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Sheet Metal Forming Processes Recent Technological Advances

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***Abstract* - The sheet metal industry has seen more technological advances than any other since the last century. Right from hand-forming processes to finite element based simulation, the transformation is very significant. They have prominent industrial applications especially in automotive industries. This may be attributed to the ease with which the final component with desired shape and appearance can be produced using simple tools. Due to wide range of applications, the process of forming the sheet metal into various shapes leads to classification of the forming processes based on specific operation. This classification involves bending, blanking, stretch forming and deep drawing. Each process has some parameters that define the quality of the work achieved. This paper aims at scattering light on the recent research and developments in the sheet metal forming processes over the last two decades. Most of the literature available on sheet metal forming focuses on the parameters that influence the quality and economic factor of the final product. The influence of process parameters based on geometry such as punch nose radius, blank temperature, and blank holding force, tooling dimensions, blank thickness and punch depth is significant. Similarly, the parameters based on the material properties like elastic strength, yield strength, plasticity and anisotropy have as much influence as the geometry based parameters. The literature raises the issue of defects in the formed parts. Defects such as wrinkling, tearing, springback, local necking and buckling in regions of compressive stresses have been analysed using both experimental and simulation techniques. Springback, the most predominant defect, has been researched thoroughly while considering sheet thickness, punch force, nose radius, binder force, die opening, punch velocity, punch height, sheet anisotropy, clearance, elastic limit and yield strength of the blank material as input parameters. Lastly, this paper also aims at reviewing the finite element based tool design, experimental and numerical investigations into sheet metal formingprocesses.**

***Keywords*- Sheet Metal Forming processes; Forming Process Parameters; Springback; Finite Element Simulation.**

I. INTRODUCTION

Pr Punch noseradius
Dr Die shoulder radius BHF Blank holdingforce
μ Co-efficient offriction
Pv Punchvelocity
C Clearance
t Blankthickness
H Drawdepth
n Hardening exponent
σs Yieldstress
E Elasticmodulus
FE Finite Element analysis Exp Experimentalanalysis
Tag Taguchi technique of DOE Ct Coating thickness
O Orientation of sheet
Do Dieopening
Ba Bendangle
Br Bendradius
W Width of thecomponent
Lb Blanking layout
TW Toolwear
Pt Punchtravel
S0 Initial thickness ofsheet
S1 Final thickness ofsheet

The dynamic activity involving the controlled movement of tooling elements results in the rise of various influencing parameters involving both physical and material properties. These parameters wholly affect the final predicted part. The prediction is a huge process because it involves coordinating the influencing parameters amongst each other and this is only for the known industry standard problems. But, due to the changing nature of industry needs every new day, the predicting process becomes challenging. Over a small scale, the trial and error methods can help overcome the challenges above said. But from an economic and manufacturing point of view, trial and error methodsfail.

The recent technological advancements have paved the way for finite element based analysis for all kinds of operations like casting, forming, cutting etc. The most important mode of FE based analysis is the simulation or Computer Aided Engineering (CAE), in general terms. By definition, simulation is a software tool capable of both designing and testing the potential of a particular operation. Many a design software like LS-Dyna, AutoForm, Hyper Form etc.

Have evolved over the years to avail best of features covering all the needs of a forming industry. This simulation based manufacturing has cut the time-cost factors significantly and in turn the money that was being wasted earlier on the trial and error practice is now used for advancements in simulation technology. In recent years, tool development and production time has been reduced by about 50% by simulation and a further 30% reduction over the next few years appears realistic [1]. Material properties, geometrical parameters, contour definition, physical parameters and output parameters, can now be defined accurately for a given operation. On the contrary, not everything is acceptable with the simulation based manufacturability. When we compare the definition of several characteristics involved in sheet metal forming between simulation models and physical reality, the incorrect description of significant factors does not go unnoticed [2].

