IMPROVED DESIGN OF DIES FOR THE HYDROSPIN PROCESS

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SUMMARY

Improved design of dies for the hydrospin process is presented. The performance of these dies is compared with that of the previous dies.

1. INTRODUCTION

Wire drawing is well established as the main process for manufacturing wire in large quantities. The amount of reduction in each pass of drawing, however, is limited and leads to a large number of passes with interstage annealing before fine wire is finally produced. In recent years new methods (1, 2, 3, 4, 5, 6) have been introduced to produce wire. These methods effect large reductions in one pass. Variations and developments of these new methods are the subject of research in many parts of the world. The common objective of all these investigations is to find a viable method, of producing wire more economically by reducing the size of wire as much as possible in one pass.

"Hydrospin" or extrusion-machining process (1, 7, 8) is notable for its ability to produce fine wire straight from billets of large diameter, thus effecting reductions of the order of 99.9 percent, i.e. corresponding to overall extrusion ratios of the order of 1,600 to 10,000. Exploded view in Figure 1 shows the essentials of this process. In this process the billet is first hydrostatically extruded to an intermediate tube through the primary die and over the piercing cone. This tube occupies the annular space formed by the primary die-land, the piercing rod and the secondary die.

The secondary die is essentially a tubular helical ramp with a cutting edge and an extrusion aperture. As the tube is pushed against this ramp by the supply fluid pressure, it fills up the annular space and conforms to the shape of the ramp. Afterwards when the secondary die is rotated against the tube, the metal is cut and extruded out of the aperture.

Normally when a metal is extruded through an extrusion ratio R, it undergoes an effective plastic strain approximately equal to ℓn R. Therefore, the pressure needed in conventional or hydrostatic extrusion for large values of R is high as it increases approximately with ℓn R. In the Hydrospin process, however, smaller effective strain is imposed on the metal by deforming it in stages. From theoretical consideration (8) it is clear that the fluid pressure provides the energy for extruding the tube through the primary die with an extrusion ratio R_1. Energy for the final extrusion to wire through an extrusion ratio R_2 is provided mainly by the torque applied on the secondary die. Cutting the intermediate tube does not need as much energy as the other two stages of extrusion. Thus, very high fluid pressure is not required to achieve large reduction with the Hydrospin process. The effective strains imposed on the metal in the first and the final stages of extrusion are $\ell n\ R_1$ and $\ell n\ R_2$ respectively. The metal hardly suffers

