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# THE FABRICATION OF WORM-SHAFTS THROUGH EXTRUSION

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***Summary**: The paper presents three methods of fabricating shaft-worms through extrusion: the direct extrusion with consistent lubrication, the direct extrusion through two dies, positioned one inside the other one and the hydrostatic extrusion. The first two methods are proposed by the authors and the third one is a popular method through which worm-shafts and toothed helical gears, as bar or tubes, can be fabricated, and then canted in length.*
***Key words**: worm-shafts, precision extrusion, small pressure of extrusion.*

The main impediment in fabricating worm-shafts through precision extrusion is the extrusion pressure $p$ which gives the value of the extrusion force $F_p$, force that also acts upon the dies. This force, over a certain value, elastically deforms the dies whose internal form coincides with the exterior forms of the worms. The elastic deformations of the dies are sustained by the worm-shaft system and become deviations from the projected contour. For the dies 'elastic deformations to be acceptable, the force, the extrusion force that is, must not exceed a certain value. That is why new methods of precision extrusion are being looked for, through which the extrusion pressure would be as small as possible. Such methods can be considered: the direct extrusion with consistent lubrication, the direct extrusion through two dies, positioned one inside the other one and the hydrostatic extrusion.

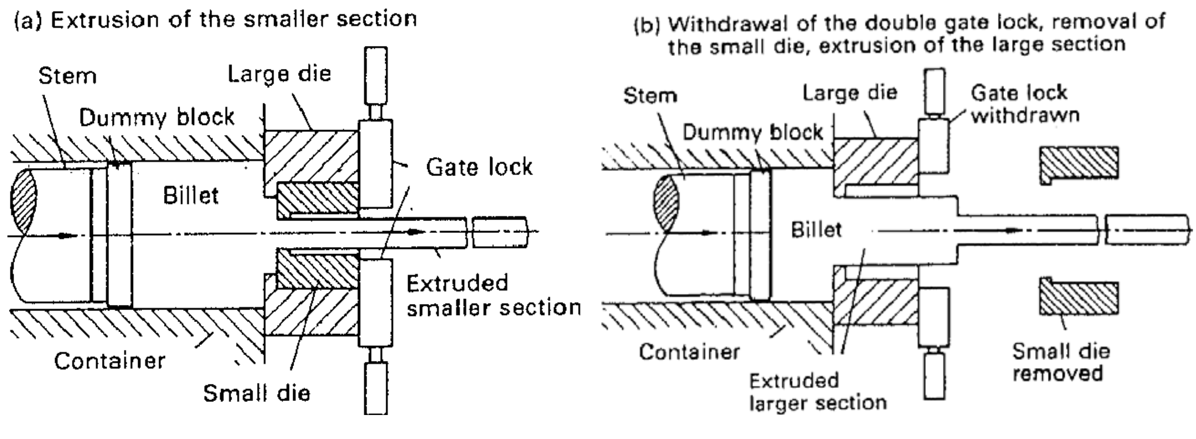



Fig. 1.Arrangement with double gate lock for strepped section.

**The direct extrusion with consistent lubrication** can be favorable to the process of fabricating worms as it can maintain the extrusion pressure at a small value, because the inferior part of the worm (the one outside the die) is always free and the friction force between the bar strip and the die, which is a resistant force, has now a relatively low value. On the free part a twist can be executed together with the upper die, which facilitates the extrusion of the pieces as screws, hobs or worm-shafts. To fabricate this type of pieces , the process can be used as the free part is long and both ends of the extruded product can be cut off. Further more, in the case of the shaft with different diameters the problem of forming the flash can be avoided by interrupting the extrusion in the crest part, as in fig. 1 and fig. 2. Through the process in fig.1 the dies for the two steps are positioned one inside the other and fixed with a blocking system. At the end of the first step the system frees the small die, blocking only the large one, and the extrusion of the large part starts at once, and the small die, executed from two pieces, gets out and detaches itself from the extruded product. Trough the process in fig. 2 the first part is extruded after which the die is removed, a second die is assembled and the second part is also extruded. Through direct precision extrusion with consistent lubrication other pieces can be obtained, including long ones, pieces with symmetrical and unsymmetrical ribs, etc.

