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NUMBER 104

AUTOMATIC SCREW MACHINE PRACTICE

PART VI

THREADING OPERATIONS ON THE BROWN & SHARPE AUTOMATIC SCREW MACHINES

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Automatic Screw Machine Practice for the Brown & Sharpe automatic screw machines is covered in eight Reference Books, Nos. 99 to 106, inclusive. Reference Book No. 99, "Operation of the Brown & Sharpe Automatic Screw Machines," deals with the construction of these machines and the setting-up of the tools. No. 100, "Designing and Cutting Cams for Automatic Screw Machines," gives detailed instruction on cam design, and describes a simplified method for milling cams. No. 101, "Circular Form and Cut-off Tools for the Automatic Screw Machine," deals with the general arrangement and the calculations of these tools, and describes the different methods employed in their making. No. 102, "External Cutting Tools for the Automatic Screw Machine," deals with the design and construction of box-tools, taper turning tools, hollow mills, and shaving tools. No. 103, "Internal Cutting Tools for the Automatic Screw Machine," deals with centering tools, cross-slide drilling attachments, counterbores, reamers, and recessing tools. No. 104, "Threading Operations on the Automatic Screw Machine," treats on cam design for threading operations, threading dies, taps and tap drills, die and tap holders, and thread rolling. No. 105, "Knurling Operations on the Automatic Screw Machine," describes the construction of knurling holders, and gives directions for the making of knurls and the design of tools and cams used in connection with knurling operations. No. 106, "Milling, Cross-drilling and Burring Operations on the Automatic Screw Machine," describes screw-slotting attachments, index drilling attachments, and burring attachments, giving directions for their use and for the design of cams for them.

CHAPTER I

ARRANGEMENT OF MACHINE FOR THREADING OPERATIONS

The subject of threading on the Brown & Sharpe automatic screw machine is a subject which confuses the beginner on account of the calculations necessary for determining the rise on the cam due to the relation between the speed of the spindle and the driving shaft. The various reversing devices, tripping devices and threading attachments are also of importance. Until the various devices and arrangements used are fully understood, good results cannot be expected.

Reversing the Spindle

On the No. 00 Brown & Sharpe automatic screw machine the spindle is reversed by means of a spring plunger shown at *A*, Fig. 1; this plunger, acting through the medium of the friction clutch *B*, reverses the spindle, from forward to backward, instantaneously. But, to reverse the spindle from backward to forward, onto a slow speed (as is sometimes necessary when cutting a thread), requires one revolution of the driving shaft. This shaft runs at 120 R. P. M. In a given case, the spindle speed equals, say, 2400 R. P. M.; then the revolutions required for reversing the spindle equal $\frac{2400}{120} = 20$ revolutions of the spindle. The 20 revolutions used for this purpose represents lost time, and to obviate this, the Brown & Sharpe Mfg. Co. has provided a speed ratio threading attachment which is used in the turret. This attachment will be described later.

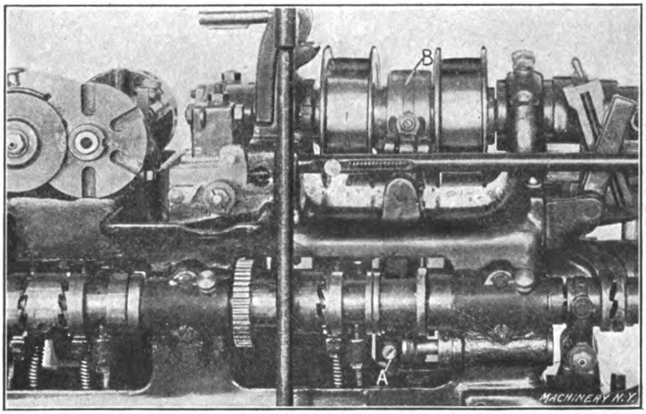

Fig. 1. Rear View of No. 00 Brown & Sharpe Automatic Screw Machine showing Reversing Mechanism

On the No. 0 and No. 2 Brown & Sharpe automatic screw machines, the spindle is reversed instantly from forward to backward by means of cam *A* and lever *B*, Fig. 2. The spindle is reversed from backward to forward by means of the same cam *A* on the driving shaft. There are two lobes on this cam, and it, therefore, requires one-half revolution of the driving shaft to reverse the spindle. For example, let the spindle speed equal 1800 revolutions per minute; let the speed of the driving shaft equal 180 revolutions per minute. Then the number of revolutions required to reverse the spindle $= \frac{1800}{180 \times 2} = 5$ revolutions. To reverse the spindle from forward to backward and then forward again (as would be necessary where two threading operations come in succession) requires 4¾ hundredths of the cam surface on account of the tripping dogs on the drum, which cannot be placed any closer together. This will be referred to further under the heading "Setting the Tripping Dogs for Threading."

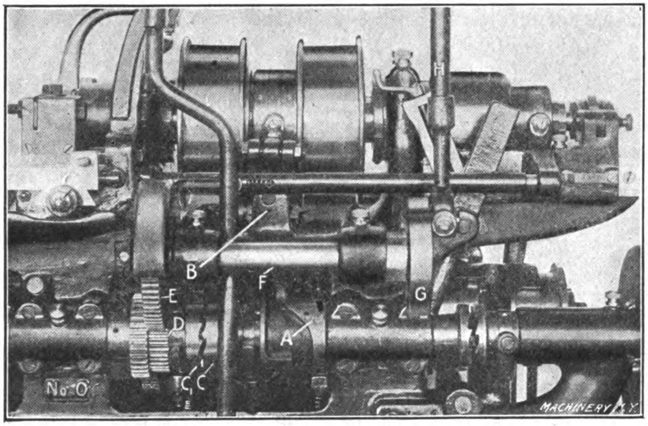

Fig. 2. Rear View of No. 0 Brown & Sharpe Automatic Screw Machine showing Reversing Mechanism and Belt Shifting Attachment

On the No. 2 Brown & Sharpe automatic screw machine, the spindle is reversed in the same manner as on the No. 0. For example, let the spindle speed equal 1200 revolutions per minute; let that of the driving shaft equal 120 revolutions per minute. Then the number of revolutions required to reverse the spindle from backward to forward $= \frac{1200}{120 \times 2} = 5$ revolutions; to reverse the spindle from forward to backward and forward again (as we explained regarding the No. 0 machine) requires 3¾ hundredths of the cam surface.

Setting the Tripping Dogs for Threading

The tripping dogs *a*, Fig. 3, which are used for reversing the spindle, feeding the stock, and revolving the turret are placed on the various drums on the front shaft as follows: The dog for reversing the spindle is placed on drum *A*, for feeding the stock, on drum *B*, and for revolving the turret, on drum *C*. These dogs operate the levers *D*, *E*, and *F*, respectively, which, in turn, disengage a clutch on the driving shaft on the rear of the machine, thus operating the reversing, feeding and revolving devices. Where two threading operations follow in succession, the time required to revolve the turret is not always sufficient to bring the second tap or die into position. This is illustrated in Fig. 4, where two tripping dogs are shown in position on the drum. To illustrate the method of determining whether extra time should be allowed for clearance, take a practical example. Assume that a set of cams is required to be used on the No. 2 Brown & Sharpe automatic screw machine. Let the spindle speed equal 1200 revolutions per minute; let the time required to complete one

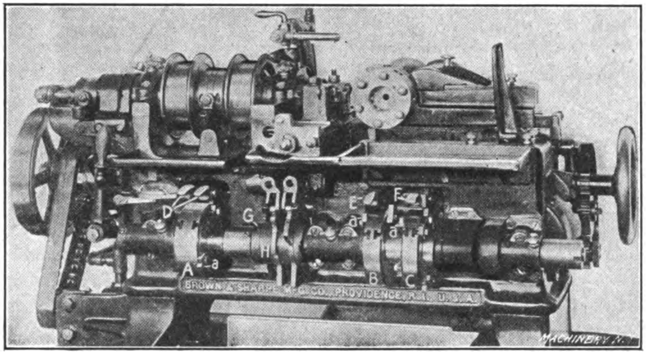

Fig. 3. Front View Showing Feeding, Reversing and Revolving Devices

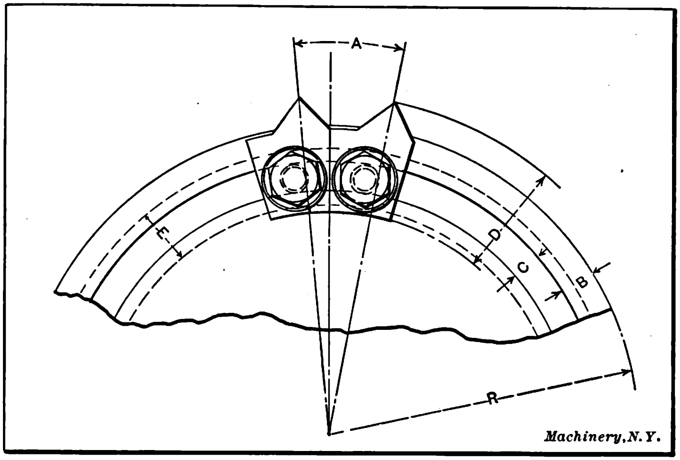

Fig. 4. Reversing Dogs in Position on Drum

piece equal 20 seconds. Then the number of revolutions to complete one piece $= \frac{1200 \times 20}{60} = 400$ revolutions. Referring to the tables for laying out cams in MACHINERY'S Reference Book No. 100, we find that it requires five hundredths to feed stock, plus one hundredth for clearance. This gives 6 hundredths to revolve the turret. Referring to the accompanying Table I we find that the angle *A* is 14 degrees. Then if the number of hundredths of the cam surface utilized in revolving the turret is less than the equivalent of 14 degrees, we would have to add more for clearance. In this case it requires 6 hundredths to revolve the turret. Then, reducing 14 degrees to hundredths, we have, $\frac{100 \times 14}{360} = 3.88$ hundredths. Therefore, additional cam surface would not be necessary in this case.

TABLE I. GENERAL DIMENSIONS OF DRUM AND REVERSING DOGS

No. of Machine	A	B	C	D	E	R
00	20°	$\frac{15}{64}$	$\frac{1}{4}$	$\frac{15}{16}$	$\frac{1}{2}$	2
0	17°	$\frac{5}{16}$	$\frac{1}{4}$	$1\frac{1}{32}$	$\frac{1}{2}$	$2\frac{3}{4}$
2	14°	$\frac{13}{32}$	$\frac{5}{16}$	$1\frac{1}{4}$	$\frac{9}{16}$	$3\frac{1}{4}$

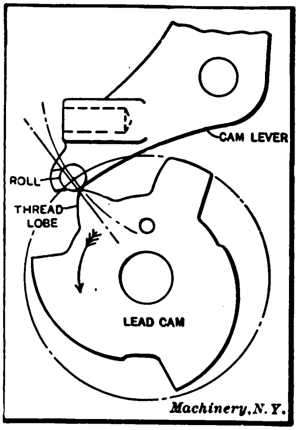

Fig. 5. Position of Roll on Thread Lobe when Spindle is reversed

Setting the Machine for the Use of Taps and Dies

Before the reversing mechanism can operate, the clutch *G* must engage with clutch *H*. (See Fig. 3.) After engaging these clutches, we set the reversing dog *a* so that the spindle will reverse just as the roll passes over the highest portion of the thread lobe on the rear cam, as shown exaggerated in Fig. 5. When the spindle is reversing at the exact point as mentioned, the die or tap holder containing the die or tap is placed in the turret, and brought into position as shown in Fig. 6. The cam roll is set on the thread lobe in the position shown. Here a button die holder *A* (draw-out type) is shown in position ready to start on the work. The face of the die should be set a distance *a*, which varies from 1/16 to 3/16 inch, depending on the pitch of the thread and the length of the threaded portion, away from the part to be threaded. If the die does not travel onto the work far enough at the first setting, the holder can be brought further out of the turret. The same procedure can be followed in setting the tap, except that it should be set more carefully, only going into the work a slight distance in starting, and then moving the holder out of the turret until the desired depth is reached. It is sometimes found necessary, after setting the tripping dog, to adjust it slightly, especially when using a draw-out die or tap holder. The turret should not be revolved until the die or tap is clear of the work.

When calculating the revolutions of the spindle required for threading, a greater number of revolutions should be allowed than the exact number of threads required on the piece, depending on the pitch of the thread, and in some cases on the length of the threaded portion, as when a short thread has to be produced, necessitating the threading of a longer portion and then facing it off. This is to allow the die to approach the end of the piece on the rise of the thread lobe. The actual number of revolutions required for threading can be found by the aid of the following formulas:

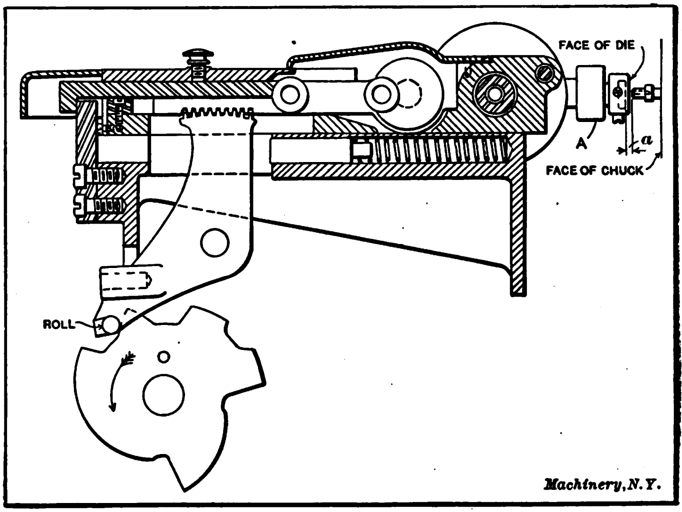

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Fig. 6. Position of Roll on Thread Lobe when setting Die or Tap

From 14 to 24 threads per inch, $R = Lp + 1.5$
From 28 to 48 threads per inch, $R = Lp + 3$ (1)
From 56 to 80 threads per inch, $R = Lp + 4.5$

where $L =$ length of the threaded portion, $p =$ the number of threads per inch, and $R =$ the revolutions of the spindle required for threading.

Owing to the inconvenience of dividing the cam surface into the same number of equal parts as the revolutions required to complete one piece, the Brown & Sharpe Mfg. Co. has adopted the system of dividing the cam surface into one hundred equal parts. The number of hundredths of cam circumference required for any operation is obtained by dividing the number of revolutions for each operation by the total number of revolutions required to complete one piece, taking the nearest decimal with two places. For example, if the number of revolutions required for the die to advance on to the work is 10, and the total number of revolutions required to complete one piece is 200, then $\frac{10}{200} = 0.05$, or 5 hundredths of the cam surface.