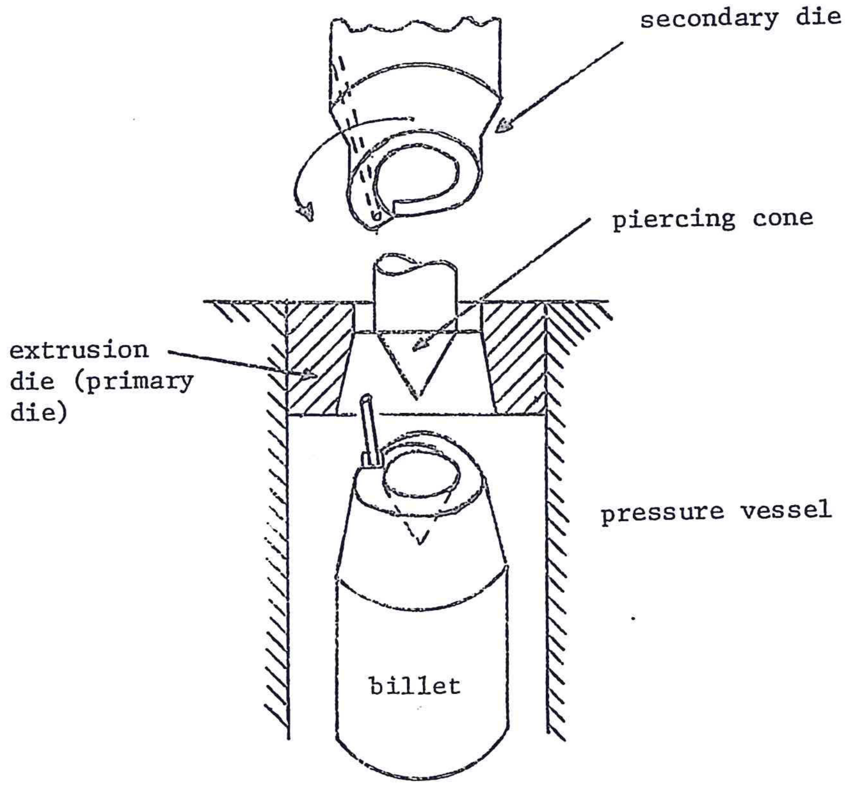

FIGURE 1

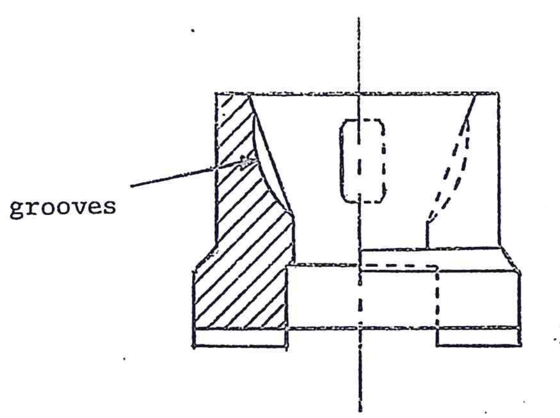

FIGURE 2

any strain in the cutting stage. Thus, the total effective strain suffered by the metal is approximately $\ell n\ R_1R_2$. This means the process consumes much less energy per unit volume of wire produced when compared with that in wire drawing or extrusion. However, a considerable amount of energy is dissipated in overcoming friction in the actual process.

2. DESIGN CONFIGURATIONS

Two configurations are possible for the design of a machine for the Hydrospin process.

1. A rotating secondary die cutting and extruding the tube of metal that is fed to it. In this case the wire will emerge rotating.

2. The billet and the primary die rotate together and feed the tube to a stationary secondary die. Wire emerges without rotation, but a large thrust bearing has to support the extrusion load on the rotating pressure vessel.

Configuration (2) was used in the design of a machine for the process described elsewhere (7). Alternative designs of the dies used in the machine, which are important for efficient operation of the process, are considered in this paper. Two major objectives in the design of the dies are:

(a) to minimise the fluid pressure

(b) to keep the torque needed to drive the secondary die at a minimum.

3. DESIGN OF THE PRIMARY DIE

The objectives to be realized in the design of the primary die are:

(a) to minimise the fluid pressure

(b) to prevent relative rotation between the die and the deforming metal when torque is applied to the intermediate tube.

(c) to prevent leakage of high pressure fluid through the die.

Figure 2 shows the early design of a primary die with four grooves machined on its conical surface. The metal deforming into these grooves provides the resisting torque to prevent relative rotation between the die and the deforming metal. Total area of the grooves multiplied by the yield shear stress of the metal and the mean radius should be more than the torque applied to the metal. This is a conservative design as friction between the die and the deforming metal would provide substantial resistance to rotation. The torque to be applied on the tube is calculated from the extrusion pressure needed in the final extrusion multiplied by the area of the step and the mean radius. On this basis the die shown in Figure 2 would prevent relative rotation for values of R_2 up to about 10.

The shape and the depth of the grooves are determined on the following basis:

(1) the deforming metal must be able to fill the grooves fully - this limits the depth of the grooves.

(2) the depth of the grooves must be sufficient for the bearing stresses due to the applied torque not to result in the plastic deformation of the "ribs".

(3) the high pressure fluid must not leak through the grooves. This is partly effected by the grooves not being too deep and partly by starting and ending the grooves at some distances from the entry and exit sections of the die.

With the type of die shown in Figure 2, it was found that a minimum extrusion ratio R_1 of about 6.3 was needed to satisfy the above conditions. The grooves, however, introduced considerable redundant deformation and resulted in a larger extrusion pressure than that with a simple conical die.

Figure 3 shows the improved design which is more effective in realizing the objectives of the primary die. Basically this die consists of two conical surfaces and plane surfaces between them. Two, three or four symmetrically placed plane surfaces can be used. Figure 3 shows such a die with three flats. The larger the number of flats, the less the redundant work would be. However, the resisting torque provided by the die will be reduced as the number of flats is increased. It is clear from the geometry of the die

