Effects of Light Peening on the Yielding of Steel

Plastic elongation of mild steel strips axially loaded below the yield point subjected to transverse hammering

by Howard L. Harrison and Blake D. Mills, Jr.

WHEN a steel beam in a bridge or other structure has been bent by an accident, it has sometimes been found practicable to straighten the member in position, instead of replacing it. The straightening procedure has usually been based on the judicious application of localized heat, which causes the metal to expand and yield locally, then upon cooling to contract in such a manner as to accomplish the desired straightening. In some instances, however, it has been found necessary to supplement the heat-and-contraction technique with a certain amount of cold straightening.

For cold straightening of a beam, a heavy transverse force may be applied, utilizing a jack or a cable. If only a steady force is applied, it must produce bending stresses exceeding the yield point of the steel, in order to accomplish permanent straightening. However, if the tension side of the bent member is lightly hammered during application of the steady transverse force, straightening can be effected under a steady force which alone is insufficient to produce yielding. This observed behavior has led to the present laboratory studies of the effect of light hammering on members carrying steady axial tension. The investigation is related also to the peening of welds for the relief of residual stress.

This investigation has been undertaken under the sponsorship of the Engineering Experiment Station of the University of Washington. To date, the work has been only of an exploratory nature, using a simple type of specimen under steady tensile stress. The experimental results are not yet sufficient to warrant any sweeping conclusions. However, the tests indicate the

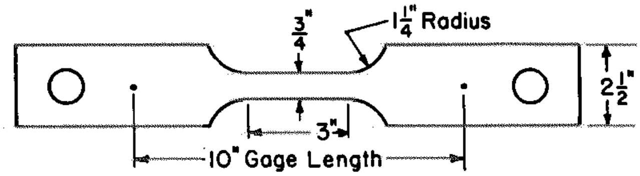

Fig. 1 Test specimen, machined from hot-rolled mild steel sheet; 0.078-in. thick

considerable plastic elongation which can result from light transverse hammering on a tension member whose steady stress is well below its yield point.

The test specimens were all machined from the same 14-gage, hot-rolled mild steel sheet (0.078-in. thick), to the dimensions shown in Fig. 1. Figure 2 shows the testing fixture, in which the specimen rests on a small rectangular anvil, and is subjected to a steady tensile load produced by a 100-lb. weight hanging from the long arm of a bell-crank lever. The hammering action was accomplished by repeated 3-in. drops of a 1-lb. piece of $1^1/_8$-in. round steel stock, having a flat striking face.

Before hammering or applying tensile load, a 10-in gage length was laid off with punchmarks on each test specimen, straddling the reduced section. The 10-in. length was chosen to accommodate a 10-in. Whittemore

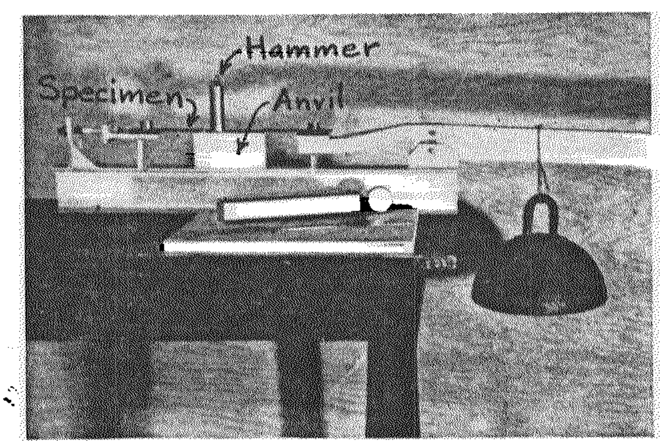

Fig. 2 The testing fixture, with a specimen in place. The 10-in. Whittemore strain-gage is in the foreground

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strain gage, which was used for measuring elongation of each specimen. The Whittemore gage was applied to each specimen, immediately before the hammering began, and again after appropriate numbers of hammer blows. For each hammer blow, the 1-lb. weight was raised 3 in. with a string and allowed to fall freely, guided within a loosely fitting vertical tube. The location of the hammer blows was slowly shifted back and forth along the reduced section of the test specimen, as hammering proceeded. Timing of the blows was synchronized with the swings of a simple pendulum consisting of a small weight hanging from an appropriate length of string. The frequency was 90 blows per minute in all tests, except where stated to be otherwise.