Coming to the parameters influencing the sheet metal forming process, there are two distinct types; geometrical and material parameters. The influence of geometrical parameters such as punch nose radius, die shoulder radius, blank temperature, and blank holding force, tooling dimensions, blank thickness and punch depth is significant. Similarly, the parameters based on the material properties like elastic strength, yield strength, plasticity and anisotropy have as much influence as the geometry based parameters. These all parameters, if defined incorrectly, results in defects such as wrinkling, tearing, springback, local necking and buckling in regions of compressive stresses. In this paper, the literature available on the effect of process parameters on the final product of a sheet metalformingprocessincludingdrawing, bendingandto someextent, blanking and stretch form in garereviewed.

II. DRAWING

Drawing refers to the manufacture of cups, shells, boxes and similar other products from sheet metal blanks [3].The process involves the drawing of a metal blank placed on the die by the downward movement of punch with a pre decided travel speed and stroke. Generally, when the cup is no deeper than half its diameter it is called box or shallow drawing. And drawing is cup or deep drawing when the cup depth is more than half its diameter [3]. A typical deep drawing process to produce a cup is shown in Fig1.

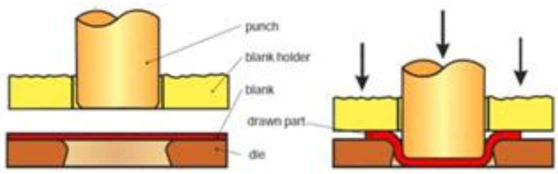

Fig.1. Deep Drawing Process [19].

1. Processparameters

Every sheet metal process is governed by various parameters. In case of drawing the following parameters play a significant role.

1. Punch noseradius
2. Die shoulderradius
3. Blank holdingforce
4. Friction
5. Materialproperties

The process parameters such as blank holder force, lubrication, punch nose radius and die shoulder radius, die– punch clearance affect the formability of a sheet metal [4]. In an effort to understand the influence of die shoulder radius, blank holding force and friction co-efficient on the formability of a stainless steel sheet metal into a deep drawn cup, Padmanabhan et al. [4] conducted FE analysis coupled with Taguchi technique of experimental design. Further, the variance analysis based on ANOVA technique was used to analyze the percentage influence of each of above mentioned parameters on the final product. In the Taguchi method, a L9 (33) orthogonal array fitting 3 levels for each of 3 parameters was constructed. When die shoulder radius, BHF and friction were varied, the test results indicated that, over the final product, the die shoulder radius had a major influence of 89.2% followed by 6.3% for friction and 4.5% for BHF.

The above analysis is based only on finite element theory and simulation. In order to analyze a particular process, experimental analysis coupled with finite element based analysis is highly effective. Clogan et al. [5] conducted combined experimental and FE analysis (Numerical analysis) of a deep drawing process. The theory behind the deformation of blank over the entire process of drawing is beautifully explained. The influencing parameters considered in this study include punch nose radius, die shoulder radius, punch velocity, clamping force, friction (type and position of lubrication) and draw depth. For the experimental purpose a test rig was designedand manufactured. The geometrical dimensions for the elements of the test rig were taken from the literature and mild steel EN10130 FeP01 of 1 mm thickness was used as the test blank material. Simultaneously FE analysis was carried out using

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AutoForm starting with FE modeling.Similar to the works Padmanabhan et al., ANOVA technique was used in determining the most and least influencing factors for the given process following which a L8 {27(2 levels and 7 parameters)} array was constructed. The tests conducted by experiments and FE analysis were compared over the resulting thickness of the final product. The results of ANOVA for wall thickness and for maximum punch force at 20mm depth reveal punch nose radius and die shoulder radius to be the most influencing parameters. Although friction does not influence the thickness distribution, it has a major influence on the maximum punch force at 20mm depth. In all, this study helps in deciding major influencing parameters on the final product but does not decide on their values or range of workingvalues.

In a way, as confirmation of the test results mentioned above and going a notch higher, Zein et al. [6] conducted FE analysis (Simulation analysis) for the deep drawn cup of mild steel. The test parameters considered are die shoulder radius, punch nose radius, sheet thickness, radial clearance, BHF and three friction co-efficient values between blank and die, punch and blank holder. Before proceeding with the analysis, validation of the FE model and corresponding results for thickness variation was done against experimental work done by Clogan et al., for the same geometric model. Sufficient ranges of values were considered for all the parameters while conducting tests. The results are discussed considering two types of parameters; tool geometry parameters and physical parameters. The tests carried out resulted in ideal values for all the parameters to be considered while designing similar end product.