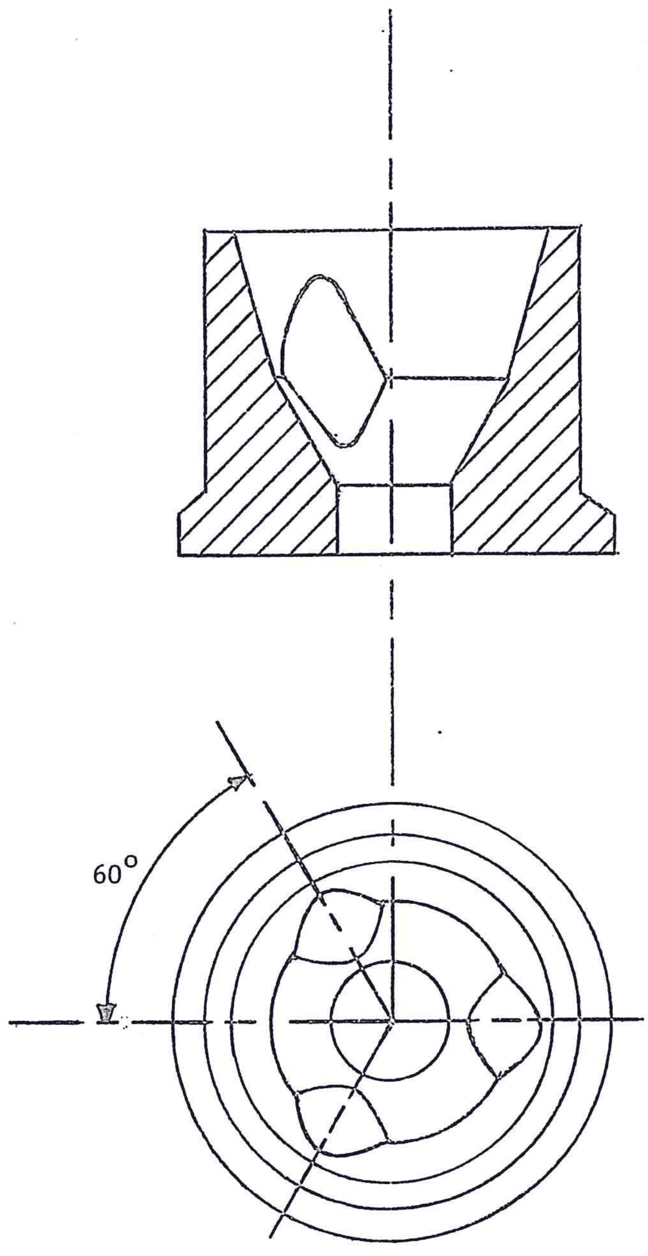

FIGURE 3

that the possibility of leakage of high pressure fluid is virtually eliminated. The redundant work with this die is much lower than that with the previous design. The areas of the flats may be increased or decreased to suit the needs of the applied torque. The optimum shape can be found by trial and error. Primary extrusion ratio R_1, could be kept very low (2 to 4) with the fluid pressure required lower than that needed with the earlier design. Thus, the improved design makes the process possible at much lower fluid pressures.

4. DESIGN OF THE SECONDARY DIE

Figure 1 shows an early design of the secondary die. The helical ramp on this die is similar to a square thread and ends in a rectangular step. From trials with a Hydrospin machine, it was found that this type of ramp resulted in considerable friction at the step leading to incomplete filling of the ramp with metal at reasonable fluid pressures. Higher pressures were needed to ensure complete filling of the ramp and to achieve almost 100 percent theoretical yield of wire (8). The rectangular step also needed a large torque on the secondary die to effect the final reduction to wire. The main functions of this die are two fold:

(1) to cut the tube of metal formed in the primary stage.

(2) to extrude the tube of metal through the final extrusion aperture.

Improved design of the secondary die was effected by a ramp with right-angled triangular cross-sections with a triangular step (Figure 4). The triangles gradually decrease in height and terminate in a line at the step (Figure 4 inset). This die is preferable to the former design in order to reduce the effect of friction on the yield of the product. The fluid pressure needed to ensure 100 percent yield of metal was lower than with the earlier design. The volume of metal cut and extruded per revolution of this die is reduced by half compared to the previous one. This resulted in a lower torque on the secondary die as the area of cross-section of the step is reduced.

The step was inclined to the ramp in order to present a sharper die angle for final extrusion. This also results in better cutting action. The angle of inclination has to be adjusted for the material to be processed. For Aluminium billets this angle was 23 degrees. Sufficient overlapping of the primary and secondary dies were allowed in the design to minimize the formation of flash between the dies.

