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A review Paper on Deformation machining

Harshil Tandel[1], Dr. P.M.George[2], C.P. Mazmudar[3]
[1]Research Scholar, [2]Professor, [3]Assistant Professor
[1]harshil5358@gmail.com
[2]pmgeorge@bvmengineering.ac.in
[3]chintan.mazmudar@bvmengineering.ac.in
[123]Mechanical Engineering Department, BVM Engineering College, V.V.Nagar, Anand, Gujarat, India

***Abstract** – DM is amalgamation of two processes-namely thin wall machining and single point incremental bending/forming. This process allows the formation of complicated geometries and structures, which would be rather difficult or on occasionunmanageable to manufacture. This process allows the formation of monolithic components with uncommon geometries which were earlier assembled. DM allowsformation of monolithic structures with complicated geometries employing conventional tooling.*

***Keywords-** thin section machining, deformation bending, thinning, monolithic component, deformation forming*

I. INTRODUCTION

DM is anamalgamation of two manufacturing processes-thin wall machining and single point incremental forming/bending. In this process, first bulk raw material is removed using high speed milling machining and thin monolithic wall structure is made (vertical/horizontal) according to the application. After machining, the thin machined structure is made incrementally using a spherical shaped tool into the required shape. Thus, this hybrid process, allows the formation of lighter weight monolithic components with different and complicated geometries in one setup. This process allows the formation of monolithic parts which were earlier assembled. Earlier, the complicated components which generally required complicated tooling and equipment can now be fabricated by using simpler tools and conventional machines. Therefore, DM helps in cost saving in assembly, equipment, fabrication, and weight of the components. Moreover, ability of DM to get a part in one setup, by a single process, instead of sequence of processes creates the operation more viable and eco-friendly.

In DM, the formation of thin structures out of the bulk raw material is employed using thin structure machining. Thin structure machining is different from conventional machining owing to the lack of stiffness of machined structure.Therefore, thin section machining requires altered machining techniques;relieved shank tooling can be used in the machiningof thin vertical geometries, which provide a relief for vibratingthin machined geometry coming in contact with the tool. Thisprocess is widely used in aerospace and marine industriesswitching assembled part with thin monolithic parts. Thus, dropping the chances of failure and improving the overall strength of thecomponent. In machining thin sections, major chunk of material isto be removed; therefore, high material removal rate is employed.

Second aspect of DM is forming the machined thin structure intothe desired shape on the same setup and machine. For this, singlepoint incremental forming (SPIF) technique is used. SPIF is a die lessforming process where a hemispherical shaped single point solidtool is used to deform the thin structure into a desired shape incrementally using CNC machines. In SPIF, a thin structure or sheet metal is deformed locallyinto plastic stage, allowing theformation of complicated shapes accordingto the tool path generated by a CNC machining centre. Thus, by incorporating SPIF along with thin structuremachining, complicatedgeometries can be easily fabricated on more conventional, simpler machines. SPIF has allowed flexibility in formation of symmetric, asymmetric and random shapes. Furthermore, it is well-known that incremental forming process allows a higher formability as matched to the conventional forming processes like stamping, stretch forming due to highly localized deforming action.

The potential of thin monolithic parts with complicated geometries in aerospace industry (e.g. mold lines of fuselage, pressurized bulk heads, avionic shelf, impellers), biomedical engineering (bone and joint support, cranial plate, prosthetics), heat transfer and dissipation (curved, irregular fins) is a close possibility.
DM is classified into two modes: (i) single point incremental bending and (ii) single point incremental stretching, based upon the orientation of the deforming tool and the component.

Deformation machining bending mode

In deformation bending mode, first thin wall structure is machined using high speed milling machining, then that thin wall is bent incrementally perpendicular to the axis of the tool. In this way, in DM bending, thin wall is bent according to the requirement. The applications of such type of structures are in mold lines of fuselage of an aircraft, straight and irregular cooling fins, which were previously assembled to the body. Fig. 1 demonstrates conceptually deformation machining of a thin wall.

