Standard Tapers

A Statement of the Case for Existing Standards—Suitability of Tapers for Specific Jobs—Some of the Objections to the Jarno Taper

By LUTHER D. BURLINGAME
Chairman, Joint Committee of A. S. M. E. and S. A. E. on Standardization and Unification of Screw Threads

A FERTILE field for investigation and discussion has been opened by the series of articles appearing in *American Machinist* under the heading "Shall We Standardize Tapers?" These articles give the opinions of fifty-eight manufacturers as to their present practice and recommendations for standardization and while it cannot be said that these fifty-eight manufacturers give quite "57 varieties" of opinion as to what should be done yet the great variety of opinions and the reasons given show the extreme difficulty in the way of finding a practical basis of standardization which would meet universal approval. In fact not only this series of articles giving such widely varying views but also an investigation which was made in 1918 with a view of establishing standards for large taper shanks and sockets and which was presented as a paper at the annual meeting of the A. S. M. E. in December of that year, lead me to believe that the greatest possibility of effective standardization will be by the adoption of at least *two standards for tapers* rather than by trying to bring all to a single standard, regardless of the needs, and regardless of what might result from the overthrow of basic standards so long recognized and so widely used.

I was much impressed with the point made by George E. Merryweather in his contribution on page 725, Vol. 56, of *American Machinist*, entitled "Shall We Standardize Machine Tools?" He shows the danger of jumping into such standardization without a conception of what it might mean, and of the results which would follow. I do not wish to be put in the position of not favoring standardization, as I am now working with several committees whose earnest efforts are to bring about practical standardization where it can be done, but I do feel that there is a danger of overdoing this matter.

Standardization should not be carried so far that it will fail to meet the requirements and where those requirements are such as to call for varying standards; they should be duly recognized, each in its turn becoming a standard.

Need of Finer Threads

An illustration of this is in the use of screw threads, where the attempt to hold all work to the United States standard screw thread, even though it is much too coarse for many uses has led to a great variety of finer threads being used because no standard for fine threads had been adopted. By frankly recognizing the need of finer threads and establishing a standard for them years ago this confusion would have been avoided, and two recognized standards would have been available, each useful for a particular field of work. The effort to bring this result about at this late date will eventually help the situation, but a far-seeing policy in the past by which at least two standards would have been recognized would have avoided the present confusion.

So it is with tapers. There are certain needs in which a taper as slight as ½ inch to the foot is preferable to a steeper taper because it is desired to have tools, such as end mills, etc., drive in so as to hold firmly, and drive by the "bite" of the taper surfaces in contact; and to have this taper just such that even when driven in tightly it can be readily removed when tools are to be changed. One-half inch taper per foot meets these requirements.

On the other hand, there are needs, such as in drill presses and lathes, where the end pressure comes on the tool or center tending to crowd it more firmly into position and where a taper of approximately ⅝ inch to the foot gives sufficient "bite" and allows for the tool or center to be more easily freed when a change is to be made.

Introduction of "Magnum" Tapers

In cases of large tapers, where auxiliary driving means are required, and where the "bite" is not depended on for driving, but instead keys or clutches are used for this purpose, and where the parts are so heavy that greater difficulty might be experienced in removing them, a steeper taper still of ¾ inch to the foot is desirable. Such a standard has already been proposed under the name of "Magnum" tapers and is an extension of the B. & S. tapers to larger sizes than had previously been standardized.

These varying needs have led in the past to the establishment of several standards each of which is best suited to its particular use and two of which have become so widely used and so firmly established as basic standards that it is believed it would be a mistake to attempt to change them.

As a result of the study given to this matter, and for the reasons which follow, I believe that the Morse taper should be adopted as a world standard, for lathes, drill presses and machines of like character, up to the largest size already established, No. 7, and that the B. & S. taper, should be made the world standard for milling machines, gear cutting machines, etc.; the "Magnum" standard being used for all types of machines where still larger tapers are required.

