

Incremental Sheet Metal Forming Process: A Review

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Abstract- In the modern engineering world, technological advancement in manufacturing technologies are very important to handle market requirement of sheet metal forming industries. Incremental sheet metal forming (ISMF) has created significant scientific attention. The process is agile, highly flexible and it able to handle the market requirement. The drawbacks for the sheet metal forming process are the production rate and part accuracy, while high formability and flexibility are consider as main advantage in ISMF. The aim of this paper is to understand the ISMF process, their key features, and parameter influencing the process, advantage, disadvantage and application.

Keywords: Incremental sheet metal forming (ISMF), Formability.

I INTRODUCTION

A. General Introduction:

Sheet metal stamping is one of the most commonly used manufacturing processes. Every day, millions of parts are formed by stamping. Now a day, customers demand more tailored products, and production series in many cases become smaller. Most of the conventional means of forming sheet metals into finished shapes having following limitations: 1. It Involve the use of expensive pressing or stamping dies, 2. Producing complicated geometries has also been difficult, 3. with traditional methods prototyping has been extremely expensive. Hence, new methods for low volume production and prototyping are required [1].

Even, still today industries are searching for validated methods for Sheet Metal Forming which can produce LOW VOLUME sheet metal products at LOWER COST, HIGH QUALITY and that are FLEXIBLE enough to produce different product geometries with a SHORT LEAD TIMES. In past few years industries are taking keen interest in incremental sheet forming (ISF), because ISF is a agile forming method for low volume flexible manufacturing system [M Tizsa, 2012]. ISF is an emerging

process to manufacture sheet metal parts that is well adapted for small batch production. ISF is a cold forming process developed in Japan to satisfy the need of automotive industries. This process involves the use of smooth rotating tool to carry out local sheet metal deformation without use of expensive die. This is the reason ISF is also known as Die less forming method [Sayed Mojta, 2014]. This process forms various materials into complex shapes. ISF gives rapid prototyping advantage for sheet metal parts which are made from a 3-D CAD model to finished product without conventional limitation of tool design [1].

B. Process Definition:

The technological advancement of stretch forming is a Incremental forming process, but ISF differs in some functional aspects. The working principle of spinning is, work piece deforms into a specific shape. Work piece confirms the shape of mandrel, and it is clamped on a mandrel which is rotating and a tool is applying a force on the sheet metal then sheet takes the shape of mould. The rotating is able to move on a straight and spiral contour. The thickness of sheet metal is more or less constant. In this process blank edge is moving inward [W. C. Emmers, 2010]. Whereas in ISF process the work piece edge is clamped and cannot move inward. The sheet takes the required shape without any mould or a die support. The tool is moving on a spiral path and stretching the sheet metal inward. The thickness of sheet metal is reduced [M. Pohlak, 2007]. This process produced asymmetric shapes, hence the process is known as Asymmetry incremental forming (ASIF) [J. Jesweit et. al, 2005].

The comparison between spinning and ISF is shown in Table 1.

Table 1 Comparison between spinning and ISF [4]

	Spinning	ISF
Blank Edge	Move inward	Clamped
Wall Thickness	More or less constant	Reduces, determined by the process ^a
Die/Mandrel required	Yes	No
Shapes basically determined by	Movement of roller or by mandrel	Movement of punch or roller
Asymmetry shape possible	Limited ^b	Yes

a. In shear spinning the final wall thickness has to be achieved by controlling the gap between roller and mandrel, in ISF the final wall thickness is determined by the characteristics of the process without need for direct control.

b. Although spinning is normally used for symmetrical products, asymmetric shapes can be made as well to some extent, (Awiszus and Meyer, 2005).

In ISF the blank edge is clamped but is having a little tendency to pull inwards. Sometimes the blank is left without support (Single point incremental forming) and there may be a simple support or a full die support (Two point incremental forming). Also in some cases supports are replaced by another rotating tool (Kinematic ISF). These variants are described in successive topics. The paper focuses on general overview of ISF which covers history of ISF, classification of process, various forming methods, and effect of process parameters, formability analysis, and innovation in experimental setups, economical analysis and capabilities of ISF over conventional sheet metal forming process [4].

C. History

This section mainly describes the early developments before the first true ISF patent (1993). Also an attempt is made to locate the origin of ISF.

As explained earlier that there is a very small difference between spinning and IS. In 20th century various patents are issued which explained variants of spinning that can be regarded as ISF process. Two of the most common are describe here. Fig 1 shows Leszak patent on disk or cup type of product from metal sheet. The blank rotates and vertical movement of tool is created by local bending that is caused by pushing the sheet into an elastic medium by a roller (patent list).

