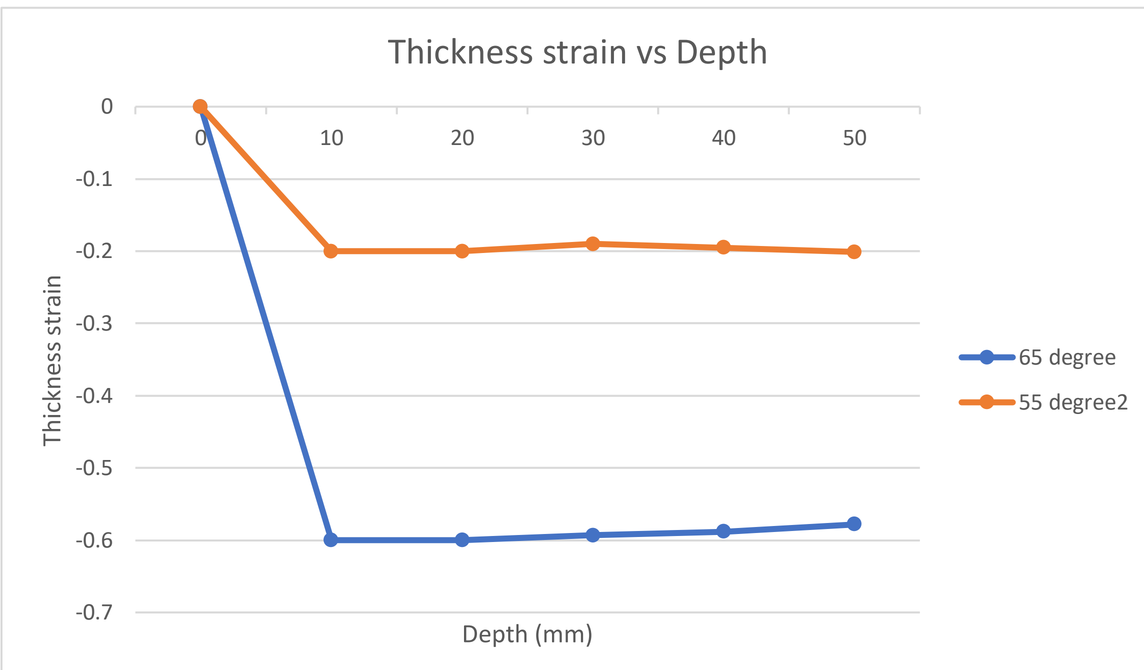


Figure 49 Thickness-strain VS Depth of cones for 2 forming angles

At greater wall angles, greater thickness reduction can be obtained experimentally, but when the wall angle will be less than 65 degrees then there should be uniformly distributed thickness. Stretching and local shearing cause deformation as the wall angle rises. Stretching causes the wall reduction will be larger towards the top than the area near the base. The relationship between the thickness decreases at various forming angles was clearly shown in Figure 3. The 50 mm depth attained without a crack towards the bottom was the greatest accomplishment. We performed multi-angle experiments to analyze the maximum forming-angle of the Al5052 sheet. In the multi-angle testing, the fracture depth was 42 mm.

5.2.2 Effect of Step size:

We performed many experiments to examine the influences of step-size (Δz) on the formability of the aluminum sheet in the Incremental Sheet Forming machine. When other parameters were held constant, a major parameter that affected the formability's limits shift from fracture to necking was the size of the step (movement of the tool) which goes down after completing each pass. There was just one process occurring during the experiment. All other parameters remained constant while the vertical step size (z) changed. The surface finish is strongly influenced by the step size. With the increase in step size, the surface roughness also increases. Step size should be minimum for a smooth surface finish. In figure 4 you can see the difference, in the figure we used 0.2 step size and we get smooth finishing but in figure b we used 0.5 step size and we get a rough surface. Local deformation was more essential than stretching for smaller step sizes.

