SMALL BATCH SIZE SHEET METAL PRODUCTS MANUFACTURED BY SINGLE POINT INCREMENTAL FORMING PROCESS : ECONOMIC ANALYSIS

By

Syed Asad Raza Gardezi[1], Mushtaq Ahmad[2], Muhammad Aslam[2], Awais Ahmad Khan[3] and Mohsin Ahmad Sadiq[2]

ABSTRACT: 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 customizes sheet metal products made in small quantity. Though the cost of the die is less, the cost of machine tool is high in this case. In this work, an attempt is made to carry out economic analysis of parts made by single point incremental forming and find out break even point for various shapes of sheet metal products. Moreover, cost models for two types of parts have also been proposed.

Key words:

1. SPIF (Single Point Incremental Forming)
2. CNC (Computer Numerical Control)
3. NC (Numerical Control)
4. ISF (Incremental Sheet Metal Forming)
5. 3D CAD (3 Dimensions Computer Aided Design)
6. CAM (Computer Aided Manufacturing)
7. Stamping (Sheet Metal Forming Process)
8. Break even point.

INTRODUCTION

A sheet metal product is usually produced with dies and punches manufactured in accordance with shape and dimension of the components. This conventional method is adequate for mass production because the cost of dies and punches can be shared with the large number of products. Recently, however, new production method for small lots is being developed, since the customer's demand was so diversified that the lot size has become small. Among various methods, using simple tool small hammer or laser, the incremental forming method with simple tool has gained a great attention.

Production in low series and small batches induces higher demands on the production system as a whole. High flexibility (fast changeover) 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.

INCREMENTAL SHEET METAL FORMING

Single point incremental forming (SPIF) is a new sheet metal forming process with a high potential economic payoff for rapid prototyping applications and for small quantity production. Fig. 1 presents the basic components of the process; (i) the sheet metal blank, (ii) the blankholder, (iii) the backing plate and (iv) the rotating single point forming tool. The blankholder is utilized for clamping and holding the sheet in position during SPIF (Single point incremental

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1. Department of Mechanical Engineering, College of Engineering and Technology Bahauddin Zakariya University, Multan
2. Rachna College of Engineering & Technology, Gujranwala.
3. Department of Mechanical Engineering, University of Engineering & Technology Lahore.

forming). The backing plate supports the sheet and its opening defines the working area of the single point forming tool. The tool is utilized to progressively shape the sheet into a component and its path is generated by a CNC (Computer Numerical Control) machining centre. During the forming process there is no backup die supporting the back surface of the sheet.

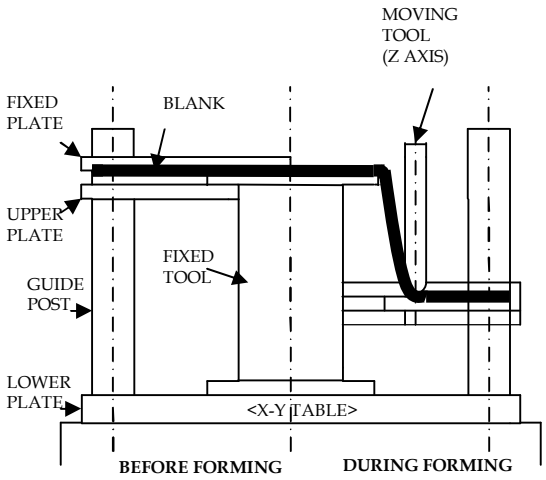


Figure 1, Principle of die-less NC (Numerical Control) forming.

Break Even Analysis

Break-even analysis is based on categorizing production costs between those, which are "variable" (costs that change when the production output changes) and those that are "fixed" (costs not directly related the volume of production).

Total variable and fixed costs are compared with sales revenue in order to determine the level of sales volume, sales value or production at which the business makes neither a profit nor a loss.