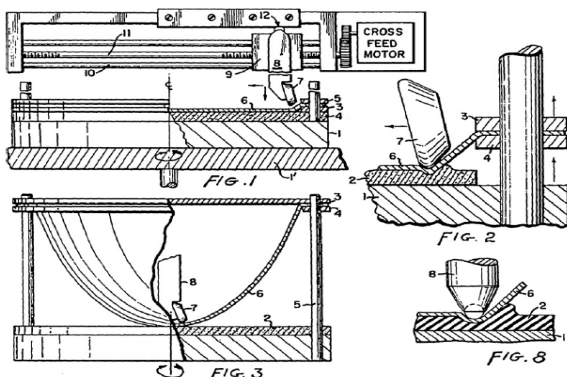


Fig 1. Process proposed by Leszak [US 3342051]. 6 = sheet, 7 = roller [4].

Berghahn [US 3316745] patent also explain manufacturing of cup type of sheet product. As shown in fig 2 a blank is rotating and clamped, while a roller moved inward along a radial line.

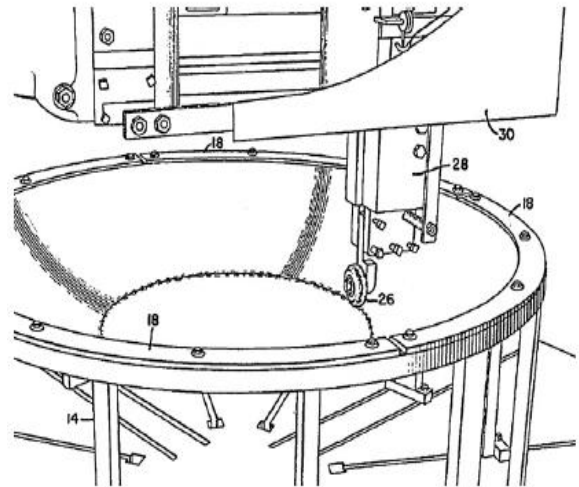


Fig. 2 Process proposed by Berghahn [US 3316745]. 26 = roller, rolling on the sheet [4].

Both the patents are developed earlier in 1898. Both proposals have a distinct difference: in the Leszak proposal the shape is created by bending of the sheet against an elastic medium, in the Berghahn proposal by the xyz movement of the roller. Jeswiet et al., 2005 says that above mentioned two patents are origins of ISF. Both patents are presented as variants of spinning. Although the

Berghahn patent can be considered as an experimental modification of spinning but cannot consider as a origin of ISF. This is proved by work done by Mason (1978) at University of Nottingham. This is considered as an origin of ISF. Mason has concentrated their studies for small batches. They have used single spherical roller. There are main three coordinates X, Y and Z is required on which the spherical roller moves. But for the simple shapes Mason has used backing material which is well explained in fig 3.

Mason's work is basically to find out suitable material for backing support. He has also explained that by forward and backward movement or by side to side of spherical roller sheet takes the shape which requires. The depth of rolling is an incremental at each pass. Some limitations is still there in Mason's work like, optimization of tool path, thinning of sheet material and most important is incapability to produce sharp corner while producing square cup. These limitations are overcome in further development in ISF continued in Japan, which will explain in further sections.

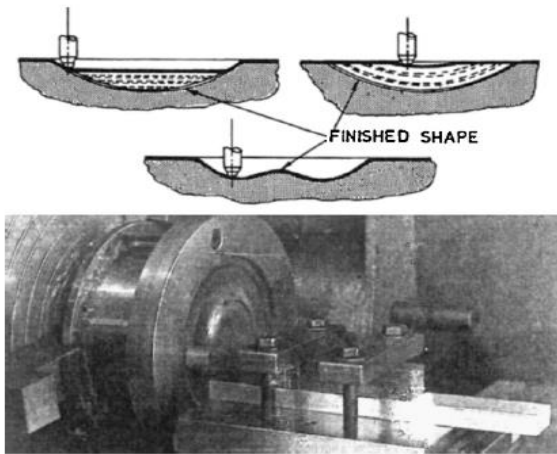


Fig 3. True ISF by Mason (1978) [4].

D. Working principle of ISF

As explained earlier Japan is a pioneer in development of ISF process. W. C. Emmers et.al has developed the primary set up which is simple and three dimensional CNC milling machine is used for proper tool path control, but table used to hold the work piece was manually operated.

As shown in fig 4, a single rotating tool was used and it moves inward by a specified step from 1 to 3 and it continued till the final geometry is achieved. The work piece was clamped properly. By the combined movement of tool and manually operated table sheet takes the required shape. The tool movement (Trajectory) was depending upon the geometry of part. Table is moving in X and Y directions and tool is stretching the sheet in Z direction.

