A study of Flexible Roll Forming of Automotive Structures

Vijay Sisarwal

Abstract*: Roll forming is a continuous profile production process to form sheet metal progressively into desired shape with closer tolerances. The process offers several advantages such as complex geometrical shapes, high strength, dimensional accuracy, closer tolerances, and good surface finish. Several parts in automobile body are produced with this process. Conventional roll forming is limited to components with uniform cross-sections; the recently developed flexible roll forming (FRF) process can be used to form components which vary in both width and depth. It has been suggested that this process can be used to manufacture automotive components from UHSS which has limited tensile elongation. In this method, the pre-cut blank is fed through a set of rolls; some rolls are computer-numerically controlled to follow the three dimensional contours of the part and hence parts with variable cross-section can be produced.Several Parts in automobile body are produced with this process. Flexible roll forming process can easily be implemented to current production lines and synchronized with other stamping units. The pipe-shaped thin-walled cross-sections and complex shaped profiles which are difficult to produce by other methods can be produced by roll forming. Nowadays flexible roll forming technology draws more attentions than before in authomotive industry.

***Index Terms*: Roll Forming, Sheet Metal, Automotive Industry, Finite Element**

I. INTRODUCTION

Roll forming is an incremental sheet forming process which was introduced more than one hundred years ago. The process has generally been used for manufacturing longitudinal profiles for different applications such as structural, household and automotive components with uniform cross-sections until early 2000. Since then the conventional roll forming technology has been advanced to produce parts with variability in width and depth [1].

Approximately 10 year ago, the roll forming know-how was merely on an on-site expertise base between the machine operator and the tool-designer, with the foundation of year of practical experience. Several possible effects were known, and in most cases the machine operator and tool-designer knew how to react. From day to day new phenomena would appear and a solution had to be developed. All that counted was the fact that the manufacturing process continued. Understanding why or what they were doing was-if at all-only second or third priority. It can be noted now. That the roll forming process is far too complex to understand and describe all interrelations on practical base only.

Nowadays, the roll forming process is being widely applied in the whole industry. This roll forming process is cost effective as well as high productive technology compared with conventional stamping method, because of its in-line forming process to manufacture the final part starting from a coil material. Especially, various automotive structural parts, such as a bumper beam, a side sill, et al, are being manufactured by the roll forming process using AHSS.

Flexible Roll Forming (FRF) is a high efficient and economical method for the production of sheet metal. Due to the complicated motion control of FRF and the intricate section geometry of sheet metal, it is required for real-time accuracy and dependable control during the course of forming in FRF. Compared to configured software such as Lab view, PMAC (Programmable Multi-axis Controller) can realize kinds of complicated control logic and is widely utilized in industry because of its versatility of programming language, high-precision control and good portability. Based on the technique characteristics of high precision, high stability and strong real-time control of FRF, this paper realizes the control system of FRF which can control the servomotor systems and actuators by adopting PMAC and industrial computer, etc. The experiment indicates that this system possesses the advantages of high-precision control and good stability, which can be utilized to kinds of production of sheet metal in FRF.

Although the roll forming process is one of useful forming technologies especially for AHSS, it can only make the part having a uniform cross-sectional profile. In order to overcome this limitation, POSCO multi-directional Roll Forming (PosRollForm) technology was suggested[2]. PosRollForm popularly referred to the flexible roll forming process. It can make a roll formed part having a variable cross-sectional along the longitudinal direction using a relative motion of each forming roll. But it is still under research and development.

Roll forming is suitable for producing constant-profile parts in continuous forming with long lengths-large quantities and coil feeding and exit cutting to length held to close tolerances. Besides, notching, slotting, punching, embossing, and curving operations can easily be combined with the roll forming process to produce finished parts for manufacturing lines. While conventional roll forming machines produce parts whose cross sections are uniform longitudinal direction, nonetheless, the integrated structural skin can be designed in the vehicle body through 3D flexible roll forming techniques. In this technique, both constant and variable cross-sectional sized profiles are produced. Nowadays, the roll forming process is capable of producing a wide range cross-section. The 3D roll forming has overcome the constant cross section limits on production [3].

