A Novel Tool For Producing Externally Splined Sleeves

Ayman A. Abd-Eltwaba, Ahmed M. Ali Khair-Allah, A. M. Atia, and Essam K. Saied

Abstract: The sleeves with external splines have an increased attention due to its use as power transmission parts in automotive, aviation, airspace, and machining equipment such as lathe, milling, and all equipment that have gear box. The manufacturing process of these sleeves by machining is expensive due to the consumed power, use of a special tool, and the material loss in machining. A new tool is proposed here to form the sleeves with external splines in one shoot. The new tool consists of a die with splines opposite to the required splines at its inner face. This die has a support for the specimen at the lower side and the specimen which has a longitudinal hole is fixed inside the die. A ball is forced inside the specimen hole to take the required sleeve shape by compelling the specimen inside the die cavities. The new tool is tested with different ball diameters to check the splines filling ratio. The forming process was conducted using a universal test machine and the forming load was recorded. The suggested process found to be successful.

Index Terms : Externally Splined Sleeves, Ballizing Technique, Process parameters, Forming rate and ball spinning.

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1. INTRODUCTION

The term 'toothed parts' usually refers to a wide variety of shapes and profiles such as bevel, super gears of a wide range of sizes and types that can be obtained by means of single or multiple metal forming or machining processes. Its primary applications are interlocking with other gears or parts, to transmit the motion and capacity in production lines, machinery, engines of all kinds, such as transportation automotive, electronic, aeronautical and astronautically industries owing to their rise contact ratio, ease transport and excellent carrying capacity and others [1, 2]. Externally toothed parts such as Gears, have many applications in the mechanical fields, in production and many industries. The most highly advantages of toothed parts are their ability to transfer power, transmit high amount of torque and compact in mechanical construction [2-4]. Because there are many advantages such as good continuity, high productivity of metal in tooth face, high strength and better wear resisting property of tooth face, forming technology is unique and widely used in production for good strength and precision spline. However, the researching area on the theory and mechanics analysis of precise forming for external spline cold rolling is limited [5, 6]. The existing forming technology and the production often depend on experience, and the systemic theory instructing the production is very lack [2, 7, 8]. HOWEVER, ALL OF THE FORMING PROCESSES OF A KIND THAT FORGING OR EXTRUSION METHOD CAN BE ECONOMICALLY USED FOR MANUFACTURING TOOTHED GEARS OR PINIONS with either external or internal toothing for production runs of much more than 1000 pieces [5].

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Like in other plastic working methods, the potential for rational applications is limited to some types of gear wheels. There is a certain number of toothed gear wheels, especially in the automotive industry, whose manufacture through extrusion may bring about economic benefits [9, 10]. Da-Wei Zhang et al [3], analyze the deformation process of external spline cold rolling from point of view of plastic deformation. The theoretical result is proportionate with the finite element analysis (FEA). A theoretical reference is produced for the precise forming process of spline cold rolling and the production of external splined shafts. Jacek Michalczyk et al [5], investigate the application of an ordinary method of plastic forming of internal toothing in flange spline sleeves. The proposed method is an alternative to the operation of forming internal spline sleeve toothing in a conical die. Yanzhong Wang et al [6], present a new internal gear drive with a high contact ratio. The teeth which have contact at the same time are more than the traditional involute gear drive. The researcher calculates the generated bending stress. Moreover, the effect of sliding ratio and contact ratio are considering. The results provided that the novel internal gear drive has promising characteristics at all aspect in comparison with involute gear drive one. Xiaolong Sun et al [9], applied and investigate a several shearing methods for metal forming to produced duplex gears. The article also studied the effects of shearing features on subsequent forming were analyzed. The results show that the imperfection shapes in conventional blanking billets at the fracture zone could produce defects in the duplex gear. So, to avoid the imperfect patterns, Xiaolong recommend the clean shear-cut from the billets to show better results. Ma et al [8], proposed an analytical model for predicting the pitch error with main of geometric relations and process parameters. Furthermore, the effect of impact factors related to the rolling tools. To verify the model, Finite Element Method (FEM) simulations and experiments were conducted. The results show how to reduce the pitch error in the gear roll-forming process. Ziyong Ma et al [11], present an analytical calculation with consideration of geometric parameters of rolling tools such as (cone angle, tooth depth and addendum) were proposed to determine the forming force and main stress carried out on rolls. Moreover, by Finite Element Method a simple model was studied. The results show that the efficient rolling tool design will reduce the deflection and main stress of gear teeth. Furthermore, eliminates the scratches on tooth flank of the formed gear. X. B. Deng et al [1], exanimate the verifying the of cold rotary forging process for a spiral bevel gear has been carried out via the finite element (FE) method instead of extensive and expensive experiments. A three-dimensional rigid plastic FE model was produced to simulate the forging process from a simple workpiece under the DEFORM-3D software. The results show the deformation mechanism of cold rotary forging of a spiral bevel gear. Moreover, provided valuable guidelines for further experimental studies.