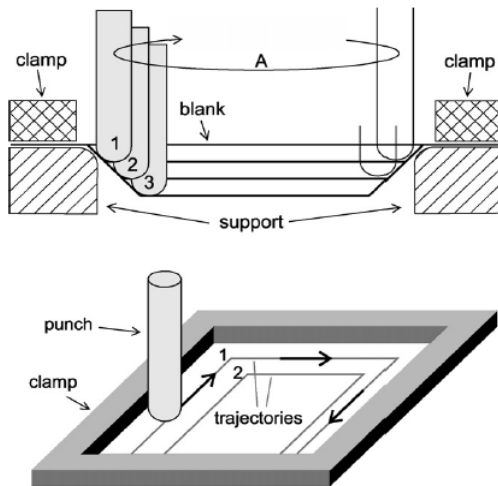


Fig 4 Principle of SPIF for a non-axis symmetric shell, originally realized by Iseki et al. (1989).

II. BASIC ELEMENTS OF ISF PROCESS

Incremental forming is a advanced technique in which sheet metal is form in step by step incremental feed by deforming tool. ISF contains for basic types of elements which is forming tool, Sheet metal, Blank holder and CNC machine as shown in fig 5.

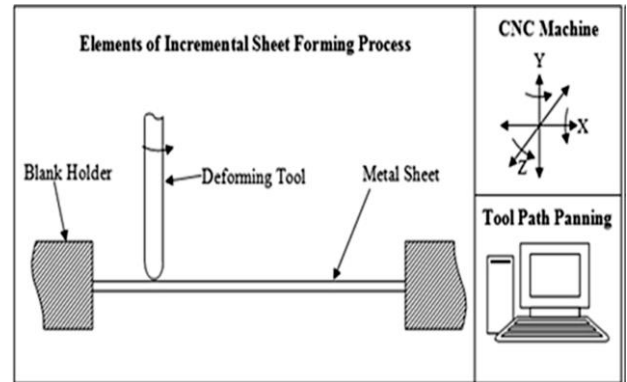


Fig 5 Basic elements of ISF [5]

CNC machine control the tool movement. A tool used in the process is simple and economical in manufacturing. The tool used is hemispherical in design and blank holder is used to clamp the sheet metal. Blank holder restricts the movement of sheet metal going inward. To deform the sheet metal properly, controlled and optimized tool path is required. Before starting the actual manufacturing a trial run of machine is important to ensure proper functioning of machine to avoid failure.

III. CLASSIFICATION OF INCREMENTAL SHEET METAL FORMING

ISMF is broadly classified into two categories; (1) Conventional ISMF and (2) Hybrid ISMF (9788). Conventional ISF is again sub-classified into two categories, (1) Single point incremental forming (SPIF) and Two point incremental forming (TPIF). Fig 6 shows the SPIF process.

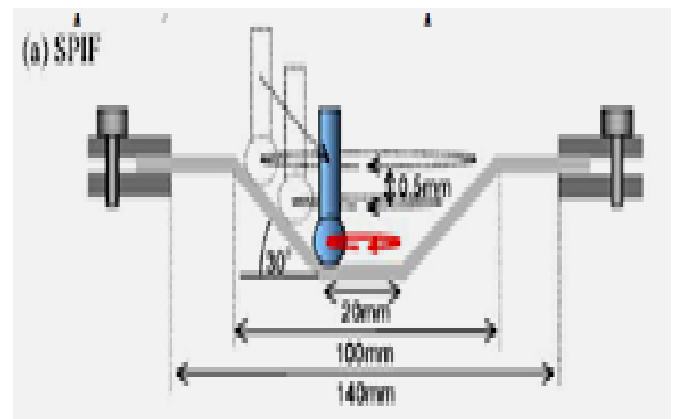


Fig 6 Single point incremental forming [16]

In SPIF only one tool is used to deform the sheet material. As explained earlier tool moves on specified trajectory and sheet metal does not have any backing support. Whereas in Two points incremental forming TPIF where backing support is use with the tool to deform material. In TPIF, two tools, one is known as deforming tool DT and another one is supporting tool; move over the surface of the sheet [16]. Fig 7 shows the TPIF process.