That it is desirable to have more than one standard is voiced by a number of those replying to the *American Machinist* questionnaire.

For example, No. 7 says:

> The value of one standard taper is questionable because of the variety of uses to which taper shank tools are put. The Brown & Sharpe taper is unquestionably superior for milling machine work, because the greater the taper the easier it is to loosen the shank in socket, due to jarring in operation; but a greater taper is more satisfactory in drilling machines, and boring machines, on account of ease of extraction . . . . No great hardship would be noticed if the Brown & Sharpe taper were continued in use for milling machines, and the Morse taper adopted for other machine tools.

No. 22 says:

> Modern milling machines are equipped with Brown & Sharpe tapers; drill presses, radial drills and boring mills

with Morse tapers . . . . the Brown & Sharpe taper having a smaller included angle is better suited for milling machines, gear cutters or any type of machine, where a great side thrust is exerted. This side thrust has the tendency to cause the tapered end of the cutter arbor to work loose. The Brown & Sharpe taper has a greater frictional driving power than the Morse. . . . all our gear-cutting machines for the trade are equipped with Brown & Sharpe tapers. In our milling department we have adopted No. 11 and No. 14 Brown & Sharpe tapers as our standard.

No. 27 says:

For drill presses and lathe centers it seems there can be no objection to the Morse taper, but for milling machines we would prefer the Brown & Sharpe half-inch taper per foot.

No. 53 says:

We will be satisfied to use Brown & Sharpe tapers for our milling tools and Morse tapers on our drill presses.

A third standard which has come into use to some extent (the Jarno taper), while having advantages in the simple relations of its various dimensions has objections which it is believed would militate against its being adopted as a universal standard.

In the discussion referred to above, published in the *American Machinist*, while the Morse taper was given the preference if a single standard was to be adopted, and the B. & S. taper was generally preferred for milling and gear cutting machines, there seemed to be quite a leaning toward the Jarno taper.

Origin of the Jarno Taper

This Jarno taper was first proposed by Oscar J. Beale of the Brown & Sharpe Manufacturing Co. in an article in *American Machinist* Oct. 31, 1889 and takes its name from the "pen name" under which Mr. Beale wrote. It is approximately the same taper per foot as the Morse taper, being a taper of 1 in 20, where the Morse taper is approximately 1 in 19½, and the B. & S. taper 1 in 24.

It is so close to the Morse taper that the fact that it has come somewhat into use is causing considerable confusion from the fact that it is not easy by inspection to determine which of the two tapers, Morse or Jarno, is used in a machine and the attempt to fit tools made to one of these tapers to machines having the other is a source of not only annoyance but of real loss. If it were not for the fact that the Morse taper, which approximates § in. to the foot, varies in nearly all its sizes from being exactly this taper, so that no two sizes are the same taper per foot, it would no doubt be more favorably considered as a standard; although this variation is not the practical objection which it appears in theory for gages once made will produce duplicate and thus interchangeable work.

Another objection to the Jarno taper is that the sizes vary uniformly by tenths of an inch in diameter at the small end. This has been pointed out by a number of those whose opinions are published in *American Machinist* as being an advantage. It is my belief, however, that it is not an advantage, but a serious objection to this system, as the proper requirements should grade the sizes of tapers in geometric progression from the smallest to the largest so that the larger sizes would be spaced much farther apart than the small sizes. See Fig. 1. I have pointed out the reasons for this in an article on "Geometric Progressions by Short-Cut Methods" on page 743, Vol. 56, of *American Machinist*.

For the same range which is covered by the Morse tapers in eight sizes the Jarno taper has 21, and this number of sizes would be increased to what would certainly be prohibitive if carried up to the sizes of the large taper shanks and sockets.

Another objection to the Jarno taper is that the formula is only applicable, as far as proportions of length to diameter go, to tapers of small or moderate size. As soon as large sized tapers are reached, such as say 4 in. in diameter, the Jarno formula would be entirely out of proportion, as it would call for a taper 20 in. in length, almost double that which good practice would require.