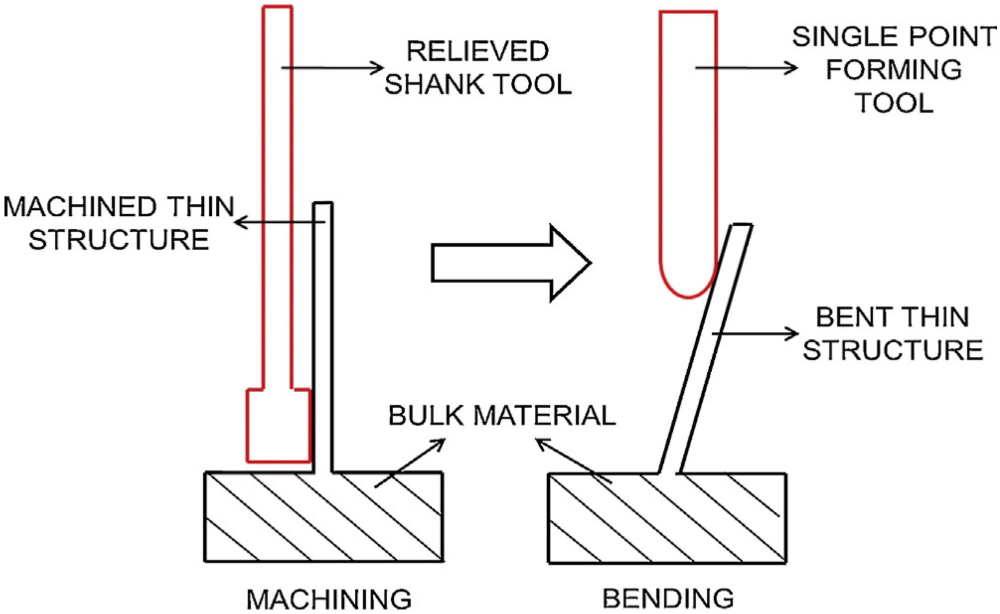


Figure 1.1 Schematic of deformation machining bending mode

Deformation machining stretching mode

In deformation machining stretching mode, the deformation is along the axis of tool resulting in stretching of thin horizontal structure. First thin horizontal sections are machined from the bulk material and then stretch formed to the desired shapes. Fig. 2 demonstrates conceptually deformation machining of a thin floor. The applications of such type of structure are in pressurized bulkheads and can also replace beaded panels to impart higher stiffness to the structures, which were previously assembled to the flanges.

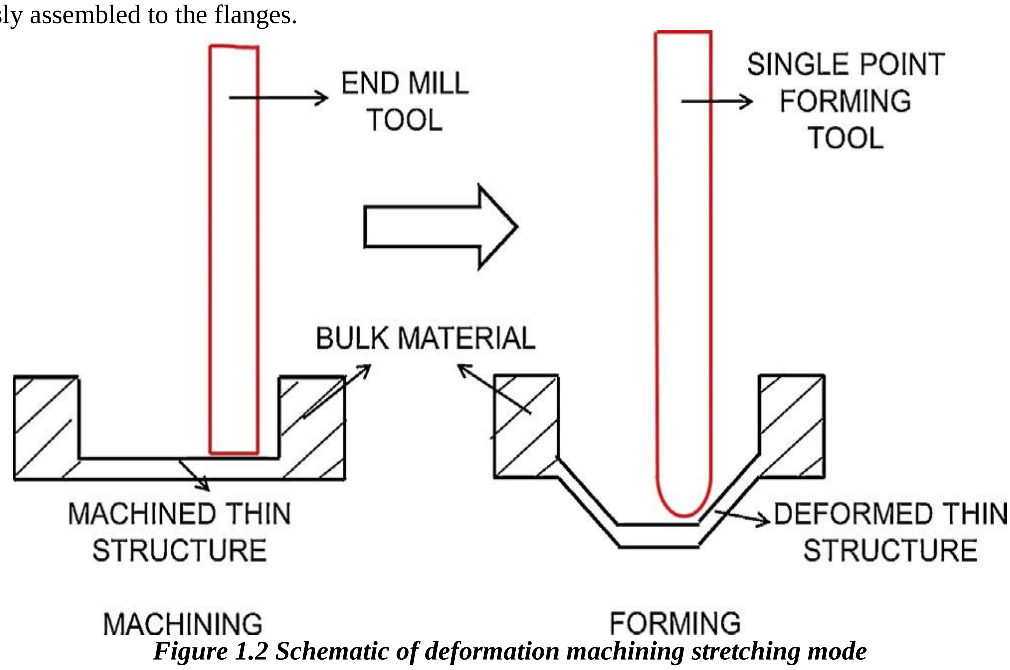
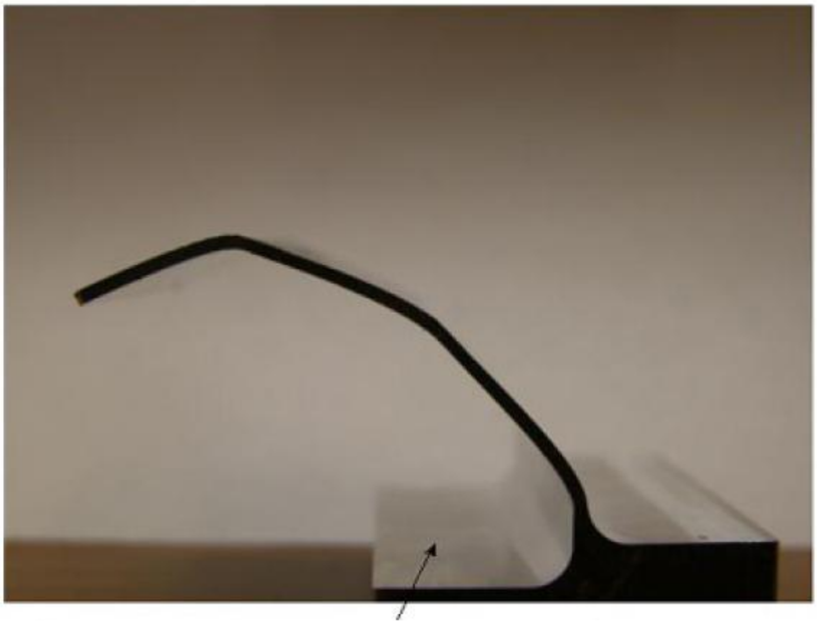


