

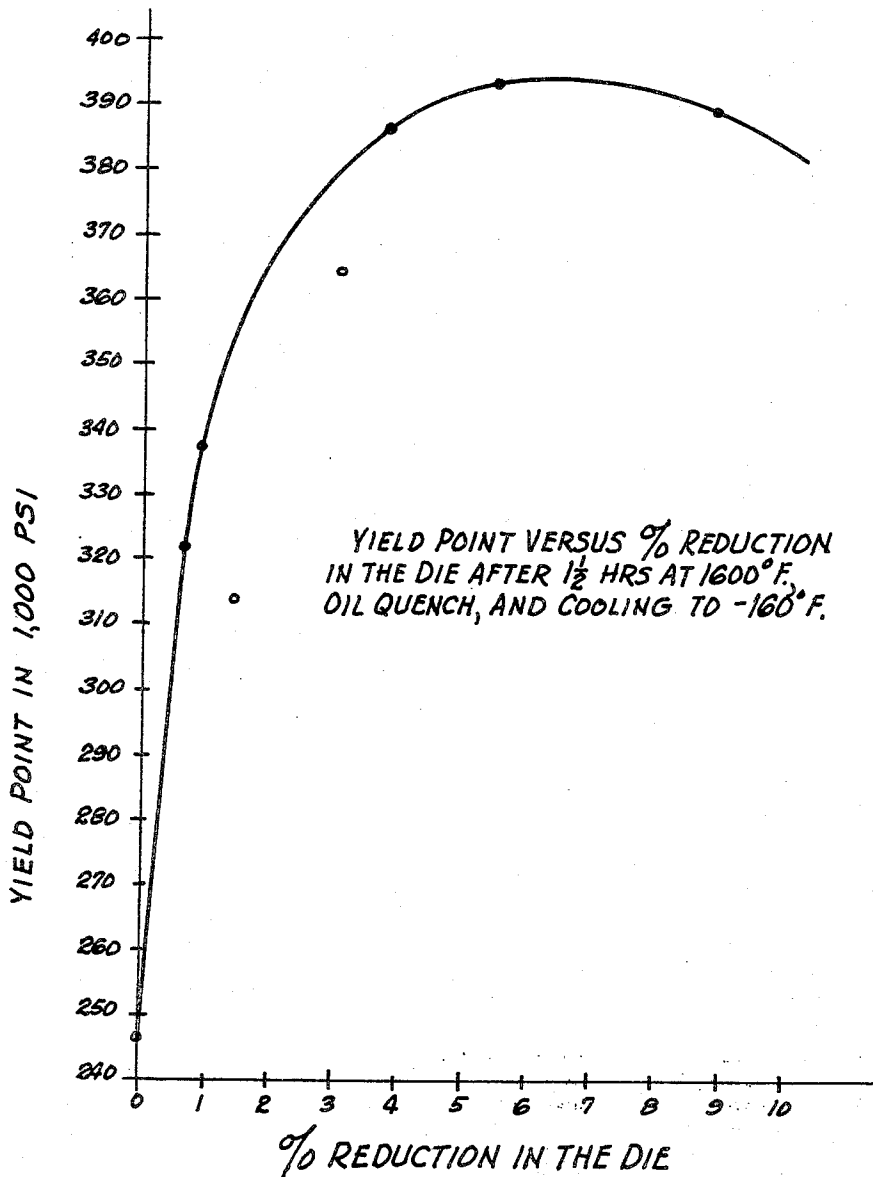
Sept. 11, 1962

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3,053,703

PRODUCING HIGH STRENGTHS IN MARTENSITIC STEELS

Filed Aug. 5, 1960



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PRODUCING HIGH STRENGTHS IN
MARTENSITIC STEELS
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Filed Aug. 5, 1960, Ser. No. 47,736
12 Claims. (Cl. 148-12)

This invention relates to the production of a new and improved steel of high strength, and it relates more particularly to a metallurgical process for creating improvements in the physical and mechanical properties of steel.

It is an object of this invention to provide a new and improved metallurgical process wherein strength properties of steel can be improved in a simple and effective manner, and it is a related object to provide a process wherein improvements can be achieved in strength properties of steel without the normally expected sacrifices of others of the desirable mechanical and physical properties of the steel.