Constructing the Thread Lobe

The method of laying out the cam lobe for threading is shown at Fig. 7. The outer circle *A* indicates the relation between the center of the fulcrum of the lead lever and the cam. This circle represents the path which would be described by the center of the lead lever if it were revolved around the cam. The radius *B* equals the distance from the center of the roll to the center of the fulcrum on the lead lever. *C* equals the vertical distance from the center of the cam to the center of the fulcrum on the lead lever, and *D* equals the horizontal distance. Before constructing the thread lobe, the number of hundredths of cam surface, the rise on the cam for threading, and the amount that the thread lobe is cut below the outer circle of the cam have to be determined. Then, after having drawn the various circles and lines necessary for the construction, we can proceed as follows: First, with the starting point *a*, the highest point *b* and the finishing point *c* of the cam lobe as centers, and with a radius equal to *B*, describe arcs intersecting the outer circle *A* at the points

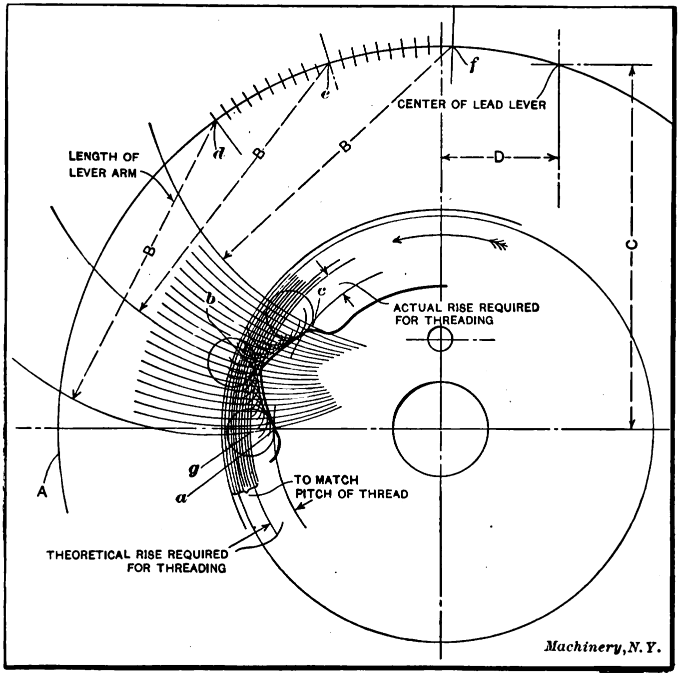

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Fig. 7. Graphical Method of Constructing Thread Lobe

d, *e*, and *f*. Then divide the spaces between the points *d*, *e*, and *f* into the same number of equal spaces as the number of revolutions required for threading. With a radius equal to *B* and with centers at the division points on circle *A*, describe arcs intersecting the thread lobe as shown. On the arc passing through point *a* locate center *g* of the roll circle so that this circle will pass through point *a*, and draw the roll circle. In a similar manner, draw the roll circle passing through point *b*, the highest point of the cam lobe. With the center of the cam as a center, draw a circle through point *g* and also a circle through the center of the roll circle which passes through point *b*. Divide the space between the two circles just drawn in the same number of equal spaces as the distances between *d* and *e* and *e* and *f* were divided. Then, with the center of the cam as a center, draw circles through these division points. The intersection between these circular arcs and the arcs drawn with the points on circle *A* as centers determine the center of the cam roll at the various steps of its progress, and cam roll circles drawn with these intersecting points as centers will determine the shape of the thread lobe. The form thus produced would, however, not give satisfactory results as crowding of the tap or die would occur, owing to the spindle speed and the speed of the driving shaft not being constantly in the same ratio. It is, therefore, avisable to cut down the cam lobe after the first couple of threads. This is shown in Fig. 7 where the actual and theoretical rise required for threading is shown.

Improved Method of Constructing Thread Lobe

In the method just described the rise on the thread lobe was determined graphically, this being a very complicated and tedious method. The advantage of the following method lies in its simplicity, as the lobe is determined mathematically. Before the thread lobe can be constructed, the length of the threaded portion, the number of threads per inch and the total number of revolutions of the spindle to complete one piece are required to be known. When the number of revolutions for threading and the number of threads per inch are known, the rise on the cam can be found by the following formulas:

$$\begin{aligned}&\text{From 14 to 24 threads per inch, } r = (R \div p) \times 0.85\\&\text{From 28 to 48 threads per inch, } r = (R \div p) \times 0.88 \qquad (2)\\&\text{From 56 to 80 threads per inch, } r = (R \div p) \times 0.90\end{aligned}$$

in which

R = revolutions required for threading,
p = number of threads per inch,
r = rise on cam.

In Tables II and III the results as obtained by formulas (1) and (2) for various numbers of threads per inch are tabulated. To show the advantages of these tables, take a practical example. Assume that a set of cams is required for the No. 00 Brown & Sharpe automatic screw machine. To make the piece as shown at *A*, Fig. 8, let the spindle speed equal 2400 revolutions per minute; the number of revo-

TABLE II. SPINDLE REVOLUTIONS AND CAM RISE FOR THREADING

Length of Threaded Portion	Number of Threads per Inch														
	80	72	64	56	48	40	36	32	30	28	24	20	18	16	14
	First Line: Revolutions of Spindle for Threading Second Line: Rise on Cam for Threading														
1/32	7.00 0.079	7.00 0.088	6.50 0.091	6.50 0.104	4.50 0.082	4.50 0.099	4.00 0.098	4.00 0.110	4.00 0.117	4.00 0.126					
1/16	9.50 0.107	9.00 0.113	8.50 0.120	8.00 0.129	6.00 0.110	5.50 0.121	5.50 0.134	5.00 0.138	5.00 0.147	5.00 0.157	3.00 0.106				
3/32	12.00 0.135	11.50 0.144	10.50 0.148	10.00 0.161	7.50 0.137	7.00 0.154	6.50 0.159	6.00 0.165	6.00 0.176	5.50 0.173	4.00 0.142	3.50 0.149			
1/8	14.50 0.163	13.50 0.169	12.50 0.176	11.50 0.185	9.00 0.165	8.00 0.176	7.00 0.171	7.00 0.193	7.00 0.205	6.50 0.204	4.50 0.159	4.00 0.170	3.50 0.165	3.50 0.186	
5/32	17.00 0.191	16.00 0.200	14.50 0.204	13.50 0.217	10.50 0.192	9.50 0.209	8.50 0.208	8.00 0.220	7.50 0.220	7.50 0.236	5.50 0.195	4.50 0.191	4.00 0.189	4.00 0.212	3.50 0.212
3/16	19.50 0.219	18.00 0.225	16.50 0.232	15.00 0.241	12.00 0.220	10.50 0.231	10.00 0.244	9.00 0.248	8.50 0.249	8.50 0.267	6.00 0.213	5.50 0.234	5.00 0.236	4.50 0.239	4.00 0.243
7/32	22.00 0.248	20.50 0.256	18.50 0.260	17.00 0.273	13.50 0.247	12.00 0.264	11.00 0.269	10.00 0.275	9.50 0.279	9.00 0.283	7.00 0.248	6.00 0.255	5.50 0.260	5.00 0.266	4.50 0.273
1/4	24.50 0.276	23.50 0.294	20.50 0.288	18.50 0.297	15.00 0.275	13.00 0.286	12.00 0.293	11.00 0.303	10.50 0.308	10.00 0.314	7.50 0.266	6.50 0.276	6.00 0.283	5.50 0.292	5.00 0.304
9/32	27.00 0.304	25.00 0.313	22.50 0.316	20.50 0.329	16.50 0.302	14.50 0.319	13.00 0.318	12.00 0.330	11.50 0.337	11.00 0.346	8.50 0.301	7.00 0.298	6.50 0.307	6.00 0.319	5.50 0.334
5/16	29.50 0.332	27.00 0.338	24.50 0.345	22.00 0.354	18.00 0.340	15.50 0.341	14.50 0.354	13.00 0.358	12.50 0.367	12.00 0.377	9.00 0.319	8.00 0.340	7.00 0.330	6.50 0.345	6.00 0.364
11/32	32.00 0.360	29.50 0.369	26.50 0.373	24.00 0.386	19.50 0.357	17.00 0.374	15.50 0.379	14.00 0.385	13.50 0.396	12.50 0.393	10.00 0.354	8.50 0.361	7.50 0.354	7.00 0.372	6.50 0.395
3/8	34.50 0.388	31.50 0.394	28.50 0.401	25.50 0.410	21.00 0.385	18.00 0.396	16.50 0.403	15.00 0.413	14.50 0.425	13.50 0.424	10.50 0.372	9.00 0.383	8.50 0.401	7.50 0.398	7.00 0.425
13/32	37.00 0.416	34.00 0.425	30.50 0.429	27.50 0.442	22.50 0.412	19.50 0.429	17.50 0.428	16.00 0.440	15.00 0.440	14.50 0.456	11.50 0.407	9.50 0.404	9.00 0.425	8.00 0.425	7.00 0.425
7/16	39.50 0.444	36.00 0.450	32.50 0.457	29.00 0.466	24.00 0.440	20.50 0.451	19.00 0.464	17.00 0.468	16.00 0.469	15.50 0.487	12.00 0.425	10.50 0.446	9.50 0.448	8.50 0.451	7.50 0.455
15/32	42.00 0.473	38.50 0.481	34.50 0.484	31.00 0.498	25.50 0.477	22.00 0.484	20.00 0.489	18.00 0.495	17.00 0.499	16.00 0.503	13.00 0.460	11.00 0.468	10.50 0.496	9.00 0.478	8.00 0.486
1/2	44.50 0.501	40.50 0.506	36.50 0.513	32.50 0.522	27.00 0.495	23.00 0.506	21.00 0.513	19.00 0.523	18.00 0.528	17.00 0.534	13.50 0.478	11.50 0.489	10.50 0.496	9.50 0.504	8.50 0.516
17/32	47.00 0.529	43.00 0.538	38.50 0.541	34.50 0.554	28.50 0.522	24.50 0.539	22.00 0.538	20.00 0.550	19.00 0.557	18.00 0.566	14.50 0.514	12.00 0.510	11.00 0.519	10.00 0.531	9.00 0.546
9/16	49.50 0.559	45.00 0.563	40.50 0.570	36.00 0.579	30.00 0.550	25.50 0.561	23.50 0.574	21.00 0.578	20.00 0.587	19.00 0.597	15.00 0.531	13.00 0.553	11.50 0.543	10.50 0.558	9.50 0.577
19/32	52.00 0.585	47.50 0.594	42.50 0.598	38.00 0.611	31.50 0.577	27.00 0.594	24.50 0.599	22.00 0.605	21.00 0.616	19.50 0.613	16.00 0.567	13.50 0.574	12.00 0.566	11.00 0.584	10.00 0.607
5/8	54.50 0.613	49.50 0.619	14.50 0.626	39.50 0.635	33.00 0.605	28.00 0.616	25.50 0.623	23.00 0.633	22.00 0.645	20.50 0.644	16.50 0.584	14.00 0.595	13.00 0.614	11.50 0.611	10.50 0.637
21/32	57.00 0.641	52.00 0.650	46.50 0.654	41.50 0.667	34.50 0.622	29.50 0.649	26.50 0.648	24.00 0.660	23.00 0.675	21.50 0.676	17.50 0.620	14.50 0.616	13.50 0.637	12.00 0.637	10.50 0.637
11/16	59.50 0.679	54.00 0.675	48.50 0.682	43.00 0.691	36.00 0.660	30.50 0.671	28.00 0.684	25.00 0.688	23.50 0.689	22.50 0.707	18.00 0.638	15.50 0.659	14.00 0.661	12.50 0.664	11.00 0.668
23/32	62.00 0.698	56.50 0.706	50.50 0.710	45.00 0.723	37.50 0.677	32.00 0.704	29.00 0.709	26.00 0.715	24.50 0.719	23.00 0.723	19.00 0.673	16.00 0.680	14.50 0.684	13.00 0.690	11.50 0.698
3/4	64.50 0.726	58.50 0.731	52.50 0.738	46.50 0.747	39.00 0.715	33.00 0.726	30.00 0.733	27.00 0.743	25.50 0.748	24.00 0.754	19.50 0.691	16.50 0.701	15.00 0.708	13.50 0.717	12.00 0.728