The authors concluded that die shoulder radius and punch nose radius have to be ideally 8 times and 3 times the sheet thickness respectively. Slightly thicker metal blanks can be gripped better as well as % thinning can be improved. Radial clearance, the final geometrical parameter, for better finish has to be more than the sheet thickness. Blank holding force, first of physical parameter, is recommended to be less than 3 tons to reduce over thinning. Co-efficient of friction values between blank & punch, blank & die and blank & blank holder, are ideally to be between the range of 0-0.3, 0-0.2 and 0-0.2 respectively. The results of this study are significant in a way that further studies can be conducted keeping in mind the obtained range of values for all the above discussed parameters.

In all the above cases the blank material is either mild steel or stainless steel. Considering AA6111 Aluminum alloy for the blank material, Reddy et al. [7] conducted experimental analysis to understand the influence of punch nose radius, die shoulder radius and blank holding force on thickness. A L9 (33) array derived from Taguchi method while considering three levels for each of three parameters was constructed. ANOVA technique was used to analyze the percentage influence of each of above mentioned parameters on the final product. The analysis helped in obtaining optimal design parameters for punch nose radius, die shoulder radius and blank holding force to attain uniform thickness. Finally, as far as the percentage influence of each parameter on thickness is concerned, blank holding force leads with 56.98% followed by punch nose radius (30.12%) and die shoulder radius (12.90%).

As stated in the introduction section, material properties like elastic strength, yield strength, plasticity and anisotropy are significant not only on the final product but also on the process parameters. En-zhi et al. [8] conducted finite element based numerical simulation of deep drawing of a thin walled hemisphere to study the influence of material properties like hardening exponent (n), yield stress (σs) and elastic modulus (E) on punch force, thickness variation and equivalent strain. Hardening exponent determines the metal behavior while being formed. Formability and hardening exponent are directly proportional to each other [9]. As all the three parameters are dependent, variation in any one of the parameter results in various suppositional materials with varying material properties. Varying elastic modulus, yield stress and hardening exponent independently resulted in a total of 18 valid FEmodels.

The results indicated that when E increases and σ so r n decreases, the equivalent plastics train increases mainly at wall regions outside die corner. But the equivalent plastic strain increases at ball top when σsor n are decreased continuously. Coming to the effect on punch force, as E, σsor n increases the punch force required to produce a defect free product increases. In particular as n increases larger is the punch force required. But as larger n results in wrinkling, care must be taken to optimally select itsvalue.
The maximum thickening in the final product decreases when E was increased and other two parameters were decreased. But when E was decreased and other two parameters increased, maximum thinning decreased. In both the cases the n plays a significantrole.

2. Consolidated parameterslist

Table 1: gives information about the influencing parameters studied by various authors.

Table 1: Combined parametric study conducted by the authors in drawing.

Authors	Pr	Dr	BHF	μ	Pv	C	t	H	n	σs	E	FE	Exp	Tag	ANOVA
Padmanabhan et al. [4]	N	Y	Y	Y	N	N	N	N	N	N	N	Y	N	Y	Y
Clogan et al. [5]	Y	Y	Y	Y	Y	N	N	Y	N	N	N	Y	Y	N	Y
Zein et al. [6]	Y	Y	Y	Y	N	Y	N	N	N	N	N	Y	N	N	N
Reddy et al. [7]	Y	Y	Y	N	N	N	N	N	N	N	N	N	Y	Y	Y
En-zhi et al. [8]	N	N	N	N	N	N	N	N	Y	Y	Y	Y	N	N	N

III. BENDING

Bending is defined as shaping metal around a straight axis which extends completely across the material. A typical tool set up for U-bending and V-bending is shown in Fig 2. The consequence is a plane surface at an angle to the original plane of the workpiece. Metal flow is even across the bend axis, with the internal surface of the bend in compression and the external surface in tension [3]. But on the removal of load total strain on the work reduces because of elastic recovery resulting in shape discrepancy. This is defined as springback. Springback is the most discussed issue when studying bending; both V and Wipe bending. There are a number of parameters that influence the springback effect while bending. In the following write-up, the work of various authors on springback is being reviewed and reported.

