EFFICIENCY OF MACHINISTS' VISES

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ABSTRACT

Although the industrial arts rest fundamentally on the simple hand tools which have been known and used for centuries, no tests have been reported previously showing the most efficient vise for a given job. This investigation was undertaken to determine the relationship between the size of the vise and its efficiency by performing typical shop operations on material held in the vise. These operations consisted of sawing, bending, and riveting steel specimens and were carried out under carefully standardized conditions, using 12 vises of the stationary bottom type having different lengths of jaw from 2 inches (9 pounds) to 9 inches (282 pounds).

In those tests which may be described as static tests (for example, the sawing tests) in which the movement of the tool was large compared with the movement of the vise, the tests showed no appreciable difference in the efficiency with which the work was performed.

On the contrary, in the dynamic tests (for example, the riveting tests and some of the bending tests on large specimens) the weight, or inertia, of the vise had an appreciable effect on the efficiency with which the work was performed. The efficiency of the 5½-inch (102-pound) vise was greater than for any of the lighter vises but was about the same for all vises larger than 5½ inches (102 pounds).

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I. INTRODUCTION

In this age of mass production of accurate machines, such as automobiles, using intricate automatic machine tools, we often lose sight of the fact that our industrial arts rest fundamentally on the

simple hand tools which have been known and used for centuries. Before there were metal cutting machine tools a casting was finished by chipping the surface using a cold chisel and hand hammer. As the piece neared the finished size hand files were used to produce a smooth surface, followed by a hand scraper if an accurate surface was required.

Unless the work is very large, vises are necessarily used to hold it in the position desired by the workman. Because there is nothing spectacular or impressive about machinists' vises, we lose sight of the fact that these gripping devices are a most essential element of our mechanical equipment.

Although some vise manufacturers have based their designs on the results of strength tests, until recently no investigation has been undertaken to determine the most efficient vise for a given job. It is evidently absurd to select the smallest vise in which the piece can be held. Whatever the operation to be performed, we know that it consists in applying forces tending to move the piece, and that these forces are resisted by the vise and the workbench to which it is bolted. It is convenient to divide the forces into static and dynamic; that is, those exerted by slowly moving bodies, such as files, which exert a more or less uniform force to the piece and those exerted by rapidly moving bodies, such as hammers, which exert great force for short periods of time.

From experience with machines it is evident that under static forces the size and weight of the vise is of comparatively little importance because the forces acting on the piece are transmitted through the vise to the bench and the floor. On the contrary, impact or dynamic forces are largely expended in moving the piece and the vise through short distances. If a larger vise is used, its greater inertia makes this distance less and decreases the portion of the energy of the blow which is expended in moving the work and the piece. Evidently under impact, the size of the vise will have an effect on the efficiency with which the work is performed. Everyone knows that the energy for vise work is the muscular energy of the workman. As this is probably the most expensive energy used in mechanical processes it is of great economic importance to conserve it.

The investigation described here on typical shop operations was undertaken by the Bureau of Standards to determine the relationship between the size of the vise and the efficiency with which the work was performed. These operations, each carried out under carefully standardized conditions, were sawing with a hack saw and bending and riveting under impact.

II. THE VISES AND BENCH

1. VISES

Twelve new vises of the stationary bottom type, typical of the vises used in this country, were used. No vises having swivel bases were used in these tests. They ranged in size from the smallest, having jaws 2 inches long (9 pounds), to the largest, having 9 inches (282

