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Errors of Axial Dimensions of Workpieces held in Collets and Machined on Capstan Lathes

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The errors in axial dimensions of workpieces machined in a capstan lathe are evaluated by statistical methods. The axial displacement of workpieces held in collets can be shown to vary approximately according to the normal distribution. The error due to the turret slide not occupying identical positions is found to be low and is of the order of 0.0001". The accuracy of axial dimensions can be enormously increased by pressing the workpiece against the end face of the collet as the workpiece is clamped.

Introduction

Theoretical calculations of locating errors due to machining in various fixtures are made assuming that the locating surface on the workpiece coincides completely with the corresponding locating surface on the fixture [1]. However, experience shows that the accuracy of workpieces depends not only on the basic scheme of the fixture, but also on how carefully the workpiece is held in the fixture and the condition (new or worn) of the fixture itself.

The aim of the present investigations has been to find out the nature of variation of axial displacement of workpieces held in collets and machined on a capstan lathe. The errors of axial dimensions of a large number of workpieces machined by automatic size maintenance are caused not only by the axial displacement of the workpieces in the collet, but also by the turret slide which does not each time occupy exactly the same end positions owing to slightly varying forces applied on to the corresponding levers or handwheels operating it. In the present investigation, the error caused by the turret slide not occupying identical end positions during the machining of a great lot of workpieces is also evaluated.

Description of Experiments

Errors due to axial displacement of workpieces in the collet Δ_y.

The workpieces held in the collet in the normal way: The experiments are performed on a southbend capstan lathe using collets of sizes ½" and ⅞". The dimensions of the workpieces tested are shown in Fig. 1. The experimental set-up is indicated in Fig. 2. The test workpiece is held in the collet and fixed by moving a lever provided for the purpose. The radial force holding the workpiece in the collect will be constant and is a characteristic of the given machine. After the test piece is clamped, the needle of the dial gauge, which is fixed by a magnetic base on the cross slide is brought against the end face of the test piece. To take into account the fact that the end face will not be exactly perpendicular to the axis of rotation of the spindle, the mean of the maximum and minimum dial gauge readings over one full rotation of the spindle, is used. After the dial gauge reading is recorded, the needle is withdrawn, the collet declamped, the workpiece pulled out and held in the collet in a new position, clamped, and the dial gauge reading taken again. A set of 100 readings for each collet size is taken.

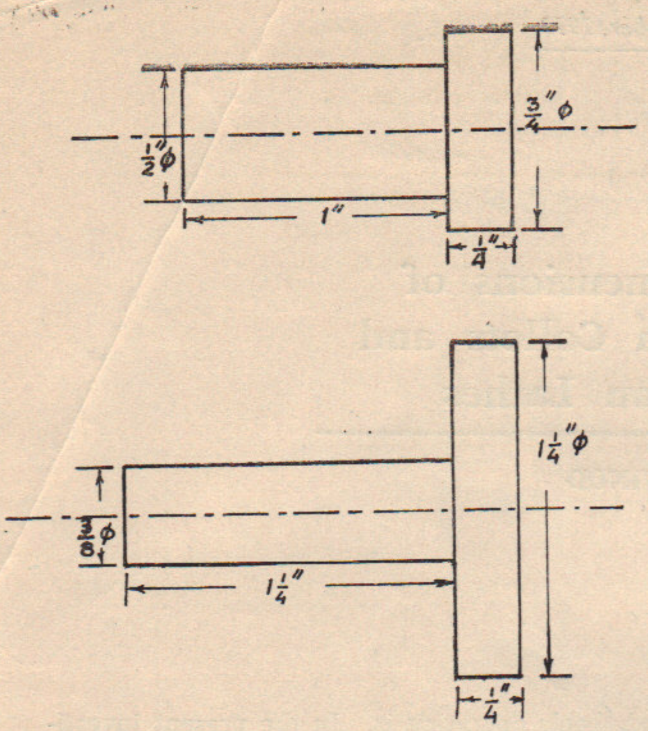

Fig : 1 : Dimensions of workpieces tested.