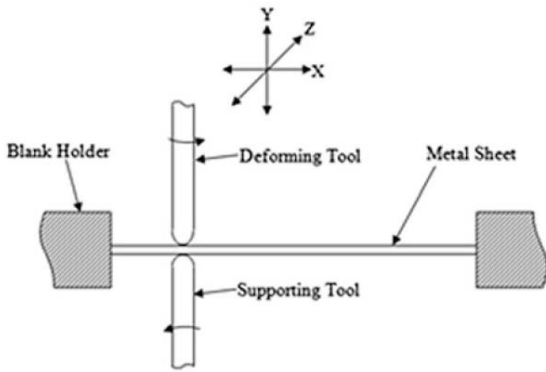


Fig 7 Two point incremental forming [5]

Now a day's a modified form of conventional ISF process is demand, which is known as Hybrid ISF (HISF). Thinning of sheet metal is crucial issue in ISF. Researchers are now a day's focusing on this part. So instead of solid supporting tool pressurized hydraulic fluid is used in the process. This is well explained by Yogesh kumar in fig 8. This process is known as Single point Hydro forming. This type of hybrid incremental forming process is different from conventional SPIF process in which single tool moves over one side of the surface of the sheet metals and other side of surface of sheet metals is supported by the pressurized hydraulic fluid.

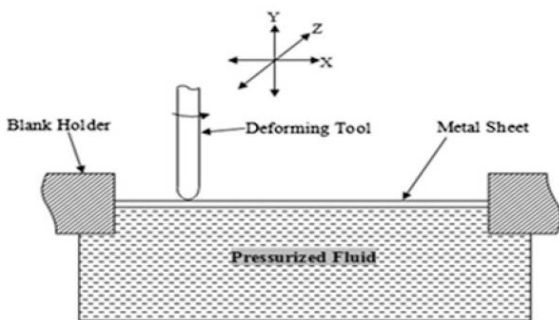


Fig 8 Single-Point Incremental Hydro-Forming [5]

Yogesh kumar has also classified TPIF process into two categories. One with the use of partial die and second with the full die.

(a) TPIF with Partial Die: In this type of hybrid incremental forming process, a single tool moves over one side of the surface of the sheet metals and other side of surface of sheet metals is supported by a partial die to get the desire impression as shown in Fig. 9.

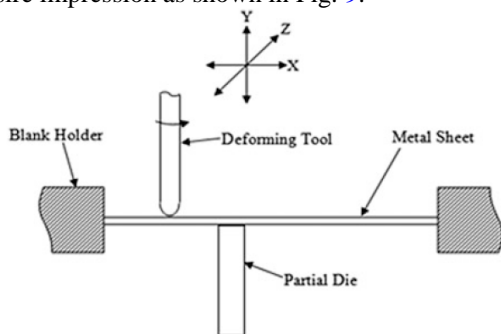


Fig 9 TPIF with Partial Die [5]

(b) TPIF with Full Die: This type of process used full die instead of partial die. As per the fig 10 full die is replica of parts to be formed. So it is used as a form tool which contains the trajectory of a part going to form in the process. One side of sheet metal deforming tool is moved and other side full die used.

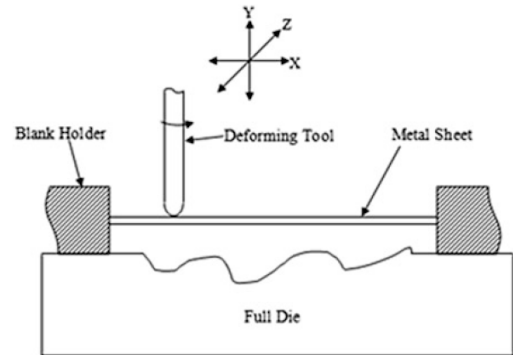


Fig 10 TPIF with Full Die [5]

IV. IMPORTANT PROCESS PARAMETERS FOR ISF

ISF is having advantages over conventional forming process, but still this process is limited in use. The reason is some parameters are not optimized yet. To understand this first we have to identify process parameters and then we have understood the influence of these parameters. So following are some parameters which are having considerable effect on the process.

A. Tool Path:

To deform the parts properly a movement of the tool on specified trajectory is very important. This trajectory is known as tool path in ISF. The tool path is generated by a commercial CAM software's and CAM software's requires proper input in terms of CAD models. Fig 11 shows the example of truncated cone type of tool path and path for square pocketing type of operation. At the time of manufacturing smaller surface roughness with tool entry and exit marks are generated. This is considering as a limitation of ISF process [Nimbalkar D. H, 2013].