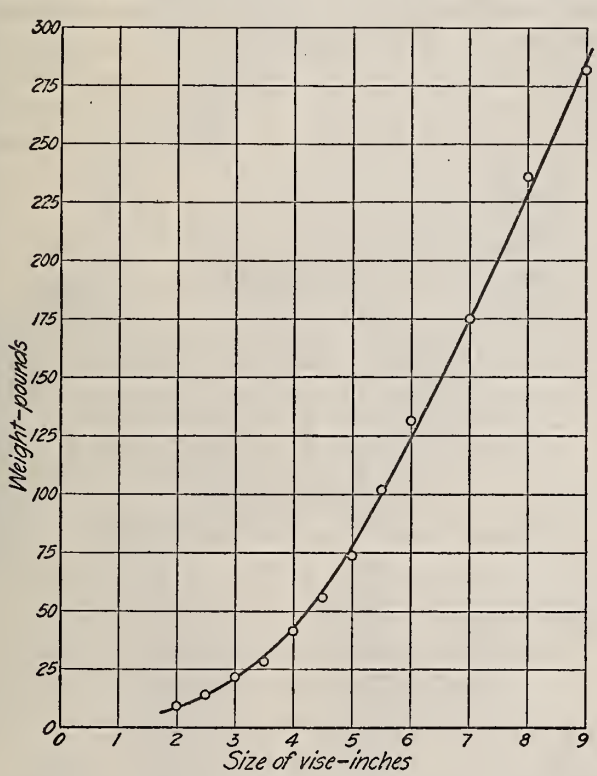

FIGURE 1.—*Relation between the size (length of jaw) and the weight of the vises*

pounds). The data for these 12 vises are shown graphically in Figure 1.

2. BENCH

Each vise was bolted to the bench shown in Figure 2, which consisted of a wooden frame, bolted together, and a top made from 2-inch planks. It was, probably, as rigid as the workbenches to which vises are attached in shops. The weight of the bench was 250 pounds.

After each vise was tested it was removed and another bolted to the bench in the same place.

III. THE TESTS

1. SAWING TESTS

As representative of operations in which a more or less constant force is applied to work—such, for example, as filing or sawing—sawing with a hack saw was chosen.

Rather elaborate apparatus would be required to measure the forces acting on the saw and the effect produced. Consequently, a statistical study of work done under less accurately controlled conditions was made by cutting off, by hand, a number of pieces from the same steel bar. In these experiments, the same downward and horizontal forces on the saw were applied, as judged by the operator.

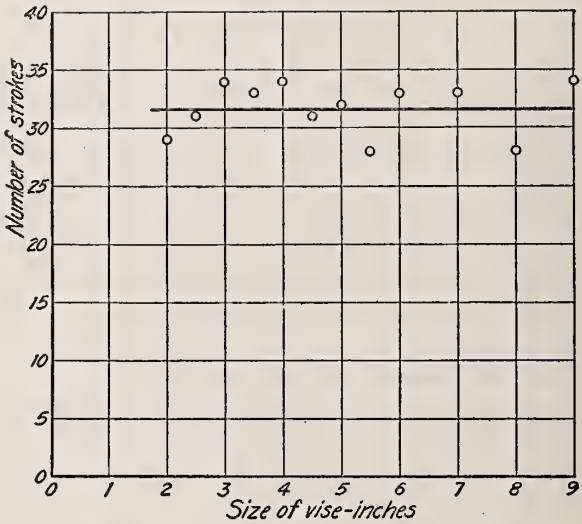

FIGURE 3.—*Results of sawing tests*

The efficiency was practically the same for all sizes of vise

A 12-inch hack-saw frame and 12-inch high-carbon tool-steel saw having 14 teeth per inch were used for all these tests.

The specimen was held horizontally at the middle of the faces of the jaws and the cut made ½-inch from the jaws, as shown in Figure 2.

Using a new blade, three cuts were made in each vise. The number of strokes required to sever the specimen was recorded, and the average for each vise is given in Figure 3. These results show that the differences were, in all probability, due to unavoidable variations in the downward force on the saw. There is no consistent difference which can be attributed to the size of the vise.

It is evident that for the conditions used in the sawing tests there is no difference in the efficiency with which filing, sawing, or similar operations are performed in vises of different sizes.

FIGURE 2.—*Method of making the sawing tests*

FIGURE 4.—*Apparatus for making the bending tests*

The specimen was held vertically in the vise and bent by the sledge swinging downward when released from a given height. Specimens after testing are shown on the bench.

2. BENDING TESTS

To simulate the bending of material held in a vise by horizontal blows of a hand hammer, an apparatus shown in Figure 4 was used. Hammer blows of known energy struck similar specimens held in the jaws of the vise. The angle through which the specimen was bent was taken as a measure of the useful work performed by the blow and served as a basis for comparing the efficiencies of the different vises.

A sledge weighing 12 pounds was swung on an axle carried by the vertical frame which allowed both horizontal and vertical adjustment of the sledge with respect to the vise.

The specimens were held vertically in the vise and bent by one or more blows of the sledge.