2 EXPERIMENTAL SETUP

2.1 Description of The Test Rig

`The set-up of the forming process using to produced externally splined sleeves consist of the (1) Universal testing machine (2) forming tool (3) Load measuring system (4) Computer device. As shown in Figure (1). The experiments were conduct using universal testing machine. The Tubular blank material used in this work was commercially [lead] with outer diameter 44 mm, with different internal diameter or hole diameter and length 50 mm Blanks used in experiments were prepared by casting process with required diameters as research program. The Punches were produced from steel with diameters small than ball diameter and were manufacture on the lathe machine, the height of the punches 250 mm. Punch holder is mounted on the middle jaw of the testing machine. This jaw remains fixed through the experimental tests. The punch was screw to the punch holder. The lower set of the test rig includes the die base and the die. The die base was tie by thick plates and screws to the movable base of the testing. Figure (2) show that forming tool parts and a cross sectional for forming tool.

1	Universal testing machine	2	Forming tool
3	Load measuring system	4	Computer

***Fig. 1**. Experimental set-up of the forming process*

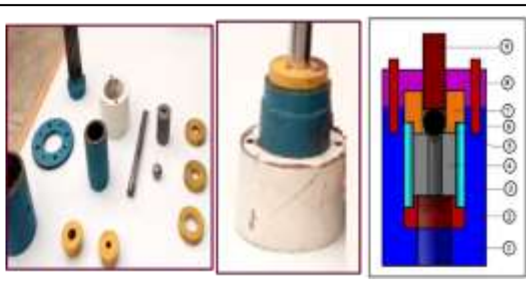

Fig. 2. Forming Tool Parts and a cross sectional for forming tool

2.2 Specimen preparation

Pure lead was received as scrap. In foundry shop, tubular blank was cast as shown in Figure (3) and then annealed by placing in boiling water for 30 min. and then allowed to cool. The tubular blank after annealing was machining at turning machine shop to required dimensions as shown in Figure (4). The specimen material is commercial pure Lead, as well as tubular blank with different hole diameters, 10, 15, 20 and 25 mm. and 44 mm outside diameter were prepared in lengths of 50 mm.

***Fig. 3**. Tubular blank preparation using by casting process*

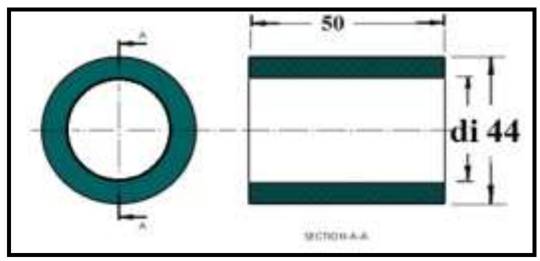

***FIG. 4**. Dimension of tubular lead tube*

2.3 Process Preparation and data collection

The forming process of sleeves with external splines is conducted here in two steps; the first step is the assembly of the tool parts and conducting the forming on the universal testing machine, then the second step is removing the sleeve from the die using also the universal testing machine. The two stages are described after: -

2.4 Setting up assembly and description of the process

In this stage, the forming die is installed inside a metallic body working as a case and tool holder. Then, the lead specimen is placed into the die and the forming ball is positioned above the specimen and in its center. The forming punch is centered above the specimen by the use of a guide as shown in figure 6. The whole assembly is ready now for the forming by positioning the assembly on the universal testing machine and forcing the punch into the die to push the forming ball into the specimen and conducting the forming process. The testing machine is recording the force during the punch stroke.

2.5 Externally splined sleeve products removable and testing

The formed sleeve ejecting from the die is conducting on the universal testing machine also by the use of a shaft with the same sleeve splines and force it into the die to eject the produced sleeve as shown in figure 5.

***FIG. 5**. Forming process procedure*

2.6 Working Conditions and Selected Parameters

Table (1), depicts the different working conditions of forming process for produced externally splined sleeves. Several experiments with different working conditions were carried out, i.e., the cross in-feed was selected values at 2.5, 5, 7.5, 10 and 12.5 mm. also the values of hole diameters for bank tube are 10mm. The experiments have been performed, the effect of this parameters on the externally splined sleeve product quality was investigated as a function of this parameters. The product quality presented in filling ratio of the external splines.