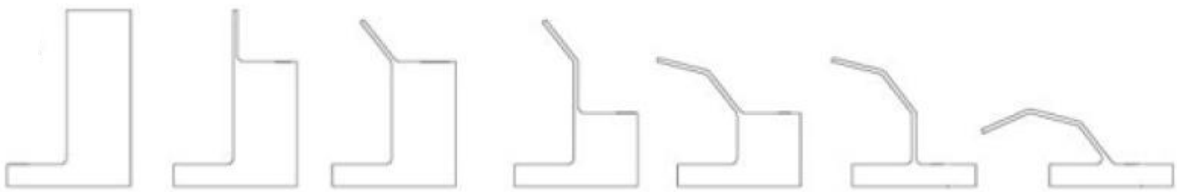
Figure 1.2 Schematic of deformation machining stretching mode

II.LITERATURE SURVEY

Smith S et al.(Dr. S. Smith, 2007), suggested the idea of deformation machining process. Deformation machining is a hybrid process of thin wall and thin floor machining with Single Point Incremental Forming (SPIF). In this work, the researcher tried to explore feasible process planning of machining and forming for numerous candidate geometries, to substantiate the scientific groundwork, i.e., comprehensive fundamental challenges in this hybrid process. This work was intended to answer some basic questions of the process like what should be the spindle speed, how does the spindle speed and feed rate changed the material formability.



The above part was produced by mixing forming and machining steps as demonstrates in fig.



Agrawal A. et al. (Agrawal, 2012)demonstrated the occurrences of fatigue life and dimensional repeatability for deformation bending mode in comparison with similar components made by using conventional sheet metal process. The dimensional repeatability of DM parts is thenmatched with sheet metal components made by conventional bending in a press brake and by single point incremental forming. The results of the study demonstrate that the DM process is not able to hold tolerance as tight as a standard milling process. Reason behind this may be the local variations in material properties that affect the yield strength and resulting springback. However, they noticed that the thin components produced by DM are less repeatable than similar components produced by conventional bending of sheet metal but more repeatable than similar components producedfrom sheet metal using SPIF. Results of the study suggest that it may be possible to hold tolerances in the range of 0.15 mm for DM bending mode components. Another side of this study is the comparison of fatigue life. Results of the study show that sheet metal SPIF parts under the present loading conditions have considerably longer fatigue life of nearly 3900-5500 cycles, matched to DM and sheet metal conventionally bent parts with nearly fatigue life of 2200-3900 cycles. It appeared like that bending incrementally leads to improved fatigue life of sheet metal parts as opposed over to bending conventionally. Reason behind this may be the less control over the bend radius in incremental bending when matched to a conventional press brake. However in DM parts the fatigue life is equivalent to conventionally bent sheet metal components. Residualstresses present due to machining may be the reason behind this.

Arshpreet Singh et al.(Arshpreet Singh, 2014)considered accuracy and the dimensional repeatability for sheet metal components and DM stretching mode. In this experimental work, studies have been done for parts created by DM stretching mode process, in which a thin horizontal floor is machined on the part using high speed machining, and then incrementally formed into a conical frustum with a single point forming tool. Ten similar parts were createdby single point incremental forming, DM stretching mode and conventional stretch forming. These components were checked at various forming depths using a co-ordinate measuring machine (CMM) and the dimensional repeatability of this process was matched. The dimensional repeatability of the DM stretching mode parts largely depends upon the accuracy of the machined floor. Other factors manipulating the repeatability of the process are elastic deformation, residual stresses generated during machining, highly localised yielding and spring back.