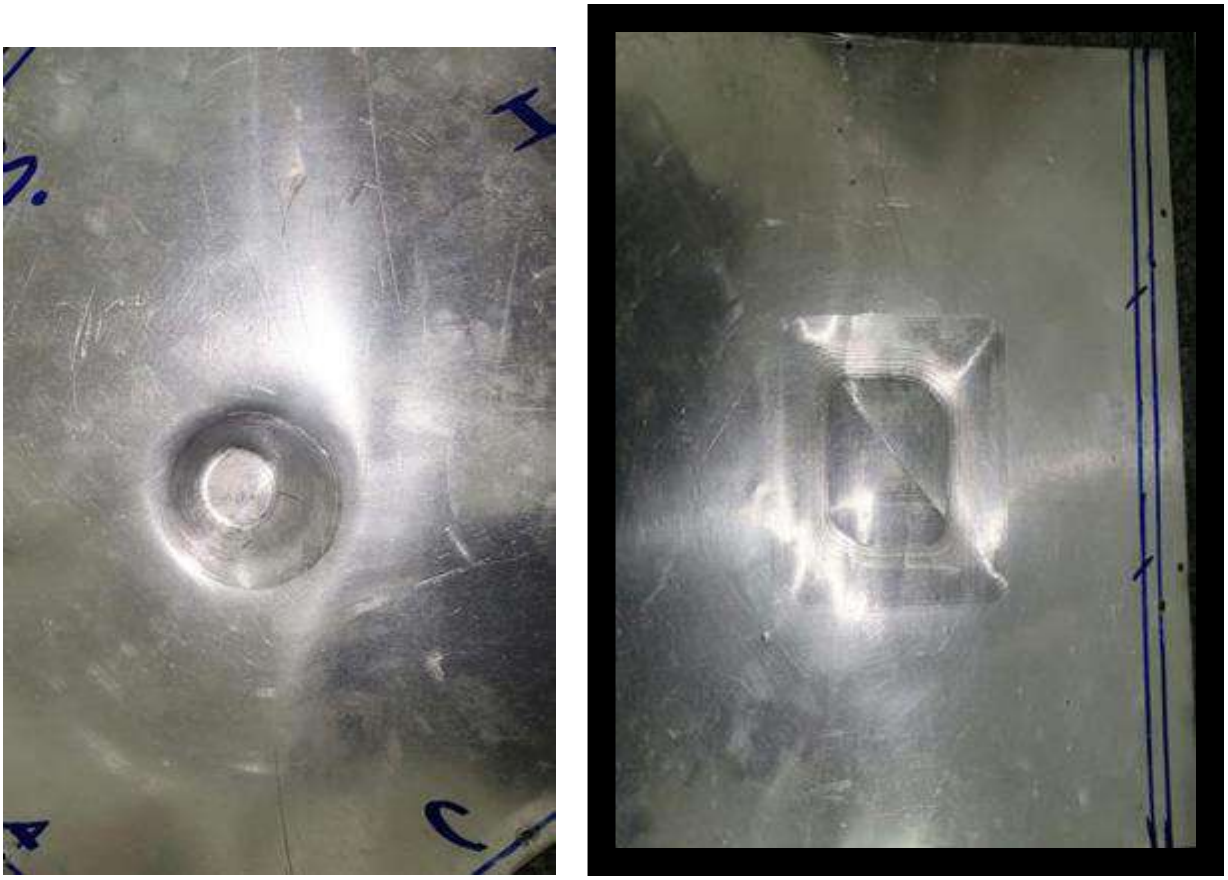


Figure 50 a) Smooth surface with 0.2 mm step-size b) Rough surface with 0.5 mm step size

5.2.3 Effect of Tool Diameter:

We have seen during the forming that Tool diameter affected the surface finish means surface smoothness also depends upon tooltip and diameter and also it affects the formability of the sheet. When we used a 6mm diameter tool then it produced less force and when we used a 10mm diameter tool then it produced greater force. Tool size influenced two thing, one formability of the designed part and 2nd the surface-finish of the designed part through the process. However, Vibrations caused by a 6 mm tool were greater than those caused by a 10 mm tool. Larger tools typically support the sheet during forming better due to a larger contact zone. Better formability was obtained by smaller tool diameter, but only to a limited extent. The concentration of stress and strain is considered to be the cause of the higher formability observed with smaller radius tools.

5.3 Discussions

Failures in the Incremental Sheet Forming machine are unpredictable as it depends on different forming parameters. Failure prediction is important to decrease the number of experiments, tooling cost and material. The forming was done with the help of two different tools. Since the deformation in Incremental Sheet Forming machine happens incrementally, the strain in the sheet increases as the component's depth increases. In Incremental sheet forming the thickness distribution of the formed parts place greater impact has on the quality of the desired finished product. The possibility of fracture may rise if the thickness reduction exceeds a specific value. The fabrication with tools of 6 mm and 10 mm diameter has a minimum expected sheet thicknesses of 0.55 mm and 0.61 mm, respectively.