However, The number of steps depends on the cross-section, tolerances, finish of the surface and material properties.

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Today there are several computer aided engineering (CAE) systems, for example ORTIC System COPRA RF , PROFIL , that can support the tool designer in creating tools.

II. SCOPE

The case study will primarily focus on the high strength steel has been widely used to improve safety and fuel efficiency in automotive industry. Roll forming is a well established forming technology to produce constant cross-sectional parts with high strength steel. Roll forming has drawn the attention of automotive industry due to its various advantages, such as high production speed, reduced tooling cost and improved quality. Various automotive parts such as bumpers, door beams, frame rails, and roof bows are made by roll forming process. In recent years, flexible roll forming process which variable cross sections of profiles by flexible rolling stands was developed.

Current trend reveals that the process in automotive will be very common in near future. When the precise, long, and high strength body parts are required in large quantity, the roll forming process will be the ultimate choice.

In this proposal flexible roll forming characteristics using ultra high strength steel will study and case study on variable width U-channel will performe using COPRA RF coupled with MSC. Hat-channel profiles which have variable depth and width will fabricate using experimental method. In this study, studies on optimum profile shall performe by analytical and experimental methods an analytical equation that can evaluate longitudinal strain will develope considering inter-distance between forming passes, base section width, side wall height and flange width. The relationship between geometrical parameters and longitudinal strain will analyze and investigations on the optimal profile design shall performe. With the results, a roll flower pattern and roll profile that can avoid process defects such as wave and twist shall designe and experimentally verified[4].

III. OBJECTIVES

Flexible roll forming characteristics using ultra high strength steel will study and case study on variable width U-channel will performe using COPRA RF coupled with MSC. Hat-channel profiles which have variable depth and width will fabricating using experimental method.

How should the roll forming process be designed for complex geometries and/or high strength steels

In this study, studies on optimum profile shall performe by analytical and experimental methods an analytical equation that can evaluate longitudinal strain occurred and considering inter-distance between forming passes, base section width, side wall height and flange width.

The relationship between geometrical parameters and longitudinal strain will analyze and investigations on the optimal profile design shall performe. With the results, a roll flower pattern and roll profile that can avoid process defects such as wave and twist shall designed and experimentally verified.

Long sections of both variable width and variable depth parts for BIW structural members. FRF is an extension of the conventional roll forming process and represents a cost effect alternative to hot stamping of automotive crash and structural components. However, the limits of the process in regard to part complexity and metal alloys that can be formed is still unknown which currently restricts the widespread application of the process.

IV. AREAS TO INVESTIGATE

The major aim of this research paper is to verify the manufacturability of automotive components by FRF that are variable in depth and high complexity and to develop part geometry guidelines for the identification of part families that are suitable for the process and can be formed with minimum tooling requirements.

Secondary focus will the investigation of the forming of complex part shapes by combining FRF with Ford`s free forming tool. The general approach will be to manufacture the initial longitudinal shape by FRF followed by the forming of small and complex regions with Ford`s free forming tool; This will permit the reasonably rapid forming of overall shape in long parts such as pillars, rocker reinforcements and roof rails. The limits of the process in regard to part complexity and metal alloys that can be formed are still unknown.

Spring-back is one of the most important problems in flexible roll forming process. A flexible roll forming setup will develope and some parameters in the simulation will discussing

Rolls stand deflection- During the plate rolling process, considerable values of the forces of material pressure on the tool occur. These pressures cause the elastic deformation of the roll, thus changing the shape of the deformation region. Plate obtained from the rolling process always exhibits a variable thickness along the width. This state enables the rolling process to be carried out correctly, as thanks to the elastic deflection of rolls mounted on the rolling stand housing it is possible to guide the rolled strip precisely in the centre of the rolling stand. Roll deformation should be, however, controlled, because it’s too large value causes the permissible deviations in the thickness of the strip along its width to be exceeded.

