Roll forming of projectile body with curved rotary profile

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Abstract. In this paper, a novel roll forming (RF) process is introduced. A kind of 120-mm projectile body with curved rotary profile is formed by the RF process. The RF process is compared with the traditional process of machine using the billet of draw. Based on the results, it can be concluded that the weight of billet reduces 28% by the presented process comparing with the traditional process and the reducing amount will increase with the increasing of the length of curved rotary profile. The presented process can use traditional draw press and has the same forming productivity. It also has the merits of lower forming force and machine time. The die of the present process is more complex and the manufacturing cost is higher than that of the traditional draw, but the die life of the present process is higher.

1. Introduction

Projectile is the largest consumable in modern warfare and the largest quantity in the production of weapons. In order to meet the requirements of high mechanical properties and mass production, large-caliber projectile bodies usually use the production process of plastic forming with machining at China and abroad [1-5]. A relatively high material utilization rate can be achieved by the traditional process of machining after cabbage, pierce and draw for the large-caliber projectile body with a cylindrical surface. However, the material utilization rate is relatively low using this traditional production process for the large-caliber projectile body with curved rotary profile, and the longer the length of the part with the smaller diameter, the lower the material utilization rate. In order to improve the utilization rate of materials, Xu Hengqiu et al. used the hot-spinning method to form the curved rotary profile of the large-caliber projectile body and formed ideal samples [6,7]. However, the production efficiency of hot-spinning is low, which can’t meet the requirements for mass production of large-caliber projectile body, and the mandrel is difficult to put out from the workpiece after hot-spinning. Therefore, the production of large-caliber projectile body with curved rotary profile does not use the hot-spinning process.

In order to increase the material utilization of projectile body with curved rotary profile and meet the requirements of its production efficiency, a roll forming (RF) method is proposed in this paper. A kind of 120-mm projectile body is taken as an example (as show in figure 1), the traditional process and RF process are compared.
2. Traditional process
The material of 120-mm projectile body is 50SiMnVB and the traditional production process is shown in figure 2. The section of the billet is a 115mm square. The billet is separated from the main bar by sawing breaking and the weight of the billet is 24.1Kg. Heating of the billet to forging temperature is accomplished in electric induction heaters and the billet is heated to a temperature of 1050°C-1150°C. Cabbage and pierce operations are performed in the same 800 ton hydraulic press by using a common bed-mounted die pot; the cabbage and pierce punches are mounted on movable slides on the ram. The draw is completed in a 315 ton hydraulic press with three draw rings. The actual object formed and an enlarged photo of the outer shape and open end of the projectile body are shown in figure 3. It can be seen from figure 3, the open end of the workpiece is high near the outer surface and low near the inner hole after drawing, which is caused by the large friction between the billet and the drawing ring during the drawing process; longitudinal grooves will be generated on the outer surface of the workpiece after drawing because the drawing ring is easy to wear.

Figure 1. 120-mm projectile body of rough turn.

Figure 2. Traditional production process of 120-mm projectile body.

Figure 3. 120-mm projectile body formed by traditional process.
3. Roll forming

3.1. Theory of roll forming

On the basis of the analysis of forming methods such as roll forging and drawing, a method of RF for projectile body with curved rotary profile was proposed and the theory of RF is shown in figure 4 [8-11]. At the time of RF, the punch is installed under the movable ram of the hydraulic press. The billet, which is pushed by the downwardly moving punch, makes the forming rollers to rotate and the curved rotary profile of the projectile body is formed by the specific groove shape on the surface of the rollers. During the RF process, part of metal will flow into the gap between the rollers and form a thin flash, which will make it is difficult to subsequent machining (as show in figure 5). In order to avoid the formation of a thin flash, a triangular flash groove is designed between the adjacent rollers, so that the metal flows into the gap between the rollers will form a triangular flash, which can be eliminated by the shaping rollers installed below the forming rollers and the shaping rollers rotate at an angle to the forming rollers (as shown in figure 6). The essence of RF is to achieve wall thickness reduction and axial elongation of thick-walled cylinders through the rotary extrusion of roller. At the time of RF, four or three rollers can be used, but two rollers cannot be used because the metal deformation is very uneven by the two rollers.

![Figure 4](image1.png)

**Figure 4.** Schematic diagram of RF for projectile body with curved rotary profile.

![Figure 5](image2.png)

**Figure 5.** Flash between rollers.

![Figure 6](image3.png)

**Figure 6.** RF for shaping.
3.2. Roll forming experiment

The RF production process of the 120-mm projectile body is shown in figure 7. The equipment used in the RF process is exactly same as that of traditional process, except that the billet’s weight becomes 17.3Kg as the curved rotary profile can be formed and the traditional three-pass drawing rings becomes a three-roller forming die (as shown in figure 8). The RF die mounted on the 315 ton hydraulic press is shown in figure 8(c). The roll-formed 120-mm projectile body is shown in figure 9. It can be seen from figure 9 that the wall thickness of the roll-formed projectile body has undergone obvious three consecutive changes, the cross-section of the workpiece has no defects such as folding and cracks, the outer surface quality is good, the open end is flat, and the size meets the design requirements.

![Figure 7. RF process of 120-mm projectile body.](image)

![Figure 8. RF die.](image)

![Figure 9. 120-mm projectile body formed by RF process.](image)
3.3. Compared with traditional process

The presented process can use traditional draw press and has the same forming productivity. The billet’s weight of the RF process can be reduced from 24.1Kg of the traditional process to 17.3Kg, which means the weight of billet reduces 28% by the presented process comparing with the traditional process and the reducing amount will increase with the increasing of the length of curved rotary profile. The 28% reduction of the billet’s weight can also reduce the consumption of heating energy by 28%, and can shorten the stroke of the punch during piercing, which will reduce the contact time between the punch and the hot billet, thereby increasing the life of the punch. As the rolling friction between the billet and the roller during the RF, and the sliding friction between the drawing ring and the billet in the traditional process, the forming force of the RF can be reduced by about 20% compared with the traditional process, thereby improving the die life and the workpiece’s quality of outer surface and open end. The subsequent machining time of the projectile body formed by RF process can be reduced by about 25% compared with the traditional process. The die of the present process is more complex and the manufacturing cost is higher than that of the traditional draw, but the die life of the present process is higher than that of traditional production process. It only need change the rollers when forming different projectile bodies.

4. Conclusion

1) The presented process can use traditional draw press and has the same forming productivity and less subsequent machining time.

2) The weight of billet can reduce 28% by the presented process comparing with the traditional process, which can reduce heating energy consumption by 28%, and the reducing amount will increase with the increasing of the length of curved rotary profile.

3) The die of the present process is more complex and the manufacturing cost is higher than that of the traditional draw, but the die life of the present process is higher.

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