CHAPTER: 6

BUDGETING AND COSTING OF THE PROJECT

BUDGET PLANNING:

The budget is the composite costs of all tasks, activities and goals that project must fulfill. In simple words, it is the total amount of money which is needed for the completion of the final year project. We created the budget of our FYP during project's initial phase and continued monitoring it until the project's completion. It was important to create a budget plan because it creates limitations and we have a total in our mind for purchasing parts. It helps to understand the progress of the project and changes can be made to plan if needed. If you have more budget then you will get more people for work and you can purchase expensive and accurate parts for the project. That's why the project cannot be completed without budget planning no matter project is bigger or small. We compiled the details estimates of the project and we added into the budget plan. Then we were able to record our FYP according to the plan during the work was in process.

DETERMINING OF RESOURCE COST RATES:

We planned who will work with us at a specific rate and we decided that we will use the aluminum material for our project. We figured out the labor and the material cost. And we marked the shops for purchasing parts and figure out those shops from where we can machine the parts. Mostly we purchased parts of the machine from Lahore Buns Road.

DEALER OFFER:

Sooner or later, you will need an outer dealer for the completion of the project. Because every person is an expert in their specific field no one can do all things. We also hired a person from Lahore for programing on the board of the machine. We had a deal with this person and we specified the amount of money in the budget plan before starting the manufacturing of the project.

RESERVE COST:

We keep some extra money for spendings. We should have some cash on hand in case something costly does happen because we are aware that our project has a danger in that respect. That's why we place some extra money.

ESTIMATING COSTS:

During the conceptual phase when we were selecting the project, the economic factor was an important consideration. The estimating cost should be precise enough so that comparison can be valid. We created an estimated budget during the selection phase, by doing so the project consumes fewer resources. Our estimation was based on the 3D printer because our project is similar to the 3-axis 3D Printer, so estimated the cost according to the common parts available in the market.

EXTRUSIONS:

We needed 3m long t-slot aluminum 4040 extrusions for making the basic structure of the machine. Then we have to cut it into different lengths. The estimated price of these extrusion was 30k pkr. And for making the bed of the machine we needed extrusions of greater height and less width so we decided we will purchase t-slot aluminum 2060 extrusion of 2m length for making the bed of the machine. The estimated price of this extrusion was around 15k pkr.

SMOOTH RODS:

2 smooth rods of length 504mm were needed for the y-axis and 2 smooth rods of length 468mm were needed for the x-axis. The total estimated cost of 4 rods was around 5k pkr.

BALL SCREWS:

For traveling on the x, y and z-axis we used ball screws. In the design, we specified that 5- and 4-mm pitch ball screws we will use, so we estimated the cost of 2 ball screws which we will be using on the x and y-axis, and 1 ball screw of 5mm pitch and 12 mm diameter use in z-axis the estimated price of 2 ball screws and DSG12H and 3 spiders coupling 8x8 was 15000 and the cost of ball screw and DSG16H used in z-axis was 8000 pkr.

ALUMINUM PLATE:

4mm thick aluminum plate was required for making the base of the bed of the machine. And the estimated cost of this aluminum plate was 3500 pkr.

LINEAR RAILS:

2 MGN12 linear rails of length 250mm and 4 carriages were required on the z-axis. The total estimated cost was 15000 pkr.

6.2.6 SPACERS:

3 Different types of spacers DSG, SC, and SCL were required to fit the motor. The total cost of 3 DSG, 2 SC and 2SCL, and linear rail offsets was approximately 15k pkr.

6.2.7 TB6600 DRIVER:

For controlling or operating the motor, a driver was required. We have 3 motors so that's why we needed 3 drivers to drive each motor. The total estimated cost of drivers was 5000.

6.2.8 NEMA24:

Nema24 is a stepper motor used for CNC-type machines because it is accurate and best after the servo motors so we wanted to buy 3 stepper motors for our project. And the calculated cost of these motors was 15000.

6.2.9 POWER SUPPLY:

The power supply was an important part of our project because our machine is working on 220v and the motors and driver required fewer voltages. We needed a 24v-28v output supply so we placed 3000 for power supply.

6.2.10 REPRAP SCREEN:

We wanted our machine can be operated manually and we can also see the readings on the screen for that purpose we required a RepRap Screen. And the estimated cost of this screen was 2000.

6.2.11 SKR2:

SKR2 is a motherboard used for processing or controlling the all-electrical components of the machine-like motors, drivers, sensors, etc. This is the most important part of our project. The estimated price of SKR2 was 20000.