Flange wrinkling-Flange wrinkling at the transition zone where the cross section changes is a major defect in the flexible roll forming process. When the flange wrinkling occurs, compressive longitudinal strain is smaller than the necessary compressive longitudinal strain calculated by mathematical modeling to obtain the intended profile geometry in the compression zone. Therefore, comparison of compressive longitudinal strain obtained from the finite element analysis and the necessary compressive longitudinal strain is a good criterion to predict the flange wrinkling occurrence.

Web warping- Web warping is one of the most common defects in variable cross section flexible roll formed profiles. In this paper, the effect of the bend curve on the web warping is investigated to find a cost-effective method for reducing the web warping. For this purpose, different bend curves (circular, quintic, linear, fractional, and Bezier) are designed for a specific variable cross section profile.

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Finite element simulations are carried out and the longitudinal edge strain and the web warping are obtained in the transition zone.

V.IMPLICATIONS

The immediate implications of the reform of the forming of complex part shapes by combining FRF with Ford`s free forming tool. The roll forming process is a high volume manufacturing process where downtime is very costly. As such, there has been a constant focus on improving the process variables in order to achieve low defect rates and predict possible problems before they appear; the final target is to have a robust process with good quality control. In this context, finite element analysis plays a major role, as it allows for the simulation of complete roll forming manufacturing lines where defects can be detected and eliminated even before the tooling is manufactured.

The problem tackled in this project will how to include deformable tooling in roll forming FEA (finite element analysis) models. This is an important innovation in roll forming simulation, and a direction to explore in depth in the future. Analyzing the forming forces during roll forming and their interaction with the various machine components is key to more precise simulations and to better detection of manufacturing defects during the design stage, leading to possible improvements which would be impossible in later development stages.

The approach uses will a combination of literature studies, and experimental and modelling work. The experimental part gave direct insight into the process and will also used to develop and validate models of the process. The work started with simple geometries and standard steel and progressed with more complex profiles of variable depth and width, made of high strength steel.

VI. PROJECT PLAN:

The major aim of this project is to verify the manufacturability of automotive components by FRF that are variable in depth and high complexity and to develop part geometry guidelines for the identification of part families that are suitable for the process and can be formed with minimum tooling requirements.

However, the experimental equipment used in the study presented in proposal. The aim of these experiments was to measure strain history, roll load, roll torque and springback during the roll forming of a U-channel and to compare the results with finite element simulations.

STAGE-I

The ultimate goal for the project was to develop an FEA model of the roll forming process which includes a representation of deformable tooling. Moreover, it is important to develop a method for the determination of the machine stiffness, so that users of the FEA model can model their own lines accurately resorting to a prescribed set of instructions and tools. The experimental setup design started with the profile selection and bending strategy development. These shall constrained due to the need to use tools already available at data M Sheet Metal Solutions. Nevertheless, the roll forming tool design process is described as it influenced the machine design in a later stage.

STAGE-II

In order to achieve these goals, an experimental roll forming line will develope during the course of this project, including several measurement devices in order to better understand the behavior of its components during the forming. The strategy to achieve a final usable FEA model included the development of FEA models with different degrees of freedom for the rolls, in order to understand what the critical variables. This way, a final model could be developed, striking a balance between precision and calculation time

STAGE-III

The use of roll-formed products in automotive, furniture, buildings etc. It will possible to produce profiles with a variable width ("3D roll-forming") for the building industry. Experimental equipment was recently built for research and prototyping of profiles with variable cross-section in both width and depth for the automotive industry. The objective with the current study is to investigate the new tooling concept that makes it possible to roll-form hat-profiles, made of ultra high strength steel, with variable cross-section in depth and width[5].

STAGE-IV

The experimental analysis of the tool deflection required the design of a dedicated roll forming line which enabled the measurement of the required parameters. The concept developed consisted of a single roll forming stand equipped with the measurement devices needed. The sheets would then be run through each forming pass individually, and the rolls would be changed after all the trials were run on each step. This isolated the measurements from the effects of previous or subsequent forming steps, focusing the investigation on what happened in each station individually.