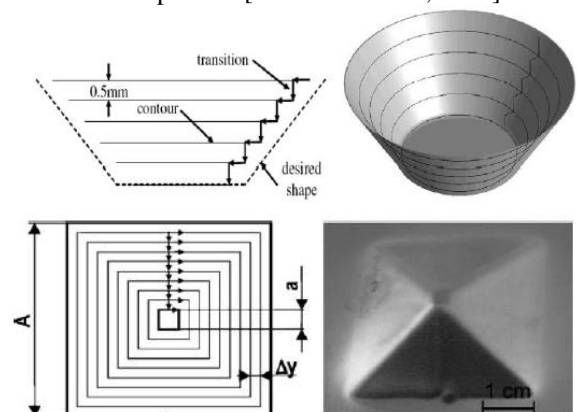


Fig 11 tool path of truncated cones and a square pocket [16]

To form truncated cone a spiral tool path is generated. This tool path is continuous with distributed over the sheet metal. In conventional contour milling or spiral path in ISF process a cavity of the part is stretched

and it increases the slope angle of parts with excess starting in sheet metal. As per the Azaoui, 2012 in conventional milling a roughing pass is followed by finished path.

The main difficulty in SPIF is orientation of part and draw angle ϕ . So to avoid this difficulty sheet metal / parts is first oriented properly and draw angle in first step is considered as 65° or greater [Saad Arshad, 2012]. In this process first part is rotated around X and Y axis. Then walls of part is become step with shallower angle relative to the Z axes. This method of forming increases the successful manufacturing of sheet metal [G. Hirth et.al, 2005].

B. Tool Size:

Kin et.al, 2002 shows that the part manufactured properly with higher surface finish, tool size is a critical parameter. Tool size is highly affecting the formability of part [Ambrogio et.al, 2012]. Experiments conducted by various researcher shows that larger tool is having bigger contact zone which gives a support to sheet metal during forming. Furthermore larger tool increases the forming forces which increase the contact area between tool and the sheet metal.

In case of smaller tool deformation zone is concentrated and higher strain is generated, which gives the higher formability [Fillice et.al, 2002]. With small tool radius forces are decreased and stresses are also reduced and because of that chance of failure is less. Surface area at a tool tip is less, so surface area of contact is reduced and concentration of force and strain is high. At this point friction is localized and the magnitude is high and heating is increased. Because of higher heating and strain flow of material is become easy which increase the formability [Kim T. J. et.al, 2000]

C. Tool rotation:

M. Durante, 2009 explained that tool rotation influence the feed and feed rate in ISF. Various authors are dedicatedly done their research on the effect of tool rotation in precise manufacturing of sheet metal parts. Kim and Park, 2002 explained that as the feed rate is decreased the formability is decrease. To achieve good results in terms of geometric accuracy and higher surface quality, it is important to use a tool path with a feed rate depending upon geometry of part [Attanasio et.al, 2006]. For significant increase in friction causes formability to decrease significantly [Strano et. al, 2004]. While Kim and park explain the friction at tool sheet interface improve formability.

D. Sheet material:

The effectiveness of sheet material is created significant interest in researcher. So many of the researcher has taken kin interest to find out how sheet material influences the ISF process. Formability differs with the material stated by Fratini et.al. Authors have tried to find out influence of material properties on formability [6]. After studying some literature it is found that strain hardening exponent (n) and strength coefficient (k) had the highest influence on formability and on ISF. Because strain hardening exponent is differs with the material. Geometry

it is found that higher the value hardening coefficient, higher the formability.

I. Cerro et.al, 2006 has carried out their experimentation on AL1050-0 sheet material with the size of 400mm X 400mm X 1.5mm thick. Now a day's researcher is giving more focus on various other kind of sheet material like, P.A.F [25]. Martins et.al has done their experiments on Five different polymers, polyoxy-methylene—POM, polyethylene— PE, polyamide—PA, polyvinylchloride—PVC and polycarbonate— PC, with material structures varying from high-crystalline (POM) to amorphous (PC) [26].

V. Franzen et.al 2009 has evaluated the performance of commercial PVC (polyvinylchloride) sheets in single point incremental forming (SPIF) applications. In the recent advancement going on in Composite material which created an interest in the researcher and to check the capabilities of the ISF process on composites K.P. Jackson et.al 2008 has concentrated their experimentation on sandwich panel [27].

E. Forming Speed:

As per the previous study of effect of tool rotation which is having remarkable influence on ISF. Forming speed is also very important and highly effective. Forming speed is considered as both rotation speed (RPM) of tool and feed rate is SPIF (Cerro et.al, 2006).

The heat generated by the friction is directly proportional to the relative motion between tool and sheet metal [14]. As it is discussed in the previous section if the heat generated is higher the formability of material is increasing, and this heat is increase if forming speed is increased. But it is having negative effect also which comes out from many researches [Fillice, 2002]. The reason behind this is higher surface roughness, which increase tool wear rate and breakdown the lubrication film provided in process [Le Van, 2009]

F. Step size:

Influence of step size is also a debatable parameter in SPIF. Some researcher says that step size does not affect the process. But Saad Arshad has noticed that step size affect the formability. Kim, 2002 says that by increasing step size formability decreases. It has been also noted that the step size not only affects the outer and inner surface roughnesses but also has an effect on the duration of forming. Small step sizes require more time to form parts since increasingly more z-plane motions are necessary. The roughness influence however tends to be coupled with the immediate forming angle of the particular part that is formed and also with the size of the tool [28].

