

"LEAD SCREW"

This invention relates to a method of making a lead screw and, although the invention is not so restricted, it relates more particularly to a method of making a lead screw for a moving head, such as a printing head in a printer or a magnetic head in a magnetic disc apparatus.

A lead screw for moving a printing or magnetic head is known which has a helical groove whose sidewalls are perpendicular to the outer peripheral surface of the lead screw, and which is, therefore, rectangular in cross section. Such a groove, however, has undercuts with the result that it has been impossible to mould the screw from plastics material. The groove has therefore had to be formed by cutting which is expensive and time consuming.

It is therefore an object of the present invention to provide a lead screw which can be moulded from plastics material without forming any such undercut.

According to the present invention, there is therefore provided a method of making a lead screw comprising moulding the lead screw from a plastics material by the use of a split mould having a plurality of longitudinally extending sections, the mould being such that said lead screw is formed on its outer peripheral surface with a helical groove satisfying the following relationship:

$$L \geq \frac{P}{360} \left(\cos^{-1} \frac{r \sin \frac{\theta}{2}}{R} - \cos^{-1} \sin \frac{\theta}{2} \right)$$

where P is the pitch of the said groove;

R is the radius of the said lead screw;

r is the radius of the said lead screw between its
5 longitudinal axis and the bottom of said groove;

θ is the angle between the side walls of said sections; and

L is half of the difference in width between the
top and bottom of said groove, said bottom being
smaller in width than said top.

10 The cross-sectional shape of the groove enables
the lead screw to be moulded from plastics material. Such
a lead screw moulded from plastics material may be light
in weight, may have a low moment of inertia and may provide
improved reliability in mechanism control. It may have
15 a low coefficient of friction and may be such as not to
require any lubrication.

The present invention enables the production of a
lead screw in a greatly shortened time, as no cutting work
is involved, and a constant supply of lead screws of high
20 quality may be produced on a mass-production basis which
are inexpensive to manufacture.

The lead screw may also be formed with a second groove
for the return of a carriage engaged with said lead screw,
the first-mentioned groove being adapted for the advance
25 of said carriage.

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The said second groove may have a pitch which is three times greater than the pitch of said first-mentioned groove. The mould which is used for producing the lead screw may have a plurality of sections whose side walls extend
5 through the intersections of said first-mentioned and second grooves. Alternatively, the mould which is used for producing the lead screw may have a plurality of sections each of whose side walls extends midway between adjacent radial lines extending through the intersections of said
10 first and second grooves.

The mould preferably has four sections.

The or each said groove may have an arcuately shaped bottom in cross section.

The invention also comprises a lead screw when made
15 by the method described.

The invention is illustrated, merely by way of example, in the accompanying drawings, in which:-

Figure 1 diagrammatically illustrates a groove of a known lead screw;

20 Figure 2 is a cross-sectional view of the groove of the lead screw of Figure 1;

Figure 3 is a broken-away cross-sectional view showing by way of example the shape of a groove formed in a lead screw according to the present invention;

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Figures 4A to 4D are cross-sectional views showing several other differently shaped grooves of lead screws according to the present invention;

5 Figure 5 is a front elevational view of a lead screw embodying the present invention;

Figure 6 is a cross-sectional view showing the shape of still another groove of a lead screw according to the present invention, and

10 Figures 7 and 8 show two different moulds which may be used to produce the lead screw of the present invention.

A known lead screw is shown fragmentarily at 1 in Figures 1 and 2. It has on its outer peripheral surface a helical groove 2 which is rectangular in cross-section, as shown in Figure 2. The outer edges 3 of the groove 2, therefore, make the inner or bottom edges 4 and the bottom of the groove 2 partly invisible, as indicated at 5 in Figure 1, when the screw 1 is, for example, looked at in front elevation. The invisible portions 5 are usually called undercuts, and have hitherto made it impossible to 20 mould the screw 1 from plastics material. There has therefore been no alternative but to make the groove 2 by cutting. The cutting of a helical groove, however, requires a high level of technique and takes a lot of time, and 25 results, therefore, in an expensive lead screw.

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Referring again to Figure 1 of the drawings, if the lead screw 1 has a particular angle β of rotation, the lead x of the groove 2 is expressed as follows:

$$x = \frac{P}{360} \beta \quad (1)$$

5 where P stands for the pitch of the groove 2.