The yield point of the steel was about 35,700 psi., as determined from tension tests of unhammered specimens. For the tests with transverse hammering, the steady tensile stresses for successive specimens were 30,000 psi., 25,000, 20,000, 15,000, 10,000, 5000 and zero. Six hundred hammer blows were applied to each specimen. Three complete series of these tests were conducted. Figure 3 shows the family of elongation curves obtained from the first series, the number of blows being plotted as abscissae. These curves show that the 600 blows produced only 0.001-in. elongation of the 10-in. gage length, when no tensile stress was applied. With 15,000 psi. steady tensile stress, the 600 blows produced 0.0045-in. elongation; and under 30,000 psi. steady stress, the same hammering caused an elongation of 0.028-in. The curves of elongation, incidentally, are seen to resemble a family of creep-time curves for steel at high temperatures.

The second and third series of tests, intended to be identical to the first series, produced similar but far from identical results. Figure 4 shows the elongation produce by 600 blows on each specimen in each of the three test series. The only known difference in the test conditions was the room temperature, which was somewhat higher for the first series than for the others.

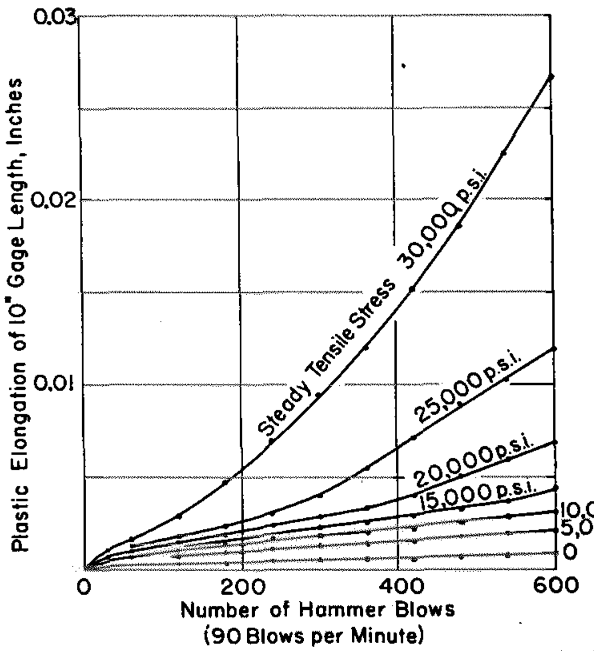

Fig. 3 Plastic elongation vs. number of hammer blows, under various values of steady tensile stress

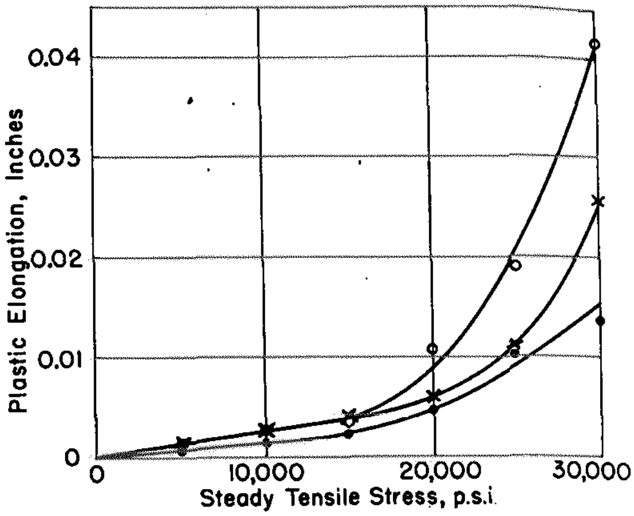

Fig. 4 Plastic elongation caused by 600 hammer blows, under various values of steady tensile stress. The three curves represent tests made on different days. Room temperature was highest for the upper curve

It was felt that the frequency of the hammer blows might have a significant influence on the amount of elongation produced. Accordingly, tests were conducted in which 600 blows were applied to successive specimen at frequencies of 120, 60, 30 and 15 blows per minute, respectively. In these tests, the steady tensile stress was 25,000 psi. on all the specimens. A series of these frequency-variation tests was conducted on each of two different days, and the results are shown graphically in Fig. 5. It is seen that the highest frequency caused the greatest elongation, but the curve of elongation versus frequency was considerably different in the two supposedly identical series of tests. Additional single tests scattered considerably from the curves shown in Fig. 5.

