A Review on Optimization and Analysis of Various Sheet Metal Forming Processes

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Abstract

The review focused in this paper is consist of various metal forming processes and methods used to analyse and optimise forming process. Various processes are introduced for high rate of production and formability. Formability and test methods are discussed together with the variables occurred in sheet metal forming process. Defects occurred during forming process are highlighted and important factors, work concerning the process principle, deformation of work piece, interactions of parameters are discussed. The methodical review of literature based on the optimization methods and analysis is highlighted in the paper corresponding to future research in the field of material forming.

Keywords: *Sheet metal forming; FEA; DOE; Simulation; Statistical method; Optimization.*

1. INTRODUCTION

Computer aided engineering (CAE) approaches are widely applied in metal forming integrated design. The implementation of advanced high strength steels, has improved the incidence of spring back. Subsequently the request for tools concerned with spring back reduction and optimization is also increases. The factors which changes the formability of the part are determined by using formability study. Frequency and mode shapes of assemblies are defined by vibration analysis. The cost related to prototypes and introduction to market are dropped due to FE simulation which are based on modern computational tools and intricate mathematical models [1].

Before development of tool numerous industrial formations are carried finite element simulation to understand formability of sheet metal parts, due to simulation tools and high speed computer technology. Much cost is involved for individual forming tool in every forming process. Forming defects such as rupture, wrinkling, thinning are predicted and controlled with the aid of CAE tools. The relation between the numerous forming parameters are considered with the application of design of experiments (DOE) procedures [2].

2. LITERATURE REVIEW

Metal forming is considered as integrated design of product and process. Die set up, material characteristics and process defects may affect the quality of product. Use of computer aided modelling, simulation, manufacturing and FEA are applied widely to integrate process set and shape design. By considering different punch and die clearances, several experiments were performed. Experimentally it is validated that, spring back and thinning effects were linearly increasing beyond a particular clearance and causes fracture propagation for every thickness of sheet metal [3]. Effects of significant parameters such as blank thickness, elastic layer thickness and hardness, blank property and punch elements on spring-back are extensively examined by FE simulations and experimentations. Pure copper and stainless steel are used as materials for trials. A negligible reduction is detected for spring back by increasing the thickness but the dimensional variations before spring back is increased because of non-uniform deformation characteristics. It is required to select accurate size of punch, as it leads to a momentous effect of spring-back, [4]. Ironing behaviour on thickness scattering regarding temperature was studied and simulating ironing process was developed. FE simulation for temperature and deformation in warm forming process is carried out using LS-DYNA. Accuracy in the simulation process can be increase by considering more number of integration points, [5]. At component design stage, the FE code is adopted to evaluate stamping force and to obtain overview of the general formability. Die compensation is an instance of this process. Accuracy of the linear coefficients can be affected by the accuracy of stamping nodal force [6]. Optimization of deep drawing process can be performed using genetic algorithm to investigate effect of related parameters. Variety of forming parameters can be considered in combinations of control system. Effect of punch, die profile and drawing force are the most vital parameters in metal forming [7]. Small variations in die radius profile shape is resulted in expressively decrease tool life. Small and localized variations from a die profile shape are examined and the effect on tool life is determined by FE simulation by explicit finite element code. Small defects at the die corner radius can effect a major rise in local contact pressures affects adverse changes in tool life. [8]. The probability of failure or the reliability of the design can be efficiently evaluated by the most probable point (MPP) analysis based on response surface methodology (RSM) [9]. Parts defect is observed due to displacements of the press components and punch tool. The machine has influence on work piece quality. This impact is important in the metal forming as a result of resulting ram movements and high forming forces. For representing the machine characteristics a hybrid multi-body simulation is a suitable approach [10]. The several process parameters such as friction conditions, expansion ratio and die cone angle as the input process condition are critically analysed. Signal to noise ratio (S/N) analysis and the analysis of variance (ANOVA) methods are used to find the optimal combination of the process parameters. Taguchi method is used to find the effective optimised process parameters and ANOVA is used to find percentage contribution [11]. The process parameters chosen for the flow forming method are speed of the mandrel, roller radius and axial feed of the roller. Effect of process parameters on mean diameter of flow formed tube are investigated by taking trials on a single roller flow forming machine using RSM. Roller feed and roller radius are the most important parameters effecting the mean diameter of flow-forming process. Strength of the material can be increase by addition of manganese, which controls the grain structure and produces superior strength [12]. The force exerting on the travelling tool is evaluated by examine the deformation behaviour, the tool path on the punch load and blank thickness. Sheet thickness, part geometry, wall angle and distribution of equivalent plastic strain is also discussed. Optimization of the incremental forming process of sheet metal is also determined by the numerical simulation [13]. Applications of the existing DOE and RSM techniques are used in the sheet metal forming component followed by vibration analysis and gauge optimization. Forming variables and their influence on formability and thinning of the sheet metal is given by DOE. Thinning of the bracket can be reduced by keeping friction and thickness as low as possible [14].