When the lead screw 1 is looked at in front elevation, the y co-ordinate of the outer edge 3 of the groove 2 is expressed as follows:

$$\begin{aligned} y &= R \cos \beta \\ &= R \cos \frac{360}{P} \beta \end{aligned} \quad (2)$$

and the y co-ordinate of its inner edge 4 is expressed as follows:

$$\begin{aligned} y &= r \cos \beta \\ &= -r \cos \frac{360}{P} x \end{aligned} \quad (3)$$

15 where R and r stand for the radius of the lead screw 1 between its longitudinal axis and outer peripheral surface and between its longitudinal axis and the bottom of the groove 2, respectively.

20 If X_a and X_b represent the x -co-ordinates of the outer and inner edges 3 and 4, respectively, at a height y_1 from the longitudinal axis of the screw 1, the difference between X_a and X_b ($X_a - X_b$) indicates the amount of an undercut

(or the width of the invisible portion of the bottom of the groove 2) at y_1 . If β_a and β_b represent the angles of rotation of the outer and inner edges 3 and 4, respectively, from the y-axis about the longitudinal axis of the lead screw 1, the amount of $X_a - X_b$ is expressed by the following equation:

$$X_a - X_b = \frac{P}{360} (\beta_a - \beta_b) \quad (4)$$

β_a and β_b are expressed as follows:

$$\begin{aligned} \beta_a &= \cos^{-1} \frac{y_1}{R} \\ &= \cos^{-1} \frac{r \sin \frac{\theta}{2}}{R} \end{aligned} \quad (5)$$

$$\begin{aligned} \text{and } \beta_b &= \cos^{-1} \frac{y_1}{r} \\ &= \cos^{-1} \frac{r \sin \frac{\theta}{2}}{r} \\ &= \cos^{-1} \sin \frac{\theta}{2} \end{aligned} \quad (6)$$

If equations (5) and (6) are substituted into equation (4), the following equation is obtained:

$$X_a - X_b = \frac{P}{360} \left(\cos^{-1} \frac{r \sin \frac{\theta}{2}}{R} - \cos^{-1} \sin \frac{\theta}{2} \right) \quad (7)$$

In view of the relationship represented by equation (7), a lead screw 6 embodying this invention has a helical groove on its outer peripheral surface which is shown at 7 in Figure 3. The groove 7 has a narrowed bottom and slanting sidewalls. Each slanting sidewall narrows towards the bottom

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of the groove 7 by an amount which is indicated at L. Thus L is half of the difference in width between the top and bottom of the groove 7, the said bottom being smaller in width than the said top. The amount of L is expressed as follows:

$$L \geq \frac{P}{360} \left(\cos^{-1} \frac{r \sin \frac{\theta}{2}}{R} - \cos^{-1} \sin \frac{\theta}{2} \right) \quad (8)$$

where θ stands for the angle of division between a plurality of longitudinally extending sections 11, 11a of a split mould 12, 12a (Figures 7 and 8) which is used for producing the lead screw 6. Thus θ is the angle between those side walls 13 of each section which are disposed alongside corresponding side walls of adjacent sections. If the values of L, P, R, r and θ are selected so as to satisfy equation (8), no undercut is formed, but the lead screw can be moulded from plastics material. In Figure 3, there is shown a carriage or other part provided with a screw member 8 engaged in the groove 7 for movement to the right or left, as seen in the drawing, upon rotation of the lead screw 6.

The groove 7 is preferably so shaped that the carriage or screw member 8 will not be subjected to any substantial vertical component of a force. It is, therefore, preferable that the sidewalls of the groove 7

have a small angle of inclination. The angle of inclination of the sidewalls can be reduced by increasing the number of sections of the mould which is used, or by making the pitch P of the groove 7 shorter. The latter method is preferable, since a mould comprising a large number of sections is complicated in construction.

A lead screw is also known having another groove for the return of a carriage in addition to the groove for its advance. The groove for the return of the carriage has a greater pitch in order to increase the speed of its return. In a lead screw of this type, it is necessary that the groove for the return of the carriage satisfy the relationship expressed by equation (8).

If the groove for the return of the carriage has, for example, a pitch of 25.4 mm/rev., while the lead screw has a diameter ($2R$) of 15 mm, the groove has an angle α_a of inclination of 56.5° as shown at 7a in Figure 4A, if a mould having only two sections is used. If a mould having three sections is used, the groove has an angle α_b of inclination of 35.9° , as shown at 7b in Figure 4B. If the mould has four sections, the groove has an angle α_c of inclination of 25.9° , as shown at 7c in Figure 4C. If the mould has six sections, the groove has an angle α_d of inclination of 16.7° , as shown at 7d in Figure 4D.

