A-00043 Drahtherstellung

Wire drawing – some considerations

1.1.01

Wire drawing is a mechanical operation that does not involve the removal of metal and is generally carried out cold. It is achieved by utilising the plasticity of the material; that is, its capacity to maintain a form assumed during a deforming action, when this is superior to its limit of elasticity.

Specific indications of elasticity of a body are: malleability, the property that allows it to be reduced to thin sheets, as occurs during rolling; and ductility, the property that allows it to be reduced to very fine wires, as occurs during drawing. This article concentrates specifically on drawing.

Drawing consists of forcing wire to pass through one or more holes (dies) with decreasing cross-sections, in order to gradually reduce the diameter to that required for the final product.

The machines used for this operation can be straight-through or accumulation type and are called drawing machines or draw benches. They comprise a series of fixed dies, in between which are located wire guide pulleys to maintain the wire under tension, and drawing blocks to pull the wire through the dies. The final pulling action is achieved with the drawing block located after the last die and from which the wire is unloaded on to spools, or in coils on to spider carriers, or into barrels, etc. Both the dies and the drawing blocks are cooled by means of flowing water, or with water and airblast to the blocks.

As the diameter gets smaller, the wire becomes longer and therefore the drawing speed must increase from the first to the last drawing block, in order to avoid excessive accumulations of wire.

Normally, the initial drawing speed is 1 to 3.5 m/sec, depending on the diameter of the wire rod, whereas the final speed depends on the finished wire diameter. Reference is usually made to the finishing speed because it is that which defines the productivity of a machine. For example, to draw wire for prestressed concrete, if diameter d = 5.00 mm, the speed would be about 6 m/sec; if d = 4.00 mm, about 8 m/sec; and if d = 1.20 mm it can reach speeds of more than 20 m/sec.

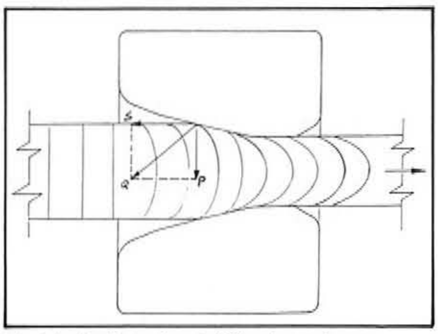

Fig 1 Indication of metal fibre layer forms during drawing

Figure 1 illustrates the deformation undergone by the wire during its passage through the die, and the stresses to which it is subjected. Due to friction caused by the sides of the die (which is greater than that inside the metal), the external layers of the wire run more slowly. Layering of the fibre after drawing thus assumes the form shown in Figure 1. Therefore if:

Q = pressure of the die on the wire.

P and S = respectively, the components perpendicular and parallel to the axis of the die.

T = the pulling force or traction necessary to draw the wire.

K_c and K_t = the safety coefficients of the metal in respect to compression and tensile stress respectively (which are obtained from the ratio between the unit compression breaking loads σ_R and tensile stress σ_R, and the safety compression loads σ_{am} and tensile strength σ_{am}; and are both expressed in kg/mm²).

d_{n-1} and d_n = diameters of the wire before and after passage through the die.

Then: T = S

$$S = \frac{\pi}{4}\left(d_{n-1}^2 - d_n^2\right) K_c$$

$$T = \frac{\pi d_n^2}{4} K_t$$

$$\frac{\pi}{4}\left(d_{n-1}^2 - d_n^2\right) K_c = \frac{\pi d_n^2}{4} K_t$$

$$\left(\frac{d_n}{d_{n-1}}\right)^2 = \frac{K_c}{K_c + K_t}$$

The ratio $\frac{K_c}{K_c + K_t}$ represents the drawing coefficient and is indicated by the letter K. The greater the toughness of the metal, that is its resistance to drawing and compression (within certain limits), the lower the value of K and therefore the easier it is to draw with a lower number of drafts and a higher reduction ratio R, without risk of breakage. (This concept will be defined later.) From the above formulae, the theoretical pulling force is thus:

$$T = 0.785 \frac{K_c \times K_t}{K_2 + K_t} d_{n-1}^2 \quad \ldots (1)$$

The tougher the material, and thus the higher the values of K_c and K_t, the greater becomes the pulling force necessary to draw the material. Depending on the coefficient K and on the initial diameter, the subsequent diameters of the dies are obtained, theoretically, with the following formulae:

$$d_1 = K D$$

$$d_2 = K^2 D$$

$$d_3 = K^3 D$$

$$d_{n-1} = K^{n-1} D$$

$$d_n = K^n D$$

Each diameter represents the diameter of the wire at the exit of one die and the inlet of the subsequent die. With these formulae, besides the diameters of the various dies, it is also possible to determine the number of drafts necessary to reduce a wire rod to the desired diameter.

At each draft, the reduction ratio as a percentage R is obtained from the difference, multiplied by 100, between the initial and final cross-sectional area of the wire, referred to the initial cross-sectional area.

$$R = 100 \frac{\frac{\pi d_{d-1}^2}{4} - \frac{\pi d_n^2}{4}}{\frac{\pi d_{n-1}^2}{4}}$$

$$= 100 \frac{d_{n-1}^2 - d_n^2}{d_{n-1}^2} \quad \ldots (2)$$

For example, again theoretically, to reduce a wire rod with D = 5.50 mm and K = 0.85 to a final diameter of d = 2.00 mm: in Table 1 are the values of the dia- ▶