It was wondered how far the effects of the hammer blows might extend from the material actually struck by the hammer. To indicate the answer, an SR-4 resistance-wire strain gage was cemented over half the

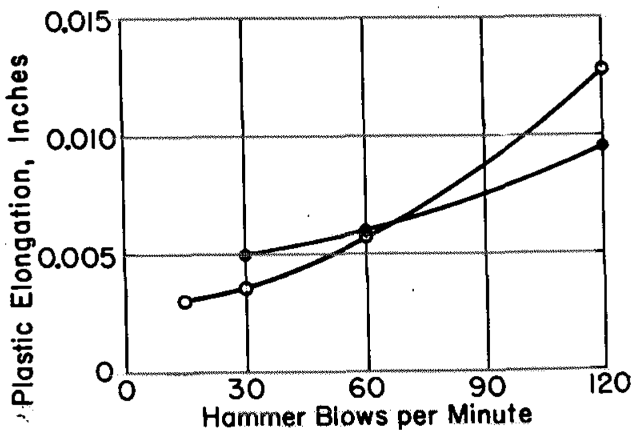

Fig. 5 Plastic elongation vs. frequency of hammer blows. Six hundred blows on each specimen, under steady tensile stress of 25,000 psi. The two curves represent tests made on different days under supposedly identical conditions

length of the reduced section of a test specimen, and the hammering was confined to the other half of the reduced section, using a steady tensile stress of 25,000 psi. This test was repeated on a second specimen, under the same conditions. In both these tests, the elongation of the unhammered portion was negligible, compared to the elongation of the hammered portion.

It would appear that the considerable variations between repeated tests may be partly attributable to nonhomogeneity among specimens cut from different parts of the steel sheet, but differences in the prevailing room temperature may also have played a significant part. Further tests are to be made, to study the effect of small differences in temperature. Each individual curve illustrated in this article, however, was derived entirely from tests conducted at practically the same temperature.

CONCLUSION

This exploratory investigation indicates a number of interesting features of the behavior of constant-stress members under light transverse hammering. Even when the steady stress was less than half the yield point, a few hundred light blows of a flat-faced hammer caused quite appreciable plastic elongation. Differences in room temperature and frequency of blows appeared to have a considerable effect. The plastic elongation was confined almost entirely to the zone actually struck by the hammer. The conditions responsible for the plastic elongation have not been established in this investigation. It is possible that the dynamic stresses during each hammer blow were sufficiently high that momentary yielding should be expected, referring to common theories for the yielding of ductile metals, such as the maximum shear theory or maximum shear-strain energy theory.

Transformation of Austenite in a Manganese-Molybdenum Steel Deposited as Weld Metal

Discussion by Hallock C. Campbell

The declassification of the N.D.R.C.'s welding studies on the N.R.C-2A electrode and particularly the publication of the transformation diagram in THE WELDING JOURNAL marks a big step forward in the science as opposed to the art of welding. The availability of the transformation diagram should greatly aid in the understanding of welding problems connected with welding armor and high-tensile steels.

An application of the transformation diagram in explaining past observations and strengthening our faith in the currently recommended procedures is presented in the accompanying graph of Charpy V-notch impact values for the manganese-moly weld metal discussed by Dr. Miller.

Each of the points in Fig. 1 is an average of six impact tests. The welds were made with $^3/_{16}$-in. manganese-moly electrodes in $^3/_4$-in. manganese-moly plate using a 45° included angle V-groove butt joint with $^1/_2$-in. root and a backing strip. The weld metal composition was 0.15 C, 1.7 Mn, 0.2 Si, 0.4 Mo. The specimens welded with 150–200° F. interpass temperature are noticeably higher in impact strength than those welded with 250–300° F. interpass. This would be expected from a knowledge of the cooling diagram. Since the cooling rates for such welds pass through the ferrite-bainite region, the use of higher interpass temperatures (which results in slower cooling rates) leads to less martensite and hence lower impact strength, as the authors have explained.

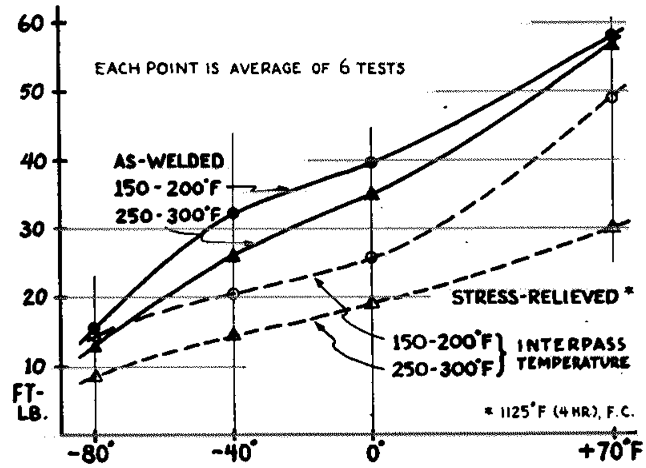

Fig. 1 Charpy V-notch impact strength $^3/_{16}$ in. Mn-Mo electrodes

It is hoped that the publication of the diagram will serve a valuable educational purpose in teaching the

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Paper by O. O. Miller, F. C. Kristufek and R. H. Aborn was published in the Research Suppl. to the September 1950 issue of THE WELDING JOURNAL, 450-s–458-s.