(*a*) First Series.—To determine the height from which the sledge should be released preliminary tests were made. Specimens were held in a vise and struck horizontally with a 2-pound hand hammer. A blow was used which, it is believed, was approximately such a blow as a workman would deliver if he were employed continuously on similar work.

Repeated tests of specimens bent with the hand hammer and others bent with the sledge showed that if the sledge was raised 8½ inches above its lowest position and allowed to swing downward and strike the specimen once at the lowest position, that the specimen was bent through approximately the same angle as it was bent by one blow of the hand hammer. This fall of 8½ inches (energy 102 in.-lb.) was therefore used in the first series of bending tests to simulate the blow which a workman would ordinarily strike with a hand hammer.

The specimens, ⅛ inch thick, ¾ inch wide, and 4 inches long, cut from hot-rolled mild steel bars, were held vertically in the vise, so that the upper end was 2⅛ inches above the jaws.

Specimens of this size were bent through a comparatively large angle, and any differences due to the size of the vise could be measured readily.

The axle was adjusted for each vise, so that the center of the face of the sledge when in its lowest position was 2¼ inches above the jaws and just touched the ¾-inch face of the specimen.

The bending tests were made by bolting the vise to the bench, securing the specimen in the jaws, drawing back the sledge and releasing it. The deformed specimen was removed from the vise and the angle measured. Twelve specimens (one for each vise) were cut from each of three similar bars. The results from the three specimens tested in each vise were averaged. In this way the effect of variations in the properties of the specimens was minimized.

The average of the results on the three bend specimens for each vise are shown in Figure 5. For one vise only did the individual values

differ by as much as 1° from the average. It is believed, therefore, that this bending apparatus gave reproducible results, and that three specimens for each vise were sufficient.

(*b*) Second Series.—Although the size of the vise had no appreciable effect on the results of the first series, it was felt that differences might be found if the sledge had been raised to a different height.

Additional tests were therefore made, raising the sledge 3, 5, 7, 9, and 11 inches, and allowing it to strike the specimen once. Three specimens, similar to those previously used and all cut from the same

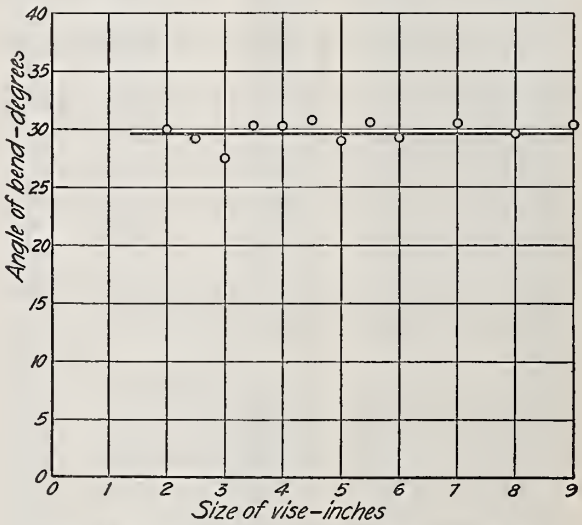

Figure 5.—*Results of the first series of bending tests*

Sledge raised 8½ inches. The efficiency was practically the same for all sizes of vise.

bar, were tested for each height. For these tests only the 2-inch (9-pound), 5½-inch (102-pound), and the 9-inch (282-pound) vises were used. The results are shown in Figure 6.

The angle of bend is directly proportional to the height to which the sledge was raised; the deformation was therefore directly proportional to the energy of the blow. It is evident from Figure 6 that the results for the three vises are the same within experimental error.

The results of the first and second series of bending tests, therefore, show that the size of the vise in which the work is held has no appreciable effect on the efficiency with which material is bent by one blow (energy 102 in.-lb.) simulating that from a hand hammer.

(*c*) Third Series.—As a workman may use a sledge requiring the use of both hands for some work, a third series of bending tests was made allowing the sledge to fall from a height of 27 inches and delivering a blow having an energy of 324 in.-lb. Specimens having

a larger cross section than in the first and second series were used for this series. They were soft steel ⅜ inch thick and 1½ inches wide and were held vertically in the vise as for the previous tests. As one blow did not bend the specimen through a large angle, each specimen was struck seven blows. Then the angle was measured. Three specimens were tested in each vise. The average angle for the three specimens tested in each vise is given in Figure 7.