G. Lubrication and shape:

Lubrication in SPIF research has been limited. Discussions reach only as far as their friction reduction tendencies and as a means to reduce tool wear and improve surface quality as it is a relatively slow process related to machining or milling so tool wear is not one of the major concerns but in case of warm forming lubrication plays a key role in terms of surface roughness's. The geometric shapes that can be

formed have a large effect on the forming forces and time depending on complexity. According to the sine law, vertical walls are not possible with this process because it would result in a zero final sheet thickness [14].

V. FORMABILITY OF METAL PARTS IN ISF

Some researchers have focused their attention on process mechanics in incremental forming and, more in detail. On the issue of material formability. Iseki [12] proposed an incremental bulge test using a ball roller and derived a set of forming limit curves. Shim and Park [15] developed a new forming tool containing a freely rotating ball and characterized the formability of an annealed Aluminum alloy taking into account a very simple incremental forming operation, in which the tool path was a square loop. The most common method of determining forming limits, in sheet metal forming (SMF), is through the development of forming limit diagrams (FLD). Forming limit diagrams are plots of major and minor principle strains, the plots show a defined safe and failure zone.

Early investigations determined the strains incurred by the material undergoing deformation by SPIF are much greater than those found in traditional methods of SMF [20]. Traditional FLDs, which are used to predict failure in SMF, underestimated the ability to form parts with the SPIF process. Thus traditional FLDs provide only part of the answer in determining sheet metal formability. Formability in SPIF can be defined in terms of the maximum draw angle (maximum forming angle). The forming angle is measured in terms of a tangent line from the unformed sheet surface to the deformed surface. Filice et al. proposed the two characteristics of deformation in this forming method. One is the deformation pattern. While the tool moves straight on a horizontal plane, the deformation that occurs at the starting and ending points of the straight line is biaxial stretching [5].

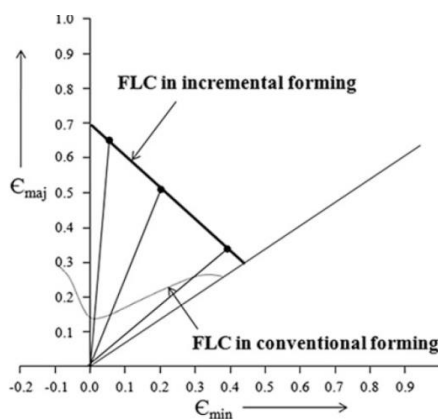


Fig 12 A comparative plot of FLC in conventional forming and incremental forming [5]

The deformation that occurs between these points is plane-strain stretching. As the curvature of the tool movement increases, the deformation turns more into biaxial stretching. The other characteristic is the

formability of the deformation. As shown in Fig. 12. The forming limit curve, which depicts the formability in the major and minor strain space, is expressed as a straight line with a negative slope. Especially, for an aluminum sheet, the formability can be quantified as a scalar number of $(\epsilon_{major} + \epsilon_{minor})$.

It is noted that formability is the greatest under plane-strain stretching, during which the minor strain is zero. Therefore, a greater deformation of a sheet metal can be achieved in the ISF (Kim and Park 2002). The ISF is characterized by a local stretching deformation mechanics which determines a forming limit curve quite different from the traditional one and such FLC has a linear shape with a negative slope in the positive ϵ minor side of FLD (Filice et al. 2002).

A. Forces in Incremental forming

Incremental forming process is still early in its development and requires much more research to reach a point where accuracy becomes comparable to some of the strictest industry standards. Achievement of this goal will not be possible without better understanding of the process mechanics and influencing parameters. The force required for forming has consequences in the design of tooling and fixtures, and also for the machinery used. Being able to predict the magnitude of the forces between tool and work piece is of importance for the development of process models for single point incremental forming as well.

The scale of the local plastic deformation, typical for this process, depends on this factor [17]. Joost Duflou investigates the effects of four commonly varied process parameters on the force required to form the sheet metal. These are the tool diameter, vertical depth increment, steepness of the parts wall or wall angle and the thickness of the sheet metal. G. Ambrogio focused on an industrially oriented methodology for detecting the approach of failure in incremental forming is proposed. The approach is based on the analysis of the trend of the forming force in order to assess whether the process can be run safely. If not, a proper strategy, to avoid material failure, is proposed and experimentally validated as shown in fig 13.

