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# Process Parameters and Thickness Reduction in Single Point Incremental Forming

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**Abstract:** The manufacturing world is being more advanced and improved day by day. The manufacturing process has been used in various forms for thousands of years. Incremental sheet forming (ISF) process came into presence to overcome limitation of conventional forming process and to tackle the requirement of high production rate. However, the major imperfections are long processing time and non-linear behaviour of material that lead to complexity in simulation of the ISF process. The visual range of prospective application of ISF process is widespread from home to satellite. The single point incremental forming (SPIF) technology is the combination of forming tool with a spherical end in which the sheet metal is mounted on the fixture for the sheet forming operation. The main aim of this work is to provide a detailed review of the individual and interactional effect of process parameters on thickness reduction of SPIF process. Particular focus is given on effects of process parameters and the thickness reduction. This paper simply presents an idea to promote the new development that may also act as an inspiration for new researcher.

**Keyword:** ISF, SPIF, thickness reduction

**Introduction**

ISF process in recent times is well-known as an innovative automation which pledges anadvanced flexibility in development, lower manufacturing cost, steer time, in adjunct to enhanced formability of material competed to conventional metal forming process. From the last two decade, on ISF process a numerous deal of attempts has been intensive on experimental study to achieve better accuracy and to extend application. However, the major imperfection is long processing time and non-linear behaviour of material indication to intricacy in simulation of the ISF process.

ISF is a latterly established automation among which a simple toolinflicts restricted plastic deformation onsheetmetal along with a formerly regulated path by a Computer Numerical Control (CNC) milling machine.

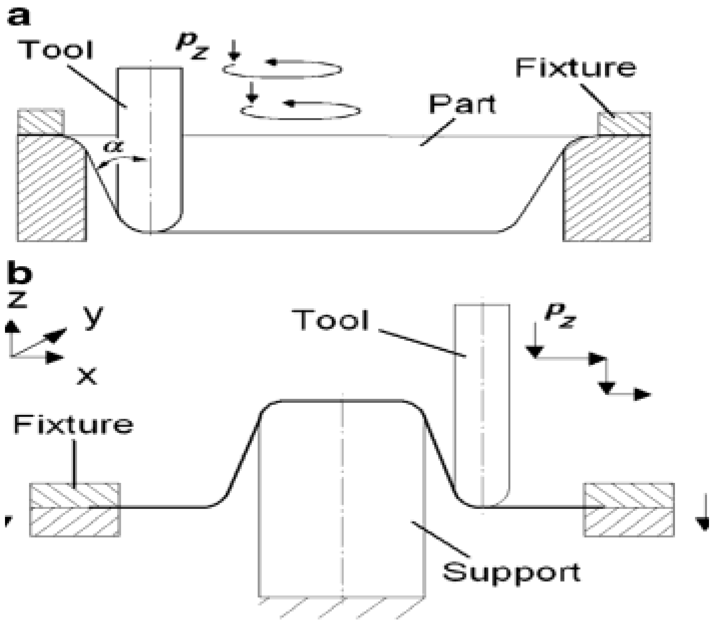


**Figure 1.** Forming principle of Incremental sheet forming a) negative forming b) positive forming [Gatea et al. 2016]

The naturally die-less ISF process establishes the proficiency of forming complicated forms of sheet metal, offering an increased stage of formability in association to the conventional approaches of forming. It is considered as a low price flexible automation that is applicable for rapid prototyping, modified and batch production of parts of sheet metal ISF can be divided into according to the contact points between sheet and tool, one is used for Single Point Incremental Forming (SPIF) process when the reverse side of the sheet is maintained by a faceplate and second is used for Two Point Incremental Forming (TPIF) when a space is occupied or part die backing the sheet.

**Historical background**

ISF has been used for different purpose in different forms several years ago. History of ISF started with the patent named as "Apparatus and Process for Incremental Dieless Forming" when Leszak attained the same in 1967.