The results of this series show that for heavy bending work requiring the use of a sledge there is a great increase in efficiency up to a certain size, if the work is held in a heavy vise.

The specimens, held in vises having 7-inch (175-pound), 8-inch (236-pound), and 9-inch (282-pound) jaws, gave on the average

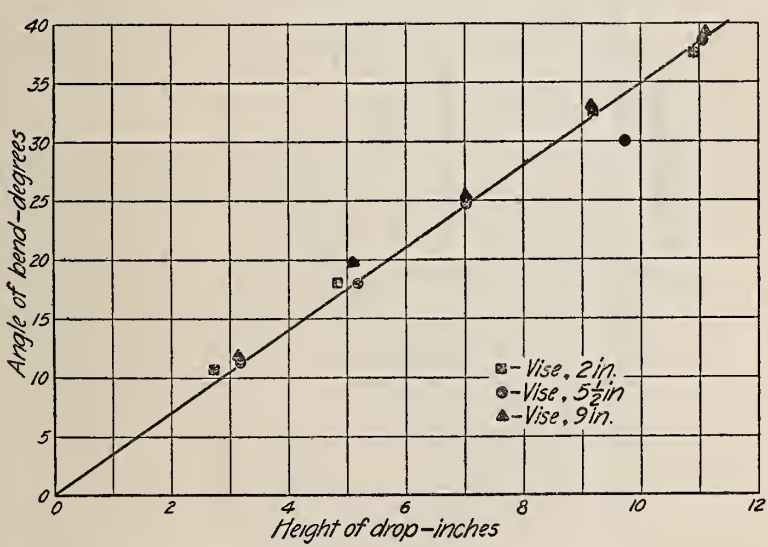

FIGURE 6.—*Results of second series of bending tests*

Sledge raised to different heights. The angle of bend is proportional to the height to which the sledge was raised.

about the same results, showing that there is no measurable advantage in using vises larger than 7-inch (175-pound) when heavy blows are used to perform the work.

3. RIVETING TESTS

(*a*) FIRST SERIES.—To determine the effect of the size of the vise when upsetting or riveting soft steel, specimens 5/32 inch in diameter and 1 3/16 inches long were cut from the same bar and the effect of axial blows observed by measuring the shortening of the specimen. To obtain deformations which could be measured readily, five blows were used for each of the riveting specimens in the first, second, and third series of riveting tests.

To avoid slipping of the specimen in the jaws, the steel holder shown in Figure 8 was used. It was held in the jaws with the hole for the specimen vertical and with the flange resting on the tops of the jaws.

The specimens were placed in the holder, projecting 5/16 inch and the sledge, used for the bending tests, adjusted to drop vertically on the upper end of the specimen. The axle was adjusted for each vise, so that the handle of the sledge was horizontal and the sledge struck the specimen in the middle of the striking face.

It was found, experimentally, that this 12-pound sledge, dropping 10 inches and striking a blow having an energy of 120 in.-lb. caused

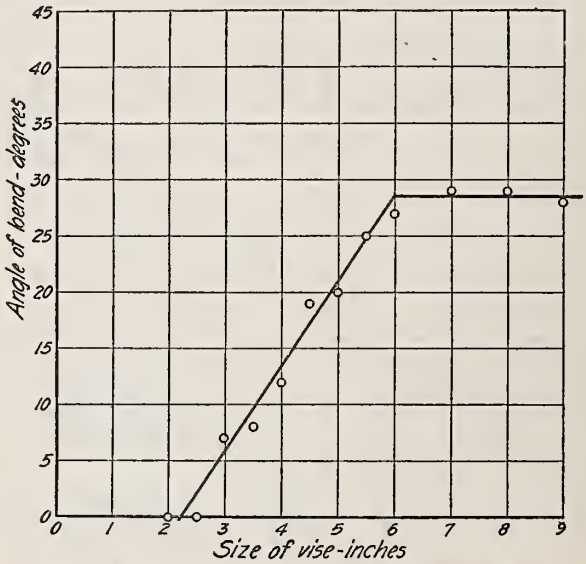

FIGURE 7.—*Results of third series of bending tests*

Sledge raised 27 inches. The efficiency increased greatly as larger vises were used up to 5½ inches. There was no increase in efficiency for vises larger than 5½ inches.

about the same shortening of the riveting specimens as a blow having energy comparable with that of a 2-pound hand hammer.