6.2.12 PROGRAMMING:

Programming was required for the SKR2 board and we wanted to hire a person who can do programming the estimated cost for that purpose was 20000.

6.2.13 NUTS AND BOLTS:

Nuts and bolts were required to fit the extrusions, rod seats, motor, drivers, coupling, etc. Different types of nuts and bolts were required like M4x10 cap head, M3x8 cap head, M5x16 CSK, M6x35 cap head, M6x35 CSK, M6x30 CSK, M6 Hex Nut, M4 Hammer Nut, M4x10 CSK, M4x12 cap head. The total estimated cost of these nuts was 5000.

6.2.14 Parts for smooth rod:

SK12 is used to hold the smooth rods, and SC12LUU and SC12UU is used for holding bed or sporting the bed and carriage in z-axis. The estimated cost of 8 SK12 was 3000 and 2 SC12LUU was 3500 and 2 SC12UU was 5000.

Sr NO.	Parts Name	Quantity/Specifications	Estimated Cost
1	4040 Extrusion	3m	30000
2	2060 Extrusion	2m	15000
3	Smooth Rods	4	5000
4	SFU1204 with BK+BK12 Seats (2x500)	2	15000
5	SFU1605 with BK16+BK16 Seats (1X250)	1	8000
6	4mm Aluminum Plate	1	3500
7	Linear Rails	6	15000
8	Spacers	9	15000
9	TB6600 Driver	3	5000
10	Nema24	3	15000
11	Power supply	1	3000
12	RepRap Screen	1	2000
13	SKR2	1	20000
14	Programming	1	25000
15	Nuts and Bolts	317	5000
16	SC12LUU	2	3500

17	SC12UU	2	5000
18	SK12	8	3000

Table 3 Estimated Budget

6.3 Actual Cost:

The cost estimation was done using analogous estimation technique because our project is similar to the 3D printer and the actual cost was 4% less than the cost estimated. The detailed result is given below:

6.3.1 Extrusions:

The estimated price of 3m length t-slot aluminum 4040 extrusions was 30000 but we have not found 4040 extrusions in the local market then we ordered these extrusions on AliExpress. The actual price of this extrusion was 27997.62 with 7% Tax and shipping was free. And we also have not found 2060 extrusion in the local market then we ordered on AliExpress, the actual cost was 13022.97 with 7 % Tax and shipping was free.

6.3.2 Smooth Rods:

The estimated cost of 4 smooth rods was 5000. The total actual cost of 2 SF12 504mm in length and 2 SF12 468mm in length were 5029 with 7% tax.

6.3.3 Ball Screws:

We ordered ball screws on AliExpress and the combined actual cost of 2 SFU1204 with BK+BK12 Seats of length 500mm and 2 DSG12H and 2 8x8 spider coupling was 17943.9 with 7% Tax and the shipping cost was 570 pkr. And the combined actual cost of the ball screw that was used in z-axis SFU1605 with BK16+BK16 Seats of length 250mm and DSG16H was 7575.6 pkr and the shipping cost was 568 pkr.

6.3.4 Aluminum Plate:

The estimated cost of a 4mm aluminum plate was 3500 pkr and the actual cost was the same.

6.3.5 Linear Rails:

The estimated cost of linear rails and carriage was 15000. But the combined actual cost of 2 MGN12 of length 250mm and 4 MGN12C Carriage was 18000.

6.3.6 Spacers:

The combined estimated cost of 3 different types of spacers and linear rail offset was 15000 pkr. But the actual cost of 3 DSG Spacer of length 4mm, 2 SC Spacer of length 3mm, 2 SCL Spacer of length 3mm, and Linear Rail Offsets was 13600 pkr.

6.3.7 TB6600 Driver:

The estimated price of 3 TB6600 Drivers was 5000 but the actual cost of 3 TB6600 Drivers was 4200 pkr.

6.3.8 Nema24:

The combined estimated cost of 3 Nema24 motors was 15000 pkr and the actual cost in the market was 11700 pkr.

6.3.9 Power Supply:

Meanwell LRS150 was used in our project as power supply and the estimated cost of power supply was 3000 pkr but the actual cost in the market was 2600 pkr.

6.3.10 RepRap Screen:

The actual cost of the RepRap Screen in the market was 1800 pkr but the estimated price was 2000 pkr.

6.3.11 SKR2:

SKR2 is a board and the actual price of the board was 18000 pkr but the estimated price was 20000 pkr.

6.3.12 Programming:

We hired a person for programming and the estimated deal was 20000pkr but he agreed to take 21000 pkr.

