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Design and Analysis of the Swaging Manufacturing Process Using CAE

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CAE에 의한 스웨이징(swaging) 제조 공정의 설계 및 해석

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요 약 스웨이징(swaging) 제조 공정의 컴퓨터 시뮬레이션에 관한 연구를 수행하기 위하여 상용 소프트웨어를 사용하였다. 시행오차를 통하여 획득한 경험에 기반을 두어 튜브 스웨이징 공정의 시뮬레이션이 이루어졌으며, 변형 경화 지수(strain hardening exponent) n과 소성계수(plastic modulus) K는 튜브재료의 실제 인장 측정 시험을 통하여 얻어졌다. 두 종류의 서로 다른 다이와 튜브 형상을 사용하여 비교하였다. 전처리는 HyperMesh(r), 해석은 LS-DYNA(r), 후처리는 LS-TAURUS(r)를의 상용 소프트웨어를 사용하였으며, 본 연구에서 얻어진 결과들을 문헌에서 이용 가능한 결과들과 비교하였다.

Abstract Computer simulation of a swaging manufacturing process is presented in this paper. Commercially available software has been used to develop the simulation algorithm. Based on the experience gained from trial runs, simulation of a tube swaging process has been carried out. The material parameters "n" (strain hardening exponent) and "K" (plastic modulus) are obtained from actual tensile test measurements of the tube material. Two different geometries for the die and the tube have been used in this work and a comparison made. Numerical simulation of the swaging process has been performed using the commercially available HyperMesh(r) for pre-processing, LS-DYNA(r) for analysis and LS-TAURUS(r) for post-processing. Some of the results obtained from this study are compared with those available in the literature.

Key Words : Swaging, Computer simulation, Material parameters

1. Introduction

According to the German standard DIN 8583, swaging is a forging method for reducing the cross sectional area of bars and tubes using two or more dies, which surround the outer diameter of the work either completely or partially [1]. These dies rotate around the work and move towards its center by applying radial forces with short strokes on the tube/bar being swaged. Swaging can be achieved either by rotating the work with the dies moving in the radial direction, or by rotating dies with work held stationary, or with both of them rotating and the dies having a superposed motion of both rotational and radial motion. Swaging of tubes is more complicated when compared to the swaging of solid bars. The increase in length, reduction in inner diameter and the change in the wall thickness all vary depending on the properties of the material and the geometry of the dies. The rotary swaging method is widely used to manufacture tubular automotive components such as steering columns, hollow piston rods for shock absorbers, drive shafts, etc. [1].

In a swaging operation, the impact energy of the swaging dies is converted into specific forming forces of the work. At the beginning of each forming operation, there is only a line contact between the work and the dies, which gradually develops into a surface contact during the swaging operation [2]. The die run out opening (the start of L_3) is used to limit the length of the calibration area L_2. However,

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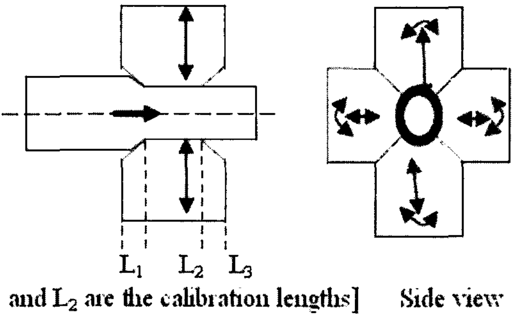

Fig. 1. Principle of a swage operation and the calibration areas.

the magnitude of the exit transition angle is not very important. These are shown in Fig. 1.

When tubes are swaged with a mandrel, it is necessary that the material between the dies and the mandrel be pressed radially against the surface of the mandrel. This allows the metal to flow in the axial direction. The principle of operation of a classical swaging system is shown in Fig. 2 with a driven swaging spindle [1].

Some of the advantages of swaging process are its short cycle time, smooth surface finish, tight tolerance, considerable material or weight savings with tubes, minimum notch effect, increased material strength, uninterrupted fiber structure.

In swaging, as in any other metal forming technology, proper design and control of the process requires, among other things, the accurate determination of deformation mechanics. Knowledge of the process variables such as friction conditions, material properties and geometry of the workpiece on the process mechanics is very important to predict and prevent the occurrence of defects. In order to reduce the costs associated with more detailed experimental studies, modern metal forming technology relies heavily on virtual manufacturing techniques that use properly validated computer simulation tools. Care should be taken, though, while using these tools and in understanding the results, as computational manufacturing simulation is still in its primitive stages of development and research.