The tests were made by supporting the sledge 10 inches above the specimen by a stick, as show in Figure 9. The stick was withdrawn quickly, allowing the sledge to drop on the specimen. This operation was repeated five times, then the specimen was removed from the holder and its length measured. Three specimens were tested in each vise, and the average results are shown in Figure 10.

These results show that the shortening was greater the larger the vise up to the 5½-inch (102-pound) vise. There was no appreciable increase in the shortening for the larger vises. The specimens tested

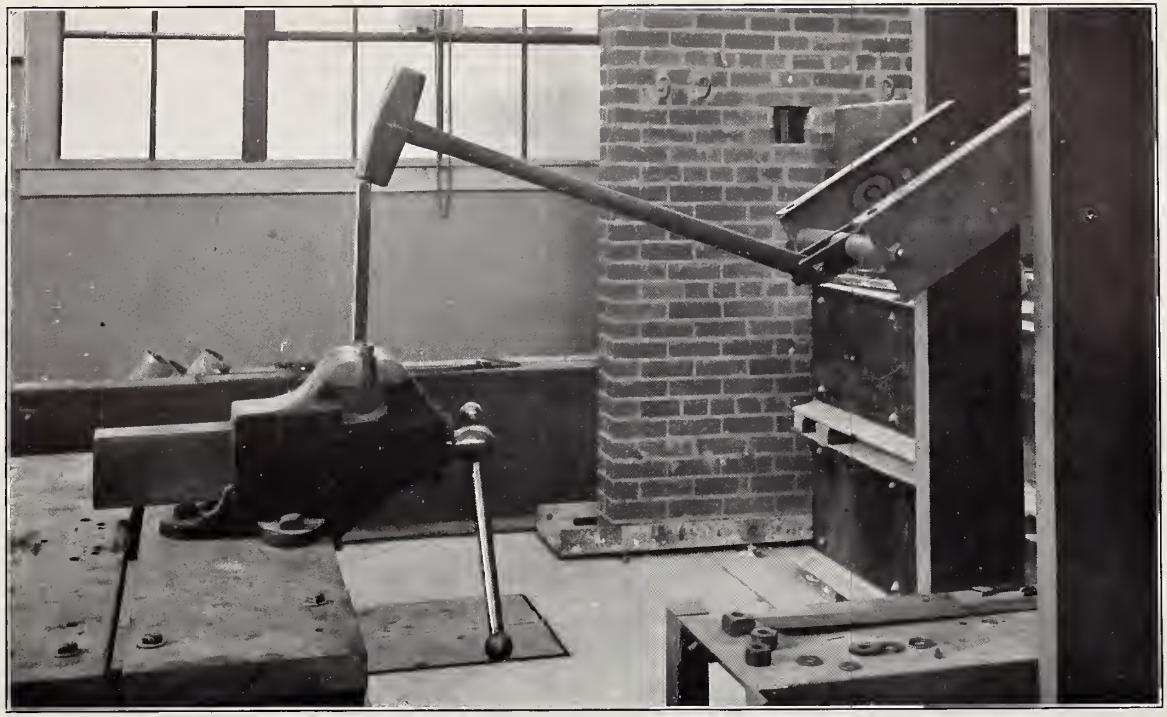

FIGURE 9.—*Apparatus for making riveting tests*

The sledge was supported at the desired height by a stick which was withdrawn quickly allowing the sledge to drop on the specimen.

in the 5½-inch (102-pound) vise shortened about three times as much as those tested in the 2-inch (9-pound) vise.

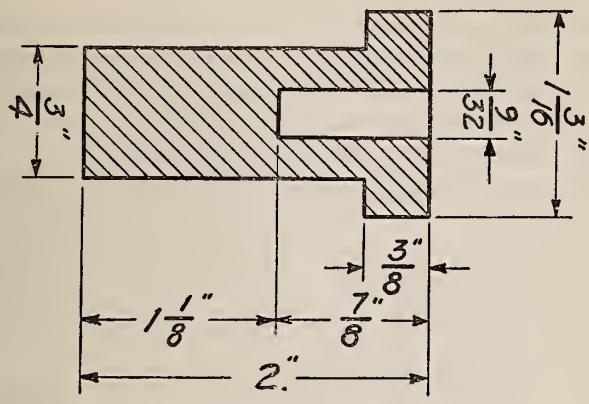

FIGURE 8.—*Holder for riveting specimens*

The holder was held vertically in the vise with the flange resting on the jaws. The specimens were placed in the recess in the holder.