TABLE III. SPINDLE REVOLUTIONS AND CAM RISE FOR THREADING

Length of Threaded Portion	Number of Threads per Inch														
	80	72	64	56	48	40	36	32	30	28	24	20	18	16	14
	First Line: Revolutions of Spindle for Threading Second Line: Rise on Cam for Threading														
25/32	67.00 0.754	61.00 0.763	54.50 0.767	48.50 0.779	40.50 0.742	34.50 0.759	31.00 0.758	28.00 0.770	26.50 0.777	25.00 0.786	20.50 0.726	17.00 0.728	15.50 0.782	14.00 0.748	12.50 0.759
13/16	69.50 0.782	63.00 0.788	56.50 0.795	50.00 0.804	42.00 0.770	35.50 0.781	32.50 0.794	29.00 0.798	27.50 0.807	26.00 0.817	21.00 0.744	18.00 0.765	16.00 0.755	14.50 0.770	13.00 0.789
27/32	72.00 0.810	65.50 0.819	58.50 0.823	52.00 0.836	43.50 0.797	37.00 0.814	33.50 0.819	30.00 0.825	28.50 0.836	26.50 0.833	22.00 0.779	18.50 0.786	16.50 0.779	15.00 0.797	13.50 0.819
7/8	74.50 0.838	67.50 0.844	60.50 0.851	53.50 0.860	45.00 0.825	38.00 0.836	34.50 0.843	31.00 0.853	29.50 0.865	27.50 0.864	22.50 0.797	19.00 0.808	17.50 0.826	15.50 0.828	14.00 0.850
29/32	77.00 0.866	70.00 0.875	62.50 0.879	55.50 0.892	46.50 0.842	39.50 0.869	35.50 0.868	32.00 0.880	30.00 0.880	28.50 0.895	23.50 0.832	19.50 0.829	18.00 0.850	16.00 0.850	14.00 0.850
15/16	79.50 0.894	72.00 0.900	64.50 0.907	57.00 0.916	48.00 0.880	40.50 0.891	37.00 0.904	33.00 0.908	31.00 0.909	29.50 0.927	24.00 0.850	20.50 0.871	18.50 0.873	16.50 0.876	14.50 0.880
31/32	82.00 0.923	74.50 0.931	66.50 0.935	59.00 0.948	49.50 0.907	42.00 0.924	38.00 0.929	34.00 0.935	32.00 0.939	30.00 0.943	25.00 0.885	21.00 0.898	19.00 0.897	17.00 0.903	15.00 0.911
1	84.50 0.951	76.50 0.956	68.50 0.963	60.50 0.972	51.00 0.918	43.00 0.946	39.00 0.953	35.00 0.963	33.00 0.968	31.00 0.974	25.50 0.903	21.50 0.914	19.50 0.920	17.50 0.929	15.50 0.941
1 1/16	89.50 1.007	81.00 1.018	72.50 1.019	64.00 1.028	54.00 0.990	45.50 1.001	41.50 1.013	37.00 1.018	35.00 1.026	32.00 1.005	27.00 0.956	23.00 0.978	20.50 0.968	18.50 0.982	16.50 1.002
1 1/8	94.50 1.063	85.50 1.069	76.50 1.076	67.50 1.084	57.00 1.045	48.00 1.056	43.50 1.061	39.00 1.073	37.00 1.084	34.50 1.083	28.50 1.009	24.00 1.020	22.00 1.038	19.50 1.035	17.50 1.062
1 3/16	99.50 1.119	90.00 1.125	80.50 1.126	71.00 1.141	60.00 1.100	50.50 1.111	46.00 1.122	41.00 1.128	38.50 1.128	36.50 1.146	30.00 1.062	25.50 1.084	23.00 1.086	20.50 1.089	18.00 1.093
1 1/4	104.5 1.176	94.50 1.181	84.50 1.188	74.50 1.197	63.00 1.155	53.00 1.166	48.00 1.171	43.00 1.183	40.50 1.187	38.00 1.193	31.50 1.115	26.50 1.126	24.00 1.138	21.50 1.142	19.00 1.153
1 5/16		99.00 1.238	88.50 1.244	78.00 1.253	66.00 1.210	55.50 1.221	50.50 1.232	45.00 1.238	42.50 1.245	40.00 1.256	33.00 1.168	28.00 1.190	25.00 1.180	22.50 1.195	20.00 1.214
1 3/8		103.5 1.294	92.50 1.301	81.50 1.310	69.00 1.265	58.00 1.276	52.50 1.281	47.00 1.293	44.50 1.304	41.50 1.303	34.50 1.211	29.00 1.233	26.50 1.251	23.50 1.248	21.00 1.275
1 7/16			96.50 1.357	85.00 1.366	72.00 1.320	60.50 1.331	55.00 1.342	49.00 1.348	46.00 1.348	43.50 1.366	36.00 1.274	30.50 1.296	27.50 1.298	24.50 1.301	21.50 1.305
1 1/2			100.5 1.413	88.50 1.422	75.00 1.375	63.00 1.386	57.00 1.391	51.00 1.403	48.00 1.406	45.00 1.413	37.50 1.328	31.50 1.339	28.50 1.345	25.50 1.354	22.50 1.366
1 9/16			104.5 1.469	92.00 1.478	78.00 1.430	65.50 1.441	59.50 1.452	53.00 1.458	50.00 1.465	47.00 1.476	39.00 1.381	33.00 1.403	29.50 1.392	26.50 1.407	23.50 1.426
1 5/8				95.50 1.535	81.00 1.485	68.00 1.496	61.50 1.501	55.00 1.513	52.00 1.524	48.50 1.523	40.50 1.434	34.00 1.445	31.00 1.463	27.50 1.460	24.50 1.487
1 11/16				99.00 1.591	84.00 1.540	70.50 1.551	64.00 1.562	57.00 1.568	53.50 1.568	50.50 1.586	42.00 1.487	35.50 1.509	32.00 1.510	28.50 1.513	25.00 1.518
1 3/4				102.5 1.647	87.00 1.595	73.00 1.606	66.00 1.610	59.00 1.623	55.50 1.626	52.00 1.633	43.50 1.540	36.50 1.551	33.00 1.558	29.50 1.566	26.00 1.578
1 13/16				106.0 1.703	90.00 1.650	75.50 1.661	68.50 1.671	61.00 1.678	57.50 1.685	54.00 1.696	45.00 1.593	38.00 1.615	34.00 1.605	30.50 1.620	27.00 1.639
1 7/8					93.00 1.705	78.00 1.716	70.50 1.720	63.00 1.733	59.50 1.746	55.50 1.743	46.50 1.646	39.00 1.658	35.50 1.676	31.50 1.673	28.00 1.700
1 15/16					96.00 1.760	80.50 1.771	73.00 1.781	65.00 1.788	61.00 1.787	57.50 1.806	48.00 1.700	40.50 1.721	36.50 1.723	32.50 1.726	28.50 1.730
2					99.00 1.815	83.00 1.826	75.00 1.830	67.00 1.843	63.00 1.846	59.00 1.853	49.50 1.752	41.50 1.764	37.50 1.770	33.50 1.779	29.50 1.791

TABLE IV. HUNDREDTHS OF CIRCUMFERENCE EXPRESSED IN MINUTES

Hundredths of Circumference	Minutes	Hundredths of Circumference	Minutes	Hundredths of Circumference	Minutes	Hundredths of Circumference	Minutes	Hundredths of Circumference	Minutes	Hundredths of Circumference	Minutes
1.00	216	9.25	1998	17.50	3780	25.75	5562	34.00	7344	42.25	9126
1.25	270	9.50	2052	17.75	3834	26.00	5616	34.25	7398	42.50	9180
1.50	324	9.75	2106	18.00	3888	26.25	5670	34.50	7452	42.75	9234
1.75	378	10.00	2160	18.25	3942	26.50	5724	34.75	7506	43.00	9288
2.00	432	10.25	2214	18.50	3996	26.75	5778	35.00	7560	43.25	9342
2.25	486	10.50	2268	18.75	4050	27.00	5832	35.25	7614	43.50	9396
2.50	540	10.75	2322	19.00	4104	27.25	5886	35.50	7668	43.75	9450
2.75	594	11.00	2376	19.25	4158	27.50	5940	35.75	7722	44.00	9504
3.00	648	11.25	2430	19.50	4212	27.75	5994	36.00	7776	44.25	9558
3.25	702	11.50	2484	19.75	4266	28.00	6048	36.25	7830	44.50	9612
3.50	756	11.75	2538	20.00	4320	28.25	6102	36.50	7884	44.75	9666
3.75	810	12.00	2592	20.25	4374	28.50	6156	36.75	7938	45.00	9720
4.00	864	12.25	2646	20.50	4428	28.75	6210	37.00	7992	45.25	9774
4.25	918	12.50	2700	20.75	4482	29.00	6264	37.25	8046	45.50	9828
4.50	972	12.75	2754	21.00	4536	29.25	6318	37.50	8100	45.75	9882
4.75	1026	13.00	2808	21.25	4590	29.50	6372	37.75	8154	46.00	9936
5.00	1080	13.25	2862	21.50	4644	29.75	6426	38.00	8208	46.25	9990
5.25	1134	13.50	2916	21.75	4698	30.00	6480	38.25	8262	46.50	10044
5.50	1188	13.75	2970	22.00	4752	30.25	6534	38.50	8316	46.75	10098
5.75	1242	14.00	3024	22.25	4806	30.50	6588	38.75	8370	47.00	10152
6.00	1296	14.25	3078	22.50	4860	30.75	6642	39.00	8424	47.25	10206
6.25	1350	14.50	3132	22.75	4914	31.00	6696	39.25	8478	47.50	10260
6.50	1404	14.75	3186	23.00	4968	31.25	6750	39.50	8532	47.75	10314
6.75	1458	15.00	3240	23.25	5022	31.50	6804	39.75	8586	48.00	10368
7.00	1512	15.25	3294	23.50	5076	31.75	6858	40.00	8640	48.25	10422
7.25	1566	15.50	3348	23.75	5130	32.00	6912	40.25	8694	48.50	10476
7.50	1620	15.75	3402	24.00	5184	32.25	6966	40.50	8748	48.75	10530
7.75	1674	16.00	3456	24.25	5238	32.50	7020	40.75	8802	49.00	10584
8.00	1728	16.25	3510	24.50	5292	32.75	7074	41.00	8856	49.25	10638
8.25	1782	16.50	3564	24.75	5346	33.00	7128	41.25	8910	49.50	10692
8.50	1836	16.75	3618	25.00	5400	33.25	7182	41.50	8964	49.75	10746
8.75	1890	17.00	3672	25.25	5454	33.50	7236	41.75	9018	50.00	10800
9.00	1944	17.25	3726	25.50	5508	33.75	7290	42.00	9072	50.25	10854

TABLE V. HUNDREDTHS OF CIRCUMFERENCE EXPRESSED IN MINUTES

Hundredths of Circumference	Minutes	Hundredths of Circumference	Minutes	Hundredths of Circumference	Minutes	Hundredths of Circumference	Minutes	Hundredths of Circumference	Minutes	Hundredths of Circumference	Minutes
50.50	10908	59.00	12744	67.50	14580	76.00	16416	84.50	18252	93.00	20088
50.75	10962	59.25	12798	67.75	14634	76.25	16470	84.75	18306	93.25	20142
51.00	11016	59.50	12852	68.00	14688	76.50	16524	85.00	18360	93.50	20196
51.25	11070	59.75	12906	68.25	14742	76.75	16578	85.25	18414	93.75	20250
51.50	11124	60.00	12960	68.50	14796	77.00	16632	85.50	18468	94.00	20304
51.75	11178	60.25	13014	68.75	14850	77.25	16686	85.75	18522	94.25	20358
52.00	11232	60.50	13068	69.00	14904	77.50	16740	86.00	18576	94.50	20412
52.25	11286	60.75	13122	69.25	14958	77.75	16794	86.25	18630	94.75	20466
52.50	11340	61.00	13176	69.50	15012	78.00	16848	86.50	18684	95.00	20520
52.75	11394	61.25	13230	69.75	15066	78.25	16902	86.75	18738	95.25	20574
53.00	11448	61.50	13284	70.00	15120	78.50	16956	87.00	18792	95.50	20628
53.25	11502	61.75	13338	70.25	15174	78.75	17010	87.25	18846	95.75	20682
53.50	11556	62.00	13392	70.50	15228	79.00	17064	87.50	18900	96.00	20736
53.75	11610	62.25	13446	70.75	15282	79.25	17118	87.75	18954	96.25	20790
54.00	11664	62.50	13500	71.00	15336	79.50	17172	88.00	19008	96.50	20844
54.25	11718	62.75	13554	71.25	15390	79.75	17226	88.25	19062	96.75	20898
54.50	11772	63.00	13608	71.50	15444	80.00	17280	88.50	19116	97.00	20952
54.75	11826	63.25	13662	71.75	15498	80.25	17334	88.75	19170	97.25	21006
55.00	11880	63.50	13716	72.00	15552	80.50	17388	89.00	19224	97.50	21060
55.25	11934	63.75	13770	72.25	15606	80.75	17442	89.25	19278	97.75	21114
55.50	11988	64.00	13824	72.50	15660	81.00	17496	89.50	19332	98.00	21168
55.75	12042	64.25	13878	72.75	15714	81.25	17550	89.75	19386	98.25	21222
56.00	12096	64.50	13932	73.00	15768	81.50	17604	90.00	19440	98.50	21276
56.25	12150	64.75	13986	73.25	15822	81.75	17658	90.25	19494	98.75	21330
56.50	12204	65.00	14040	73.50	15876	82.00	17712	90.50	19548	99.00	21384
56.75	12258	65.25	14094	73.75	15930	82.25	17766	90.75	19602	99.25	21438
57.00	12312	65.50	14148	74.00	15984	82.50	17820	91.00	19656	99.50	21492
57.25	12366	65.75	14202	74.25	16038	82.75	17874	91.25	19710	99.75	21546
57.50	12420	66.00	14256	74.50	16092	83.00	17928	91.50	19764	100.00	21600
57.75	12474	66.25	14310	74.75	16146	83.25	17982	91.75	19818	......	......
58.00	12528	66.50	14364	75.00	16200	83.50	18036	92.00	19872	......	......
58.25	12582	66.75	14418	75.25	16254	83.75	18090	92.25	19926	......	......
58.50	12636	67.00	14472	75.50	16308	84.00	18144	92.50	19980	......	......
58.75	12690	67.25	14526	75.75	16362	84.25	18198	92.75	20034	......	......

lutions to complete one piece, 400; time to make one piece, 10 seconds. Referring to *A*, Fig. 8, the length of the threaded portion is ⅜ inch and the pitch of the thread 1/32 inch, or thirty-two threads per inch. Referring to Table II, we find that the number of revolutions required is 15 and the rise on the cam 0.413. To construct the lobe, convert the revolutions into hundredths of cam surface, or $\frac{15}{400} = 0.0375$, or 3¾ hundredths. Then draw the cam circle *B*, as shown in Fig. 8, and lay off on this circle 3¾ hundredths to advance on the screw and 3¾ hundredths to withdraw. Cut down the amount *C* below the outer cam circle *B* as required. Bisect the rise at *E*, and with *OE* as a radius and *a*, *b*, and *c* as centers draw arcs intersecting each other at *d* and *e*. With *d* as a center and radius *OE* join points *b* and *a;* with *e* as a center and radius *OE* join points *c* and *a*. This gives the shape of the thread lobe. For convenience in cutting, when a Brown & Sharpe circular milling attachment is available, the cam surface used for threading is divided into minutes. Then to obtain the lead (or the number of minutes traversed for each 1/1000 inch rise) divide the number of minutes contained in the portion of the lobe used, by the rise. For example, $\frac{0.810}{0.413} = 1.96$, or approximately 2 minutes. The equivalents of hundredths and minutes are tabulated in Tables IV and V. The information as derived by the various formulas is recorded on the drawing as shown in Fig. 8, being used by the toolmaker when cutting the cam.

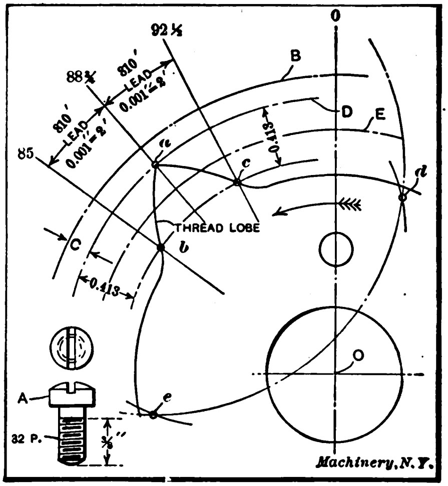


Fig. 8. Improved Method of Constructing Thread Lobe

Speed-changing Device

When threading brass, the spindle speed used for the other tools is generally also suitable for taps and dies, but when threading gun-screw iron, Norway iron, machine steel, tool steel, etc., the speed used is too high. As has been previously explained under the heading "Reversing the Spindle," time would be lost in threading if the machine were reversed from forward to backward and then forward again on the No. 00 Brown & Sharpe automatic screw machine. There are various methods of overcoming this difficulty. One method is to run the spindle backward with the large pulley and forward with the small pulley on the countershaft. There is an objection to this, however, *viz.*, as there are generally other tools in the turret besides the die or tap holder. They would either have to be made to cut left-hand or else run at the same speed as the tap or die. It can easily be seen that in the majority of cases, the tools used in the turret would not be working at their maximum capacity if made to cut right-hand.