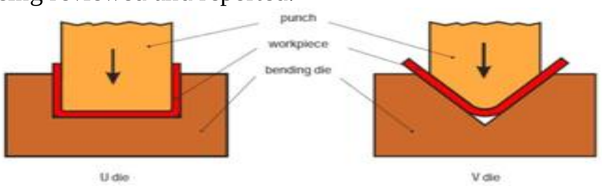

Fig.2. Die Bending Operation [19].

1. Processparameters

The various parameters that influence the manufacturability of a part by bending process are listed below.

- Punch noseradius
- Die shoulderradius
- Punchvelocity
- Dieopening
- Sheetthickness

2. Materialproperties

Vasudevan et al. [10] studied the springback effect in electrogalvanised steel sheets experimentally while considering coating thickness, orientation of the sheet, punch nose radius, die shoulder radius, die opening and punch velocity as the influencing parameters. The experiments were all conducted upon a 1mm thick AKDQ steel sheet, for both coated and uncoated type. The coating thickness was varied and two orientation angles, 0° and 90° were used for taking all the measurements. The results showed that for increasing thickness of coating, springback increased.

It may be attributed to zinc coating which reduces the friction between the tool and sheet and thereby reducing the strain rates leading to increased springback. As far as orientation of the sheet is concerned, 90° orientation showed higher springback compared to 0° for both coated and uncoated sheets. This was attributed to the fact that springback depends upon yield strength to Young's modulus ratio (σs/E) which is higher for 90° (transverse direction) orientation.

On varying the next parameter, punch nose radius, experimental results showed similar results for uncoated as well as coated sheets. With increasing punch nose radius, springback increased. As the punch nose radius increased, the effective clearance between punch and die increased leading to an increase in springback. The experiments over die openings also concluded same results for both types of sheets. As die opening was varied, higher springback angles were observed for higher die openings caused by increased bending moments. Similarly, when die shoulder radius was varied, springback angles increased proportionately.

This was attributed to increased die opening as die shoulder radius increased leading to higher bending moments. The last parameter i.e. punch velocity also had directly proportionate influence on springback. As punch velocity was varied, springback angles increased and for both coated and uncoated sheets. This was attributed to the fact that friction decreases with increased punch velocity. Although springback increased in both types of sheets, it was more dominant in EG coatedsheets.Analysis carried out through finite element based simulation help a great extent in predicting springback and the influence of process parameters on the same. Biradar et al. [11], employing ANSYS software conducted FE based springback analysis in wipe (L) bending of a copper alloy sheet while considering the influence of punch nose radius, die shoulder radius, die opening and sheet thickness. As the die shoulder radius was increased, springback increased which was attributed to increased die opening. In a similar manner as punch nose radius was increased, springback increased. But when punch nose radius was varied beyond 1mm, spring back slightly decreased. Coming to die opening effect, springback increased as die opening was increased. Contrary to the above variation, as the sheet thickness was increased, springback decreased owing to the fact that increased sheet thickness increased the effective surface contact between punch & sheet and sheet &die.

The material properties are very important factors in the analysis of springback as elastic recovery is dependent mainly on the internal structure of the material. Panthi et al. [12] conducted finite element analysis to study the effect of material properties, geometrical parameters and lubrication between the sheet and tool on springback. While studying the effect of material properties such as yield stress, Young's modulus and strain hardening exponent, arbitrary values were considered for the parameters so as to cover maximum kind of materials. The analysis was conducted by varying yield stress, hardening exponent and Young's modulus.