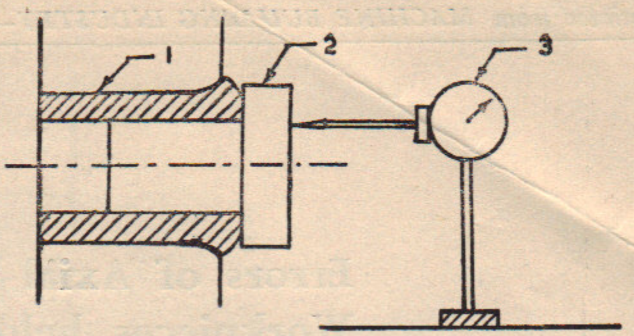

Fig : 2 : Experimental set-up : (1 : collet 2 : workpiece, 3 : dial gauge).

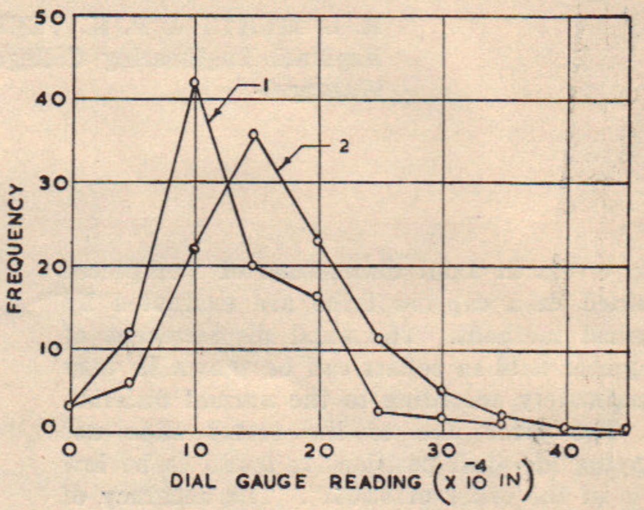

Fig : 3 : Distribution of axial displacement of workpieces held in collets : (1 : ½" collet, 2 : 7/8" collet).

The workpieces held in the collet with special care: The above experiments are repeated for the ⅞" collet, but with a slight variation in the method of clamping the workpiece in the collet. The workpiece is pressed against the end face of the collet with some force (around a kilogram) and as the force is being applied, the collet is clamped. In contrast to this, in the former case the workpiece is pressed against the end face of the collet with some force, which, however, was just released before the collet is clamped.

Error due to the turret slide not occupying identical positions (Δ_{yt}): The needle of the dial gauge is now brought against one of the end faces of the hexagonal turret. The dial gauge reading is recorded with the turret slide in the near extreme position (near to the headstock). The turret slide is moved to-and-fro 6 times and brought again to its near extreme position so that the same face of the hexagonal turret as before is against the dial gauge needle. The dial gauge reading is noted again. The procedure is repeated a number of times and the dial gauge readings obtained.

Results and Discussion

The values of axial displacement obtained as described above are shown in Table 1.

Table 1

Axial displacement of workpieces held in collets

Dial gauge reading (in)	Frequency	
	½" collet	⅞" collet
0	3	3
0.0005	12	6
0.0010	42	12
0.0015	20	36
0.0020	17	23
0.0025	3	11
0.0030	2	5
0.0035	1	2
0.0040	—	1
0.0045	—	1

Let $\bar{x}$: Mean of the distribution, in

σ : Standard deviation from the mean, in

It is found that $\bar{x} = 0.00129$ in

$\sigma = 0.000639$ in

Table 2

Comparison of the distribution of axial displacement of workpieces held in ½″ collet with the law of normal distribution

Deviation of axial displacement from the mean		% frequency In normal distribution	In actual distribution
$(\bar{X} \pm 0.3\sigma)$	0.00148 to 0.00110	25	22.6
$(\bar{X} \pm 0.7\sigma)$	0.00174 to 0.00084	50	53
$(\bar{X} \pm 1.1\sigma)$	0.00199 to 0.00059	75	74.5
$(\bar{X} \pm 3\sigma)$	0.00321 to 0	99.8	99.0

A comparison of the distribution with the normal distribution is made in Table 2, bearing in mind that in a theoretical normal distribution the region $\bar{X} \pm 0.3\sigma$ contains 25%, $\bar{X} \pm 0.7\sigma$ — 50%, $\bar{X} \pm 1.1\sigma$ — 75% and $\bar{X} \pm 3\sigma$ — 99.8% of the total number of readings.