Table 1 Drafting from 5.5 mm ∅ rod using K = 0.85

$d_1 = 0.850 \times 5.5 = 4.675$ mm; $R_1 = 27.76\%$
$d_2 = 0.723 \times 5.5 = 3.977$ mm; $R_2 = 27.60\%$
$d_3 = 0.615 \times 5.5 = 3.382$ mm; $R_3 = 27.72\%$
$d_4 = 0.523 \times 5.5 = 2.877$ mm; $R_4 = 27.60\%$
$d_5 = 0.445 \times 5.5 = 2.445$ mm; $R_5 = 27.80\%$
$d_6 = 0.378 \times 5.5 = 2.079$ mm; $R_6 = 27.80\%$

Table 2 Drafting from 5.5 mm ∅ rod using K = 0.88

$d_1 = 0.880 \times 5.5 = 4.84$ mm; $R_1 = 22.57\%$
$d_2 = 0.774 \times 5.5 = 4.26$ mm; $R_2 = 22.50\%$
$d_3 = 0.681 \times 5.5 = 3.74$ mm; $R_3 = 22.97\%$
$d_4 = 0.599 \times 5.5 = 3.29$ mm; $R_4 = 22.60\%$
$d_5 = 0.527 \times 5.5 = 2.90$ mm; $R_5 = 22.27\%$
$d_6 = 0.464 \times 5.5 = 2.55$ mm; $R_6 = 22.70\%$
$d_7 = 0.408 \times 5.5 = 2.24$ mm; $R_7 = 23.00\%$
$d_8 = 0.360 \times 5.5 = 1.97$ mm; $R_8 = 21.60\%$

Table 3 Taper drafting established using Equation 3 and Table 2

$R_1 = 22.5\%$	$d_1 = 0.88 \times 5.50 = 4.84$ mm
$R_2 = 21\%$	$d_2 = 0.89 \times 4.84 = 4.30$ mm
$R_3 = 20\%$	$d_3 = 0.89 \times 4.30 = 3.83$ mm
$R_4 = 19\%$	$d_4 = 0.90 \times 3.83 = 3.45$ mm
$R_5 = 18\%$	$d_5 = 0.91 \times 3.45 = 3.14$ mm
$R_6 = 17\%$	$d_6 = 0.91 \times 3.14 = 2.86$ mm
$R_7 = 16\%$	$d_7 = 0.92 \times 2.86 = 2.63$ mm
$R_8 = 15\%$	$d_8 = 0.92 \times 2.63 = 2.42$ mm
$R_9 = 14\%$	$d_9 = 0.93 \times 2.42 = 2.25$ mm
$R_{10} = 13\%$	$d_{10} = 0.93 \times 2.25 = 2.09$ mm
$R_{11} = 12\%$	$d_{11} = 0.94 \times 2.09 = 1.96$ mm

Table 4 Most commonly used drawing dies for medium and high carbon steel wire

Wire rod dia	(mm)	5.50	5.50	5.50	5.50	5.50
Draft No. 1		4.75	4.80	4.80	4.80	4.80
,, ,, 2		4.05	4.15	4.10	4.10	4.10
,, ,, 3		3.45	3.60	3.50	3.55	3.55
,, ,, 4		3.00	3.15	3.10	3.10	3.10
,, ,, 5		2.60	2.80	2.75	2.70	2.70
,, ,, 6		2.25	2.50	2.45	2.40	—
,, ,, 7		2.00	2.25	2.20	—	—
,, ,, 8		1.80	2.00	—	—	—

Table 5 Most commonly used drawing dies for low carbon steel wire

Wire rod dia	(mm)	5.50	5.50	5.50	5.50	5.50
Draft No. 1		4.65	4.80	4.60	4.55	4.55
,, ,, 2		3.80	4.00	3.90	3.72	3.72
,, ,, 3		3.18	3.55	3.32	3.12	3.12
,, ,, 4		2.70	2.93	2.86	2.70	2.70
,, ,, 5		2.32	2.56	2.48	2.40	—
,, ,, 6		2.02	2.25	2.20	—	—
,, ,, 7		1.80	2.00	—	—	—

meters d of the various dies, of the reduction ratios R and of the number of drafts necessary (six).

If K = 0.88 is used to obtain the maximum reduction, the following die diameters and reduction ratios would be as shown in Table 2. These two examples confirm what was said with regard to the value of drawing coefficient K.

In effect, the reduction ratio must decrease at each draft because, as the metal becomes more compressed and work-hardened, the amount of energy necessary for plastic deformation continues to increase. Consequently, the temperature of the die and of the wire rises and structural variations can occur. This is particularly true of the hard metal of the die, which can lose its hardness due to an action similar to tempering; especially if the dies are not adequately cooled, or if lubrication is insufficient.

The desired result can be achieved by increasing the number of drafts in respect to the theoretical value, using the formula below, derived from the relationship in Equation (2) to ascertain the diameters of the different dies after having determined the sequence of reduction ratios R.

$$d_n = \sqrt{1 - R/100 \times d_{n-1}} \qquad \ldots (3)$$

Applying the figures given in Table 2 produces the results shown in Table 3. The number of drafts has therefore passed from 8 to 11. Normally, the first reduction is about 22-25%. However, to avoid an excessive number of drafts, it is common practice to use higher reduction ratios, as shown in Tables 4 and 5.

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Drahtziehen — Allgemeine Überlegungen

439 Von Fall zu Fall ist es nützlich, sich daran zu erinnern, was das Drahtziehen eigentlich ist und warum es durchgeführt wird.

Das Drahtziehen ist ein am Halbzeug durchgeführter mechanischer Vorgang, der keine Materialabtragung erfordert und normalerweise im kalten Zustand erfolgt.

Der vorliegende kurze Artikel veranschaulicht einige grundlegende Theorien des Drahtziehens, fährt jedoch damit fort, praktischere Kalkulationen für zwei Ziehvorgänge von Stahldraht für im allgemeinen Gebrauch befindliche Fertiggrößen festzulegen.