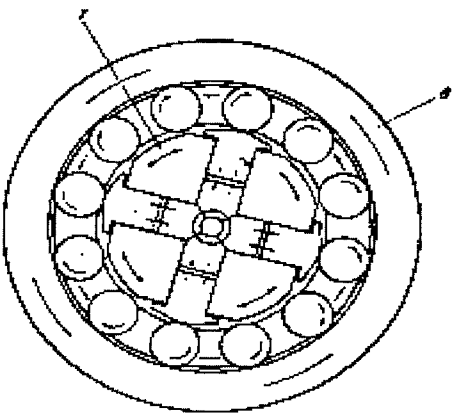

Fig. 2. Conventional swage head.

Different approximate methods of analysis have been developed in the past and applied to various forming processes [3-8]. Accurate determination of the effects of various process parameters on the detailed metal flow became possible only recently with the advent of computational power, and with the application of finite element methods for large plastic deformation processes. However, the application of FEM to metal forming is discussed only in few books [3, 9]. These references cite the main advantages of using the finite element method.

Although swaging processes seem to be commonly used to manufacture steering columns and other automotive components, modeling of the process itself is not been reported extensively in the literature. As far as application of FEM to the swaging process, some work done in Europe should be mentioned. Pietrzyk, Glowacki and Grosman [10] reported their work that deals with simulation of metal flow and heat transfer during the swaging process. Rigid-plastic flow formulation and a generalized plane strain finite element approach have been used to simulate the metal flow, while the temperature distribution in the deformation zone is calculated by the unsteady state solution of the Fourier equation. Several conclusions relating to the process parameters are discussed in their paper. Piela and his group [11-15] extended research originated by Grosman to verify some of the finite element results with experimentally observed values. They have researched several schemes involving use of a mandrel in a circle-circle sizing and in circle-square configurations.

Research reported by Siegert and Krumann [16] outlines some of the latest trends in swaging process carried by the recessing method as opposed to the feed-in method.

2. Simulation of Swaging Process

It appears from the work reported in the literature that rotary swaging is increasingly gaining importance in volume production. With the availability of high-speed computational power and well-researched numerical finite element codes, many industrial establishments are turning towards simulation of forming processes. In this way, the philosophy of virtual manufacturing of a real process is envisioned to assist the engineers in the design of correct tooling, and eventually to design a set of experiments to study the impact of the various process variables on the quality of the final product.

In this paper, an attempt has been made to simulate the cold swaging process using the commercially available software, namely, HyperMesh® (preprocessing), LS-DYNA® (analysis) and LS-TAURUS® (postprocessing) that are available on the Unix platforms [17]. In order to understand the modeling of the proposed swaging processes using the above software, several example problems have been attempted first and some of the results verified with those available in the literature. Thermal effects of the process itself are not taken into account in any of these studies.

Due to the space constraints, in this paper, only the results of cylindrical bar are presented and discussed. The dies in this simulation have reciprocating motion in the radial direction. During each time interval the dies move by a greater distance simulating a progressive radial motion. The geometric shape of the dies used for swaging is one of the major factors that decides the final shape of the tube or bar being swaged. The dies can be either flat or semicircular in shape. The number of dies used is also an important factor. In this simulation two semicircular dies are used to swage the tube or a bar. Fig. 3 to 6 show the model and the results of swaging of a bar. The two semicircular dies move in opposite directions.

From the above results it is clear that semicircular dies may not be a good option for swaging operations. Sometimes flat dies are used for computer simulation, as well as in actual swaging processes for swaging of bars and tubes. The work piece has to be rotated in each cycle if circle-circle scheme is desired.

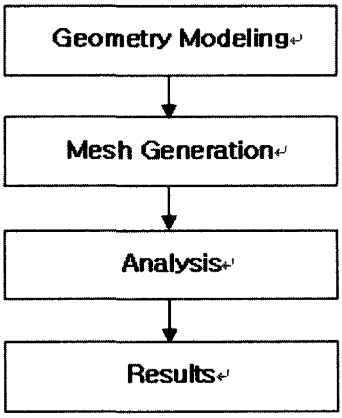

Fig. 3. Flow chart of analysis procedure.