The curves obtained by plotting the axial displacement against the corresponding percentage frequency are shown in Fig. 3. The fluctuation in axial displacement as evident from Fig. 3 and Table 1 is due to many chance causes like the following: (a) The workpiece may be pressed out as the collet is clamped. (b) The workpiece during clamping may slightly move away from the end faces of the collet due to slight clearances. (c) The workpiece is pressed towards the end face of the collet with varying pressures, before it is clamped.

As the axial displacement is affected by a number of chance causes, it is reasonable to expect that the distribution of axial displacement indicated in Fig. 3 may be close to a normal distribution.

From the Table 2 it is clear that the given distribution can be approximated to a normal distribution. As the distribution can be fairly accurately approximated to normal distribution the error due to axial displacement, Δ_y, can be characterised by 6σ. This error for a ½″ and ⅞″ is approximately equal to 0.004 and 0.005 inches respectively (for ⅞″ collet $\bar{X} = 0.000173$ and $\sigma = 0.00073$). This reveals that Δ_y, increases as the collet size is increased. This may be due to the fact that the manufacturing inaccuracies like the tolerance and form errors increase as the workpiece size is increased.

The actual curves of distribution shown in Fig. 3 are non-symmetrical and skewed to the left. The skewness may be calculated from the Karl Pearson formula [2].

$$\text{Skewness} = \frac{\text{Mean—Mode}}{\text{Standard deviation}} \qquad (1)$$

$$\text{For } \tfrac{1}{2}'' \text{ collet, skewness} = \frac{0.00129-0.0010}{0.000639} = 0.454$$

$$\text{for } \tfrac{7}{8}'' \text{ collet, skewness} = \frac{0.00173-0.0015}{0.00073} = 0.315$$

The tendency of the distribution to skew to the left is caused by the fact that the workpieces are pressed towards the left against the end face of the collet before being finally clamped in them. The above obtained values of skewness show that it reduces as the collet size increases, or in other words the distribution becomes more symmetrical. This is explained by the fact that as the workpiece size increases, the influence of its being pressed to the left before being clamped is diminished.

The curve indicating the distribution of axial displacement when the workpieces are clamped as described earlier is shown in Fig. 4, drawn to the same scale as Fig. 3. The error Δ_y is now only about 0.0001 in and so about 50 times less than the earlier value of 0.005 in. Thus where the tolerances on axial dimensions are especially narrow, it is desirable to press the workpieces against the collet with some force while they are clamped.