(*b*) SECOND SERIES.—To determine the effect of varying the energy of the blow by varying the height of drop, riveting tests were also made, using drops of 4, 6, 8, 10, and 12 inches. For these tests only

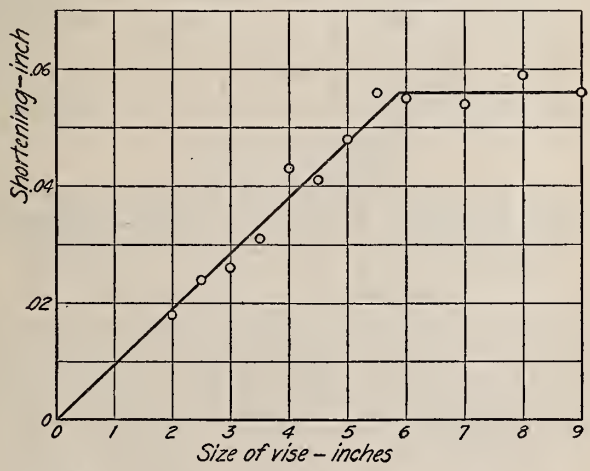

FIGURE 10.—*Results of the first series of riveting tests*

Sledge raised 10 inches. The efficiency increased greatly as larger vises were used up to 5½ inches. There was no increase in efficiency for vises larger than 5½ inches.

the 2-inch (9-pound), 5½-inch (102-pound), and 9-inch (282-pound) vises were used.

The results are shown in Figure 11. They show that the deformation increased as the height was increased, and also that the defor-

mation is greater for the 5½-inch (102-pound) vise than for the 2-inch (9-pound) vise, but that the 5½-inch (102-pound) and the 9-inch (282-pound) vises give about the same results.

These riveting tests show that up to a certain size the larger the vise the more efficiently work, such as riveting and chipping, is performed, using blows having energy comparable with that of a 2-pound hand hammer, but that there is no appreciable increase in efficiency if vises larger than 5½-inch (102-pound) are used.

(*c*) Third Series.—To determine the effect when a sledge requiring the use of both hands is employed, riveting tests were made on large

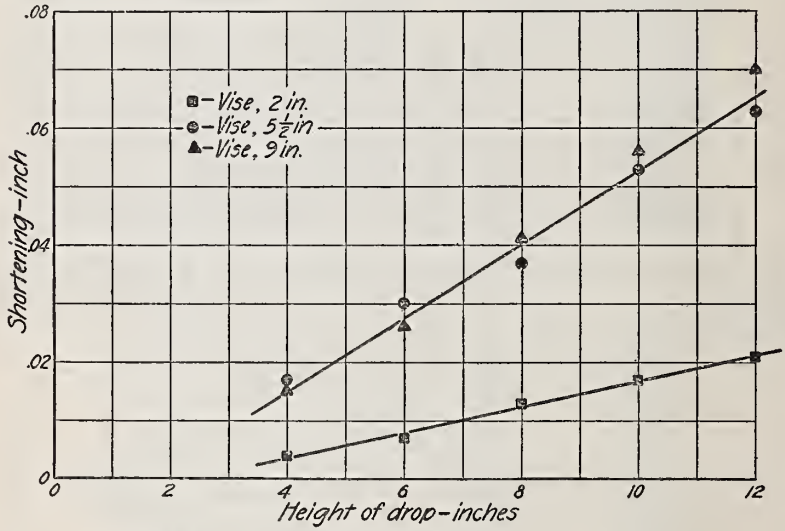

Figure 11.—*Results of the second series of riveting tests*

Sledge raised to different heights. The deformation of the specimens is greater for 5½-inch vise, than for the 2-inch vice, but the 5½-inch and 9-inch vises give about the same results.

specimens ⅝ inch in diameter and 1⅞ inches long. The sledge was allowed to fall from a height of 27 inches (energy 324 in.-lb.) and strike the specimen as in the previous riveting tests. The specimens were supported in a steel holder similar to the one previously used. Each specimen was struck 60 blows, then removed from the holder and the length measured. Four specimens were tested in the 6-inch (132-pound) vise and six in the 8-inch (236-pound) vise. Three specimens were tested in each of the other vises used. The average results are shown in Figure 12.