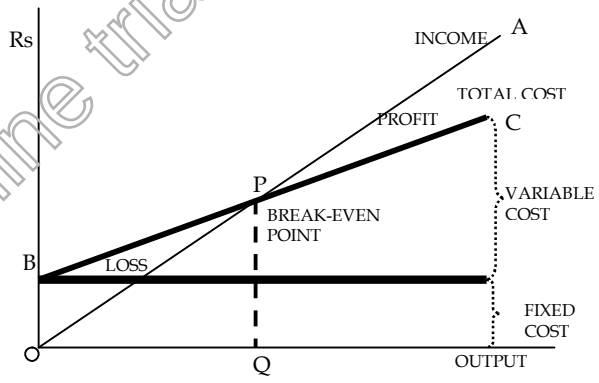


Figure 2: schematic of Break Even point

In the diagram above, the line OA represent the variation of income at varying levels of production activity i.e., output. OB represents the total fixed costs in the business. As output increases, variable costs are incurred, meaning that ***Total Cost/Product = Fixed Cost + Variable Cost/Product*** also increases. At low levels of output, total cost/product is greater than income. At the point of intersection, P, total cost is exactly equal to income, and hence neither profit nor loss is made.

Fixed cost consists of, for conventional forming, press machine, dedicated dies etc. and for SPIF (Single Point Incremental Forming), NC (Numerical Control) Machine. Variable costs are sheet metal and direct labor and will be same for both the processes. However, the level of skill required to operate the machine and wastage of sheets will be different in the two cases.

Methodology: Comparison between ISF and Stamping

In order to compare the two processes economically and determine their respective break- even points, the difference in their approach is highlighted in Figure 3 below:

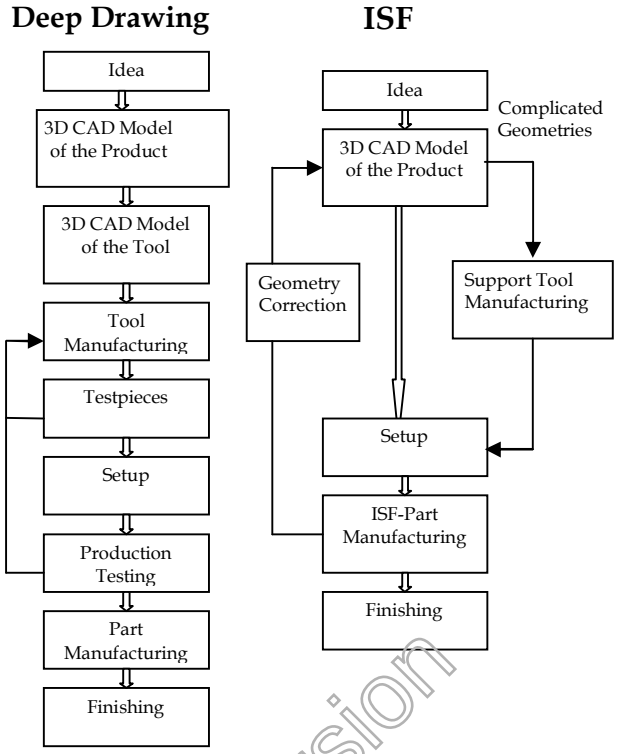


Figure 3: Comparison of production process of deep drawing and incremental forming

It is evident from the Fig.3 that production cycle (i.e manufacturing lead time) of incremental forming is shorter than the conventional production methods. The forming paths are generated directly from the 3D CAD file (3 Dimensions Computer Aided Design), and often no tooling is needed. If a support tool is required, the same 3D CAD file (3 Dimensions Computer Aided Design) can be used for making the support tool. In many cases the support tool is not needed and the process is shorter. Moreover, the test piece manufacturing is also not needed, because ISF produces one piece at a time. If corrections are needed, the CAD file (Computer Aided Design) is changed, the programme is converted again and the next piece can be manufactured. It is noticeable that corrections to the model are easy to make in any part of the process. The support tool materials are inexpensive and easy to work, and a new support tool can be made fast when needed.