Ratio Threading Attachment

The attachment *A*, shown in position in the turret in Fig. 9, serves to revolve the die or tap in the same direction as that in which the spindle is rotating, but at one-half the spindle speed. As before mentioned, it is used where no other slow movements are required except for threading, enabling the spindle to run at its maximum speed for all the other operations. The attachment is driven by a ⅜-inch round belt from the overhead works, the shaft passing through the turret head connecting pulley *C* with bevel gears *D*, thus driving the attachment *A*. Spring *E* acts in the same manner as the spring in the ordinary draw-out die or tap holder. The method of determining the shape of the cam lobe when using this attachment is as follows: Let the spindle speed for the forming and cut-off operations equal 2400 revolutions per minute; then the forward speed of the spindle for threading is 1200, and the speed of this attachment 600 revolutions per minute. Assume the length of the threaded portion to be 3/16 inch and that 40 threads per inch are to be cut. Referring to Table II, we find that the thread cutting will require 10.5 revolutions. But considering that the speed of this attachment is one-half the spindle speed, we would require 10.5 × 2 = 21 revolutions of the spindle for cutting the thread. Again, as this attachment rotates in the same direction as the spindle, the speed of the attachment when backing off the work would be 2400 + 600 or 3000 revolutions per min-

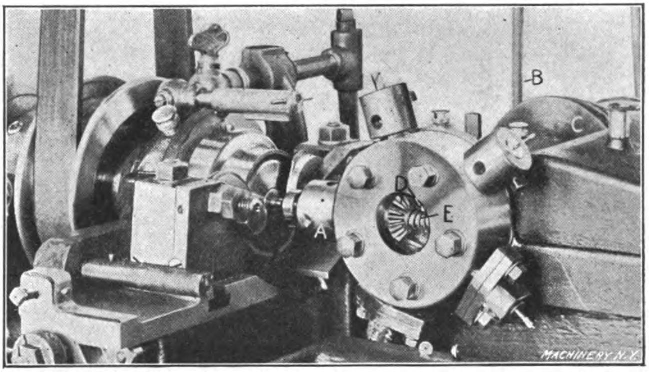


Fig. 9. Ratio Threading Attachment

ute. Then the number of revolutions of the spindle required for backing off the work would be $\frac{2400}{3000} \times 10.5$, or 8.5 revolutions, approximately. The same rise, 0.231, as given in Table II, is used for each side of the thread lobe, but the distance along the cam circumference in each part of the lobe is different, as it requires 21 revolutions to advance and only 8.5 revolutions to retreat.

Belt Shifting Attachment

The ratio threading attachment as shown in Fig. 9 is only suitable for cutting brass and fine threads on Norway iron, machine steel, etc.

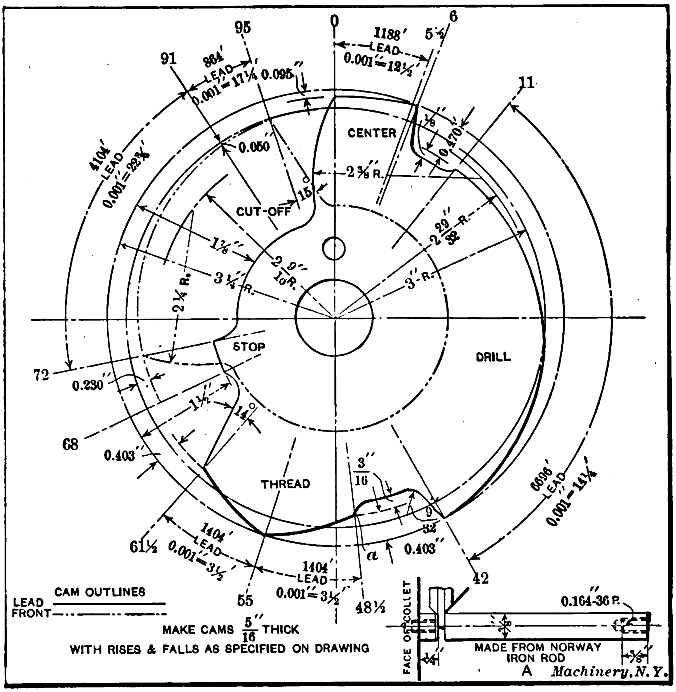


Fig. 10. Example of Design of Thread Lobe when using Belt Shifting Attachment

This attachment would not be entirely satisfactory for the No. 0 or No. 2 Brown & Sharpe automatic screw machine, as a more positive drive is generally required for these machines. In Fig. 2 is shown the No. 0 Brown & Sharpe automatic screw machine equipped with a speed-changing attachment. The countershaft is supplied with a large and a small pulley which will give the desired spindle speeds. This attachment is operated by the same dog and lever that reverse the spindle. When the dog on the cam shaft trips the lever, the clutches *C* and C_1 engage, thus driving gears *D* and *E*. Gear *E*, being attached to shaft *F*, revolves disk *G* on which the eccentric connecting-rod *H* is attached. When the rod *H* is drawn up or down it shifts the belt from the large to the small pulley or *vice versa*. The system of gearing provided shifts the belt twice for every revolution of the driving shaft. The number of revolutions of the spindle required to shift the belt with the spindle running at 1800 R. P. M. forward speed equals 7½ revolutions.

To explain the method of designing the thread lobe, we will take a practical example. Assume that it is required to make the piece as shown at *A*, Fig. 10, on the No. 0 machine, the spindle speeds being 1800 and 900 revolutions per minute, respectively, using the 900 revolutions per minute for tapping. The cams for making this piece are shown in Fig. 10. The time required to make one piece is 17 seconds, or 510 revolutions. The number of revolutions for threading found in Table II is 16.5; but as the tap will run at 900 revolutions per minute instead of 1800, we will require a time equivalent to 16.5×2 or 33 revolutions at the 1800 R. P. M. speed for threading. Then the hundredths required equals $\frac{33}{510} = 0.0647$, or approximately 6½ hundredths. The rise on the cam is given in Table II as 0.403. Referring to Table II, MACHINERY's Reference Book No. 100, we find that it will require 4/100 to feed the stock, or 5/100 to revolve the turret; this equals 25.5 revolutions to revolve the turret. Then the actual number of hundredths of cam circumference between the last operation and the starting of the thread lobe, to revolve the turret and reverse the spindle is $25.5 + 7.5 = 33$ revolutions. Converting this into hundredths, we get 6.47 or approximately 6½ hundredths. It is always good practice to allow plenty of clearance for threading as the die or tap holder intended for the job may have to be replaced by one which would require more clearance.

CHAPTER II

TAPS AND DIES FOR SCREW MACHINE WORK

In Fig. 11 is shown the common form of spring screw threading die with its adjustable ring. Dies of this type are used to a large extent on the Brown & Sharpe automatics, but the results obtained are not always entirely satisfactory. There are a number of objections to this type of die. The common method of making these dies is to hob them out with a tap larger in diameter than the basic screw, and then to close them in by means of the adjusting ring shown. This produces an imperfect thread if a tap much larger in diameter than the basic size of the screw is used. The correct method of tapping out a die of this kind is to use a taper tap which gives clearance at the back of the die. This necessitates the making of taper taps which adds to the expense of the die. This type of die is also difficult to harden without springing the prongs, thus causing chattering and producing a thread which is not correct in shape. Making a die with three prongs or cutting edges obviates chattering and produces a more nearly perfect thread. When cutting a small screw, the work sometimes breaks off in the die, making it practically useless, because in drilling out the broken pieces, the thread in the die is almost always injured. A type of die which overcomes this latter objection is shown in Fig. 12, the die here shown being split, allowing the broken screw to be easily removed. The location of the cutting edges on spring screw threading dies should be radial for brass, and about one-tenth of the diameter ahead of the center for Norway iron, machine steel, etc.

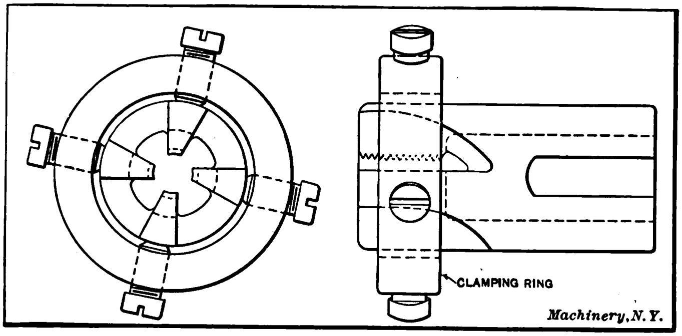


Fig. 11. Spring Screw Threading Die and Adjusting Ring

Adjustable Round Split Threading Dies

The adjustable round split die has an advantage over the spring screw threading die for the following reasons: It can be hardened without springing out of shape, and can be held more rigidly, which produces good results; and although it cannot be ground to advantage, its first cost is so much less than that of the spring screw threading die that it can be discarded when dull. On account of the rigid manner in which this die can be held, the cutting edges in all cases can be located ahead of the center about one-tenth of the diameter which gives good results. In Fig. 13 is shown a type of adjustable round split button die as used by the Northern Electric & Mfg. Co., Ltd., of Montreal. This type of die has been found to give such favorable results that it is used by this firm in preference to all other types for screw machine work. In Tables VI and VII are given the sizes used by the above firm in making their dies for the A. S. M. E. standard and special screw sizes. The formulas used for the dies are as follows:

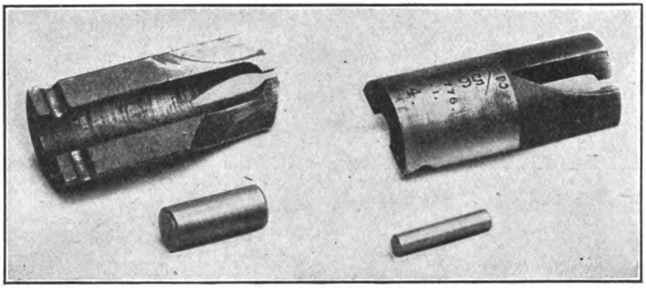


Fig. 12. Split Spring Screw Threading Die

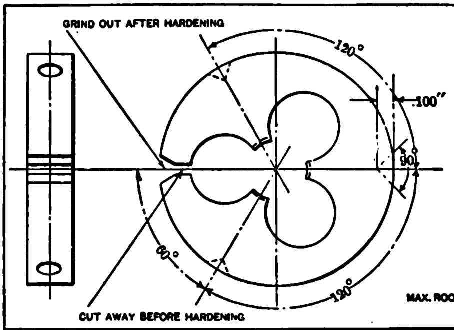


Fig. 13. General Dimensions and Design of Approved Type of Adjustable Round Split Button Die

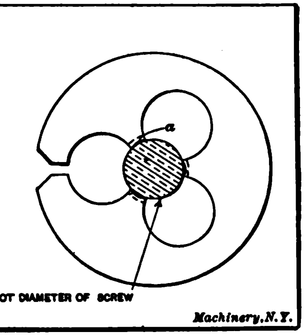


Fig. 14. Illustration showing Clearance for Adjustable Round Split Button Die

External diameter = basic external diameter of screw,

Pitch diameter = basic pitch diameter of screw,

$$\text{Root diameter} = \text{basic root diameter of screw} + \frac{0.10825}{\text{No. of threads per inch}}$$

This latter amount $\frac{0.10825}{\text{No. of threads per inch}}$ is added to the basic root diameter to provide for wear. While the sizes as given have been used by the firm mentioned, for a considerable time, theoretically it is not the correct way of making the die, because, to cut a clean thread, a die should have clearance as shown at *a*, Fig. 14, and as a screw is generally cut below the maximum diameter, the sizes as given would not provide any clearance at all; in fact it would be just the reverse, as the die would have to be closed, instead of opened up. When good results are desired the die should be tapped out smaller than the basic screw, and then opened up, as this would give a good clearance as shown, enlarged, at *a*, Fig. 14. Making the root diameter of the die the same as the minimum screw would give the desired results. This has been experimented with and the results obtained were perfectly satisfactory. The following formulas should then be used for obtaining the sizes of adjustable round split button dies:

TABLE VI. ADJUSTABLE ROUND SPLIT SCREW THREAD BUTTON DIE SIZES FOR A. S. M. E. STANDARD SCREWS

Size of Screw and Number of Threads Per Inch	External Diameter	Pitch Diameter	Root Diameter
0.060 — 80	0.060	0.0519	0.0424
0.073 — 72	0.073	0.0640	0.0535
0.086 — 64	0.086	0.0759	0.0640
0.099 — 56	0.099	0.0874	0.0739
0.112 — 48	0.112	0.0985	0.0827
0.125 — 44	0.125	0.1102	0.0930
0.138 — 40	0.138	0.1218	0.1028
0.151 — 36	0.151	0.1330	0.1119
0.164 — 36	0.164	0.1460	0.1249
0.177 — 32	0.177	0.1567	0.1330
0.190 — 30	0.190	0.1684	0.1431
0.216 — 28	0.216	0.1928	0.1658
0.242 — 24	0.242	0.2149	0.1834
0.268 — 22	0.268	0.2385	0.2040
0.294 — 20	0.294	0.2615	0.2236
0.320 — 20	0.320	0.2875	0.2496
0.346 — 18	0.346	0.3099	0.2678
0.372 — 16	0.372	0.3314	0.2841
0.398 — 16	0.398	0.3574	0.3101
0.424 — 14	0.424	0.3776	0.3235
0.450 — 14	0.450	0.4036	0.3495

External diameter = basic external diameter of screw,

Pitch diameter = minimum pitch diameter of screw, or basic pitch diameter of screw $- \frac{0.168}{\text{No. of threads per inch} + 40}$

Root diameter = minimum root diameter of screw or basic root diameter $- \frac{0.10825}{\text{No. of th'ds per inch}} + \frac{0.168}{\text{No. of th'ds per inch} + 40}$

Making the external diameter equal to the basic external diameter allows for clearance, which is necessary, as the external diameter of the die should not be used for cutting the screw to size. This should be accomplished either by a finishing box-tool or by the cross-slide forming tools. It is obvious that making the dies to the sizes given in the formulas permits them to be used longer and still cut a clean thread. The work should be turned slightly smaller than the finished diameter required, depending on the material and the pitch of the thread.

TABLE VII. ADJUSTABLE ROUND SPLIT SCREW THREAD BUTTON DIE SIZES FOR A. S. M. E. SPECIAL SCREWS

Size of Screw and Number of Threads Per Inch	External Diameter	Pitch Diameter	Root Diameter
0.073 — 64	0.073	0.0629	0.0510
0.086 — 56	0.086	0.0744	0.0609
0.099 — 48	0.099	0.0855	0.0697
0.112 — 40	0.112	0.0958	0.0768
0.112 — 36	0.112	0.0940	0.0729
0.125 — 40	0.125	0.1088	0.0898
0.125 — 36	0.125	0.1070	0.0859
0.138 — 36	0.138	0.1200	0.0989
0.138 — 32	0.138	0.1177	0.0940
0.151 — 32	0.151	0.1307	0.1070
0.151 — 30	0.151	0.1294	0.1041
0.164 — 32	0.164	0.1437	0.1200
0.164 — 30	0.164	0.1424	0.1171
0.177 — 30	0.177	0.1554	0.1301
0.177 — 24	0.177	0.1499	0.1184
0.190 — 32	0.190	0.1697	0.1460
0.190 — 24	0.190	0.1629	0.1314
0.216 — 24	0.216	0.1889	0.1574
0.242 — 20	0.242	0.2095	0.1716
0.268 — 20	0.268	0.2355	0.1976
0.294 — 18	0.294	0.2579	0.2158
0.320 — 18	0.320	0.2839	0.2418
0.346 — 16	0.346	0.3054	0.2581
0.372 — 18	0.372	0.3359	0.2938
0.398 — 14	0.398	0.3516	0.2975
0.424 — 16	0.424	0.3834	0.3361
0.450 — 16	0.450	0.4094	0.3621

Tables for laying-out button dies are given in MACHINERY'S Data Sheet Book No. 3, "Taps and Dies," pages 30 and 31.

Machine Taps

Internal threading on the automatic screw machine presents certain difficulties. There is a tendency for the chips to clog and to break the tap at the moment of reversal, as the chips then lodge back of the cutting edges, tending to prevent the tap from reversing. The spindle revolving at a high rate of speed also has a tendency to break the tap. Taps for screw machine work should have liberal space for the chips, the lands being made just strong enough to resist the cutting pressure.