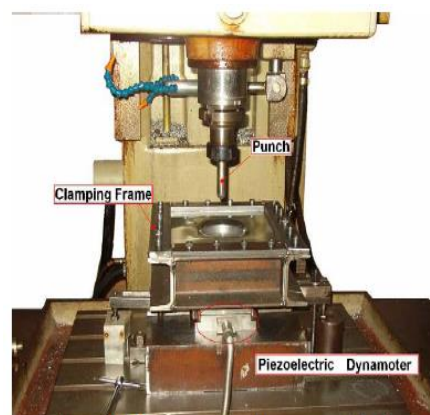


Fig 13 The force measuring system [16].

VI. EXPERIMENTAL SET UP AND FORMING TOOLS IN ISF

The total package needed to incrementally form sheet metal consists of a forming tool and the machinery that moves the forming tool in a controlled manner. These are discussed in the following. The main element is the single point forming tool. Solid hemispherical tools are usually used when plastically deforming sheet metal incrementally. A wide variety of solid tools is used, however, other types of tooling, such as water jets, are being investigated and these are reviewed. Tools are designed and made by the users, they are not yet part of an assortment made available in the market [16].

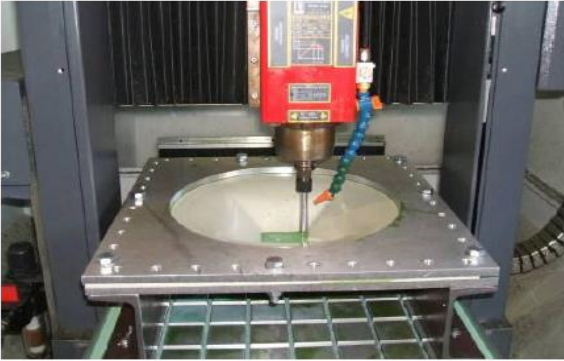


Fig 14 CIELLE CNC machine using for SPIF process with polymeric materials [16]

I. Cerro et.al, 2006 has carried out their experimentation to predict thickness and stress distribution on the sheet in an ANAKMATIC-7 CNC milling machine equipped with FANUC MOD2.1iMA numerical control. For modeling ABAQUS/Explicit™ software is used.

A. Solid Forming Tools:

A solid hemispherical head is generally used for asymmetric single point incremental forming; see Figure 3. This assures a continuous point contact between sheet and forming tool. At very steep wall angles it can become necessary to use a smaller tool shank than the sphere diameter. Contact between shank and sheet metal is avoided this way. This must be taken into account while generating the tool path. Once a tool shape is established, usually a specific radius with a hemispherical ball-head, tool materials must be chosen. In most instances, the ball-head tools are made out of tool steel, which is suitable for most applications [16]. To reduce friction, and to increase tool lifetime, the tool can be coated with or even be made out of cemented carbide. For some tasks plastic tools are necessary to avoid chemical reactions with the sheet material and thus increase the surface quality. Wear of the tool can then become an important consideration. In addition, lubrication helps reduce the wear.



Fig 15 Forming tools for SPIF process [16]

Next the diameter of the ball-head must be chosen. A wide range of tool diameters is used, starting at small diameters of 6 mm and going up to large tool diameters of 100 mm for the manufacturing of large parts. These require much more power because of the much larger angle of contact involved. The diameter used depends upon the smallest concave radius required in the part. It also has an influence upon the surface quality and/or the manufacturing time. Furthermore small tools can reach their loading limit while forming materials like stainless steel or titanium. The most commonly used diameters are 12 mm and 12.5 mm.

VII. ECONOMIC ANALYSIS OF SPIF

Due to high cost of die in sheet metal forming, conventional forming processes are suitable only for high-volume production. However the pattern of demand for sheet metal product has undergone a change, which necessitates small-batch sizes. Single point incremental forming is a die-less forming process and can be employed for customized sheet metal products made in small quantity [29].

The economics of the ISF over conventional forming process are well explained by comparing some of the factors. The common factors which affect the process are cost of die, cost of machine tool, production time and design and cost of clamping mechanism.

- (a) **Cost of Die:** This we can say that the strong advantage of ISF over the conventional process. M. Durante et.al has compared two processes by a table 2, which explain that for a simple stamping process the cost of the die of around 6,00,000/- and at the other end the cost of the tooling is just 27,500/- in ISF process. This main reason why this process is so popular in the industries because for the normal forming operation the cost of tooling (Die and Punch) is very high whereas in ISF process these is minimized. Because of this reason this process is also named as Die less forming method.
- (b) **Cost of Machine tool:** In the conventional process hydraulic press machine is used which is having low cost whereas in the ISF process specialized CNC machine is used. The initial cost of the CNC machine is very high and a conventional press machine is available at low cost.
- (c) **Production time:** From the literature of M. Durante the production time is very high in the ISF process (30 Min) and in the conventional stamping process this time is just a 5 sec. This is the main disadvantage of ISF process.
- (d) **Design & cost of clamping arrangement:** In the ISF process proper clamping of the work piece results in the good quality and wrinkle free product. So naturally the cost of clamping high as compared to conventional forming process. The specially designed fixture is required in the ISF process so the design is quit complex.