These and other objects and advantages of this invention will hereinafter appear and for purposes of illustration, but not of limitation, an embodiment of this invention is illustrated in the accompanying drawing, in which—

The FIGURE is a curve representing the improvements in yield strength that are secured in accordance with the practice of this invention.

In accordance with the practice of this invention, the procedure for the production of a martensitic steel is followed to the point of rapidly cooling the steel to martensite formation except that instead of directly following martensite formation with a tempering operation this invention introduces a step of taking a light deformation of the steel at a temperature below 200° F. and, preferably, at ambient temperature, while the steel is still in the martensitic state. After this deformation of the preferably freshly formed martensitic steel, the steel can be used as is, or tempered. Thus, the process forming the subject matter of this invention resides in the introduction of a deformation step following the step of rapidly cooling steel heated to above the transformation range for martensite formation and before tempering. It has been found that an unexpectedly large increase in strength properties is secured when the martensitic steel is subjected to a small amount of plastic deformation in accordance with the practice of this invention, as compared to the same steels processed in the same way without the described intermediate deformation step.

It has been found that the strength properties of the steel increase at a significant rate in response to reductions of the martensitic steel within the range of from a fraction of a percent up to about 4% and, preferably, within the range of about 0.25-4%. Additional increase in strength properties is secured in response to reductions greater than 4%, but the rate of increase levels off considerably by comparison with the reduction in the preferred range. While the described improvements in strength properties are secured in response to reductions greater than 10%, the amount of improvement is no greater than that secured by reductions below 10% and there is a serious degrading of the ductility properties as measured by elongation and reduction of area. It becomes more desirable and practical to limit the reduction to less than 10% and preferably to within the most effective range of from 0.25-4%, since processing difficulties at 10% result in frequent material and tooling failures.

It is preferred to take the slight reduction of the freshly formed martensitic steel by advancement of the steel

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through a draw die, but other plastic deformation processes, such as extrusion or rolling can be employed.

The described improvements in strength properties are capable of being developed in steels capable of undergoing martensite transformation followed by rapid cooling. These steels include plain carbon steels, low and medium carbon steels, and alloy steels. A-4340 steel can be used as representative of the steels to illustrate the practice of this invention. It will be understood that corresponding results will be secured when the same process is employed with other steels of the types described.

For purposes of illustration, a series of bars of A-4340 steels, 5/8 inch in diameter, were heated to a temperature above the transformation range for the steel. In this instance, the steel was heated to a temperature of 1600° F. to ambient temperature, with the accompanying conversion of the steel structure to martensite. The bars were cooled to -160° F. to convert retained austenite to martensite. The quenched steel bars were pickled and limed to clean the surface and then advanced through draw dies to subject the bars to different amounts of reduction ranging from 0.67-8.92%. The bars were then tested for tensile strength, yield strength, reduction in area and elongation without further heat treatment or tempering, with the following results:

Percent Reduction	Tensile Strength, p.s.i.	Yield Point, p.s.i.	Elongation, Percent	R/A, Percent	R.
0.00-----	304,050	246,700	9.0	35.3	60
0.67-----	332,650	322,250	10.0	39.5	61
0.95-----	337,650	337,650	6.0	33.3	61.5
1.44-----	315,900	313,900	6.5	35.6	61.5
3.09-----	364,900	364,900	5.5	31.5	62
3.83-----	390,900	386,650	5.5	31.9	62
5.48-----	395,250	393,000	4.5	25.5	62
8.92-----	395,850	389,700	2.0	10.5	62.5

It will be apparent that a rapid rise in yield strength occurs in response to reductions within the range above 0 up to about 4%. Beyond 4% reduction, the curve begins to flatten out, indicating a lesser rate in the increase in strength upon reduction in amounts greater than about 4%. Beyond 8% reduction, no further significant increase in strength properties is experienced, while the ductility as measured by elongation and reduction of area are reduced.

It will be noted further from the data developed that the increase in tensile strength and yield strength is achieved without a proportionate loss of elongation, indicating a reversal of the trend normally to be expected in the older processes for hardening steel.

Instead of an oil quench, use can be made of a water quench, fast cooling air quench, or other quenching medium for rapid reduction of temperature of the steel from the transformation range to about ambient temperature for martensite formation. The steels produced in accordance with the practice of this invention can be tempered by normal tempering techniques after reduction of the martensitic steel.