The results showed that springback angles increased with increasing yield stress as well as increasing hardening exponent. But, springback angles decreased with increased values of Young's modulus. While studying the effect of friction between blank & punch and blank & die on springback, it was found out that friction had no significant effect on springback. The study also involved the analysis of influence of geometrical parameters such as sheet thickness and die shoulder radius on springback. The results indicated that springback increased as die shoulder radius increased which is due to increased die opening. And as sheet thickness increased, springback decreased. This may be attributed to increased surface contact between blank & punch and blank &die.

Although springback is dominant in V-bending and wipe bending, a finite element based study conducted by Lokhande et al. [13] reveals springback effect in U-bending. Sheet thickness and blank holding force were considered for influencing parametric study on springback. Using HyperForm for pre-processing and Radioss for solving, a material provided in the database of HyperForm, IS513D, was considered for the blank. As the sheet thickness was varied, springback increased with increase in sheet thickness. This is in contrast to the effect of sheet thickness on springback in V-bending or wipe bending. The other parameter, blank holding force, when increased resulted in decreased springback. In order to attain the dimensional accuracy on the final product, the punch velocities are set to operate at low values. But, lower punch velocities lead to increased springback. Krinninger et al. [14] conducted experimental study of the influence of punch velocity, bend angle, bend radius and component width on springback. The study was done on free bending of two materials; a microalloyed steel HX260LAD and a stainless steel 1.4310 (higher yield strength) of 0.84 mm and 1.00 mm sheet thickness respectively. Springback was observed to be lower at smaller bend angle and highest at larger bendangles.

But the results were not sufficient to establish a linear relation between springback and bend angle. On the other hand, a linear relationship between band radius and springback was established owing to increased springback with increase in bend radius. This was attributed to larger zone of plastic deformation at higher bend radius. As component width was varied, springback increased for wider components.

This was due to increased residual stresses as width and thereby area of the component increased. When punch velocity was varied, springback decreased with increase in punch velocity. This variation was attributed to reduction in recovery at higher velocities. The same trend of variation between parameters and springback was observed for both the materials but the magnitude of springback was higher for stainless steel 1.4310 due to its higher yieldstrength.

1. Consolidated parameterslist

Table 2: gives information about the influencing parameters studied by various authors.

Table 2: Combined parametric study conducted by the authors in bending

Authors	Pr	Dr	BHF	μ	Pv	Ct	θ	Do	n	σs	E	t	Ba	Br	W	FE	Exp
Vasudevan et al. [10]	Y	Y	N	N	Y	Y	Y	Y	N	N	N	N	N	N	N	N	Y
Biradar et al. [11]	Y	Y	N	N	N	N	N	Y	N	N	N	Y	N	N	N	Y	N
Panthi et al. [12]	N	Y	N	Y	N	N	N	N	Y	Y	Y	Y	N	N	N	Y	N
Lokhande et al. [13]	N	N	Y	N	N	N	N	N	N	N	N	Y	N	N	N	Y	N
Krinninger et al. [14]	N	N	N	N	Y	N	N	N	N	N	N	N	Y	Y	Y	N	Y

IV. BLANKING

Unlike the above two forming processes, blanking and punching are two cutting operations performed on a sheet metal. In blanking, as shown in Fig 3, the stock left on the die after punching is scrap while in punching, the cut part is the scrap. One of the most common examples for both punching and blanking operations, combined, is the manufacturing of a washer [3].

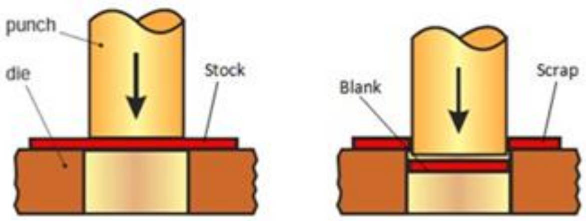

Fig.3. Blanking Process [19].

4. Processparameters

1. Clearance
2. Punchradius
3. Sheetthickness
4. Friction
5. Punchvelocity
6. Toolwear

In an effort to study the influence various parameters on sheet metal blanking, Maiti et al. [15] conducted finite element based analysis of blanking of a thin mild steel sheet. The parameters considered in this study are tool clearance, friction, sheet thickness, punch/die size and blanking layout. The analysis was done using ANSYS while considering a plain-strain condition for all the tests. The analysis was done for two cases; single blanking and double blanking. As the clearance increased, punch load decreased. This was attributed to increased plastic deformation zone with increasing clearance.