Though the cost of the die is less, the cost of machine tool is high in this case. Cost models for two types of parts have also been proposed. A sheet metal product is usually produced with dies and punches manufactured in accordance with shape and dimension of the components. Production in low series and small batches induces higher demands on the production system as a whole and short decision times are important. Apart from adapting the organization to low volume, the right forming process must be chosen. Regarding the forming process, the following guidelines can be used for efficient low volume production: Reduced -lead-time for each product, and reduced changeover time between products, Reduced time and cost for development and manufacturing of tool, Flexible production units and production lines Lower time between different products by using flexible tooling, e.g. incremental forming or fluid forming. Saad Arshad (M. Tech Thesis, 2012) has done cost models which give the difference between ISF and Stamping process shown in table 2.

Table 2 Cost Comparison – ISF and Stamping [29]

ISF	Cost Rs/ Time min	Stamping	Cost Rs/ Time min
Personal Cost	3000/hr	Personal Cost	3000
Machine Cost	3000/hr	Machine Cost	3000
CAM Development	30 min	Die Setting up time	30 min
Part Forming	30 min	Part Forming	5 sec
Die Cost	27500	Die Cost	600000

Comparison between ISF (Incremental Sheet Metal Forming) and Stamping is carried out for the forming of various shapes with different degrees of geometrical complexities i.e. car hood, oil tank cover, cup shape, pyramid with various radii. The Cost Model for ISF (Incremental Sheet Metal Forming) and Stamping are constructed by using estimated costs of dedicated die (fixed cost), machine (fixed cost), personnel cost (variable cost) etc [16].

VIII. ADVANTAGES AND DISADVANTAGES OF ISF

A. Advantages:

- Useable parts can be formed directly from CAD data with a minimum of specialized tooling. These can be either rapid prototypes or small volume production runs.
- The process does not require either positive or negative dies; hence, it is die-less. However, it does need a backing plate to create a clear change of angle at the sheet surface.
- Changes in part design sizes can be easily and quickly accommodated, giving a high degree of flexibility.
- Making metal rapid prototypes is normally difficult, but easy with this process.
- The small plastic zone and incremental nature of the process contribute to increased formability, making it easier to deform low formability sheet.

- A conventional CNC milling machine or lathe can be used for this process.
- The size of the part is limited only by the size of the machine. Forces do not increase because the contact zone and incremental step size remain small.
- The surface finish of the part can be improved.
- The operation is quiet and relatively noise free.

B. Disadvantages:

- The major disadvantage is the forming time is much longer than competitive processes such as deep drawing.
- As a result, the process is limited to small-size batch production.
- The forming of right angles cannot be done in one step, but requires a multi-step process.

C. Applications of ISF

There are a number of areas, where high precision of the products is required for the accuracy of the performance. Areas of products can manufacture by ISF are as follows:

- Aerospace Industry: Instrument panel, body panel, passenger seat cover, etc.;
- Automobile: Door inner/outer panel, hood panel, engine cover, etc.;
- High customized products: Denture plate, ankle support, metal helmet, etc.
- Cellular phones;
- IC lead frames;
- Electronics;
- Health care;
- Miniature fasteners;
- Hard disk drives;
- Products of national security and defense;
- Automobiles; and
- Sensors.

IX. CONCLUSION:

The objective of this work is to understand some basics regarding ISF process. Based on the review following conclusions are made,

- The ISF process is a flexible forming process, and it can be easily used for producing 3D complex shapes. • The process can be used for larger forming angles with proper forming methodology.
- The process parameters that are used have a major impact on the process conditions and the most significant are: Tool size, Tool rotation, material properties and sheet thickness.
- Material properties and the property evolution of the ISF parts are of interest for presenting the method for wider industrial use.
- The material property evolution affects the process itself, and is of importance for increasing process accuracy and control.
- Modeling property and process evolution offers means for control. Sheet thinning of the formed part has been proposed as a drawback for the process.

- The properties of incrementally formed products as compared to other forming methods are of interest when introducing this new method for wider use.
- Despite its shortcomings, ISF may be considered as a viable alternative to traditional sheet forming methods.

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