The correspondent of *American Machinist* No. 48, criticises the length of the Jarno taper even for the comparatively small sizes. He says: "In order to use a Jarno taper we have considered modifying the length, as there is no doubt that the general feeling exists that the Jarno taper is rather long."

Another reason, important from a practical standpoint, why the Jarno taper should not be used as a

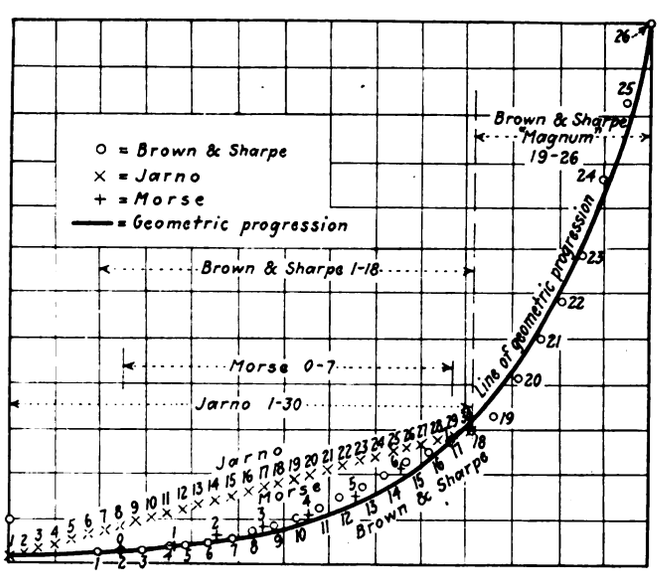

FIG. 1—TAPER SIZES IN RELATION TO A GEOMETRIC PROGRESSION CURVE

basis for a general standard to supplant the use of the Morse and B. & S. tapers now used, each in well-defined lines of machines, is that these latter standards are at present so extensively in use that great expense and confusion through a long period of years would be caused by attempting to make a change. Take the milling machine, for example, with its collets, arbors, shank cutters, etc., with vertical spindle and many other kinds or attachments now interchangeable not only with machines of the same make but also in various makes of machines. It is little realized through what a long period such a product must be interchangeable.

A short time ago, when the question of standards for tapers was raised as to whether they could be modified through a long period of years, an arbor with a taper shank was taken from stock and placed in the original universal milling machine built by J. R. Brown & Sharpe in 1861. It was found that the taper hole of the old machine was still standard after more than sixty years, so that the present day equipment would interchange.

Correspondent No. 40, after speaking of the many hundreds of thousands of machines in use, using tapers, says:

We should think it would be a very serious matter after so many years of having an established taper, such as the Morse taper, to consider making any change. From our own standpoint you can understand it would be a very

serious matter for us to consider, and we should hesitate about doing so.

No. 14 says:

If the Jarno taper were considered at the present time as the standard, there would be more opposition from the general public because it is little known, and this would require replacing the two well-known tapers, Brown & Sharpe and Morse.

Twenty-five years ago, there were many more tapers in use than at present, and the need for standardization was more apparent. Today the Brown & Sharpe and Morse tapers greatly predominate.

The records of our factory show that we have 721 machines with the Morse taper, 327 machines with the Brown & Sharpe, and 23 with the Jarno.

Attitude of British Engineers

It is believed that what has been said regarding the American practice would also hold true of practice throughout the English-speaking world. The British Engineering Standards Association has given much study to this matter of tapers. As far back as July, 1918, the sub-committee on milling cutters and small tools discussed the question of tapers with a view of arriving at the most suitable standard to recommend for end mills. They recognized three accepted tapers, the Morse, the Brown & Sharpe and Jarno, and after consideration in detail the vote was unanimous in favor of the Brown & Sharpe for this particular use. The considerations leading up to this decision as given by the committee were:

Jarno taper. Difficulties in adoption owing to its present limited use, although its simplicity and practical advantages were appreciated.