In Japan research done in a huge amount the individuals involved as a part in the investigation were: Kitazawa, Iseki and Matsubara.

In 1992, 1993 computer controlled setup was introduced by Iseki for obtaining the variety of shapes in manufacturing and from 1994to 1996 with a 50 KN forming force.Rotational symmetric parts were formed in aluminium to be feasible were brought into realityby Kitazawa in 1996 [Emmens, 2010]. The principle of SPIF using a simple tool with contour path line is shown in Figure 2 [Emmens (2010)].

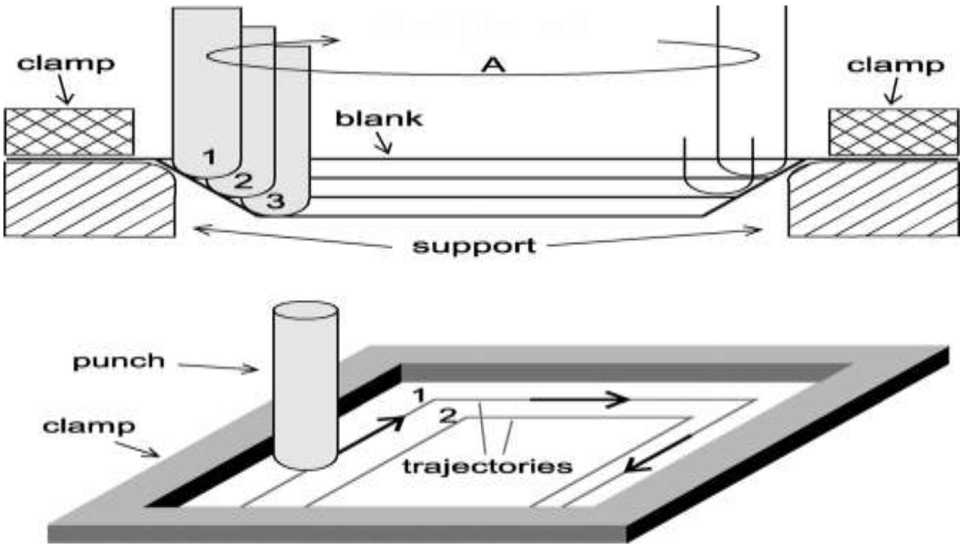


**Figure 2** Principle of SPIF for tool path [Emmens (2010)]

In 2001 ordinary CNC milling machine studied for using capability instead of a main purpose machine tool apparatus but in metal forming exploration communal 2002 was the preparatory point for efficacious and was in rapid progress. In 2004, 2005 the mostly studied on mechanical properties, surface finishing, formability, constant thickness to perform experimental for wide range of potential applications and fabricated in regular commercial use to demonstrate its feasibility in SIPF, In fact it was used at industry level. Numerical studied on mechanical properties was carried in 2005 but the theoretical study conceded in 2008 [Silva et al. 2008].

A number of researches conducted on incremental sheet forming process in 2007 which discussed about the different process parameters effects on the sheet surface. From these researches one by Micari, (2007) who discussed about the geometric accuracy in SPIF process which might be offset with the optimization of tool path.

Earlier that only devoted CNC machines 2008 Ph.D Project through Martin Skjoedt were being depleted for SPIF. That was the preparatory point for research separated from Japan. Certain of the maximum dynamic investigators since then have been Jeswiet, Hirt, Micari, Duflou and Allwood .

Forming Limit Curve (FLC) denoted the failure of hydrostatics stress, shear and bending mechanism which effects on necking growth of sheet material in ISF process these stated by Emmens in 2008 but in 2009 stated the assessment on historical elaboration of ISF process which was mostly based on TPIF process [Gateaet al. 2016].

**Literature Review**

Choi et al. (2018) author established a mathematical model to predict the thickness distribution by adopting a hybrid technique consisting of incremental forming process combined with stretch forming and result compared with experimental formed parts. Aluminium alloy 5052 sheet was used with a thickness of 0.5mm. Result shows that the hybrid forming process have lower thickness reduction rate, more uniform thickness distribution and more endurance stress than the pure incremental forming process.