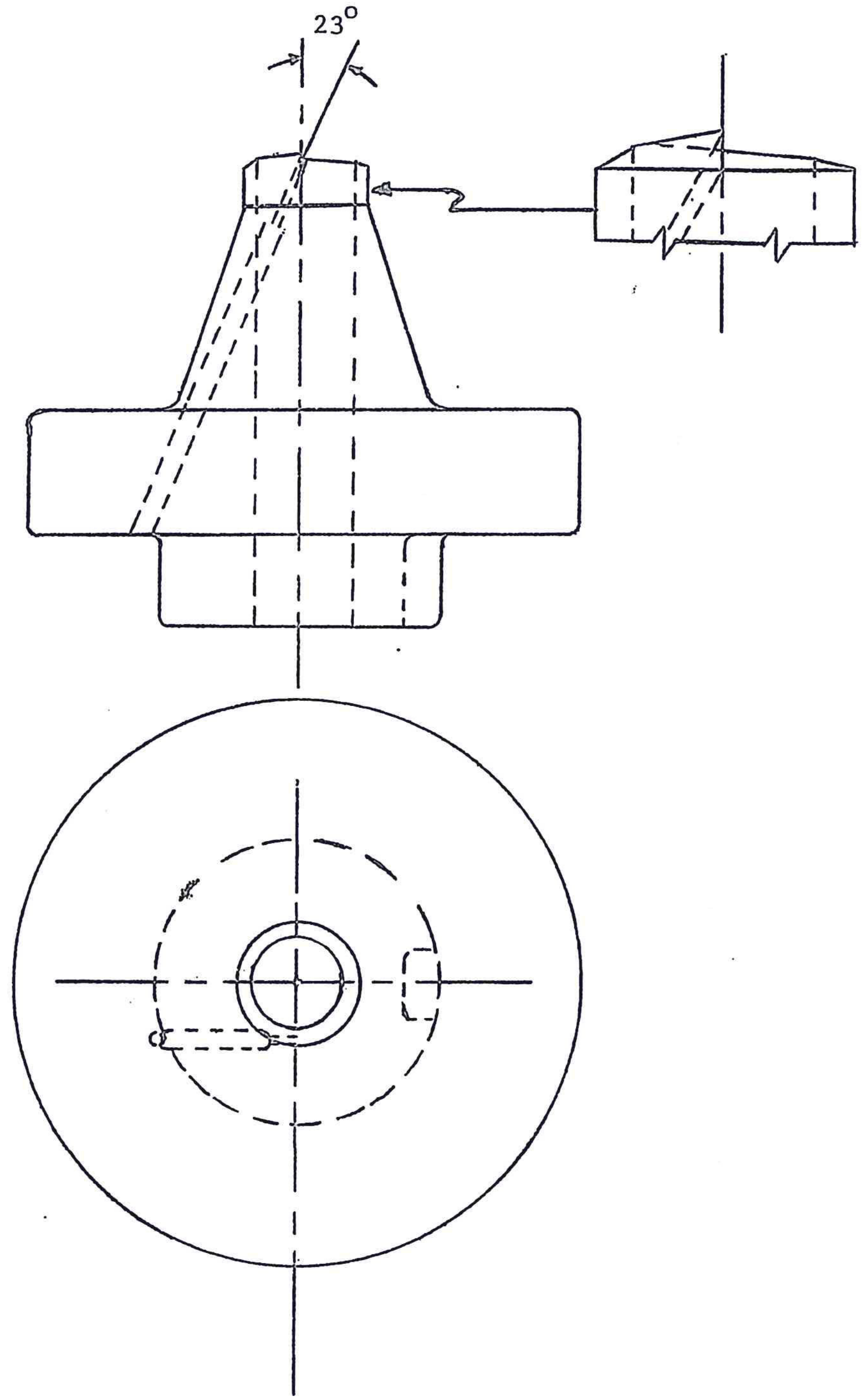

FIGURE 4

5. DISCUSSION AND CONCLUSION

Compared to the early design, the improved design is more effective in performing all the functions of the primary die. The fluid pressure needed for the process can be reduced substantially by decreasing R_1. At lower values of R_1, the optimum die angle for hydrostatic extrusion becomes lower. Thus the average cone angle of the die can be kept at this value. Since this angle is low a large effective area of flats can be provided on the die to resist the torque. By decreasing R_1 even further ($R_1 < e$), fluid pressure may be completely eliminated. This would make the design of a machine for the process much easier. The possible leakage of high pressure oil through this die is eliminated by the present choice of geometry of the die. The formation of flash is also reduced as the primary extrusion ratio is reduced.

The improved design of the secondary die resulted in achieving theoretically 100 per cent yield of wire at a lower fluid pressure. It also resulted in reducing the torque required to drive this die by almost half - thereby enabling the use of a smaller motor for the drive. In conclusion, the improved dies make the process more efficient.

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