A split mould adapted for the production of a lead screw having both of the grooves for the advance and return of a carriage is preferably composed of a plurality of sections which are identically shaped except for the opposite ends of the grooves, so that the mould may be simplified in construction as far as possible. This requirement can be met by selecting appropriately the pitches of the two grooves and employing as lines for the separation of the mould sections from each other a plurality of straight lines passing longitudinally through the intersections of the two grooves. This arrangement provides a split mould of simple construction comprising a plurality of sections which are identical in groove contour.

A lead screw satisfying these requirements is shown at 9 in Figure 5. The lead screw 9 has a first groove for the advance of a carriage (as shown in Figure 3 at 8) and a second groove for its return. The second groove has a pitch which is three times greater than the pitch of the first groove. The intersections of the two grooves coincide with four straight lines extending longitudinally of the screw 9 and spaced apart from one another by 90° around the screw 9. This enables the use of a mould comprising four sections. If the second groove has a pitch of 25.4 mm/rev., while the lead screw has a diameter (2R) of 15mm, and if the four mould sections

have an angle θ of division of $\frac{2\pi}{4}$, the groove is of the shape shown at 7c in Figure 4C and its sidewalls have an angle α_c of inclination of 25.9° . This shape does not subject the carriage 8 to any substantial vertical component of a force.

As shown in Figure 7, the lead screw 6 may be produced by means of a split mould 12 having four longitudinally extending metal mould sections 11. In this case, parting lines a, b, c, d will be formed on the outer periphery of the lead screw 6 at positions defined by the side walls 13 of the mould sections 11.

If the mould 12 is used to produce the lead screw shown in Figure 5, the intersections of the first and second grooves appear at the four positions e, f, g, h indicated in Figure 7 when the lead screw 6 is viewed from the side, each of these intersections e, f, g, h lying on a radial line 14 through the mould 12. It will be noted that each of the side walls 13 extends along a line disposed midway between two adjacent radial lines 14. Thus in the case of the mould 12 of Figure 7, each of the intersections e, f, g, h is disposed midway between a pair of adjacent parting lines a, b, c, d.

In the case of the four part split mould 12a shown in Figure 8, the parting line a is disposed at the intersection e, the parting line b is disposed at the

intersection f, the parting line c is disposed at the intersection g, and the parting line d is disposed at the intersection h. Thus in this case each of the side walls 13 extends through the respective intersection of the first and second grooves.

Although the invention has been described with reference to a preferred embodiment thereof, it is possible to obtain a variety of modifications by employing a mould comprising a different number of sections or forming a differently pitched groove if they satisfy the requirements of equation (8). In a lead screw having a means, other than a groove, for the return of a carriage, its groove for the advance of the carriage satisfies the requirements of equation (8).

A differently shaped groove is shown at 6'c in Figure 6. It has an arcuately shaped bottom in cross section, and a carriage 10 has a projection 10a which is substantially complementary to the groove 6'c.

It is also possible to use a mould split along lines displaced by 45° about the longitudinal axis of the lead screw from the lines passing through the intersections of the grooves.

CLAIMS

1. A method of making a lead screw comprising moulding the lead screw from plastics material by the use of a split mould having a plurality of longitudinally extending sections, the mould being such that said lead screw is formed on its outer peripheral surface with a helical groove satisfying the following relationship:

$$L \geq \frac{P}{360} \left(\cos^{-1} \frac{r \sin \frac{\theta}{2}}{R} - \cos^{-1} \sin \frac{\theta}{2} \right)$$

where P is the pitch of the said groove;

R is the radius of the said lead screw;

r is the radius of the said lead screw between its longitudinal axis and the bottom of said groove;

θ is the angle between the side walls of said sections;

and

L is half of the difference in width between the top and bottom of said groove, said bottom being smaller in width than said top.

2. A method as claimed in claim 1 in which the lead screw is also formed with a second groove for the return of a carriage engaged with said lead screw, the first-mentioned groove being adapted for the advance of said carriage.

3. A method as claimed in claim 2 in which said second groove has a pitch which is three times greater than the pitch of said first-mentioned groove.



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4. A method as claimed in claim 2 or 3 in which the mould which is used for producing the lead screw has a plurality of sections whose side walls extend through the intersections of said first-mentioned and second grooves.
- 5 5. A method as claimed in claim 2 or 3 in which the mould which is used for producing the lead screw has a plurality of sections each of whose side walls extends midway between adjacent radial lines extending through the intersections of said first and second grooves.
- 10 6. A method as claimed in claim 4 or 5 in which the mould has four sections.
7. A method as claimed in any preceding claim in which the or each said groove has an arcuately shaped bottom in cross section.
- 15 8. A method of making a lead screw substantially as hereinbefore described with reference to any of Figures 3-8 of the accompanying drawings.
9. A lead screw when made by the method of any preceding claim.

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