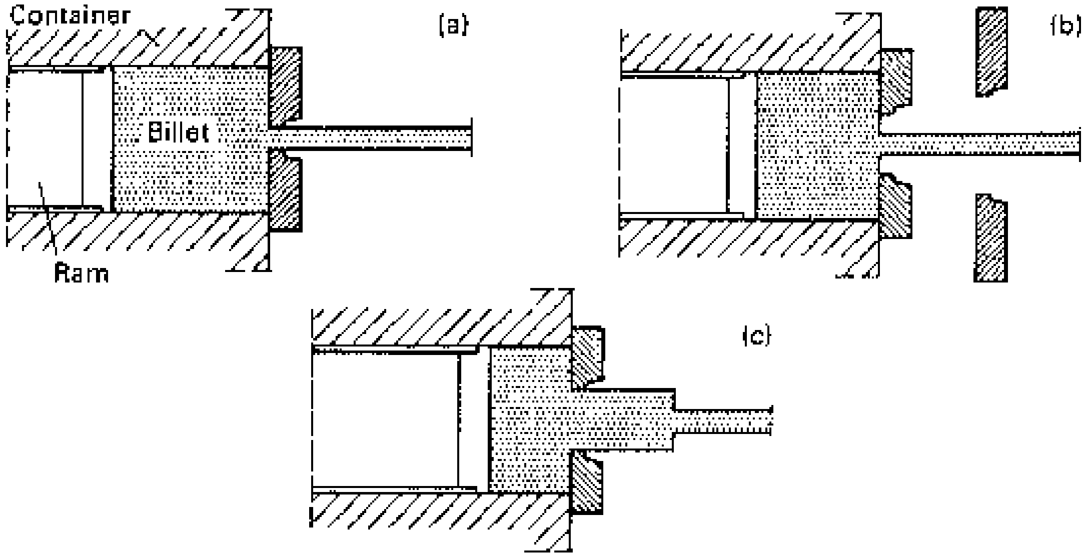



Fig. 2.Extrusion of stepped products: a) extrusoin of small cross section; b) exchangic the die for the small section with that for the larger; c) extrusion continued with the large cross section.

The direct extrusion with consistent lubrication can be executed by lubricating the conic die with pressured mineral oil introduced directly through the die as in fig. 3. The die can be made concave in order to form the oiling pad. The thickness of the oil layer can be of maximum 1 mm.

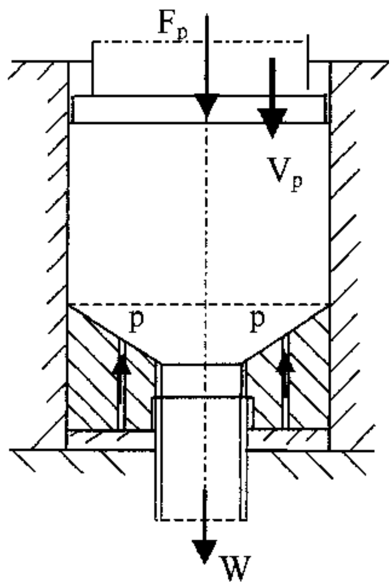


Fig. 3. Lubrication of die with mineral oil with pressure privy to die.

The pressure of the oil must be very well chosen. It must be close to the extrusion pressure $p$ , in the die area. If the pressure is too low, the oil is restrained from getting to the die 's walls. If the pressure is too high, the oil layers can get into the product causing damages to its surfaces.