Multi objective reliability-based design optimization (MORBDO) procedure is proposed to highlight the vehicle door design. The optimization of the parameters is carried out using Multi objective particle swarm optimization (MOPSO) algorithm. Pareto frontier of reliable solutions can be generated by the proposed optimization procedure [15]. The global Pareto solutions are found by model based on the response surface, process combination of the blank holding force and the stamping velocity. Advantage of the multi-objective genetic algorithm are studied to optimize the responses of the effective parameters. A set of reliable solutions is proposed considering all-purpose optimization method to deal with complex hot stamping processes. This approach is verified as effective and robust for finding the optimal parameters by conducting experimental trials [16]. Kriging interpolation and Sequential Quadratic Programming (SQP) algorithm are used to optimise forming parameters in multistep stamping tool. The numerical technique are suggested to decrease the number of forming stages and therefore increasing the process productivity. Finite element code ABAQUS is developed using integrated optimization approach for constructing the objective function as per the design variables and numerical results are validated with the experimental tests [17]. FEA and DOE are used to optimise the effective process parameters for warm forming of lightweight component to offer fast and relatively precise design of process. When the punch and die friction are maintained at the similar level, decrease of formability is observed with rising coefficients of friction [18]. Experimentations are conducted to control the spring back using optical measurement technology for metal forming analysis and optimisation. It is becoming more affordable to use optical measurement equipment and software based on photogrammetric [19]. The principles of multi-point die forming (MPDF) and multi-point press forming (MPPF) are defined and then the rules to control a scope of an element are stated. A flexible forming technique proposed for sheet metal part, multi-point forming (MPF) technology is also discussed. Large size steel plate is bent with the line heating technique, in which geometrical precision and forming quality is mainly subject to experience in shipbuilding field. Using CAD data, shape of the element group changed rapidly by various MPDF methods like sectional MPDF for big size sheet forming, flexible blank holder procedure for thin sheet metal forming, closed loop MPDF for great accuracy forming and reverse engineering were investigated in detail. In finds application in various field of engineering like vehicle engineering, aeroplane engineering and medical engineering [20]. Many intricate sheet metal forming problems can be solved using FE simulation as, inverse methodologies and alternative approaches. The shape optimization and parameter identification problems are solved using analysis and simulation technique. Parameter identification problems is to evaluate the input parameters that lead to the best precise results related to experimental trials. Shape optimization is used to determine initial geometry of a given component to provide anticipated final geometry after the process. A finite element codes are developed using optimisation approach to solve optimisation approach. Final results of both approaches are tested using algorithm and found satisfactory [2]. Linking mathematical optimisation with simulation shows good contribution in improvement of product and overall cost reduction. Numerous expertise in optimisation is required in metal forming process, which will be the obstacle in general industrial application. Only the most important design variables are selected by screening to minimise the depth of optimisation problems and solved using well organised optimisation algorithm. Optimisation problems and structured method for solving these problems to improve their products and processes, allows non-optimisation specialists to apply optimisation practises. The optimisation approach is effectively applied in a hydroforming process to validate the importance of the optimisation in metal forming processes [21]. Concurrent engineering approach using integrated system greatly reduce cost and the development time for availability of product in market. At the time of formability analysis an optimal die face is identified, as stamping parts are sharp edged and complex in geometry. This type of analysis can significantly decrease the trial period and forming failure percentage. Design process time is reduced drastically by using the solid model of the component. This model is gone through interference analysis and structural analysis to avoid defects [22]. The increased rate of production is explained using example of gun smiting which was a craft-bound cottage industry earlier the industrial revolution shown in Figure 1. In 1848, industry was able to produce only 10,000 rifles per year although the requirement was more. When the rifles were finally used in 1866, it was required 26 years to make 300,000 [23].

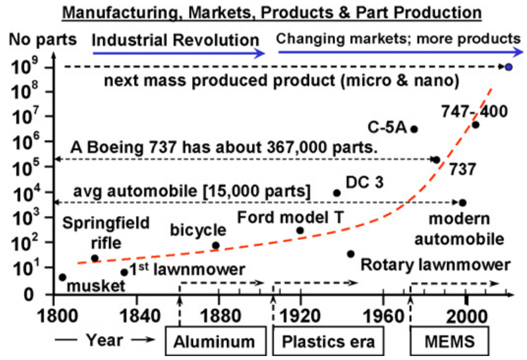

Figure 1. The upsurge in intricacy of parts from the industrial revolution [23]

3. CONCLUSION

Literature explained in the paper shows that much more things are still remains in all areas of metal forming. Manufacturing with lightweight materials and warm forming are vigorously used in production processes nowadays. In changing economic scenario, aid of CAE is vital in metal forming technology to provide the changes in technology and productivity aspect. The future work should focused on improve the optimum set of effective process parameters as tool path, friction, wall angle, sheet thickness, clearance, tool diameter, spring back characteristics, geometrical accuracy, punch load and forming limit. The defects in the forming process can be minimised by optimization through properly selecting the effective process parameters. Optimization methods, FE simulation & analysis of process create the major impact in defects reduction in sheet metal forming process.

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