Cost Models: 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. The data is shown in the form of Table below:

Table: Cost comparison between ISF (Incremental Sheet Metal Forming) and Stamping

ISF(Incremental Sheet Metal Forming)	Sta
Personnel Cost=RS 3000/h	Per /h
Machine Cost=3000/h	Mac
CAM (Computer Aided Manufacturing) Development=30 min	Die
Part forming: 30 Min	Part
Die Cost: RS 27500	Die

Two pyramid shapes i.e., one with ISF (Incremental Sheet Metal Forming) and other through stamping are produced for the purpose of comparison. These shapes are shown in figure 4 & 5 respectively. The data is entered in the excel spreadsheet in the form of following relationships. Cost per part for **ISF** (Incremental Sheet Metal Forming) as shown in Fig.4 is calculated using the given data as under

Let N= No of Parts

Total Cost = Die cost + (CAM (Computer Aided Manufacturing) development time) (Personnel cost) + N (Part forming time) (Personnel cost) +N (Part forming time) (Machine cost)

----------**Eq-I**

Finally cost per part= Total cost/N

For N=50

Total Cost = 27500+0.5×3000+50×0.5× 3000+50×0.5×3000 = 206,500

Cost Per Part = 206500/50 = 4130

Similarly cost per part as shown in figure 4 for **Stamping** is calculated. Let N= No of Parts

Total Cost = Die cost + (Die setting up time)(Personnel cost) + N(Part forming time) (Personnel cost) + N(Part forming time) (Machine cost)----------**Eq-II**

Finally cost per part = Total cost/N

For N=50

Total Cost = 600,000+0.5×3000+50× 5/3600×3000 +50×5/3600×3000 = 601,916

Cost Per Part = 601916/50 = 12038

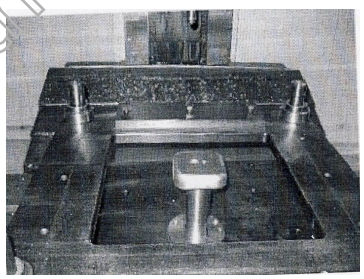


Figure 4: Die for ISF(Pyramid Shape)

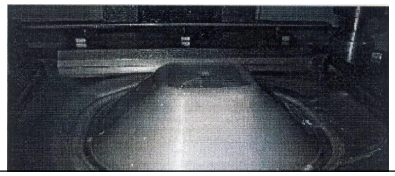
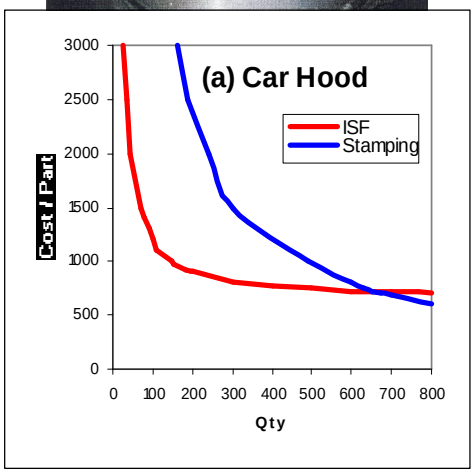
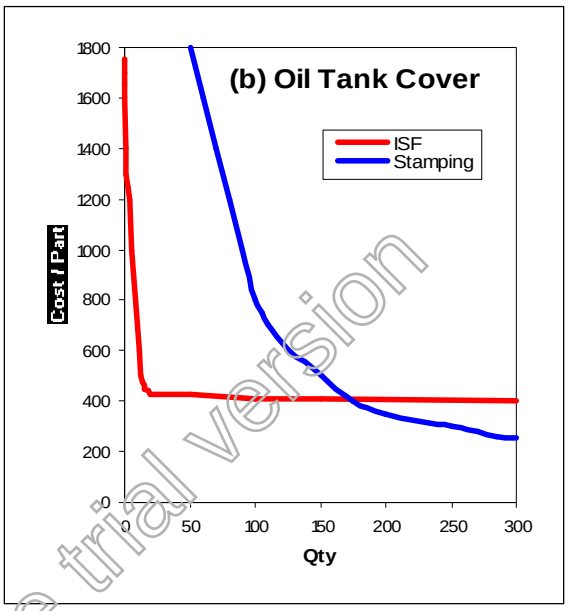
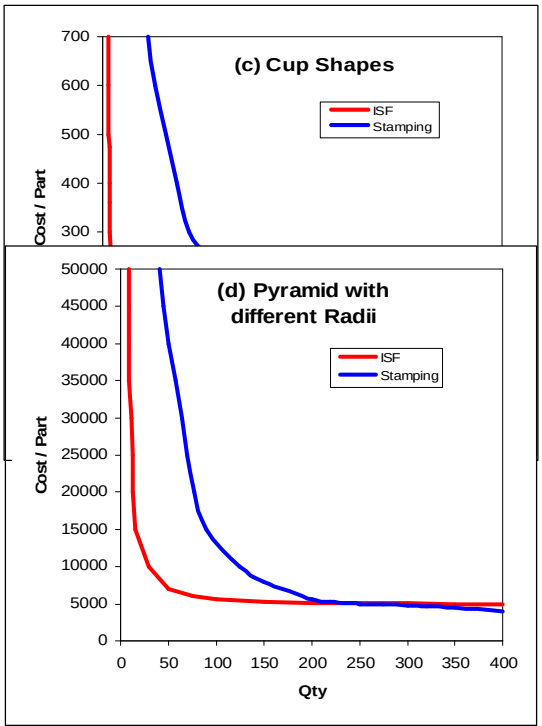