This series showed that there is an increase in efficiency as the size of the vise increases up to 5½ inches (102 pounds). For larger vises there is no appreciable increase in the efficiency even with these heavy blows having an energy of 324 in.-lb.

IV. DISCUSSION

In these tests the vises were tightly bolted to a bench having approximately the rigidity of workbenches usually used in a shop. If the bench had been much less rigid, these tests would not have simulated reasonably good shop conditions. It is believed that for the sawing tests and the first and second series of bending tests the rigidity of the bench was not an important factor, because the forces applied to the specimens acted through relatively long distances, and the deformation of the bench was negligible compared with the distances through which the forces acted.

To determine the magnitude of this deformation, the movements of the 2-inch (9-pound), 5½-inch (102-pound), and 9-inch (282-pound) vises were measured under loads applied to a specimen held

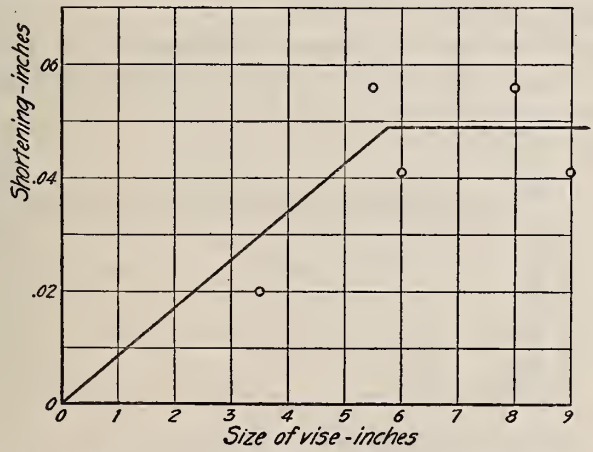

FIGURE 12.—*Results of the third series of riveting tests*

Sledge raised 27 inches. The efficiency increased as larger vises were used up to 5½ inches. There was no appreciable increase for vises larger than 5½ inches, even with these heavy blows having an energy of 324 in.-lb.

in the vise. The vertical displacements of the vises were measured, using a dial micrometer, under a 50-pound load applied by a weight. The horizontal displacements were similarly measured under a horizontal load of 50 pounds applied through a spring balance. The results are given in Table 1.

TABLE 1.—*Movement of vises*

Size of vise (in inches)	Movement	
	Vertical force, 50-pound	Horizontal force, 50-pound
	Inch	*Inch*
2	0.005	0.040
5½	.003	.022
9	.004	.048

The movement, of course, depends somewhat upon the forces exerted by the bolts used to attach the vise to the bench, but as these bolts were tightened until the washers under the nuts crushed into the wood it is believed that these forces were as high as good shop practice permits. The movement of the vises is probably caused, at least in large part, by the deformation of the bench under the load.

Considering the sawing tests, we may draw the hypothetical work diagram shown in Figure 13, in which the ordinates *BD* represent the horizontal forward force parallel to the blade and *OE* the length of the cutting stroke (11½ inches). When a cut is started, the force increases as shown by *OB* and is then constant for the remainder of the stroke. The deformation of the bench and vise are represented by the distance *OD*, which is less than 0.05 inch for a force of 50 pounds. It would be much less, about 0.01 inch, for the force used in the sawing tests.

The area *OBD*, then, represents the work done in deforming the bench and vise before the saw moves relatively to the specimen.

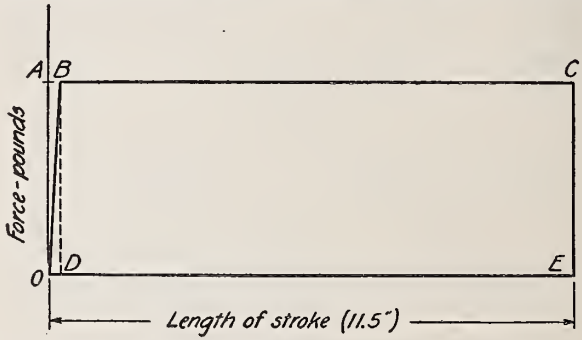

FIGURE 13.—*Work diagram for sawing tests*

The area *OBD* represents the work required to deform the vise and bench. The area *DBCED* represents the work expended in cutting the specimen.