6.3.13 Nuts and Bolts:

The combined cost of different types of nuts and bolts was 5000 pkr and the actual cost of 73 M4x10 cap heads, 16 M3x8 cap heads, 28 M5x16 CSK, 6 M6x35 cap heads, 8 M6x35 CSK, 8 M6x30 CSK, 16 M6 Hex Nut, 146 M4 Hammer Nut, 16 M4x12 cap head was 6458 pkr.

6.3.14 Parts for smooth rod:

The actual cost of 8 SK12 in the online market was 2936.08 with 7% Tax and the shipping was free and the cost of 2 SC12LUU was 2237.37 pkr with 7% tax and the shipping price was 1001 pkr and the cost of 2 SC12UU was 4258.6 pkr and the shipping price was 1001 pkr.

Sr NO.	Parts Name	Quantity/Specification	Base Price	With 7% Tax	Shipping
1	4040 Extrusion	3m	26166	27997.62	0
2	2060 Extrusion	2m	12171	13022.97	0
3	Smooth Rods	4	4700	5029	0
4	SFU1204 with BK+BK12 Seats (2x500) DSG12H Spider Coupling 8x8	2 2 3	16770	17943.9	570
5	SFU1605 with BK16+BK16 Seats (1X250) DSG16H	1 1	7080	7575.6	568
6	4mm Aluminum Plate	1	3500	0	0
7	Linear Rails	6	18000	0	0
8	Spacers	9	13600	0	0
9	TB6600 Driver	3	4200	0	0
10	Nema24	3	11700	0	0
11	Meanwell LRS150	1	2600	0	0
12	RepRap Screen	1	1800	0	0
13	SKR2	1	18000	0	0
14	Programming	1	21000	0	0
15	Nuts and Bolts	317	6458	0	0
16	SC12LUU	2	2091	2237.37	1001

17	SC12UU	2	3980	4258.6	1001
18	SK12	8	2744	2936.08	0

Table 4 Actual Cost

The total cost on the purchasing of materials and the operations done on them was 185000 PKR.

6.3.15 Miscellaneous:

The miscellaneous cost during the whole project was around 15000 PKR that includes transportations, travelling and the foods that we had during travelling.

6.4 Total Cost:

The total money spent on purchasing and the operations done on the purchased material was 1,85,000 PKR.

Other than that, the miscellaneous charges on the whole project were 15000 PKR.