TABLE VIII. MACHINE TAPS FOR A. S. M. E. STANDARD SIZES

Size of Screw and Number of Threads Per Inch	Manufacturing Limits						Diameter of Shank, Stubbs' Wire Gage or Inches	Length of Threaded Portion	Length Overall
	External Diameter		Pitch Diameter		Root Diameter				
	Maximum	**Minimum**	Maximum	Minimum	Maximum	Minimum			
0.060 — 80	0.0632	0.0623	0.0538	0.0533	0.0466	0.0447	51	3/8	1 1/4
0.073 — 72	0.0765	0.0755	0.0660	0.0655	0.0580	0.0560	47	1/2	1 3/8
0.086 — 64	0.0898	0.0888	0.0780	0.0775	0.0689	0.0668	42	9/16	1 3/8
0.099 — 56	0.1033	0.1021	0.0897	0.0892	0.0793	0.0770	36	9/16	1 1/2
0.112 — 48	0.1168	0.1155	0.1010	0.1004	0.0888	0.0862	31	5/8	1 1/2
0.125 — 44	0.1301	0.1288	0.1129	0.1122	0.0995	0.0968	29	5/8	1 1/2
0.138 — 40	0.1435	0.1421	0.1246	0.1239	0.1097	0.1069	26	5/8	1 1/2
0.151 — 36	0.1569	0.1555	0.1359	0.1352	0.1193	0.1164	21	11/16	1 1/2
0.164 — 36	0.1699	0.1685	0.1489	0.1482	0.1323	0.1294	17	11/16	1 1/2
0.177 — 32	0.1835	0.1819	0.1598	0.1590	0.1411	0.1380	12	3/4	1 5/8
0.190 — 30	0.1968	0.1952	0.1716	0.1708	0.1515	0.1483	8	3/4	1 5/8
0.216 — 28	0.2232	0.2215	0.1961	0.1953	0.1745	0.1712	1/4	1	2 1/2
0.242 — 24	0.2500	0.2483	0.2184	0.2176	0.1931	0.1896	9/32	1	2 1/2
0.268 — 22	0.2765	0.2747	0.2421	0.2412	0.2144	0.2108	9/32	1	2 1/2
0.294 — 20	0.3031	0.3013	0.2653	0.2643	0.2346	0.2309	5/16	1	2 1/2
0.320 — 20	0.3291	0.3273	0.2913	0.2903	0.2606	0.2569	11/32	1	2 3/4
0.346 — 18	0.3559	0.3539	0.3138	0.3128	0.2796	0.2758	3/8	1	2 3/4
0.372 — 16	0.3828	0.3808	0.3354	0.3344	0.2968	0.2928	13/32	1	2 3/4
0.398 — 16	0.4088	0.4068	0.3614	0.3604	0.3228	0.3188	7/16	1	2 3/4
0.424 — 14	0.4359	0.4338	0.3818	0.3807	0.3374	0.3333	15/32	1	2 3/4
0.450 — 14	0.4619	0.4598	0.4078	0.4067	0.3634	0.3593	1/2	1	2 3/4

TABLE IX. MACHINE TAPS FOR A. S. M. E. SPECIAL SIZES

Size of Screw and Number of Threads Per Inch	Manufacturing Limits						Diameter of Shank, Stubbs' Wire Gage or Inches	Length of Threaded Portion	Length Overall
	External Diameter		Pitch Diameter		Root Diameter				
	Maximum	Minimum	Maximum	Minimum	Maximum	Minimum			
0.073 — 64	0.0768	0.0758	0.0650	0.0645	0.0559	0.0538	47	½	1⅜
0.086 — 56	0.0903	0.0891	0.0767	0.0762	0.0663	0.0640	42	9/16	1⅜
0.099 — 48	0.1038	0.1025	0.0880	0.0874	0.0758	0.0732	36	9/16	1½
0.112 — 40	0.1175	0.1161	0.0986	0.0979	0.0837	0.0809	31	⅝	1½
0.112 — 36	0.1179	0.1165	0.0969	0.0962	0.0803	0.0774	31	⅝	1½
0.125 — 40	0.1305	0.1291	0.1116	0.1109	0.0967	0.0939	29	⅝	1½
0.125 — 36	0.1309	0.1295	0.1099	0.1092	0.0933	0.0904	29	⅝	1½
0.138 — 36	0.1439	0.1425	0.1229	0.1222	0.1063	0.1034	26	⅝	1½
0.138 — 32	0.1445	0.1429	0.1208	0.1200	0.1021	0.0990	26	⅝	1½
0.151 — 32	0.1575	0.1559	0.1338	0.1330	0.1151	0.1120	20	11/16	1½
0.151 — 30	0.1578	0.1562	0.1326	0.1318	0.1125	0.1093	20	11/16	1½
0.164 — 32	0.1705	0.1689	0.1468	0.1460	0.1281	0.1250	17	11/16	1½
0.164 — 30	0.1708	0.1692	0.1456	0.1448	0.1255	0.1223	17	11/16	1½
0.177 — 30	0.1838	0.1822	0.1586	0.1578	0.1385	0.1353	12	¾	1⅝
0.177 — 24	0.1850	0.1833	0.1534	0.1526	0.1281	0.1246	12	¾	1⅝
0.190 — 32	0.1965	0.1949	0.1728	0.1720	0.1541	0.1510	8	¾	1⅝
0.190 — 24	0.1980	0.1963	0.1664	0.1656	0.1411	0.1376	7	¾	1⅝
0.216 — 24	0.2240	0.2223	0.1924	0.1916	0.1671	0.1636	¼	1	2½
0.242 — 20	0.2511	0.2493	0.2133	0.2123	0.1827	0.1789	9/32	1	2½
0.268 — 20	0.2771	0.2753	0.2393	0.2383	0.2087	0.2049	9/32	1	2½
0.294 — 18	0.3039	0.3019	0.2618	0.2608	0.2276	0.2238	5/16	1	2½
0.320 — 18	0.3299	0.3279	0.2878	0.2868	0.2536	0.2498	11/32	1	2¾
0.346 — 16	0.3568	0.3548	0.3094	0.3084	0.2708	0.2668	⅜	1	2¾
0.372 — 18	0.3819	0.3799	0.3398	0.3388	0.3056	0.3018	13/32	1	2¾
0.398 — 14	0.4099	0.4078	0.3558	0.3547	0.3114	0.3073	7/16	1	2¾
0.424 — 16	0.4348	0.4328	0.3874	0.3864	0.3488	0.3448	15/32	1	2¾
0.450 — 16	0.4608	0.4588	0.4134	0.4124	0.3748	0.3708	½	1	2¾

Of course, the flutes must not be made too deep, so as to reduce the cross-section of the tap too much. The cutting edges are, in general, radial.

In Tables VIII and IX are given the manufacturing limits, as adopted by the Northern Electric & Mfg. Co., Ltd., Montreal, for the A. S. M. E. standard and special sizes. The taps are made from Stubbs' imported drill rod. The diameters of shank used are given in the tables, and also the length of the threaded portion and the over-all length. All taps 0.100 inch in diameter and less, have three flutes, and all taps over 0.100 inch in diameter have four flutes. The formulas used by the above firm for the manufacturing limits are as follows (*T. P. I.* = threads per inch):

EXTERNAL DIAMETER

$$\text{Maximum} = \text{basic external diameter of screw} + \frac{0.10825}{T.P.I.} + \frac{0.224}{T.P.I. + 40}$$

$$\text{Minimum} = \text{basic external diameter of screw} + \frac{0.10825}{T.P.I.} + \frac{0.112}{T.P.I. + 40}$$

PITCH DIAMETER

$$\text{Maximum} = \text{basic pitch diameter of screw} + \frac{0.224}{T.P.I. + 40}$$

$$\text{Minimum} = \text{basic pitch diameter of screw} + \frac{0.168}{T.P.I. + 40}$$

ROOT DIAMETER

$$\text{Maximum} = \text{basic root diameter of screw} + \frac{0.336}{T.P.I. + 40}$$

$$\text{Minimum} = \text{basic root diameter of screw} + \frac{0.112}{T.P.I. + 40}$$

The only changes from the A. S. M. E. formulas for the taps are the minimum external diameter, and the minimum pitch diameters. The reason for increasing the minimum external diameters can easily be seen by comparing the results as obtained by the formulas used by the Northern Electric & Mfg. Co. and the A. S. M. E. respectively. For example: Take a tap 0.164—36 threads per inch. The minimum external diameter given by the A. S. M. E. is 0.1656 inch. Now the maximum or basic screw is 0.164 inch. This leaves 0.0016 inch for wear, when the tap has been made the minimum size. This amount has been found not to be sufficient. The minimum external diameter, as found by the formula used by the Northern Electric & Mfg. Co., is 0.1685 inch, which gives 0.0045 inch over the basic screw. As will also be noted, this decreases the limit between the maximum and minimum external diameters of the tap, allowing only 0.0014 inch. In all cases the limits as derived by these formulas have been found to be sufficient. It will also be noted that the minimum pitch diameter is also increased to extend the life of the tap. In Table X the results as obtained by the various formulas are given, which simplifies the calculations necessary in determining the limits, as the amounts given are added to the basic sizes of the screw. In the last two columns are given the single and double depth of the thread.

TABLE X. CALCULATED VALUES FOR FORMULAS FOR FINDING MANUFACTURING LIMITS FOR TAP AND DIE SIZES

No. of Threads Per Inch	Value of $\frac{0.10825''}{\text{T.P.I.}}$	Value of $\frac{0.112''}{\text{T.P.I.}+40}$	Value of $\frac{0.224''}{\text{T.P.I.}+40}$	Value of $\frac{0.336''}{\text{T.P.I.}+40}$	Value of $\frac{0.168''}{\text{T.P.I.}+40}$	Value of $\frac{0.64952''}{\text{T.P.I.}}$	Value of $\frac{1.29904''}{\text{T.P.I}}$
80	0.0014	0.0009	0.0019	0.0028	0.0014	0.0081	0.0162
72	0.0015	0.0010	0.0020	0.0030	0.0015	0.0090	0.0180
64	0.0017	0.0011	0.0022	0.0032	0.0016	0.0101	0.0203
56	0.0019	0.0012	0.0023	0.0035	0.0018	0.0116	0.0232
48	0.0023	0.0013	0.0025	0.0038	0.0019	0.0135	0.0271
44	0.0025	0.0013	0.0027	0.0040	0.0020	0.0148	0.0295
40	0.0027	0.0014	0.0028	0.0042	0.0021	0.0162	0.0325
36	0.0030	0.0015	0.0029	0.0044	0.0022	0.0180	0.0361
32	0.0034	0.0016	0.0031	0.0047	0.0023	0.0203	0.0406
30	0.0036	0.0016	0.0032	0.0048	0.0024	0.0217	0.0433
28	0.0039	0.0016	0.0033	0.0049	0.0025	0.0232	0.0464
24	0.0045	0.0018	0.0035	0.0053	0.0026	0.0271	0.0541
22	0.0049	0.0018	0.0036	0.0054	0.0027	0.0295	0.0590
20	0.0054	0.0019	0.0037	0.0056	0.0028	0.0325	0.0650
18	0.0060	0.0019	0.0039	0.0058	0.0029	0.0361	0.0722
16	0.0068	0.0020	0.0040	0.0060	0.0030	0.0406	0.0812
14	0.0077	0.0021	0.0041	0.0062	0.0031	0.0464	0.0928

An ordinary machine tap is suitable for cutting brass, but it does not give satisfactory results when tapping Norway iron, machine steel, etc. In Fig. 15 is shown a tap which gives good results in threading Norway iron or machine steel. This tap should be slightly tapered towards the back for clearance. The end is ground at an angle of about 55 degrees, and slightly cupped at the center, and backed off as shown. A groove is ground the entire length of the threaded portion, after the tap has been hardened. This allows the oil to penetrate to the point in threading, and also provides clearance for the chips to back out. When made from Stubbs' imported drill rod and carefully hardened, this tap can be worked at a cutting speed of from 35 to 40 feet per minute, which would be impossible with an ordinary tap. Taps for threading copper have their flutes cut spirally and should

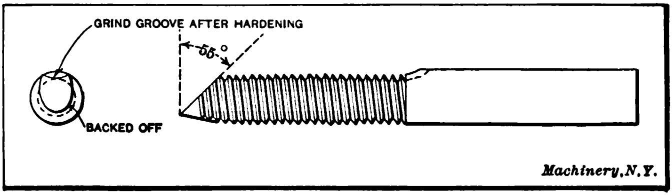


Fig. 15. A Tap Suitable for Norway Iron and Machine Steel

also have an odd number of flutes. A right-hand spiral of about one turn in 12 inches should be used.

Tap Drills

The tapping size drills as recommended by the A. S. M. E. are not suitable for general work. The question of tap drills cannot be settled by giving a table and saying that the sizes therein contained are the best. Of course, to a certain extent, the sizes used in various shops do not vary greatly, but nevertheless there is really no standard size. Considering this, the writer submits a list of tapping size drills which have been adopted by the Northern Electric & Mfg. Co. for general work. These sizes have given good results in practice. The sizes as given in Table XI are used for all classes of work and material. The amount of thread obtained by these sizes is from ⅝ to ¾ of a full thread.