Similarly, as the friction increased, punch load increased. While varying sheet thickness, punch load did not vary proportionately and it was concluded that sheet thickness had no direct impact on punch load. But, when blank diameter was increased keeping sheet thickness constant, punch load increased. The effect of friction and clearance in both cases of single and double blanking was same. In a similar but exclusive study of influence of clearance on the formability in a blanking process, Fang et al. [16] conducted FE based numerical simulation of blanking operation of an aluminum alloy 2024.

The study was aimed at optimizing the clearance values for the material considered. The clearance between the punch and die was varied while keeping 1mm sheet thickness constant for all the tests. As clearance increased, blanking forces decreased but this trend was observed to be insignificant when the clearance was between 0-20percent of sheet thickness. The study also revealed that clearance had significant effect on the dimensional and shape accuracies. Extreme values for clearance resulted in bad profiles on the final product. A clearance of 0.5mm was considered to be resulting in favorable dimensional accuracy.

Husson et al. [17] studied the influence of punch-die clearance, tool wear and friction on sheared edge (blank profile) obtained on the final product of a blanking process. The study involved FE based simulation of blanking of thin copper sheets of 0.58mm thickness. Commercially available ABAQUS/Explicit software was used to perform blanking simulations. The blank profile was divided into 4 regions. Starting from bottom, the blank profile was divided as burr, fracture, burnish and rollover regions. When the clearance was varied, it was observed that it had no effect on burr region. However both fracture and rollover regions are increased with increase in clearance.

The tool wear is a direct impact of sharp (0.01mm) and dull (0.10mm) edges on punch and die. It was observed that dull edges and higher clearance resulted in under quality blank profile while sharp and lower clearance resulted in good quality blank profile. Coming to friction, it was observed that there was no significant effect on sheared edge when co-efficient of friction was varied.The application of blanking process is multi-disciplinary ranging from mechanical to electrical fields. An example of such kind is ferromagnetic sheet metal blanking.

Marouani et al. [18] conducted FE based numerical analysis on blanking of a 0.65mm thick FeSi (3wt. %) steel sheet. Commercially available ABAQUS/Explicit software was used to perform blanking simulations. The influencing parameters considered were clearance and punch velocity while performance parameters considered are punch force and punch penetration. The results showed that for all punch velocities, punch forces increased as punch penetration increased but decreased as punch penetration further increased. Similar to all the previous findings, increased clearance resulted in decreased punch forces. The relation between clearance and punch penetration is observed to be notdocumented.

Consolidated parameterslist

Table 3: gives information about the influencing parameters studied by various authors.

Table 3: Combined parametric study conducted by the authors in blanking

Authors	C	t	µ	Lb	TW	Pv	FE	Exp
Maiti et al. [15]	Y	Y	Y	Y	N	N	Y	N
Fang et al. [16]	Y	N	N	N	N	N	Y	N
Husson et al. [17]	Y	N	Y	N	Y	N	Y	N
Marouani et al. [18]	Y	X	N	N	N	Y	Y	N

V. STRETCH FORMING

Stretch forming is a process of tensile forming used to impart impressions on curved or flat sheet whereby enlargement is due to decreased sheet thickness [19]. In Fig 4, as the sheet is stretched between the two collets, the thickness is reduced from S0 to S1, while imparting the convex impression on the sheet.

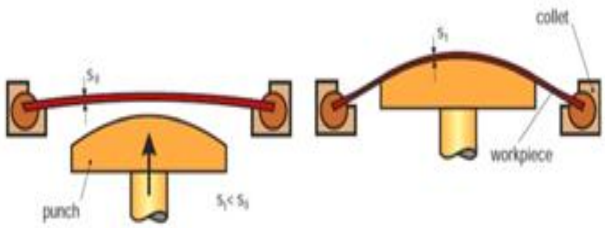

Fig.4.Stretch Forming Process [19].