Morse taper. Insufficient range of sizes, and in some cases lack of sufficient length. It was also felt that comparatively few machines were now being made with Morse taper hole in the spindle.

B. & S. taper. Was considered to offer a reasonable range of sizes, a suitable taper, and, in addition, had the advantage of being the standard generally in use.

In their published "Book of Standards for Milling Cutters and Reamers No. 122-1920," the British Engineering Standards Association gives data for and recognized both the Brown & Sharpe and Morse tapers to be used for shanks of end mills.

It is reported by Robert Grimshaw, in *American Machinist*, May 9, 1907, that the German manufacturers of twist drills meeting in Hanover declared that the proposed introduction into Germany of the metric taper, instead of being an advantage would be a disadvantage; that while these manufacturers realize that there were some variations in the Morse tapers, they claimed that this would not be a serious disadvantage to the use of that taper "because such tapers are not made according to measure but according to gages ground exactly to size, so that it makes no difference whether or not the measurements are in even millimeters or fractions thereof. . . . Twist drill manufacture has become a specialty; they are made in great quantities, and all dimensions are exact to the standards."

Mr. Grimshaw goes on further to say that from the German standpoint—

"There are further commercial reasons for keeping the Morse taper. Twist drills are a staple commercial article, price, dimensions and quality of which cannot be established by German makers. At present there are necessary a great number of special machines to make them. If it were required to bring out a metric taper it would be necessary to put in new special machinery specially therefor. Furthermore to double the amount of stock necessary to be kept by dealers would be a heavy burden. . . . The expense of such increased stock would have to be borne not only by manufacturers, but also by the dealers."

The question was raised with the Brown & Sharpe Manufacturing Co. by the British committee on cutters as to the arguments for having varying lengths of taper for a given size. They were answered, based on the experience at the Brown & Sharpe works in the following way:

"A reason for having several varying lengths is that in some cases the shank of the taper extends through

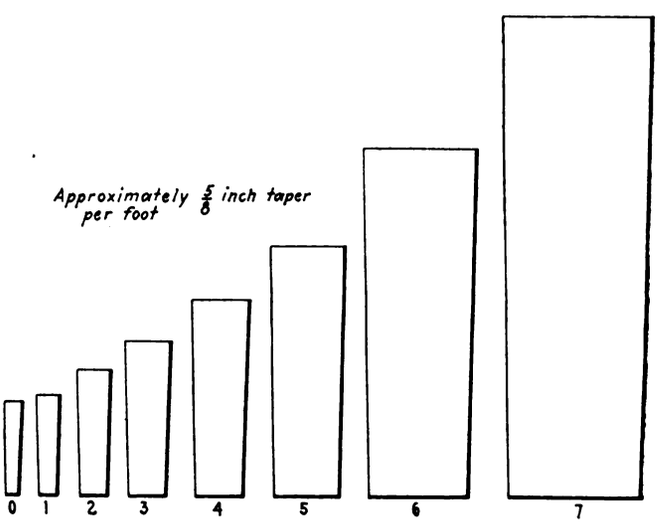

FIG. 2—PROPORTIONS OF MORSE TAPERS

the bearing for the spindle, so that the key for driving out the shanks will come back of the bearing. This necessitates a taper longer than would otherwise be required, an illustration being No. 10 used in milling machines with a depth of 5⅛ in. In other cases, where the taper is used in a collet, and it is desired to drive the shanks out without previously driving out the collet, it is necessary to have the keyway forward of the end of the spindle, or forward of the larger sized collets, and unless the taper holes are made shorter than standard, an excessive overhang results. For this reason shorter tapers are used in such places, so that it will be found that some are shorter and some longer than standard.