Bouhamedet al. (2019) author proposed a non-associated model and Hill_R and Hill_s model for an aluminium alloy sheet of AA1050 H-14 with a thickness of 0.6mm. For numerical simulation in FE model based on ABAQUS standard and ABAQUS Explicit software that used a defined material subordinate UMAT and VMAT to simulate both (U-bending process and three- point bending) and SPIF process respectively. Result shows that the thickness strain distribution in transverse and rolling directions predict by the non-associated model given the more significant value than the experimental value. Non- associated model have less value of stress concentration in the final shape prediction than the Hill_R and Hill_S model.

Salem et al. (2016) author investigation of thickness variation in SPIF of AA7075 sheet with five truncated cone having depths:20mm,30mm,35mm,40mm and 55mm. FEM model was created for the validation of the stress -strain along the wall and thinning area, location and its size. Result show that thinning localization depending on the tool path and thickness variation analysed through the three regions such that bending thinning and study state along the wall of the truncated cone. For analysis of the method some process parameters such as sheet thickness 1.6 mm, step size0.5mm and forming angle $67^0$ were used.

Cao et al. (2015) authors calculated the thickness distribution in multi-step ISF process by using developed method, the geometric profile and positions of Aluminium alloy AA5052 and AA1100 sheet with initial thickness of 1mm. Analysed four different shape including a cone shape with a constant forming angle, parabolic cone, non –axisymmetric part and hemisphere to predict the thickness distribution, this method was faster than conventional FE approach .This experiment Under the influence of contour-based tool path , ball head tool, of a radius 5mm and a step down value of 0.2mm form the parts with the feed rate of 2000mm/min.

Chao et al. (2015) author investigated thickness distribution of multi stage which effected by forming stage (n) and angle interval between the two adjacent stage ($\Delta a$) under the influence of FEM simulation model to form a frustum of cone with wall angle $30^o$and optimal thickness distribution was obtained with $\Delta a$ of $10^o$. The principle of invariable volume method was applied to predict the thickness of multi stage forming but sine law for single pass forming. A DC06 sheet of 0.8mm thickness used with process parameter such as tool diameter (D) = 10mm, tool depth increment ($\Delta z$) = 0.3mm and wall angle (a) = $30^0$,$35^0$,$40^0$,$45^0$,$50^0$,$60^0$.

Mirnia et al. (2014) author compared SLA and Abaqus based FE model to predict the thickness distribution using AA1050 sheet with a thickness of 1.5 mm,( 20mm, 10mm ) tool diameter and a step down of (2mm, 0.5mm )for both simulation in SPIF. AS result show that SLA gave better accuracy to predict the thickness distribution than the FE based model under the influence of a truncated cone with $50^0$ wall angle. The value of tool diameter and step down size was varying, causes thickness distribution variations in SPIF, as an application of SLA.

Mirnia et al. (2013) described that the thickness distribution in multistage SPIF has predicted by using of SLA (sequential limit analysis) and this result is compared with FEM code ABAQUS. Result showed that modelling of SPIF using SLA has given better result than the modelling of SPIF using ABAQUS, this experiment implemented on a 1.5mm thick sheet of AA1050 with a tool 10mm diameter moves along circular path and truncated cone with $70^0$ wall angle for multistage SPIF. According to this result SLA required less solving time than FEM code ABAQUS to predict thickness distribution in multistage SPIF.

**Conclusion**

The process parameters of single point incremental forming and factors affecting them has been reviewed. The study also extends to the thickness reduction of single point incremental forming process. This review shows that still here are conflicts, so the systematic experimental study of thickness reduction of SPIF process is required. Many factors are required to be improved before calculate for the formed part of sheet metal in ISF for commercial applications. To predict the thickness reduction some model analysis are required also.

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