2.7 Instruments and devices used in forming process

The instruments and devices using in this work was introduced such as, The Universal Testing Machine, Slicing and polishing machine and measured devices, The Universal Testing Machine of type computer-controlled servo-hydraulic universal testing machine (Model UH – 500 kN Schematize, Japan) used as forming machine and as a recorder of the forming load during the process. The crosshead speed ranges from 0.1 to 50 mm/min and the maximum distance between the two cross heads was 900 mm for tension and between the movable crosshead and the base was 800 mm. Having the forming process of specimen sleeves completed, the specimens prepared for measuring the filling ratio. The specimens are sliced using cutting machine of samples then polished by polishing machine to obtain a smooth surface specimen. A photo scan for the die and formed workpiece is illustrated in Figure (6). The actual and theoretical areas were computed by AutoCAD program. The ratio is the sum of division of the actual and theoretical values.

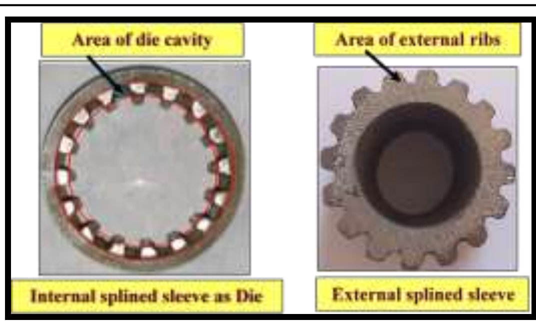

***FIG. 6**. Photo scan for die and externally splined sleeve products to computed*

TABLE 1

OUTLINE OF WORKING CONDITIONS AND SELECTED PARAMETERS

No.	Investigation parameters	Values
(1)	Cross in Feed (Δt)	2.5, 5, 7.5, 10 and 12.5 mm (5)
(2)	Hole Diameters	10 mm
(3)	Ball speed, v	5, 15, 25 and 35 mm/min
(4)	Material	Lead Tube with outer diameter 44 mm, Length 50 mm

The filling ratio was calculated as follows:

1. Theoretical geometry (complete filling) was calculated from the spline dimensions
2. Obtained contour of formed parts is magnified to a predetermined scale using a microscope to calculate the actual volume filled.
3. The filling ratio is computed as the following

FR = (actual volume of external ribs)/(theoretical volume of die cavity)= (actual area of external rib * sleeve length)/(theoretical area of die cavity * sleeve length) (1)

3 RESULTS AND DISCUSSION

The products of the suggested forming tool are shown in figure 7. It can be concluded from the figure that the tool has the ability of successfully producing sleeves with external splines. The splines filling ratio is about 99.5% at specimen No. 1 in the figure which is a very good ratio for the tool from one shoot. A cross-section into the specimens is shown in figure 8. Also, it can be seen that the product numbered e in figure 8 is accepted in the area of splines dimensions and surface quality.

***FIG. 7**. Successful specimens at different balls*

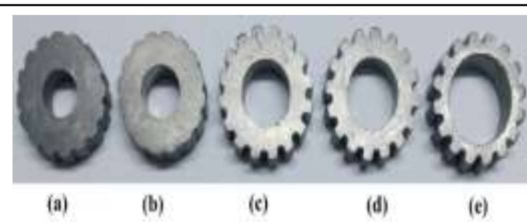

***FIG. 8**. The external splined sleeve product using ballizing process at different cross in feed for hole diameter 10 mm and ball speed 5 mm/min*

The relation between the cross-infeed and the splines filling ratio at different forming ball speed of 5, 15, 25, and 35 mm/min is shown in figure 10. It can be concluded from the figure that the forming ball speed is slightly affecting the filling ratio and its effect can be neglected. On the other hand, the effect of the cross-infeed on the filling ratio is remarkable. The increase in the cross-infeed increasing the filling ratio till a certain value near the optimum value of 100% filling ratio which was reached at 7.5 mm cross-infeed. This may lead to that any cross-infeed higher than or equal 7.5 will produce sleeves with accepted filling ratio about 100%.

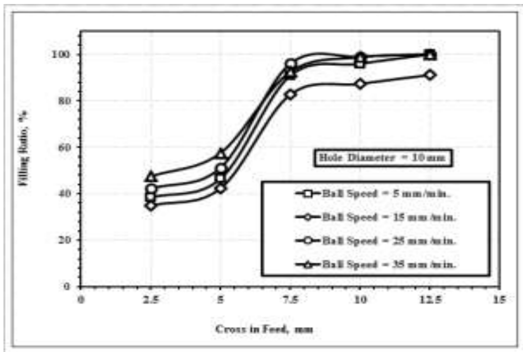

FIG. 9. *The effect of cross in feed on the filling ratio at hole diameters 10 mm for ball speed 5, 15, 25 and 35 mm/min*

4 CONCLUSION

From the experimental work the following conclusions can be obtained:

1. When comparing the suggested process to process found to be easier in conducting and with a simple tool.
2. The process parameters such as forming depth and forming balls diameters affected the produced splines filling ratio.

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