MORSE AND BROWN & SHARPE TAPERS COMPARED

Morse				Brown & Sharpe			
No.	Taper Ft.	Diam. Small E	Depth Taper	No.	Taper Ft.	Diam. Small E	Depth Taper
				1	0.500	0.200	⅛
0	0.625	0.252	2	2	0.500	0.250	1/16
				3	0.500	0.312	1¼
1	0.600	0.369	2¼	4	0.500	0.350	1⅜
				5	0.500	0.450	2¼
2	0.602	0.572	2 7/16	6	0.500	0.500	2½
				7	0.500	0.600	2¾
3	0.602	0.778	3 7/16	8	0.500	0.750	3 1/16
				9	0.500	0.900	4¼
4	0.623	1.020	4 7/16	10	0.516	1.045	5
				11	0.500	1.250	5⅛
5	0.630	1.475	5 7/16	12	0.500	1.500	7¼
				13	0.500	1.750	7¾
				14	0.500	2.00	8¼
6	0.626	2.116	7¼	15	0.500	2.25	8¾
				16	0.500	2.50	9¼
7	0.625	2.750	10	17	0.500	2.75	9¾
				18	0.500	3.00	10¼

B. & S. "Magnum"

No.	Taper Ft.	Diam. Small E	Depth Taper
19	0.750	3.25	12
20	0.750	4.125	14
21	0.750	5.00	16
22	0.750	5.875	18
23	0.750	6.75	20
24	0.750	8.50	24
25	0.750	10.25	28
26	0.750	12.00	32

"Morse" recommended as World Standard for Lathes, Boring mills, drill Presses, etc.]

"B. & S." recommended as World Standard for Milling Machines, Gear Cutting Machines, etc.

"Magnum" recommended as World Standard for all cases where large sizes are required.

"Where no such limiting conditions exist, it is intended to have the lengths of tapers made standard."

The variation of some of the Morse tapers and of the No. 10 Brown & Sharpe taper from a taper uniform with the remainder of the series was challenged by C. Franklin Rothera in *American Machinist*, page 893, Vol. 56, where he speaks of the difficulty of answering the queries of his pupils as to the reasons for these variations of tapers, he considering that these variations are an important reason for bringing about a change.

Difficulty of Changing Now

This question was also raised by the above-mentioned British committee as to whether a change could be made in the Brown & Sharpe No. 10 taper so that it would in future be made exactly ½ in. taper per foot. They were answered in this way:

The No. 10 Taper was no doubt originally intended to be ½ inch per foot but in the early days, before measuring tools of precision were available, before the importance of standardization was realized, and after Brown & Sharpe had adopted this taper from others who had begun to use it, this standard became so firmly established that when it was known that it was not of an even ½-in. taper to the foot it was thought best to perpetuate the variation rather than to become involved in the difficulty of making a change.