Typical examples of pieces that can be obtained through this method are presented in fig. 4. The part with the coiled groove can be formed in combination with the part of the interior groove at the other end. These products have advantages as: excellent alignment and equilibration of each portion, reduction of total length and improvement of resistance owing to cold hardening of the metal, etc. Another example of a product that can be obtained through direct precision extrusion is the endless screw presented in fig. 5.

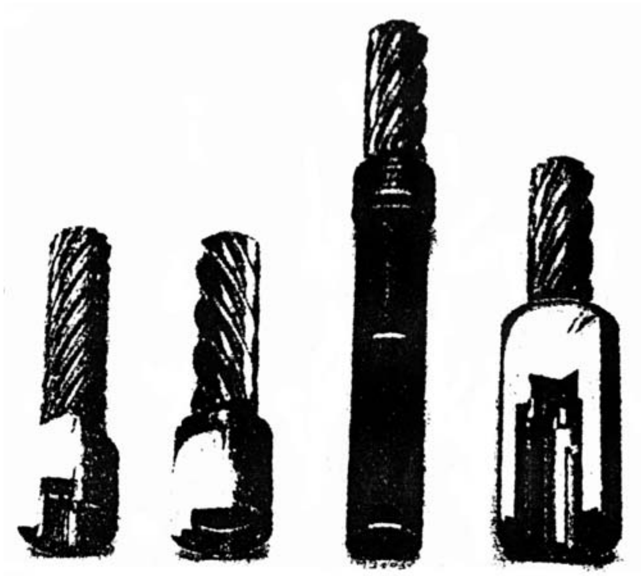


Fig. 4. Chamfering hobs obtainable for precision direct extrusion.

Fig. 5. Chamfering screw obtainable for precision direct extrusion.

**The direct extrusion through two dies** of worms, an internal one, through which the extrusion is effectively done, and an exterior one, inside which the first die is positioned, is presented in fig. 6. The contact between the two dies must be well lubricated in order to avoid wedging and to ease the internal die's movement. During extrusion, the diameter of the calibration slot of the internal die enlarges as the work force increases and the diameter of the worm changes as this form varies. To control the diameter of the product, an adjustment method of the internal die's calibration slot is used , allowing it to slide on the side of the exterior die. When increasing the work pressure, the exterior diameter of the internal die enlarges and enters the external die's cone and the diameter of the calibration slot, and implicitly the outing diameter of the worm, decreases and reciprocally, when lowering the work pressure , the exterior diameter of the internal die decreases and the die is pushed up and the outing diameter of the extruded product grows.

If the angle of inclination of the exterior die is well chosen, the diameter of the extruded product is maintained constant whatever the force on the mandrel, as fig. 7 shows, where $\alpha$ represents the angle of inclination of the exterior die. The position of the internal die automatically adjusts without the usage of an external control system.

Fig. 7 presents the chart for the extruded product deviations in diameter according to the reduction level for the direct extrusion of a steel bar with the rate between the height and the diameter $h/d = 1{,}38$ , through an internal die having the inclination angle of $\alpha = 10°$ and different angles of inclination for the external die. It is observed that for an angle $\theta = 8°$ the deviations are small and can be tolerated for the extrusion of worm-shafts. Still in fig.7 it is observed that direct extrusion through two dies allows a lot smaller deviations, no matter the angle $\theta$, than in direct extrusion of a product with the same characteristics, through a single die.

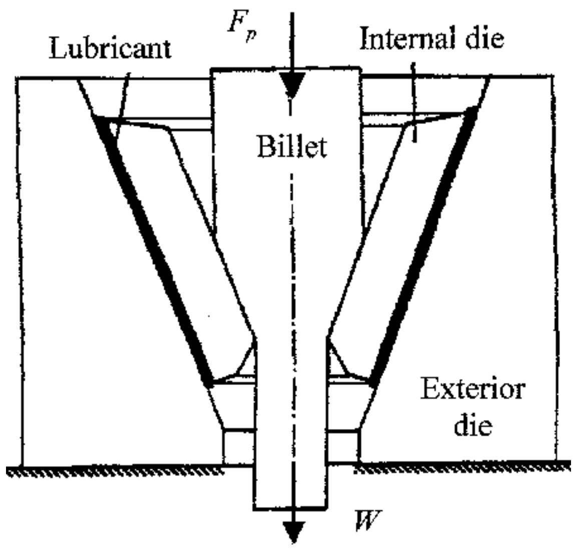



Fig. 6. Direct extrusion for two dies.