Effects of Light Peening on the Yielding of Steel

Discussion by N. H. Polakowski

I wish to congratulate the authors for their simple and ingenious approach to a problem which is practically important but inherently complex at the same time. It may perhaps be of interest to reproduce here some of my own results which not only bear out the observations made by Professor Mills and Mr. Harrison but, I believe, also explain their reasons.

In the course of an investigation of the discontinuous yield phenomenon, steel rods 0.25 in. in diameter and 10 in. long were hammered by hand with a 4-oz. wooden mallet for different time intervals. The blows were divided as uniformly as possible over the whole length of each sample and afterwards the rods were tested in tension by using a plain 4-in. extensometer attached to an autographic recording device. A set of records obtained with a 0.14% C, commercial-quality steel, normalized from 900° C. is shown in Fig. 1.

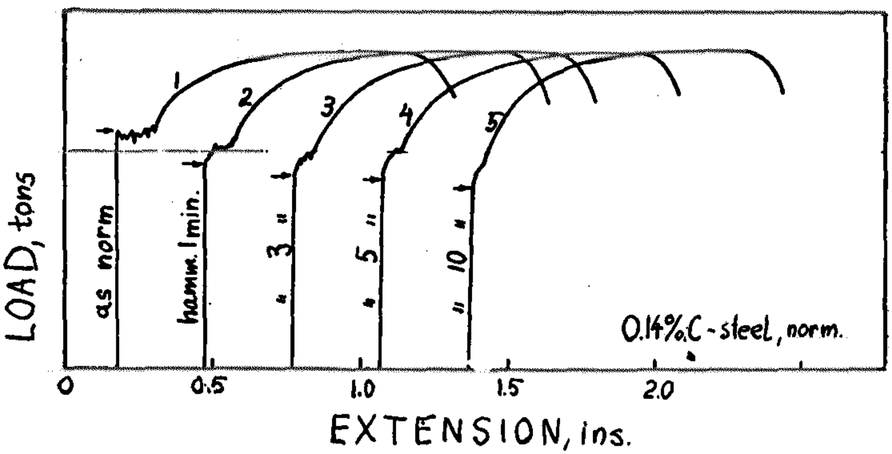

Fig. 1 The effect of hammering for periods indicated on the yield-point behavior of normalized, 0.14% C–steel rods, 0.25 in. in diameter, and 10 in. long. Gage length 4 in. in all tests

It is seen that the initial yield stress (or load) values decrease systematically with increasing intensity of the hammering treatment applied, as indicated by the small arrows. Since the actual yield stress is depressed by hammering, it is only natural that large permanent sets are found at relatively low stresses. In fact, yielding begins at much lower stress values than those indicated on the consecutive curves in Fig. 1, because a steel subjected to hammering and not allowed to age has probably no elastic range at all, just like common nonferrous metals. This could not be detected in my experiments because of the crude extensometer used, but it is a well-known fact since Bauschinger's time.

The fall of the yield stress and the simultaneous disappearance of the yield discontinuity can be accounted for if it is assumed that discontinuous yielding of steel is caused by a brittle "grain-boundary skeleton," as already suggested by numerous prominent investigators in the past. The above "skeleton" consists most likely of cementite, some nitrides and perhaps of other inclusions as well. Hammering destroys the brittle structure embedded in the soft ferrite without seriously affecting the ductility of the matrix, which has a much lower inherent yield stress value than the "composite body," i.e., the annealed but mechanically unworked steel.

The above concept is consistent with the authors' observation that the elongation was confined to that portion of the test-piece which was actually hammered (p. 253, top, left), because only in this portion was the yield point depressed.

A reference to their Fig. 3 suggests that some small stretching was caused by the action of the hammer alone (lowest curve), and this would indicate that some work-hardening must have occurred.

I would be glad to know whether the changes of hardness caused by different numbers of blows are available to the authors (Vickers or Brinell values preferably), as some increase could be expected in spite of the simultaneous depression of the yield point.

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