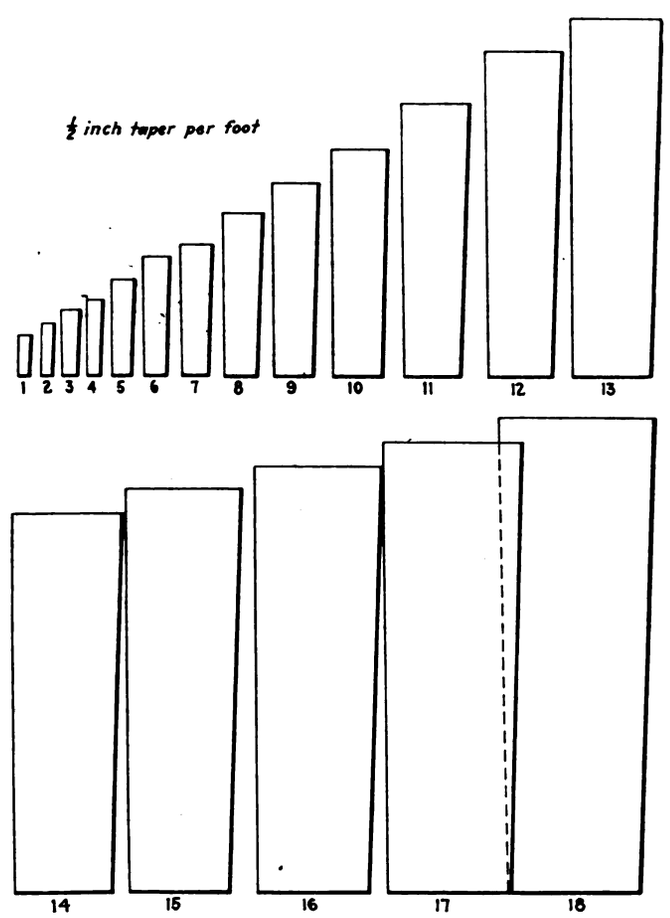

FIG. 3—PROPORTIONS OF B & S TAPERS

This difficulty of making a change applies in a still greater degree at the present time, there now being hundreds of thousands of machines and attachments having this taper and many times that number of arbors, end mills and other tools which fit the taper holes, besides the equipment of gages found in every manufactory where these tapers are produced, both in America and abroad.

The change from 0.5161 to 0.5 per foot would be so great that the parts would not practically interchange, that is, an end mill or arbor made to the new standard could not be satisfactorily used in a spindle or collet of the old standard. At the same time they would be so nearly alike that it would be difficult to detect the difference by inspection, and through a long period of time this would cause great annoyance and expense, besides bringing serious criticism upon the manufacturers on the ground that their work was not being accurately made.

If this were changed the new standard would not be the Brown & Sharpe taper which through a period of sixty years' use we feel has become so established and so widely used as to make us in a sense custodians for its preservation.

The comparative sizes of the Morse and Brown & Sharpe tapers are indicated in Figs. 2 and 3 where each size is shown to a scale of approximately one-half full size, the sizes including the "Magnum Tapers" being given in the accompanying table, Fig. 4.

For any who are interested in a more complete study of the origin and development of the different standards for tapers and the principles on which tapers depend, reference may be made to the article, "Standards for Large Taper Shanks and Sockets" by the author, reprinted on page 537, Vol. 50, of *American Machinist*.

Now is the Time

It is felt that all the information it is possible to give regarding tapers should be brought to the front at this time, as there is a joint committee of the American Society of Mechanical Engineers and the National Machine Tool Builders' Association working on standardization. The matter of tapers is one of the subjects to have attention by the committee.

Charles le Maistre, secretary of the British Engineering Standards Association, who is working in close co-operation with American interests looking toward standardization, while speaking at a recent meeting of the North East Coast Institution of Engineers and Shipbuilders held at Newcastle-upon-Tyne said, regarding the general principles underlying standardization: "Industrial standardization does not necessarily involve the idea of actual perfection; it is rather the registering of what is best in present practice as against attempting to set up an ideal. It is quite easy to set up a standard, but it is altogether another thing to get that standard widely adopted, and a standard which is not in accordance with the fundamental needs of industry, that is, which does not fulfill a recognized want is economically a bad one. It is a wasted effort and a pitfall for the unwary."

It is believed that applying this sound advice, based on most extended experience in standardization, to the question of tapers will lead to the recognition as standard of the two tapers here advocated, namely the Morse and the Brown & Sharpe.

Awakening the Worker's Interest

By Robert Grimshaw

A foreman's first step in awakening interest on the part of the worker is to have it himself. Next, he should prove that he has it by manifesting it. To be interested merely in the product is not, in itself, sufficient. He must be interested also in the means of making it and, above all, he must impart this interest to the operatives to whom he entrusts the carrying out of his orders or the orders of his superiors transmitted through him.

Interest is like magnetism—it can be imparted. True enough, its degree and permanence vary with the material magnetized, but as the choice of the human material usually rests very largely with the foreman, he can seldom complain if he gets poor results.