한국소성가공학회 2005년도 추계학술대회 논문집 pp. 95~98

비대칭 축류형 제품의 점진성형공정 개발

알리 알툰[1]· 이석렬[1]· 홍진태[1]· 양동열[#]

Development of a Flexible Incremental Forging Process to Manufacture Asymmetric Shafts

A. O. Altun, S. R. Lee, J. T. Hong, D. Y. Yang

Abstract

Shafts having asymmetry or odd number of symmetry in the cross-section can not be simply manufactured by conventional incremental radial forging. In order to manufacture such shafts, the new concept of incremental forging with one punch and a flexible fixture is developed by suggesting a flexible fixture, instead of two opposed punches used in radial forging, so that the flexible fixture only supports the workpiece while the punch is moving during forming. A new flexible fixture is designed using the steel shots and vacuum technology. An equilateral triangular cross-section is selected as the sample shape to be manufactured by the proposed manufacturing method. The desired triangular cross-sectional shaft is manufactured with the errors of 3.0%.

Key Words : Incremental Forging, Radial Forging, Flexible Fixture

1. Introduction

Shafts are one of the critical machine parts which should be manufactured with high strength at any cost. In manufacturing shafts having certain shapes, incremental radial forging has been widely used. Incremental radial forging is an open die forging process which makes use of two simple shaped punches mostly in symmetric locations. A desired shape of the product is obtained after tens or hundreds of punch strokes. In radial forging, the forming forces are balanced by the symmetrically located punches.

With radial forging, shafts having cross-sections with even number of symmetry planes can be obtained. But, shafts having asymmetry or odd number in symmetry in the cross-section can not be manufactured using simple radial forging with symmetrically located punches.

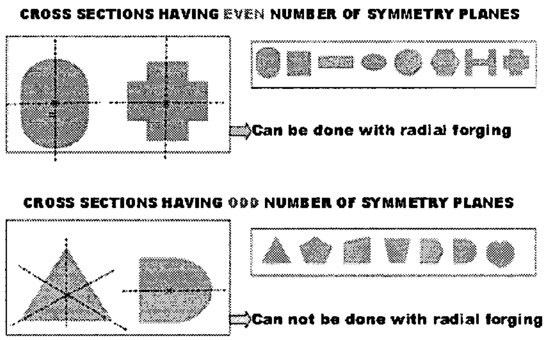

Fig. 1 Classification of cross-sections according to the number of symmetry planes

1. 한국과학기술원 기계공학과
교신저자: 한국과학기술원 기계공학과,
E-mail : dyyang@kaist.ac.kr

Classification of cross-sections according to the number of symmetry planes is shown in Fig.1.

Related to various applications of radial forging, many works have been done. In 1969, Prof. Strandell [1] at the Technical College in Stockholm developed a new swaging die to manufacture circular cross-sectional shafts from rectangular ones. In 1984, for the Advanced Technology of Plasticity Conf. held in Tokyo, Prof. Soda [2] et. al. presented an automatic open die forging machine that can manufacture various forms of products. Again in 1984, Prof. Lange et. al. [3] presented a radial forging machine with a tool magazine that was commercialized with the name of RUMX 2000. In 2002, K.H. Lee and D.Y. Yang [4,5] in KAIST presented the radial-axial incremental forming method to manufacture stepped shafts. With this method, the shafts having a larger diameter than the original workpiece could be obtained.

Various flexible fixtures have been used in the industry. The most common type of the flexible fixture used in the industry is modular fixtures where the flexibility is derived from the different configurations of the prefabricated standard components [6]. Another type of flexible fixture is phase-change fixtures. The flexibility of this type is derived from the use of a medium that physically changes its phase from liquid to solid and back to liquid again. Reference Free Part Encapsulation method [7] developed in Berkeley Manufacturing Institute is a good example to phase-change fixtures. Urethane clamps are used for holding and feeding prismatic feedstocks [8]. Terekhin [9] obtained a Russian Patent of a flexible fixture with elastic balls and vacuum technology. The fixture can fix workpieces with complex shape in arbitrary position but it is not stiff enough to be used in metal forming applications.

2. The Concept of Radial Forging with One Punch and a Flexible Fixture

In usual radial forging operations as one of the punches makes the forming, the other second one has two purposes: to balance the forming load of the first punch and to perform the forming operation in the same manner as the first one. It is the second purpose that results in the even number of symmetry in the cross section.

As seen in Fig. 2, the idea of incremental forming with one shaft and a flexible fixture is simple. The second punch is replaced by a flexible fixture so that, the flexible fixture will only support the workpiece as the first punch does forming. There will be no deformation done by the fixture. Since the forming is done by one punch in one way, shafts having asymmetry or odd number in symmetry in the cross section can be obtained.