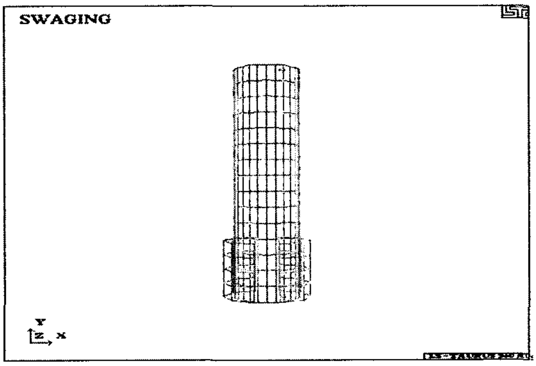

Fig. 4. Swaging model using two semi-circular dies.

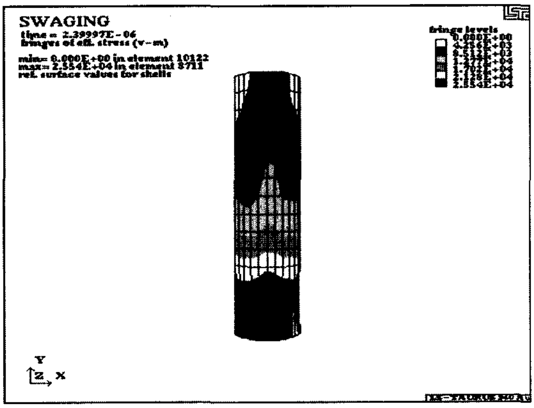

Fig. 5. Von-Mises stress distribution in the swaged bar.

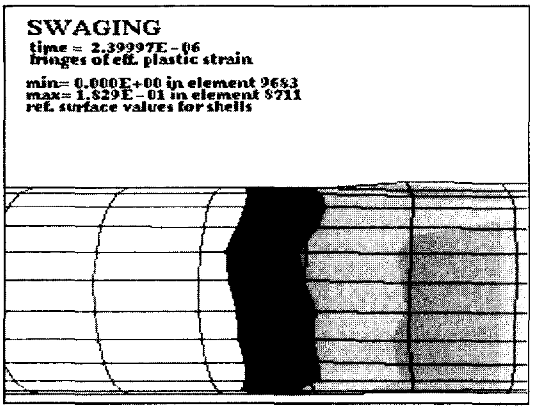

Fig. 6. Plastic strain in the swaged bar.

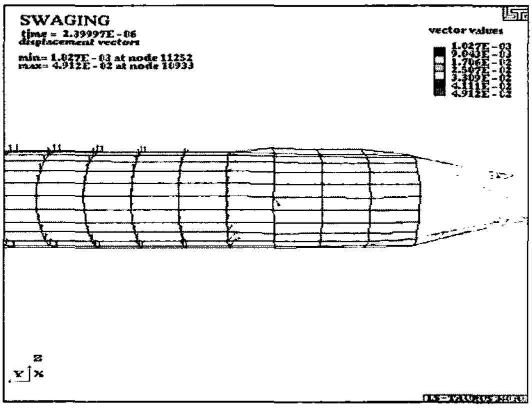

Fig. 7. Displacement vectors in the swaged bar.

3. Conclusions

Some of the results of this preliminary study, namely, the stress and strains are compared with those available in the literature.

1) In this study, a simple procedure to simulate the swaging manufacturing process of a tube is developed using HyperMesh®, LS-DYNA® and LS-TAURUS®

2) The results of the maximum stress, the maximum strain and the maximum displacement vector are 2.554E+04, 1.829E-01 and 4.912E-02 respectively.

3) The material parameters for the tube are obtained by an actual tensile test in the laboratory.

However, virtual manufacturing of products and processes yields results that are still far from real life situations. In spite of this, the scenario looks promising as one gains a better understanding of the interactions of the various process parameters on the quality of the final product being manufactured.

Table. 1. Result of simulation

Time = 2.399E-06

	Von-Mises stress	Stain	Displacement vector
Max	2.554×10^{4}	1.829×10^{-1}	4.912×10^{-2}
Min	0	0	1.027×10^{-3}

4. Acknowledgements

The "n" and "K" material properties were obtained from an actual tensile test of the stainless steel and titanium alloy samples by Professors William J. Riffe and Arlan E. Rathke both Professors of Industrial & Manufacturing Engineering and Business (IMEB) Department at Kettering University. Their help with this test and for providing helpful comments in this paper are sincerely acknowledged.

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