Arshpreet Singh et al.(Arshpreet Singh, 2016)carried out experimental work to compare residual stresses and the deformation forces in DM (bending and stretching mode) with incremental sheet metal bending/stretch forming and conventional machining. A considerable reduction in deforming forces in DM and incremental bending/forming over conventional bending/forming process was noticed. Residual stress generated across the part section of deformation machined process was equivalent to conventional bending and was less equal to conventional stretch forming process.

Arshpreet Singh et al.(Singh, et al., 2016)carried out the experimental and numerical investigations on thinning evolutions, structural thinning and compensation stratagem in DM stretching mode. In this work, he found out that the structural thinning was very much non uniform along the forming depth across all the investigated fixed and variable forming angles profiles.

Arshpreet Singh et al.(Singh, et al., 2015)carried out experimental investigation on the effect of the residual stresses produced during the machining and forming on the product life cycle and properties of the end product. It is essential to realize the process effects on the residual stress distribution. In this work, nano indentation technique has been used to inspect the residual stresses. The results have demonstrate the generation of tensile surface residual stresses during forming operations and compressive surface residual stresses during machining. Substantial variation in the surface residual stresses with varying machining and forming parameters has been noticed. The results demonstrate primarily compressive surface residual stresses in thin machined sections at the tested parametric levels. Incremental bending resulted in increase in compressive residual stresses on the compressive face and lessening of compressive residual stresses on the tensile face of the DM bending mode components. Decrease of compressive surface residual stresses was noticed at different forming depths on DM stretching mode components. Incremental step size, forming feed rate and increase in incremental angle also results in reduction of surface compressive residual stress generated by prior machining. Overall, stresses in DM bending and stretching mode component were compressive in nature due to the dominating effect of compressive surface residual stresses generated during the thin section machining.

Arshpreet Singh et al.(Singh, et al., 2016)carried out experimental work to calculate force needed for DM stretching mode for aluminium alloys. In this investigation, Aluminium AA 6063–T6 is used as work material. A table-type force dynamometer has been employed to record the deforming forces in three Cartesian directions. The influence of five process parameters—tool diameter, floor thickness, wall angle, floor size and incremental step size on the deforming forces is studied.The results of this study indicate that average resultant force during DM process primarily depends on floor thickness to be deformed and incremental depth in the tool path. With these two the floor thickness is alsonoticed to be the primary parameter. Whereas the effect of deforming wall angle, floor size and tool diameter were found not as significant. Using regression analysis empirical relation between the average resultant force and individual force components for investigated parameters was established with good level of accuracy. The model has been matched and validated for different aluminium alloys at varied levels of parameters, within an error range from 2.5 to 11.4%. The effectof shape of the formed part on the average resultant forces has also been studied and found to be dependent on the geometry. Forces during DM process and SPIF on sheet metal have been carried out and were noticed to be more during DM process. It could be due to the work hardening of the component during machining, prior to deformation.

Arshpreet Singh et al.(Singh, et al., 2015)carried out experimental investigation to see the effect of elastic spring back in deformation machining bending mode. Elastic spring back is a major contributor to dimensional inaccuracy of the thin formed structures. Correct prediction of elastic spring back and its compensation is important for the overall quality of the formed components. The components were made using a 3 axis CNC vertical milling machine and inspected for elastic spring back on a coordinate measuring machining (CMM).In the present study influence of elastic spring back in DM Bending Mode process has been presented. The results divulge that feed rate during bending, the maximum bent angle and dimensional attributes like wall thickness and height to length ratio have significant bearing on the elastic spring back. In addition to elastic spring back, other factors affecting the dimensional accuracy of the bent thin sections, i.e. curvature in the bent section and inclination along the length of section have also been explored. This study would help in providing an accurate compensation in the tool path for incremental bending over a wide range of process parameters, to achieve necessary dimensional accuracy.

III. CONCLUSION

From the above literature we can say that DM is a new emerging process which needs further investigation. There are so many problems involved during deformation machining process. Future work should be to check the viability of commercialization of deformation machining process. DM reduces the overall cost by reducing the tooling, set up and assembly cost as one can do DM process in a single set-up. As thin monolithic structure is to be made from raw bulk material, there is high material removal rate, which increases the material cost.

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