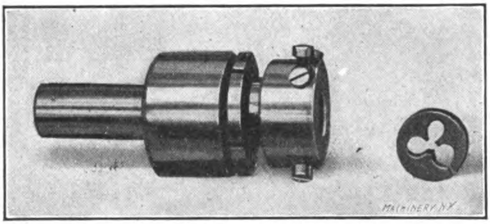


Fig. 16. Button Die Holder of the Draw-out Type

Speeds for Dies and Taps

As a general rule, a die can be operated at a higher rate of speed than a tap, for the following reasons: A die can be left harder than a tap; and the die can be supplied with oil much easier than can the tap. The following surface speeds have been found suitable for taps and dies made from ordinary carbon steel and used on the materials specified below:

SURFACE SPEEDS FOR DIES

Material	Feet per Minute
Brass (ordinary quality)	190-200
Norway iron and machine steel	30-40
Drill rod and tool steel	20-30

SURFACE SPEEDS FOR TAPS

Material	Feet per Minute
Brass (ordinary quality)	150-160
Norway iron and machine steel	25-30
Drill rod and tool steel	15-20

Die and Tap Holders

The manner in which a die or tap is held when being applied to the work has a considerable bearing on the results obtained. The die or tap holders supplied by the Brown & Sharpe Mfg. Co. give satisfactory results in most cases, and, therefore, these holders should be used for general automatic screw machine work. In Fig. 16 is shown a button die holder of the draw-out type, as made by the above firm. This holder gives good results when the work is not required to be threaded up to a shoulder. In Fig. 17 is shown an improved design of releasing button die holder also made by this firm, a section through the holder

TABLE XI. TAP DRILLS FOR A. S. M. E. STANDARD AND SPECIAL MACHINE SCREWS

Special sizes are marked *

Size of Screw and Number of Threads Per Inch	Size of Tap Drill	Decimal Equivalent of Tap Drill	Size of Screw and Number of Threads Per Inch	Size of Tap Drill	Decimal Equivalent of Tap Drill
0.060 — 80	56	0.0465	*0.177 — 24	27	0.1440
0.073 — 72	53	0.0595	*0.190 — 32	19	0.1660
*0.073 — 64	53	0.0595	0.190 — 30	20	0.1610
0.086 — 64	49	0.0730	*0.190 — 24	21	0.1590
*0.086 — 56	50	0.0700	0.216 — 28	13	0.1850
0.099 — 56	45	0.0820	*0.216 — 24	14	0.1820
*0.099 — 48	46	0.0810	0.242 — 24	5	0.2055
0.112 — 48	42	0.0935	*0.242 — 20	7	0.2010
*0.112 — 40	43	0.0890	0.268 — 22	1	0.2280
*0.112 — 36	43	0.0890	*0.268 — 20	1	0.2280
0.125 — 44	37	0.1040	0.294 — 20	1/4	0.2500
*0.125 — 40	37	0.1040	*0.294 — 18	1/4	0.2500
*0.125 — 36	38	0.1015	0.320 — 20	J	0.2770
0.138 — 40	32	0.1160	*0.320 — 18	J	0.2770
*0.138 — 36	33	0.1130	0.346 — 18	19/64	0.2968
*0.138 — 32	32	0.1160	*0.346 — 16	19/64	0.2968
0.151 — 36	30	0.1285	*0.372 — 18	21/64	0.3281
*0.151 — 32	1/8	0.1250	0.372 — 16	P	0.3230
*0.151 — 30	1/8	0.1250	0.398 — 16	11/32	0.3437
0.164 — 36	28	0.1405	*0.398 — 14	11/32	0.3437
*0.164 — 32	28	0.1405	*0.424 — 16	3/8	0.3750
*0.164 — 30	28	0.1405	0.424 — 14	U	0.3680
0.177 — 32	24	0.1520	*0.450 — 16	13/32	0.4062
*0.177 — 30	24	0.1520	0.450 — 14	25/64	0.3906

being shown at *A*. The main feature of this die holder is that it can be reversed without shock; therefore, when threading small screws, it has less tendency to break off the screw in the die. At *B* and *C* are shown two views at the cross-section *X Y*. At *B* and *C* are also shown two small balls *e* which are used, allowing this die holder to reverse without shock. The operation of the holder is as follows: When the die holder or spindle *a* draws out from the body *b*, the driving pins *c* are also withdrawn, so that the ends of these pins are drawn out flush with the plate *m*. When the machine spindle is reversed, spindle *a* revolves with the work, the centrifugal force throwing the ball *e* out of the deep part of the pocket as shown at *B* into the position as shown at *C*. This locks the holder, allowing it to be backed off the work. This holder can be used either for right- or left-hand threading simply by inserting the balls *e* in the different pockets, *e. g.*, when ball

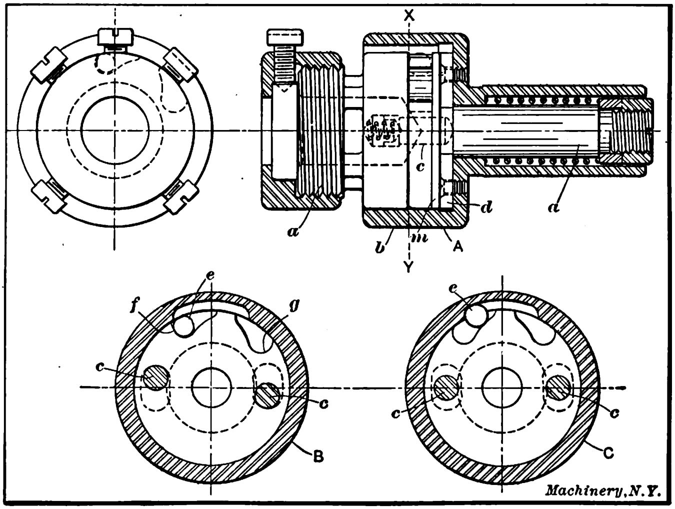


Fig. 17. Illustration showing Operating Parts of Releasing Button Die Holder

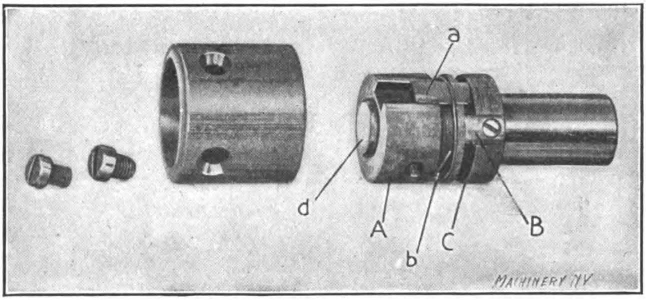


Fig. 18. Releasing Tap Holder

e is placed in pocket *f* it will cut a right-hand thread, and when placed in pocket *g* it will cut a left-hand thread. This holder is used to advantage, especially when cutting up to a shoulder.

In Fig. 18 is shown a releasing tap holder. The spindle *A* carries a pawl *a*, which is held back against the shoulder *C* by the spring *b*. When the spindle *A* is drawn out, the beveled portion on the pawl *a* allows it to slide past block *B*, thus allowing the spindle *A* to make one revolution, when the opposite face of pawl *b* comes in contact with block *B*, thus allowing the tap to back out of the work. A blank bushing *d* is shown in the holder.

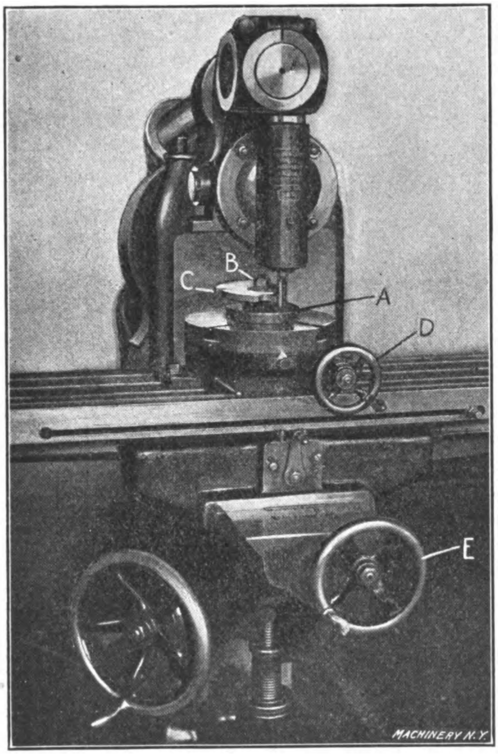


Fig. 19. Cutting Thread Lobe on a Circular Milling Attachment

Using Two Taps

When a full thread is desired and the size of the tap will not stand the cutting pressure, it is sometimes found convenient to use two taps. The first tap should be ground tapered somewhat similar to a starting tap used for hand tapping. The taper should extend back a distance equal to that which the tap is to go into the work, so that the first thread in the work will be to the full diameter. The second tap is left with a full thread. To set the taps, the dogs on the drum should be set so that the spindle will be reversing at about the same point on both the thread lobes. Then the first tap is set and made to travel into the work the desired distance. The second tap is then set in the turret, the distance from the face of the turret being the same as for the first tap. If this procedure is followed, little difficulty will be encountered. A releasing tap holder as shown in Fig. 18 is preferable to the draw-out type for this purpose, as the taps are not required to be set as accurately.

Cutting the Thread Lobe

In Fig. 19 is shown a circular milling attachment in position on the Brown & Sharpe universal milling machine, equipped with a vertical milling attachment. Before cutting the cam the various lobes are laid out in their respective positions as designated on the drawing, and the metal is removed either by shearing in a punch press or by drilling a series of 3/16-inch holes about 1/16 inch from the outline of the various lobes. The cam is then placed on block *A*, as shown, which has a projecting stud, nut *B* being used to hold down the cam tightly against the face of this block. The block is held to the circular milling attachment by two screws not shown in the illustration. To cut the cam, raise the knee until the end mill passes the lower face of the cam *C* as shown, and bring the end mill into position at the bottom of the lobe, in other words, at the point where the die would start on the work. Then feed in the end mill the desired distance. The micrometer collars on the shafts carrying handles *D* and *E* are then set at zero. Referring to Fig. 10, we find that the lead on the lobe is one thousandth inch for each 3½ minutes of its circumference, but the smallest division on this attachment is five minutes. We will, therefore, revolve the attachment five minutes for each 0.0015 inch that we feed in the cam, continuing in this manner until that side of the lobe is finished. The attachment is then swung around and the other side of the lobe completed in the same manner. Milling the cam in this manner leaves a series of slight flats on the lobe which can be removed by filing, giving the cam lobe an approximately true curve.

CHAPTER III

THREAD ROLLING

The rolling of threads has for a considerable time been practiced in the manufacture of machine and wood screws, the threads being formed by dies which have V-grooves in their opposing faces, cut at an angle equal to the helix of the thread. The operation of rolling a screw in a thread rolling machine consists in passing the screw between two flat dies, one of which is stationary and the other reciprocating. This is the principle on which some of the thread rolling machines on the market work, while others have one stationary hollow cylindrical die and one revolving circular die. However, the principle on which they act is the same; that is, part of the material is raised to form the thread by forming a corresponding depression in the blank. This action makes the diameter of the finished screw larger than the blank.

The adaptation of thread rolling to the automatic screw machine is, however, of comparatively recent application—hence the scarcity of definite information on the subject. After considerable experimenting with this class of work, the Brown & Sharpe Mfg. Co. has found that the rolling of threads on steel parts is a very unsatisfactory practice, and thus confines the rolling of threads to brass and similar materials. The information given in this chapter, therefore, applies exclusively to the rolling of threads on these materials.

Obtaining the Diameter of the Blank

The rolling of a thread differs from cutting a thread with a V-tool, in that by the former method no material is cut away, the thread being formed by displacing the material, as stated. Theoretically, in a sharp V-thread, the volume of one convolution of thread above the pitch diameter should be greater than that of the space between the threads below the pitch diameter, on account of the greater circumference. Therefore, the diameter of the blank before rolling should presumably be greater than the pitch diameter. This, however, is not the case for all materials, brass in particular being an exception. As a rule, the diameter of the blank for brass should be approximately equal to the pitch diameter.

When rolling a U. S. standard thread, the pitch diameter is found to be slightly greater than the required diameter of the blank, because of the impracticability of making the thread roll with a flat top. If a thread roll is not made with a sharp V at the top, it will require a considerably greater pressure to force it into the work, and the roll does not produce as smooth and perfect a thread. Therefore, it has been found advisable to make all thead rolls, whether for forming a sharp V or a U. S. standard thread, with a sharp V top and bottom.

It is not necessary to make the bottom of the thread on the roll sharp, but there would be no advantage in having it flat, as the outside diameter of the screw is governed by the diameter of the blank.

The shape of the thread produced by a thread roll when the U. S. standard form is required is shown at *B* in Fig. 20. The pitch diameter d_2 is the same as the pitch diameter of the U. S. standard form shown at *A*. The root diameter d_3, however, is less than the root diameter d_1 of the U. S. standard thread shown at *A*. The pitch diameter d_2 is slightly greater than the required diameter of the blank, which can be found approximately by the following formula:

$$D = d_2 - \frac{d_5}{8} \qquad (1)$$

in which

D = diameter of the blank,
d_2 = pitch diameter of the screw,
d_5 = depth of U. S. standard thread. (See *A* Fig. 20.)

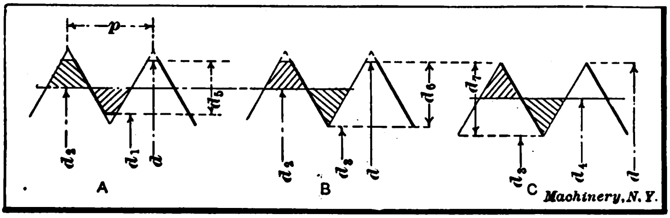


Fig. 20. Notation used in Calculating Diameters of Thread Rolls

The depth of the thread d_5 can be found by the following formula:

$$d_5 = \tfrac{3}{4} \times p \times \cos 30 \text{ deg.} = 0.6495\,p \qquad (2)$$

where p = the pitch of the thread or $\dfrac{1}{\text{number of threads per inch}}$

The pitch diameter is found by the formula:

$$d_2 = d - d_5 \qquad (3)$$

where d = the nominal external diameter of the screw.

When rolling a thread having a sharp V-form, the pitch diameter d_4, as shown at *C* in Fig. 20, can be used as the approximate diameter of the blank. The correct diameter of the blank in any case cannot be found by any formula, but by experiments only. It might be possible, however, to derive an empirical formula by making a series of experiments, and in each case determining the hardness of the metal. Then the results could be tabulated and used under similar conditions —when the metal is of the same hardness and the thread of the same shape. It is a simple matter, however, in the automatic screw machine, to reduce or increase the diameter of the blank, so as to give the correct finished diameter; thus it seems that any elaborate method of accurately obtaining the diameter of the blank by calculation is unnecessary.

Preparing Work for Thread Rolling

In most cases that part of the work on which a thread is to be rolled can be formed by the circular form tool. The thread to be rolled is generally at the rear of a shoulder, so that the thread roll has to be of a certain width, thus making it necessary to bevel the edges of the roll to prevent the threads at the ends from chipping. It is, therefore, desirable, when the work is to be threaded up to a shoulder, to make the form tool of such a shape that it will neck the work, as shown at *A* in Fig. 21, and also to reduce the diameter at *B* where the work is to be cut off.

The angle *a* should be 45 degrees, and the distance *C* should be equal to at least half the single depth of the thread, so that the part *B* will be slightly smaller than the root diameter of the finished piece. The distance *E* should be made equal to *C*, and the distance *F* equal to at least the pitch of the thread. When it is not necessary to roll the thread up to a shoulder, the work need not be necked. However, better results are obtained, in most cases, by necking the work, whenever it would not be seriously weakened thereby.

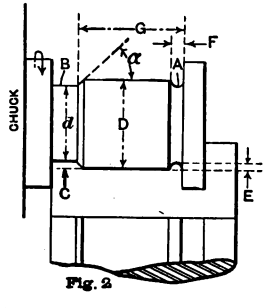


Fig. 21. Preparing a Piece with a Circular Form Tool

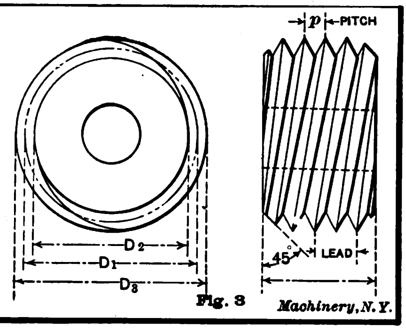


Fig. 22. Thread Roll with a Double Thread —Note Beveled Edges

Making the Thread Roll

The best results are obtained by using a thread roll with a single thread, but when the piece to be rolled is less than 5/8 inch in diameter, it is necessary to make the roll with a multiple thread in order to have it of the proper size. The roll should be made the opposite hand to that which it is required to produce; that is to say, for a right-hand thread, the thread roll is cut left-hand.