The area *DBCED* measured the work done in cutting the specimen. Assuming that *OD* is 0.01 inch and *OE* 11½ inches, the work lost due to the deformation of the bench and vise is 0.04 of 1 per cent of the total work, which is inappreciable.

The distance through which the force acted in the first and second series of bending tests was about ¾ inch. This, again, is large compared with the movement of the vise. As the variation of the force as the specimen bends is unknown, no attempt will be made to estimate the loss but, as in the sawing tests, it, in all probability, is negligible.

It should be noted that in both the sawing tests and in the first and second series of bending tests the forces acted for an appreciable length of time. For this reason the inertia of the vise has little

effect and the vise moves until the bench exerts forces sufficiently great to counteract the forces exerted on the specimen. This conclusion is justified by the fact that the size of the vise had no appreciable effect on the efficiency with which sawing or bending was performed.

In the third series of bending tests each specimen was struck seven blows. As the specimens held in the two smallest sizes of vise were not bent, all of the energy must have been expended in elastic deformation of the specimen, vise, and bench.

Figure 7 shows, however, that whatever the magnitude of this elastic deformation, using a vise larger than 6 inches (132 pounds) does not increase the efficiency with which bending is performed with a sledge.

In the third series of bending tests and in all the riveting tests the forces on the specimen act for a very short time and their magnitudes are unknown. It is therefore impossible to estimate the movement of the vise in these tests.

We can, however, reason from the laws of impact that for the same energy of blow the motion of the vise would be less the lighter the hammer used. Consequently, the relative advantage of using a larger vise found with the 12-pound hammer is greater than could be expected if a smaller hammer was used, such, for example, as a 2-pound hand hammer. As no hammer heavier than 12 pounds is likely to be used on work in a machinists' vise, no greater efficiency can be expected from the use of larger vises than are shown by these tests.

The load required to cause permanent shortening of the riveting specimens was found to be about 4,000 pounds, and the top of the bench would have deflected considerably under a static load of this magnitude. It is evident, therefore, that in all the riveting tests the ineritia or "anvil effect" of the vise was much more important than the support offered by the bench. The results showed a great increase in the efficiency with which riveting was performed as the size of the vise was increased up to 5½ inches (102 pounds). The fact that no appreciable increase was shown for larger vises tends to show that for pieces which can be held in smaller sizes there is little advantage in using vises larger than 5½ inches (102 pounds) if the work is to be performed either with a hand hammer or a sledge.

V. CONCLUSIONS

1. Tests made by sawing steel specimens held in vises of different sizes, from 2-inch (9-pound) to 9-inch (282-pound), showed no appreciable difference in the efficiency with which the work was performed.

2. Tests made on small steel specimens held in vises of different sizes, from 2-inch (9-pound) to 9-inch (282-pound), by blows having energy comparable with that delivered by a 2-pound hand hammer used under average working conditions, showed no appreciable difference in the efficiency with which the work was performed.

3. Tests made by bending large steel specimens held in vises of different sizes, from 2-inch (9-pound) to 9-inch (282-pound), by blows having energy comparable with that delivered by a 12-pound sledge used under average working conditions, showed an increase in the efficiency with which the work was performed as the size of the vise was increased up to 6 inches (132 pounds). The efficiency was about the same for all vises larger than 6 inches (132 pounds).

4. Tests made by upsetting or riveting small steel specimens held in vises of different sizes, from 2-inch (9-pound) to 9-inch (282-pound), by blows having energy comparable with that delivered by a 2-pound hand hammer used under average working conditions, showed that the efficiency using a 5½-inch (102-pound) vise was about three times that found for a 2-inch (9-pound) vise. The efficiency was about the same for all vises larger than 5½ inches (102 pounds).

5. Tests made by upsetting or riveting large steel specimens held in vises of different sizes, from 2-inch (9-pound) to 9-inch (282-pound), by blows having energy comparable with that delivered by a 12-pound sledge used under average working conditions, showed that the efficiency using a 5½-inch (102-pound) vise was greater than for any of the smaller vises. The efficiency was about the same for all vises larger than 5½ inches (102 pounds).

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