STAGE-V

It will be possible to produce profiles with a variable width ("3D roll-forming") for the building industry. Experimental equipment was recently built for research and prototyping of profiles with variable cross-section in both width and depth for the automotive industry. The objective with the current study is to investigate the new tooling concept that makes it possible to roll-form hat-profiles, made of ultra high strength steel, with variable cross-section in depth and width. The result shows that it is possible to produce 3D roll-formed profiles with close tolerances[5].

VII. METHODOLOGY:

In order to validate and improve the FEA model, an experimental line will designe. with help of 3d FRF, This line consisted of a single roll forming stand with entry and exit guiding for the metal strip. A roll set for forming a U-channel profile will use. A single roll stand will use in order to isolate and understand the interaction of the strip with the stand, eliminating the effects stemming from the interaction with the stands adjacent to it. A high strength steel material will use in order to ensure high forming forces and because advanced high strength steels and ultra-high strength steels are being processed by roll forming with ever increasing success and to setup large manufacturing use.

VIII. CONCLUSION:

In order to answer the research question initially posed, this study, as it progressed, will divide in three parts: modelling, high strength steels and 3D roll forming. However, when designing a roll forming process these research areas go hand in hand. On the basis of research of others and from the present work, the following overall conclusions can be drawn: Today, it is possible to successfully develop profiles of complex geometries (3D roll forming) in high strength steels and finite element simulations can be a useful tool in the design of the roll forming process. Listed below are some suggestions about future work in the above mentioned areas in order to further improve the competitiveness of the roll forming process and enable the development of new, advanced products:

a) Develop finite element models for the 3D roll forming process. b) Develop material models of advanced high strength steels. Investigate, through simulations, the potential of partially heating materials. c) The aim is to enable a production of profiles in high strength steel,in a process based on small bending radius and fewer forming steps.

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AUTHORS PROFILE

My name is Vijay Sisarwal, a student of Master of Engineering program at the Department of Heat Power engineering of Rajiv Gandhi Technical University (Bhopal) and four years of Bachelors program at the Department of Mechanical Engineering. I initiated my undergraduate program in 2004 and completed it by the end of 2008. I have completed my Master of Engineering in 2013.

Academically, I have always tried to do better for myself. I pursued my bachelor's degree from Patel College of Science & Technology; Bhopal affiliated with Rajiv Gandhi Technical University, Bhopal. The Institute offered me an opportunity to graduate in a unique inter-disciplinary course - Mechanical Engineering, which combines subjects from the fields of Heat & Power, Information Technology, Electronics and Communication Technology. Studying the fundamentals of each of these fields and understanding their co-dependence, while specializing in Mechanics, has given me a distinct edge over people with backgrounds in just one of these fields, subject like Heat Power, Thermal Power skills came into my way and it was this interest of mine i.e. to amalgamate technology with effective management that pushed me to further enhance my interest and knowledge.

During my Master degree I always tried to be an all rounder, for that I actively participated in various training programs & published a paper in international Journal of Engineering Research and Application (IJERA).

After my master degree, I got placed in Madhav Group of Institutes as a Research Asst., where I planned and performed various Direct, plan, or implement policies, objectives, or activities of organizations or businesses to ensure continuing operations, to maximize returns on investments, or to increase productivity. After working with Madhav Group of Institutes, I switched to Safeful ever free healthcare Sol. Pvt. Ltd, Raisen as a Research Supervisor where I was working for Plan, design and conducts and handle Project work and also investigates and formulate the policies or plans. After working with Safeful ever free healthcare Sol. Pvt. Ltd , I switched to Parashar Ayurvedic Medical College and hospital, Bhopal as a Research Supervisor, where I represent organization or promote their objectives at official functions and Direct or conduct studies or research on issues affecting areas of responsibility. After working with Parashar Ayurvedic Medical College and hospital, the Management has promoted me as Assistant Professor in their Engineering wing, currently I am working here from 2018.