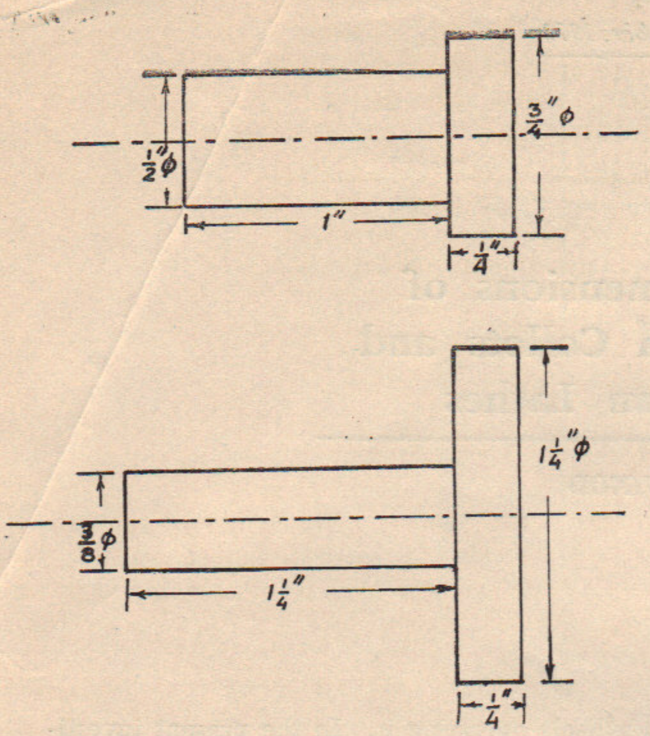

Fig : 1 : Dimensions of workpieces tested.

The workpieces held in the collet with special care: The above experiments are repeated for the $\frac{7}{8}''$ collet, but with a slight variation in the method of clamping the workpiece in the collet. The workpiece is pressed against the end face of the collet with some force (around a kilogram) and as the force is being applied, the collet is clamped. In contrast to this, in the former case the workpiece is pressed against the end face of the collet with some force, which, however, was just released before the collet is clamped.

Error due to the turret slide not occupying identical positions (Δ_{yt}): The needle of the dial gauge is now brought against one of the end faces of the hexagonal turret. The dial gauge reading is recorded with the turret slide in the near extreme position (near to the headstock). The turret slide is moved to-and-fro 6 times and brought again to its near extreme position so that the same face of the hexagonal turret as before is against the dial gauge needle. The dial gauge reading is noted again. The procedure is repeated a number of times and the dial gauge readings obtained.

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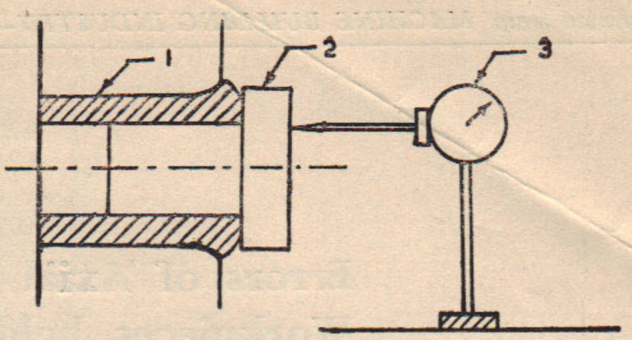

Fig : 2 : Experimental set-up : (1 : collet 2 : workpiece, 3 : dial gauge).

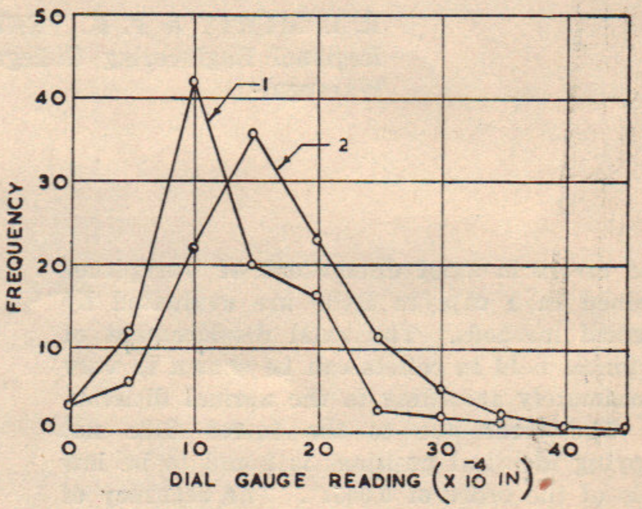

Fig : 3 : Distribution of axial displacement of workpieces held in collets : (1 : $\frac{1}{2}''$ collet, 2 : 7/8" collet).

Table 1

Axial displacement of workpieces held in collets

Dial gauge reading (in)	Frequency	
	$\frac{1}{2}''$ collet	$\frac{7}{8}''$ collet
0	3	3
0.0005	12	6
0.0010	42	12
0.0015	20	36
0.0020	17	23
0.0025	3	11
0.0030	2	5
0.0035	1	2
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