1. Processparameters

1. Punchradius
2. Sheetthickness
3. Punchtravel
4. Friction
5. Materialproperties

As in the case of bending process, springback is a dominant part of stretch forming. Most of the literature available on stretch forming deals with the springback analysis. Fahd Fathi [20] conducted FE based simulation on stretch forming of Al 3003-H14 aluminum alloy using ANSYS and studied the influence of blank thickness, punch travel, punch radius and friction between tooling & blank on springback. Before proceeding with the analysis, the FE model was validated against experimental benchmarks.

The sheet thickness was varied while keeping punch radius as 17.5mm and μ as 0.3. It was observed that as sheet thickness increased, springback decreased. This was attributed to increased stretch forming forces as sheet thickness increased. Next, as the punch travel increased, springback also increased. This was due to higher elastic recovery at higher plastic deformations. Two values for punch radius were considered to study its influence on springback. It was observed that at lower punch radius, springback observed was less compared higher punch radius. When friction values were varied, it was observed that springback decreased with increasing friction co-efficient between punch andblank.

The material properties of the blank being stretched play an important role in springback analysis. Study of influence of material properties like yield stress (σs) and strain hardening exponent (n) along with sheet thickness on springback was carried out by Hardt et al. [21] experimentally. Although no values are provided for each of the three parameters, the analysis was done considering % changes in the values. The study revealed that springback increased with increasing yield stress and strain hardening exponent owing to lower plasticity overall. But, as the thickness of the sheet increased, springbackdecreased.

Forming Limit diagram (FLD) is an important tool in knowing the failure points in a formed part. Manikandan et al. [22] conducted both experimental and finite element analysis of stretch forming of HIF and IF galvanized steel sheets. The influencing parameter studied in this work is friction. In both experimental and finite element analysis, it was observed that friction had a negligible effect (minimal) on the left side of FLD but significant effect on the right side. The results showed that in the absence of friction, both major and minor strains were equal. But as the friction co-efficient increased, major strain was observed to be greater than minor strain.

2. Consolidated parameterslist

Table 4 gives information about the influencing parameters studied by various authors.

Table 4: Combined parametric study conducted by the authors in stretch forming

Authors	P_r	t	μ	P_t	σ_s	n	FE	Exp
Fahd Fathi [20]	Y	Y	Y	Y	N	N	Y	N
Hardt et al. [21]	N	Y	N	N	Y	Y	N	Y
Manikandan et al. [22]	N	N	Y	N	N	N	Y	Y

VI. CONCLUSIONS

It is evident from all the literature available that finite element based simulations in sheet metal industry is of great advantage over trial and error technique of optimization. The manufacturability becomes efficient eliminating time and cost liabilities. Coming to the sheet metal forming processes itself, drawing and bending are the two most widely used techniques in sheet metal industry. Both experimental and FE based simulation works have been done in analyzing these two processes.

It is understood from the literature that punch nose radius and die shoulder radius coupled with appropriate blank holding force are the main parameters that influence the manufacturability of a part using drawing. Similarly, the most important study in bending is the influence of process parameters such as punch nose radius, die shoulder radius, friction between the blank and tooling and material properties on springback.Again, the influence of punch no seradius and die should erradius is found out to be more significant than other parameters.

Blanking and stretch forming techniques are used for specific purposes but for mass production. While the influencing parameters in blanking process include clearance between punch and die, sheet thickness, friction and punch travel, stretch forming process depends upon punch radius, sheet thickness, friction and punch travel. In both the cases punch travel and sheet thickness have significant effect on the manufacturability of the final product. Also, springback plays an important role in stretch forming. Although FE based simulation yields favorable outcomes, the factors that are involved in a sheet metal forming or cutting operation are not accurately defined owing to simulation limitations [2]. Therefore, the future research should be focused on performing efficient simulations considering all factors. One such example is definition of friction between tooling and blank in case of deep drawing of a cup. Most of the literature available uses a constant value for friction throughout the drawing process. But in reality, the values change as the punch stroke increases from initial to final position [23]. In order to attain better and accurate results, the simulation interface has to be properly developed and used for design and testing.

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