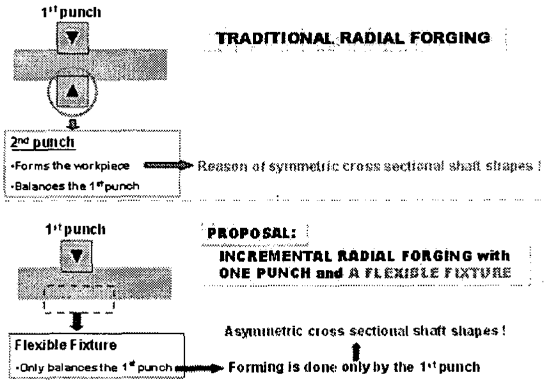

Fig. 2 Concept of radial forging with one shaft and a flexible fixture

3. Proposed Flexible Fixture

Fig. 3 shows the schematic drawing of the proposed flexible fixture. The half-spherical rubber covers a volume in which stainless steel shots are filled in. The rubber and steel shots will have the shape of the surface of the workpiece that is to be supported. There is a volume adjuster with an adjustable steel shots container with a screw drive. When the workpiece is placed on the fixture and the fixture takes the shape of the surface of the workpiece conformingly, the vacuum pump is operated so that the atmospheric pressure makes the half spherical rubber and steel shots stiff. Therefore, the rubber should be air tight.

In Fig. 4, the schematic drawing of the possible configurations of punch, workpiece and the proposed flexible fixture is shown form side and front views.

The solid modeling of the fixture is shown in Fig. 5. As seen in this figure, the fixture consists of mainly two parts: the upper detachable half-spherical part and the main base with movable chucks.

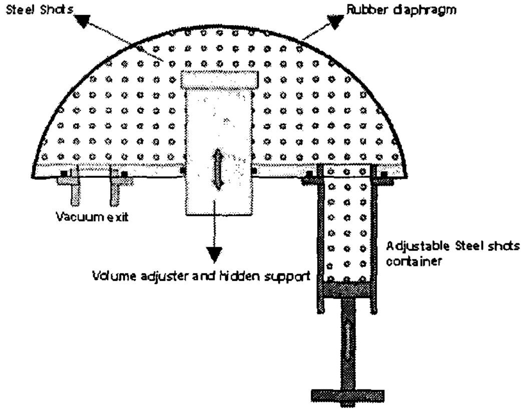

Fig. 3 Schematic drawing of proposed flexible fixture

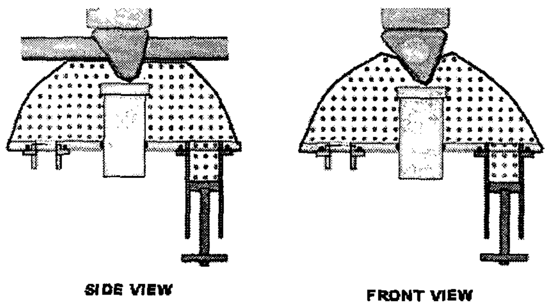

Fig. 4 Schematic drawing of punch, workpiece and the proposed flexible fixture

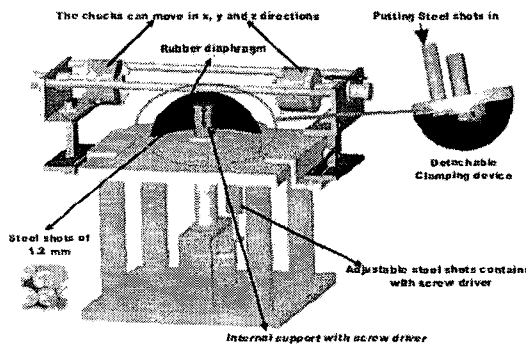

Fig. 5 3-D Solid modeling of the fixture

The Picture of the fixture is shown in Fig. 6. In the experiments, leather was used to support the rubber during the forming operations. The rubber is very weak so leather protects it from the sharp edges of steel shots and the workpiece.

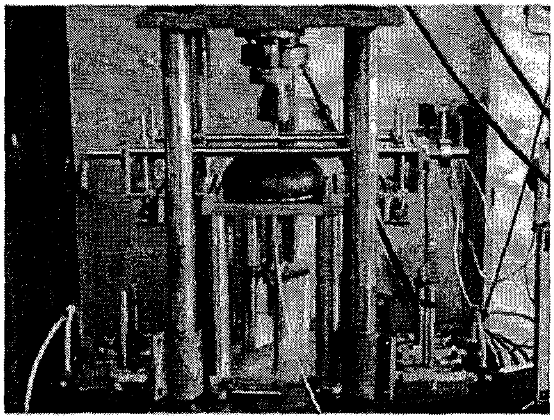

Fig. 6 Picture of the fixture

4. Experiment to manufacture triangular cross-sectional shaft

From a billet of 25 mm in diameter, an equilateral triangular cross-sectional shaft having the width of 18 mm for each lateral surface is chosen to be manufactured. In Fig. 7, the manufactured triangular cross-sectional shaft is shown from different directions. The widths of the three lateral sides were measured from twelve cross sections at equal intervals. Fig. 8 shows the comparison of these dimensions with the desired dimension of 18 mm. Fig. 9 shows the percentage error of the measured width and the desired width values. The maximum percentage error in the width of three lateral sides is 3.0%.