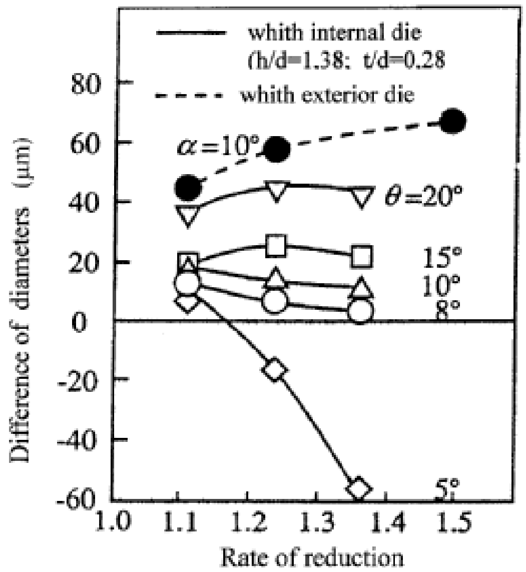


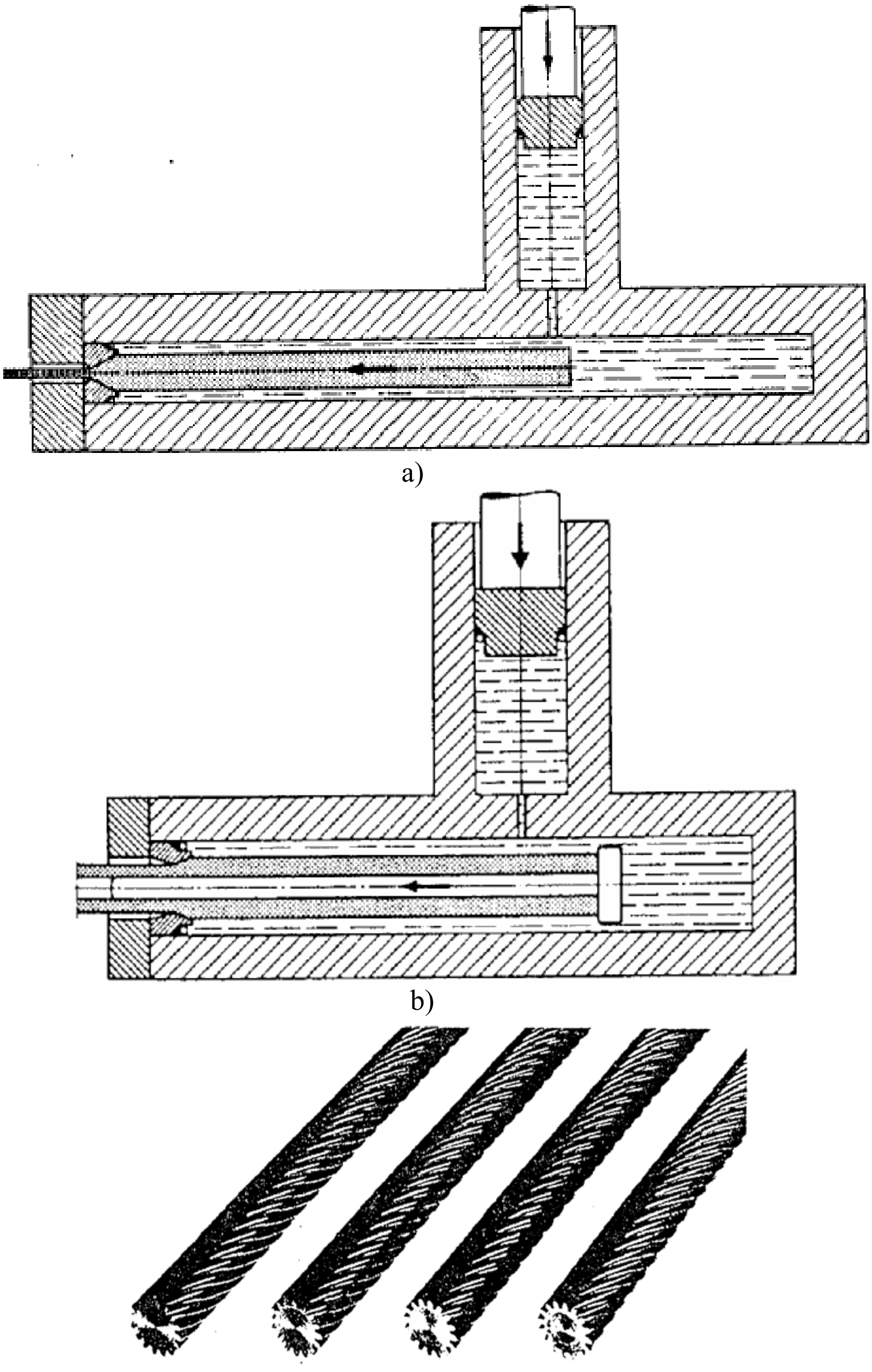

Fig. 7. Comparison tolerances at direct extrusion with two dies with angle $\theta$ another and between process of direct extrusion an whith one or two dies.

With the **hydrostatic extrusion** of the worms long semi-products and construction presses are used, as the ones in fig. 8, at which the pressing piston of the liquid is operated by the cross-bar of a vertical press and the initial semi-product (full or drilled) is positioned horizontally in the container, along eith the die, respectively the mobile mandrel. The working liquid is pressed by the piston towards the horizontal container, through an opening, having a well-defined section. In the first case, the worms' hydrostatic extrusion from drilled semi-products with the usage of a mobile mandrel, is realized.(fig. 8.*a*.)

Alike it, the extrusion by a fixed mandrel can be realized, too, in which case the support of the mandrel is positioned in the horizontal container with the die. Through this process long full semi-products can be extruded, too, to obtain worms (fig.8.*b*) or even toothed helical gears as bars that will be cut at the necessary lengths.(fig.8.*c*).These can be full or drilled bars, from tempered or hardened steels. In order to decrease the hydrostatic pressure there can be used a system of pulling and twisting the worms, after their exit from the die.

**Conclusions**

For worm-shafts cold extrusion it is necessary to obtain a dimensional precision of less than 10 μ.m. The biggest problem in obtaining the precision is the elastic deformation of the die. To reduce it, semi-products with constant mechanical dimensions and characteristics are required and also, a system of lubrication with a constant friction coefficient. It is mostly important to apply methods of extrusion that would maintain the work pressure as low as possible. Therefore we suggest in this paper two such methods: that of direct extrusion with constant lubrication , and the one with two dies, and we present the possibility of hydrostatic extrusion of worms and toothed helical gears. The second method the control possibilities for the elastic deformation of the tools. The optimum angle of inclination $\theta$ of the exterior die is difficult to calculate. So we suggest that for each specific case, it should be determined through tests. The first two methods can be applied at cold, but also at hot and semi-hot working. In the case of hot and semi-hot extrusion, when designing the die, the contractions and expansions of the extruded steel and of the tool will be taken into consideration.



a) b) c)

Fig. 8. Hidrostatic extrusion for warm-shafts and spur wormwheel gears a long bar:

a) extrusion of cast of pipe; b) extrusion of cast of bars; c) warm-shafts of cast of bars or pipes.

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