Figure 5: Die for Stamping (Pyramid Shape)



The Equations I & II for total cost, developed above are plotted graphically in fig.6 (a,b,c,d,e) to show the break-even point for the two processes for various shapes under study.





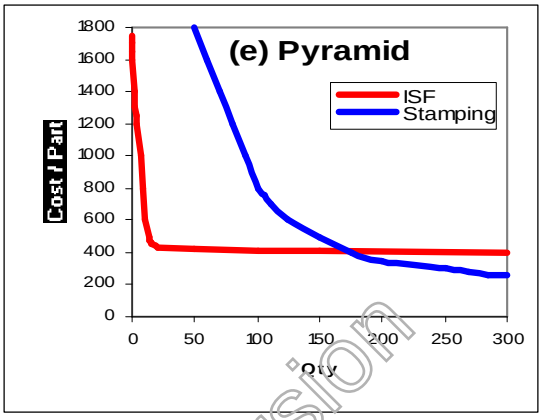


Figure 6: Comparison of Break-Even Points for two processes

It is clear from these break-even points that whatever the geometry of part produced is the incremental forming has much lower break - even points as compared to conventional process. It means that incremental forming is well- suited for low-volume and customized products.

Part	Breakeven points/No. of parts								
Car Hood	ISF(Incremental Sheet metal Forming)							Stamping	
Oil Tank Cover	ISF(Incremental Sheet metal Forming)							Stamping	
Cup Shapes	ISF(Incremental Sheet metal Forming)							Stamping	
Pyramid with different radii	ISF(Incremental Sheet metal Forming)							Stamping	
Pyramid	ISF(Incremental Sheet metal Forming)							Stamping	
No. of parts	100	200	300	400	500	600	700	800	□

Figure 7: Graphical Comparison

Figure 7 is a graphical comparison of Incremental Sheet Metal forming and conventional process for various sheet metal parts. It shows that the break even point have slight dependence on the size of the part produced in the case of incremental forming. For relatively large parts; there is an increase in the break even point as compared to smaller part in ISF.

Conclusions:

Comparison between ISF (Incremental Sheet metal Forming) and Stamping is made and it is concluded:

- ISF (Incremental Sheet metal Forming) is capable to produce various complex shapes.
- ISF (Incremental Sheet metal Forming) is suitable technology for the low volume production, prototyping and spare part production as the break-even point is lower for all the shapes studied in this paper.
- For ISF (Incremental Sheet metal Forming) parts, the break-even shows dependence on the size of the produced part.
- Lead time in case of ISF (Incremental Sheet metal Forming) is much smaller as compared to conventional processes.

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