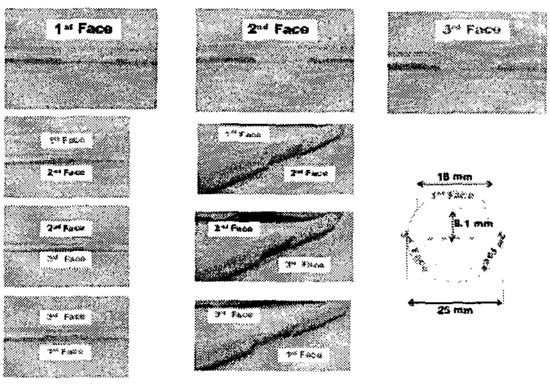

Fig. 7 Equilateral triangular cross-sectional shaft with different views

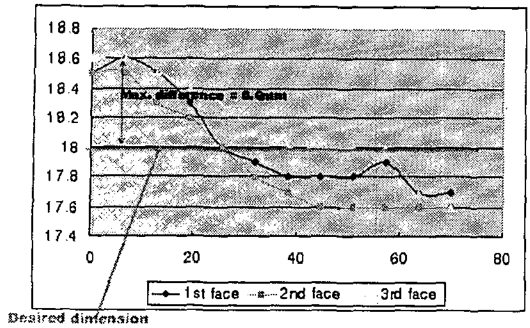

Fig. 8 Comparison of the measured dimensions with the desired width

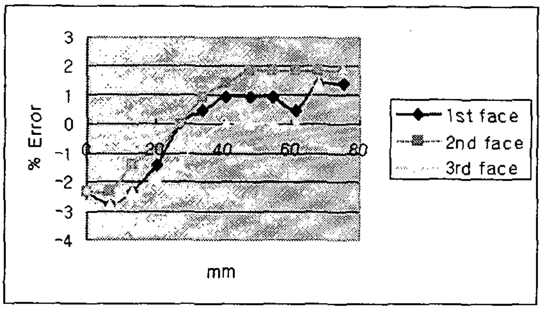

Fig. 9 Percentage errors of the measured dimensions with respect to the desired dimensions

5. Conclusions

New flexible forming method, "incremental radial forging with one die and a flexible fixture" has been developed. A flexible fixture to realize the suggested method has been designed making use of steel shots and vacuum technology. The new incremental forming method was applied to manufacture triangular cross-sectional shaft. An equilateral triangular cross-sectional shaft has been manufactured with 3.0% error

As a future work, some kind of composite material can be developed which is strong, flexible and heat resistant enough to use it during hot incremental forming of steels. In addition, the concept of flexible fixture with steel shots and vacuum technology can also be used in other manufacturing fields such as machining or sheet metal forming.

References

[1] Swedish Patent Application number: 324 and 345, 1969J

[2] C. Soda, T. Sano. and K. Matsuno, 1984, Metal forming machinery developed in the national project of the FMSC, Proc. Advanced Technology of Plasticity Conference, Tokyo, Japan, Vol. 1, pp 449-460.

[3] K. Lange, 1984, Flexible Manufacturing Systems for Plastic Working, Proceedings of 1st International Conference of Technology of Plasticity, Tokyo, Vol. 1, pp 434-435.

[4] K. H. Lee, 2003, Study on Incremental Radial-Axial forging of Flanged Shaft Parts, Doctoral Dissertation at KAIST.

[5] K. H. Lee, S. R. Lee and D. Y. Yang, 2004, Rigid-plastic finite element analysis of incremental radial forging process using the automatic expansion of domain scheme, Engineering Computations, Vol. 21, No. 5, pp 470-487.

[6] Z. Yan, 2004, Lecture notes about fixtures, Department of Mechanical Engineering, Helsinki Technical University, Lecture on March 18.

[7] S. H. Ahn, J. Plancarte and P. K. Wright,2000, The Impact of Reference Free Part Encapsulation (RFPE) on Design for Manufacturability with CNC Machining, Proceedings of the ASME International Design Engineering Technical Conference. Baltimore, MD, pp 10-13.

[8] S. Thiruvarudchelvan, 1993 A urethane clamp as a metal forming tool, Journal of Material Processing Technology, Vol. 38, No. 3, pp 491.

[9] Terekhin SU A.C. 1165553, 1985, Method and device for fixing workpiece