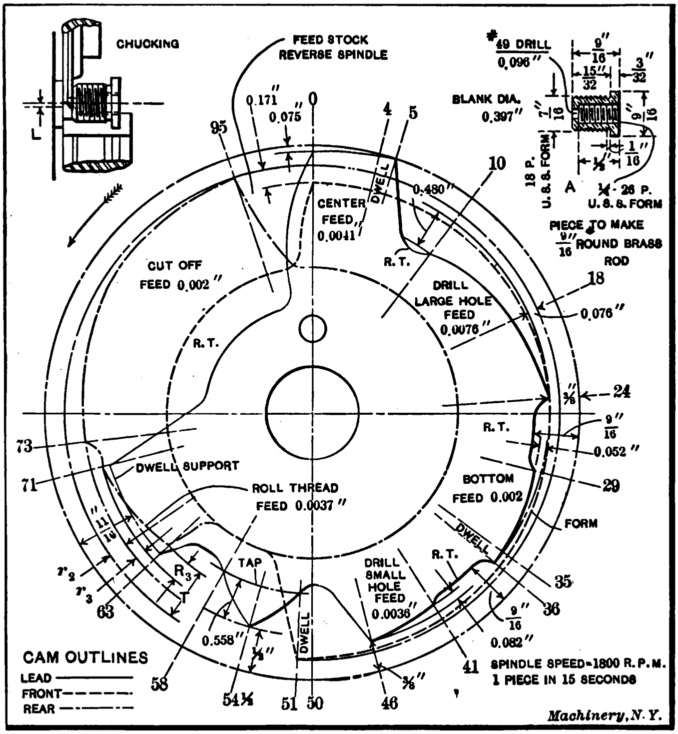
Owing to the displacement of the metal in forming a thread by rolling, there is no point in the formation of the thread where the contact is perfect. If the pitch diameter of the roll was made an exact multiple of the pitch diameter of the piece to be rolled, the contact would be perfect when the thread was completed, but not at any other point during the formation of the thread, and, therefore, would not allow the metal to flow. The Brown & Sharpe Mfg. Co. has found that the pitch diameter of the roll should not be an exact multiple of the pitch diameter of the finished piece, but should be slightly less. The pitch diameter of the roll for a U. S. standard thread can be found by the following formula:

$$D_1 = N \times \left(D - \frac{d_6}{3}\right) \qquad (4)$$

in which,

D_1 = pitch diameter of roll (see Fig. 22),

N = approximate ratio between pitch diameter of roll and pitch diameter of piece to be threaded,



Machinery, N.Y.

Fig. 23. Lay-out of a Set of Cams for Performing a Thread-rolling Operation

D = diameter of blank (see Fig. 21),

d_6 = depth of thread (see *B*, Fig. 20).

The depth of a U. S. standard thread as produced by thread rolling can be found by the following formula (for notation see *B*, Fig. 20):

$$d_6 = \tfrac{7}{8} \times p \times \cos 30 \text{ deg.} = 0.7578\, p \qquad (5)$$

where p = the pitch of the thread.

To illustrate clearly the method used in designing a thread roll for producing a U. S. standard thread, as shown at *B* in Fig. 20, take a practical example: Assume that it is necessary to design a thread roll for producing the thread on the piece shown at *A* in Fig. 23. As this is a U. S. standard thread, and it is impracticable to use a roll with a flat top, we use the blank diameter for calculating the pitch diameter of the roll, instead of the pitch diameter of the thread, as would be the case with a sharp V-thread. The blank diameter can be found by Formula (1). Before finding the blank diameter, however, it is necessary to find the depth of the thread, which can be found by substituting the known values in Formula (2), as follows:

$$d_5 = 0.6495\ p = 0.6495 \times 0.0555 = 0.0360 \text{ inch.}$$

Then

$$d_2 = d - d_5 = 0.4375 - 0.0360 = 0.4015 \text{ inch}$$

and

$$D = d_2 - \frac{d_5}{8} = 0.4015 - \frac{0.036}{8} = 0.4015 - 0.0045 = 0.397 \text{ inch.}$$

The pitch diameter of the thread roll can then be found by Formula (4), but before finding the pitch diameter it is necessary to find the depth of the thread d_6 (see *B*, Fig. 20) by inserting the values in Formula (5):

$$d_6 = p \times 0.7578 = 0.0555 \times 0.7578 = 0.042 \text{ inch.}$$

Then

$$D_1 = N \times \left(D - \frac{d_6}{3}\right)$$

$$= 2 \times \left(0.397 - \frac{0.042}{3}\right) = 0.766 \text{ inch.}$$

The root diameter D_2 and the outside diameter D_3 of the thread roll (see Fig. 22) can be found by the following formulas:

$$D_2 = D_1 - d_7 \text{ (See } C\text{, Fig. 20)} \tag{6}$$

$$D_3 = D_1 + d_7 \tag{7}$$

inserting the values, we have:

$$D_2 = 0.766 - 0.048 = 0.718 \text{ inch,}$$

and

$$D_3 = 0.766 + 0.048 = 0.814 \text{ inch.}$$

The same method as that given for the U. S. standard form of thread is used for the A. S. M. E. standard screws when designing a thread roll. A thread roll for a sharp V-thread, however, is calculated from the pitch diameter, which is also used as the approximate diameter of the blank. For a sharp V-thread the root, pitch and outside diameters of the roll are found by the following formulas:

$$D_1 = N \times \left(d_4 - \frac{d_7}{3}\right) \tag{8}$$

$$D_2 = D_1 - d_7 \tag{9}$$

$$D_3 = D_1 + d_7 \tag{10}$$

in which

D_1 = pitch diameter of thread roll,

D_2 = root diameter of thread roll,

D_3 = outside diameter of thread roll,
N = approximate ratio between pitch diameter of roll and pitch diameter of piece to be threaded,
d_4 = pitch diameter of thread or diameter of blank,
$d_7 = 0.866\,p$ (see C Fig. 20).

In making a thread roll the outside diameter is turned to the size required, and the ends are beveled at an angle of 45 degrees, as shown in Fig. 22, to prevent the threads on the ends of the roll from chipping. If the roll is to be made with a multiple thread, the lathe must, of course, be geared to correspond. Before cutting the thread it is preferable to bevel the edges at an angle of 30 degrees, or equal to the angle of one side of the thread. This facilitates the starting of the thread tool. After the threads have been cut, the roll should again be beveled, but at an angle of 45 degrees.

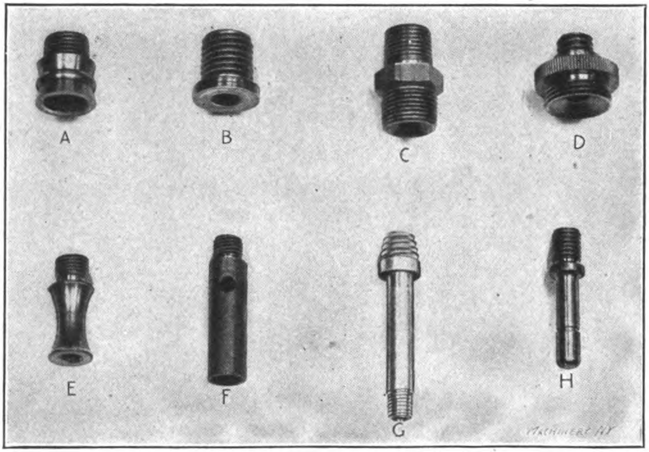


Fig. 24. Samples of Pieces having Rolled Threads

Thread rolls should be made from steel containing a high percentage of carbon. Precautions should be taken in hardening, because if the sharp edges become burnt the roll will be useless. Thread rolls, as a rule, are lapped after hardening. This is done by holding them on an arbor in the lathe, and using emery and oil on a piece of hard wood. A thread roll, to give good results, should not be made to fit loosely in the slot in the holder, but should be made a good running fit. If the roll is made to fit loosely in the holder, it will "chew up" the threads. The hole in the roll should also be made a good running fit on the pin in the holder, and in most cases should not be larger than 5/16 inch, ¼ inch being usually adopted for rolls 1 inch in diameter or less.

Applying a Thread Roll to the Work

The shape of the work and the character of the operations necessary to produce it, govern, to a large extent, the method employed in applying the thread roll. There are, however, other considerations to be observed, some of which are as follows:

1. Diameter of the part to be threaded.
2. Location of the part to be threaded.
3. Length of the part to be threaded.
4. Relation that the thread rolling operation bears to the other operations.
5. Shape of the part to be threaded, whether straight, tapered or otherwise.
6. Method adopted in applying the support.

When the diameter to be rolled is much smaller than the diameter of the shoulder preceding it, a cross-slide knurl-holder should be used.

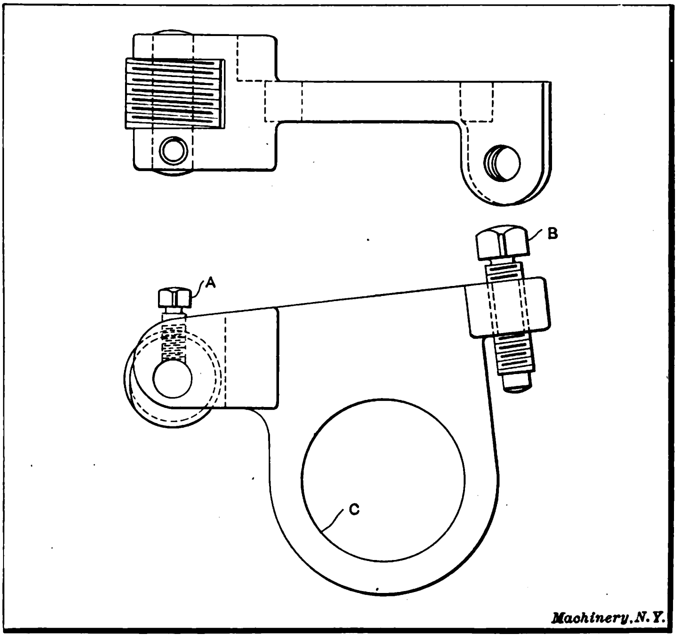


Fig. 25. Top Cross-slide Roll-holder

If the part to be threaded is not behind a shoulder, a holder on the swing principle should be used. When the work is long—greater in length than two-and-one-half times its diameter—a swing roll-holder should be employed, carrying a support. When the work can be cut off directly after the thread is rolled, a cross-slide roll-holder should be used. The method of applying the support to the work also governs to some extent the method of applying the thread roll, but as this depends entirely on the shape of the work, it would be impossible to say what method should be employed, unless the shape of the work were known.

When no other tool is working at the same time as the thread roll, and when there is freedom from chips, the roll can be held more rigidly by passing it under instead of over the work. When passing the roll over the work, it has a tendency to raise the cross-slide, while, on the other hand, if the roll is passed under the work, the pressure is downward, and hence the holder is more rigidly supported. Where the part to be threaded is tapered as shown on the aluminum piece *G* in Fig. 24, the roll can be best presented to the work by holding it in a cross-slide roll-holder.

Holders for Thread Rolls

As previously mentioned, certain considerations govern the method of applying the thread roll; the holder for the roll, therefore, has to be designed to suit these requirements. There are various types of special holders in use for holding thread rolls; a few of the more common or standard types will be described.

In Fig. 25 is shown what is called a "top" roll-holder. This holder is held on a boss turned on the circular cut-off tool, and is clamped by the circular cut-off tool and the screw which holds the latter to the toolpost. The thread roll is held in a slot cut in the forward end of the holder on a pin, the latter being driven into the holder, as shown. As considerable pressure is required to force the roll into the work, there is a tendency to turn the pin in the holder; to obviate this, a flat is filed on the pin and a setscrew *A* is provided. The set-screw *B* is used for setting the roll to the proper depth, and rests on the toolpost. By making hole *C* in the holder to fit the screw in the toolpost, this holder could be held on the outside of the toolpost, instead of fitting on the circular cut-off tool. This thread-roll holder can be used for holding rolls for threading pieces such as shown at *A*, *B* and *C* in Fig. 24.

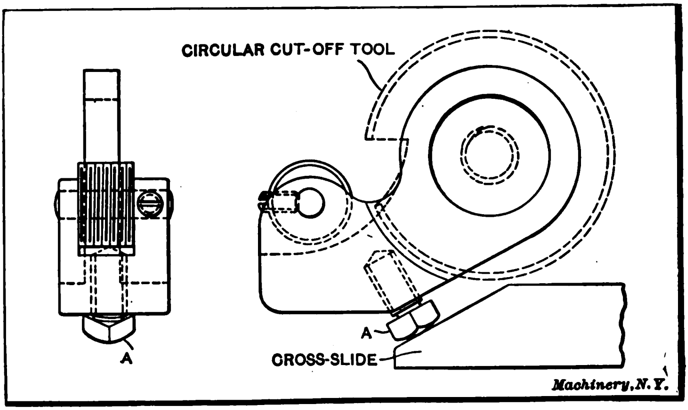


Fig. 26. Holder used when the Roll is passed under the Work

A thread-roll holder which is held on the cross-slide but passes under the work is shown in Fig. 26. This holder is held on a projection on the cut-off tool in a manner similar to that shown in Fig. 25. The support, the set-screw *A*, rests on the cross-slide, and is used for adjusting the roll to the proper depth, as well as for supporting the holder. This holder can be held more rigidly than the top roll-holder shown in Fig. 25; it is used when no other tool is operating on the work at the same time, and also where there is an absence of objectionable chips. Thread-roll holders which are held on the cross-slide can only be used when the work is cut off directly after the thread is rolled, and for this reason they should be held on the same slide as the cut-off tool. If the roll is brought back over the work, it produces a poor thread.

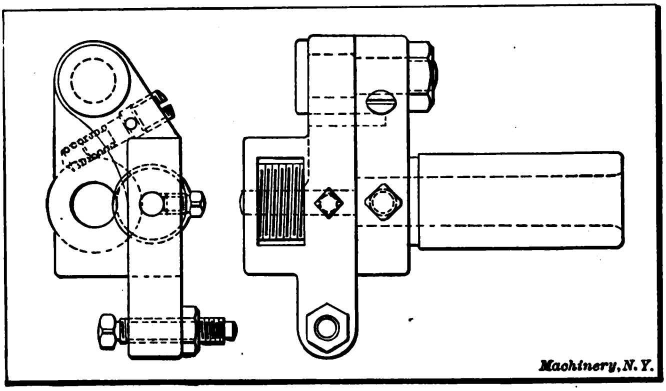


Fig. 27. Swing Holder for Holding a Thread Roll

When it is necessary to bring in the cut-off or form tool more than once for the same piece, a cross-slide holder should not be used. Of course it would be possible to design a holder in which the roll would be held in a member free to oscillate, and held in position by a spring. This type of holder would be objectionable, however, owing to the fact that chips would get in between the movable member and the body, and prevent the part holding the roll from coming back into the same place each time, thus causing an endless amount of trouble.