So, the total cost on completing the project was 2,00,000 PKR

CHAPTER 7

CONCLUSIONS

In this work, the rupture and the denseness disposal are thought for ISF process. In experiments, the rupture takes place at complementary wisdom for the making with two together, 8 mm and 10 mm width finishes. The CDM located Lemaitre damage test supports an acceptable forecast of making insight and break area and an average mistake of 6 % is deliberate between experiment and imitation results. The form width shows less effect on the formability. As constituent future work, exercise of alike model for various arithmetic and exploratory computation of density classification in the parts will be deliberate. The greatest deviation maybe erects for one difference of obstruction angle of making. Greater formability and wisdom maybe completed for obstruction angle inferior 75 point. As the obstruction angle increases extended plays a main role in deformity than shearing. When obstruction angle decreases deformity is for the most part takes place on account of shearing. With tinier upright step making forces decreases and best insight maybe reached accompanying better surface finish. Tool amount affects two together the formability and the surface finish of the made part. Biaxial elongated at the corners and plain strain elongated at the hands caused. This is the reason crack happen generally at the corner. A parametric case was attempted in consideration of determine a better understanding of the connection betwixt three key ISF limits, namely the step-below, feed rate and finish width, and the formability and rupture incident of grade 1 and 2 clean Ti utilizing exploratory experiment and FE study in cooperating the stress triaxiality reduced GTN damage model. In addition, the strength of nervousness of material types to the ISF limits was interpreted. The following conclusions grant permission be tense from duplicate review: The corresponding 'tween the exploratory results and FE reasoning utilizing the stress triaxiality reduced GTN damage model emphasize allure veracity in thinking fracture incident in the ISF of shortened embellished strobile and conical shapes accompanying various making limits. The step-unhappy, feed rate and finish width have various strengths of effect on the formability and break occurrence of the ISF process, and the grade 2 clean Ti is more awake making limits than grade 1 clean Ti. The maximum divider angle of the grade 1 clean Ti embellished shortened strobile increases by 0.85o , 2.73o and 5.68o when the step-below is altered from 0.6 mm to 0.4 mm to 0.2 mm; the feed rate changes from 3000 mm/brief time period to 2000 mm/brief time period to 1000 mm/brief time period and the tool width changes from 15 mm to 10 mm to 8 mm, individually, when in fact the increase in the maximum obstruction angle of grade 2 clean Ti is 5 grade , 6.1degree and 7.65 grade accompanying the unchanging changes of the ISF limits. With the raised step-below, feed rate and form width, the vertical making force increases therefore accompanying both types of clean Ti. The increase in the making force accompanying raised step-below and finish width maybe assign to the increase of material to disfigure and to the raised contact district between the form and the coating, individually. Whilst the increases in feed rate influence a grade of strain rate thickening effect in ISF. The level of important strain at break decreases accompanying in folded making limits (step-unhappy, feed rate and finish width) for both types of clean Ti. The increases in the step-below, feed rate and form width can help to nucleate new voids in a clean Ti model and quicken the tumor of primary voids, chief to an increase in the profit of outer space capacity fraction in the change district betwixt the contact and non-contact zones; also, rupture happens when outer space book part reaches the profit (0.305 in clean Ti Grade 1 and 0.116 in clean Ti grade 2).More diminishing maybe seen in the obstruction of the embellished shortened pyramid in the change domain middle from two points the contact and non-contact district when the step-unhappy, feed rate and form width decrease on account of a larger divider angle being reached when these parameters are cut down. Increase in feed rate and therefore strain rate speeds up break incident in the ISF process. In this study, the GTN damage model was grown to forecast rupture in the ISF process established the assumption that the material behaviors of the coating were isotropic. The GTN model maybe widespread to contain the belongings of kinematic thickening and anisotropy of the Ti material to study the effect of hardening behavior and material an isotropy on the site and wisdom of rupture in ISF. It is not adequate to believe break of the surfaces of grinder panels to display loss; added deterioration ways to a degree gist humiliating and delamination that are within to the committee bear be thought-out. ISF maybe used to distort MS/PP/MS and Al/PP/Al grinder panels. This is causing these panels have flexible and mostly firm cores and faceplates that remain the local gouge in ISF without collapse or rupture. The Mechanics of Incremental Forming of Sandwich Panels 156 • A MS/PP/MS grinder committee and a massive aluminum covering are made accompanying akin styles in form forces in ISF, as long as the motions of the above and lower surfaces and the veracity of the sine regulation prediction of divider density are identical in two together cases. Hence ISF of few grinder panels grant permission be a smooth progress asking existent information of ISF of massive coating metals. The deformity mechanisms of a MS/PP/MS grinder committee and a massive aluminum covering made by SPIF are mainly extended at right angles to the finish route accompanying through-width clip close the tool course.

CHAPTER 8

FUTURE ASPECTS

Finally, the change of automobile designs is submitted as an main field for future research to optimize the range of geometries which it is likely to form. The ideal arrangement of delay and supplies for ISF is individual that admits the most expansive possible range of geometries expected made to the capital attainable characteristic. Factors that concede possibility be thought-out contain the intensity of workpiece that is likely to form, the introduction of the workpiece, either the workpiece is transported a suggestion of correction the indenter, the axes and range of motion of the indenter, the substance and inflexibility of the indenter support, the number of indenters and the design of the workpiece clamping. For example, it is more strength efficient to move the workpiece a suggestion of correction the indenter if the workpiece is limited, even though this demands more room than custody the workpiece fixed and affecting the indenter. Mounting the workpiece across requires less floor room if the blank is a flat page, but if the production is a three-spatial book of equal ranges therefore this has no benefit. Indenters on ISF machines are frequently restricted to activity on three axes outside turn, and so the range of possible geometries maybe shortly extended by growing the range of movement of the indenters, such as by utilizing a travelling android arm. Workpiece support is frequently limited to two-spatial clamping frames, therefore spending around the circumference of the made shape maybe decreased and the range of possible shapes of offset blanks maybe extended by utilizing a flexible 3D clamp. The potential of the engine maybe further extended by admitting identical delay to act perfecting operations to a degree ray of light incisive, polishing or canvas. Furthermore, narrow and inconsequential machines are specifically acceptable to localized result, and hence skilled can be a future for ISF in the localized result of customized merchandise, preventing the long conveyance distances and beating the boredom of designs all-inclusive production. It is likely that the consolidation of a limited, inconsequential and flexible automobile accompanying a advanced original-time process control arrangement hopeful enough for ISF to enhance a established covering hardware making process secondhand in industry.