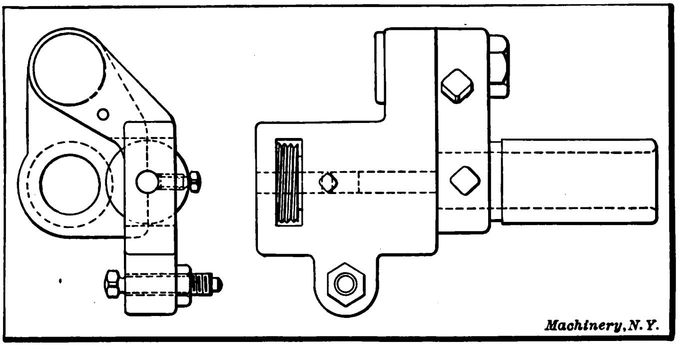


Fig. 28. Another Swing Roll-holder

When the work is of such a shape as to necessitate bringing in the form and cut-off tools more than once for the same piece, a swing holder should be used. Two holders of this type are shown in Figs. 27 and 28. These holders are made on the same principle as the ordinary swing tool, with the exception of the change in the swinging member to hold the roll. A hole is drilled in the shank of the holder and a set-screw provided for holding a support.

A thread-roll holder which is held on the cross-slide and holds a roll for threading the beveled piece shown at *G* in Fig. 24, is shown in Fig. 29. This holder is held to the toolpost in a manner similar to that of the holders previously described, but the roll in this case is held at an angle on the stud *A*.

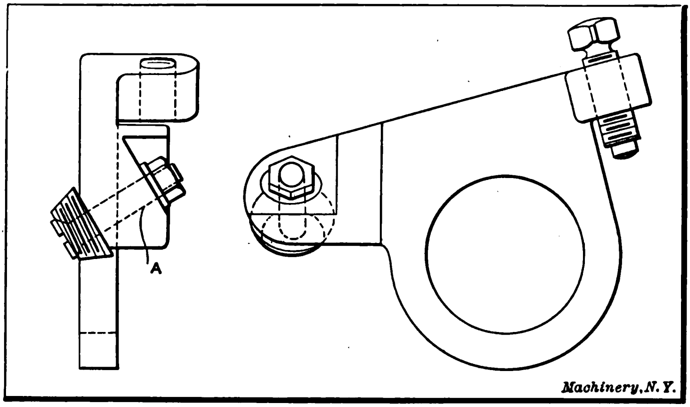


Fig. 29. Cross-slide Holder for applying a Thread Roll to a Beveled Piece

Rise on Cam when using Cross-slide Roll-holder

In thread rolling, the roll is first brought against the work, then fed at a certain feed per revolution until the center of the roll is in line with the center of the work, and finally removed from the work on the quick rise of the cam. As the roll is removed from the work, the cut-off tool is brought into position. The rise on the cross-slide cam for thread rolling, when using a holder held to the toolpost, can be found by the aid of the following formulas derived from the diagram Fig. 30. This shows the outside circumference of the thread roll touching the circumference of the blank, and a horizontal line is drawn tangent to the root diameter of the finished screw.

Let D = diameter of blank,
d_3 = theoretical root diameter of screw,
R = blank radius,
R_1 = largest or outside radius of thread roll,
d = difference between radius of blank and radius of root of thread.

Then,

$$A = R + R_1 \tag{11}$$

$$B = R + R_1 - d \tag{12}$$

$$C = \sqrt{A^2 - B^2} \tag{13}$$

For example, let it be required to find the rise on the cross-slide cam for threading the piece shown at A in Fig. 23. Substituting the known values of the diameter of the roll and the diameter of the blank in the above formulas, we have:

$A = 0.1985 + 0.407 = 0.6055$ inch.
$B = 0.1985 + 0.407 - 0.0218 = 0.5837$ inch.
$C = \sqrt{(0.6055)^2 - (0.5837)^2} = \sqrt{0.02634} = 0.162$ inch.

Then the rise R_3 on the cam (see Fig. 23) equals C (Fig. 30) plus from 0.010 to 0.015 inch, depending on the diameter of the roll and work.

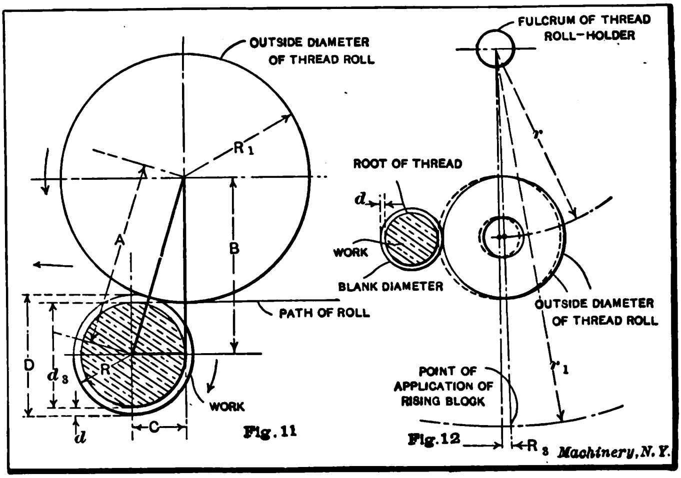


Fig. 30. Diagram used in Calculating the Rise on the Cam for Thread Rolling when a Cross-slide Holder is used

Fig. 31. Diagram used in Finding Rise on Cross-slide Cam when using Roll-holder of the Swing Type

This calculation is for rolling a U. S. standard thread, but the same method can be used for rolling any other shape, substituting, of course, the correct values.

Total Rise on Cross-slide Cam

As the work is cut off with the same cam, it is necessary to find the total rise on the cam for thread rolling and cutting off the piece; this can be found by the following formulas, which are derived from the diagram Fig. 32. Here the thread roll is shown touching the circumference of the blank, and the circular cut-off tool and thread-roll holder are shown in their relative positions.

Let T = total rise on cam (see Fig. 23),
C = distance from center of roll to center of work,
R_3 = actual rise required to roll thread, which equals C + from 0.010 to 0.015 inch,

R = radius of theoretical root of thread on piece,

r_1 = radius of work turned down with circular form tool, or $\frac{d}{2}$ (see Fig. 21),

L = distance of bevel on cut-off tool (see Fig. 23),

r_2 = actual rise on cam to cut off piece, which equals $r_1 + L +$ 0.010 inch (to approach) + 0.005 inch (to pass center),

R_1 = outside radius of thread roll,

R_4 = largest radius of circular cut-off tool,

R_5 = radius of thread-roll holder,

c = distance that cut-off tool is cut below center,

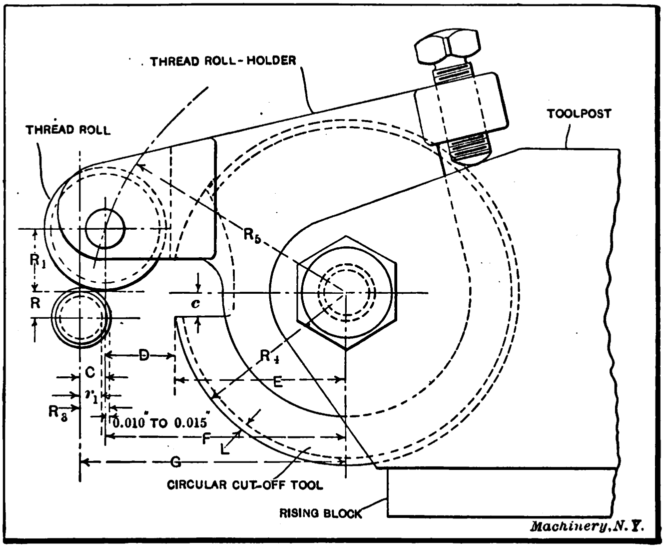


Fig. 32. Diagram used in Finding the Total Rise on the Cam for Thread Rolling and Cutting-off

E = distance from center of circular tool to edge, when tool is cut down below center,

F = distance from center of cut-off to center of roll, when it is touching piece as shown,

Then if

$$X = R + R_1 - c$$
$$F = \sqrt{R_5^2 - X^2}$$

Now the difference between the dimensions E and F, or the distance D, always remains constant, so that it is only necessary now to find the actual distances or rises required on the cam for thread rolling, approaching the work with the cut-off tool, and cutting the piece from the bar.

The rise r_3 required to bring the cut-off tool up into position, after thread rolling, to cut off the piece $= D - r_1 + 0.010$.

The total rise T on the cam equals $R_3 + r_2 + r_3$.

TABLE XII. FEEDS FOR THREAD ROLLING WITH CROSS SLIDE HOLDERS

Root Diameter of Blank	Number of Threads per Inch																
	80	72	64	56	48	44	40	36	32	30	28	24	22	20	18	16	14
	Feed per Revolution in Inches																
1/8	0.0050	0.0045	0.0040	0.0035	0.0030	0.0025	0.0020	0.0015	0.0010	0.0005	......	......	......	......	......	......	......
3/16	0.0055	0.0050	0.0045	0.0040	0.0035	0.0030	0.0025	0.0020	0.0015	0.0010	0.0005	......	......	......	......	......	......
1/4	0.0060	0.0055	0.0050	0.0045	0.0040	0.0035	0.0030	0.0025	0.0020	0.0015	0.0010	0.0005	0.0005	......	......	......	......
5/16	0.0065	0.0060	0.0055	0.0050	0.0045	0.0040	0.0035	0.0030	0.0025	0.0020	0.0015	0.0010	0.0010	0.0005	0.0005	......	......
3/8	0.0070	0.0065	0.0060	0.0055	0.0050	0.0045	0.0040	0.0035	0.0030	0.0025	0.0020	0.0015	0.0015	0.0010	0.0010	0.0005	0.0005
7/16	0.0075	0.0070	0.0065	0.0060	0.0055	0.0050	0.0045	0.0040	0.0035	0.0030	0.0025	0.0020	0.0020	0.0015	0.0015	0.0010	0.0010
1/2	0.0080	0.0075	0.0070	0.0065	0.0060	0.0055	0.0050	0.0045	0.0040	0.0035	0.0030	0.0025	0.0025	0.0020	0.0020	0.0015	0.0015
5/8	0.0085	0.0080	0.0075	0.0070	0.0065	0.0060	0.0055	0.0050	0.0045	0.0040	0.0035	0.0030	0.0030	0.0025	0.0025	0.0020	0.0020
3/4	0.0090	0.0085	0.0080	0.0075	0.0070	0.0065	0.0060	0.0055	0.0050	0.0045	0.0040	0.0035	0.0035	0.0030	0.0030	0.0025	0.0025
7/8	0.0090	0.0090	0.0085	0.0080	0.0075	0.0070	0.0065	0.0060	0.0055	0.0050	0.0045	0.0040	0.0040	0.0035	0.0035	0.0030	0.0030
1	0.0100	0.0095	0.0090	0.0085	0.0080	0.0075	0.0070	0.0065	0.0060	0.0055	0.0050	0.0045	0.0045	0.0040	0.0040	0.0035	0.0035

TABLE XIII. FEEDS FOR THREAD ROLLING WITH SWING HOLDERS

Root Diameter of Blank	Number of Threads per Inch																
	80	72	64	56	48	44	40	36	32	30	28	24	22	20	18	16	14
	Feed per Revolution in Inches																
1/8	0.0030	0.0025	0.0020	0.0015	0.0010	0.0005	......	......	......	......	......	......	......	......	......	......	......
3/16	0.0033	0.0028	0.0025	0.0020	0.0015	0.0008	0.0005	......	......	......	......	......	......	......	......	......	......
1/4	0.0036	0.0030	0.0030	0.0025	0.0020	0.0010	0.0010	0.0005	0.0005	0.0005	0.0005	......	......	......	......	......	......
5/16	0.0040	0.0035	0.0035	0.0030	0.0025	0.0015	0.0015	0.0010	0.0010	0.0010	0.0010	0.0005	......	......	......	......	......
3/8	0.0043	0.0040	0.0040	0.0035	0.0030	0.0020	0.0020	0.0015	0.0015	0.0015	0.0015	0.0010	0.0005	0.0005	0.0005	......	......
7/16	0.0046	0.0045	0.0045	0.0040	0.0035	0.0030	0.0025	0.0020	0.0020	0.0020	0.0020	0.0015	0.0010	0.0010	0.0010	......	......
1/2	0.0050	0.0048	0.0048	0.0045	0.0040	0.0035	0.0030	0.0025	0.0025	0.0025	0.0025	0.0020	0.0015	0.0015	0.0015	0.0005	0.0005
5/8	0.0053	0.0050	0.0050	0.0048	0.0043	0.0040	0.0035	0.0030	0.0030	0.0030	0.0028	0.0025	0.0020	0.0020	0.0018	0.0010	0.0010
3/4	0.0056	0.0055	0.0052	0.0050	0.0045	0.0043	0.0040	0.0035	0.0035	0.0032	0.0030	0.0028	0.0025	0.0022	0.0020	0.0015	0.0013
7/8	0.0060	0.0058	0.0055	0.0052	0.0048	0.0045	0.0043	0.0040	0.0038	0.0035	0.0032	0.0030	0.0028	0.0025	0.0022	0.0018	0.0015
1	0.0062	0.0060	0.0058	0.0054	0.0050	0.0048	0.0047	0.0043	0.0040	0.0038	0.0035	0.0032	0.0030	0.0028	0.0025	0.0022	0.0018

Rise on Cross-slide Cam when using Swing Roll-holder

When using a roll-holder of the type shown in Figs. 27 and 28, the rise on the cam can be found by the following formula derived from the diagram Fig. 31, where the thread roll is shown in two positions—before and after rolling the thread. The distance *d*, which in this case is taken to be 0.020 inch, represents the distance between the radius of the blank and the theoretical root diameter of the thread of the piece to be rolled. To this dimension, from 0.010 to 0.015 inch is added for the roll to approach the work. Let $d_1 = d +$ from 0.010 to 0.015 inch.

Then,

$$R_3 = \frac{d_1 \times r_1}{r} \qquad (16)$$

For example, let $d_1 = 0.030$ inch, $r = 1\frac{1}{8}$ inch, and $r_1 = 2\frac{1}{4}$ inches.

Then,

$$R_3 = \frac{0.030 \times 2\frac{1}{4}}{1\frac{1}{8}} = 0.060 \text{ inch.}$$

There is another method of holding the thread roll when applying it to the work which has not been mentioned. This consists in holding the roll in a holder fastened to the cross-slide, but instead of passing the roll over or under the work, it is presented radially to the work. The rise on the cross-slide would then be $d +$ from 0.010 to 0.015 inch (see Fig. 31).

Speeds and Feeds for Thread Rolling

When the thread roll is made from high-carbon steel and used on brass, a surface speed as high as 200 feet per minute can be used. Better results, however, are obtained by using a lower speed than this. When the roll is held in a holder attached to the cross-slide, and is presented either tangentially or radially to the work, it can be fed at a considerably higher speed than if it is held in a swing tool. This is due to the lack of rigidity in a holder of the swing type. Table XII gives the feeds to be used when a cross-slide roll-holder is used; and Table XIII gives the feeds to be used for thread rolling with swing tools.

The feeds given in Tables XII and XIII are applicable for rolling threads without a support when the root diameter of the blank is not less than five times the double depth of the thread. When the root diameter is less than this amount, a support should be used. A support should also be used when the width of the roll is more than two-and-one-half times the smallest diameter of the piece to be rolled, irrespective of the pitch of the thread. When the smallest diameter of the piece to be rolled is much less than the root diameter, the smallest diameter should be taken as the deciding factor for the feed to be used.