By way of further illustration of the concepts of this invention, reference will be made to a further series of data developed with 8645 steel. In this procedure, rods of 8645 steel were austenitized by heating at 1600° F. for one and one-half hours followed by quenching the rods in an oil bath. The rods containing martensite were divided into various groups, some of which were cold drawn at room temperature for reductions up to about 4.6 to 4.8 percent, while others were heated to a temperature of about 212° F. before drawing. The following table will set forth the results that were secured.

[AISI 8645—Austenitize at 1600° F. for 1½ hours, oil quenched]

Predrawing Treatment		Percent Reduction	Tensile Strength, p.s.i.	Yield Point, p.s.i.	Elong., Percent	Red. of Area, Percent	R.
Before Drawing	In-Temp. of Drawing						
None.....	Not Drawn...	Not Drawn...	295, 100	233, 500	9.5	30.9	58.0
None.....	Cold.....	4.6.....	376, 000	376, 000	3.5	20.7	59.0
None.....	Cold.....	3.75.....	378, 750	378, 750	5.0	27.8	62.2
212° F. (3 Min.).....	Not Drawn...	Not Drawn...	301, 600	290, 300	7.0	16.0	52.8
212° F. (3 Min.).....	Cold.....	3.4.....	373, 200	373, 200	5.5	22.1	61.0
212° F. (45 Min.).....	Cold.....	3.75.....	340, 050	340, 050	5.0	30.1	62.9
212° F. (3 Min.).....	180° F.....	4.8.....	366, 900	364, 800	5.5	24.5	58.5

It will be noted that considerable improvement in strength properties, without material loss of elongation, is obtained when a light reduction is taken of the steel while in a martensitic state. From the values obtained after the steel has been heated to 212° F., it will be further apparent that somewhat similar improvements are achieved when light reductions are taken of steels which still contain martensite although, for the most part, the increase in strength properties is not as great as that which is experienced without pre-treatment with heat. Equivalent results are not secured when the steel is heated prior to drawing to a temperature in excess of 300° F., but heat treatment at temperatures below 300° F. can be conducted over an extended period of time, as evidenced by the results secured by heat treatment for 45 minutes at 212° F. without destroying the ability to achieve the desired strength increase without material loss of elongation by taking light reductions in accordance with the practice of this invention. In these instances, it is believed that heat treatment at temperatures below 300° F. does not affect the martensitic structure whereby the discovered unexpected strength increase is capable still of being achieved by the light reduction step. This is especially significant since no one, to the best of my knowledge, has attempted to draw martensitic steel because of the recognized inability to draw without rupture. However, as I have found, reductions can be taken without rupture and with unexpected improvements in strength properties without material loss in elongation if the steel containing martensite is given but a light reduction—all of which is contrary to the general beliefs in the art. For the present, no clear explanation has been developed for the unique and unexpected creation of high strength in the steel, but it appears that such creation is markedly influenced by the combination of the light reduction and the presence of martensite in the steel.

The described phenomena is also capable of development in other metal working processes, such as swaging, forging, peening and other processes for metal deformation when such metal working is carried out within the limits described on martensitic steels.

It will be apparent that I have provided a new and novel combination of steps whereby a simple and effective means has been provided for the improvement of strength properties of steel, whereby such improvements can be achieved without the normally expected reduction of elongation.

It will be understood that changes may be made in the details of arrangement and conditions of operation without departing from the spirit of the invention especially as defined in the following claims.

I claim:

1. The method of producing a high strength steel comprising the steps of heating a steel capable of conversion to martensite to a temperature above its transforma-

tion temperature, quenching the steel with corresponding transformation to a steel consisting essentially of martensite, and advancing the martensitic steel through a die to effect reduction in cross-sectional area by an amount within the range of 0.25 to 10% while the steel consists essentially of martensite.

2. The method as claimed in claim 1 in which the reduction step is taken almost immediately after quenching to martensite.

3. The method as claimed in claim 1 in which the steel is quenched in an oil bath to martensite formation.

4. The method as claimed in claim 1 in which the steel is quenched in air rapidly to cool the steel from the transformation temperature.

5. The method as claimed in claim 1 in which deformation is effected by advancing the steel through a draw die.

6. The method as claimed in claim 1 in which reduction is effected by advancement of the steel through an extrusion die.

7. The method as claimed in claim 1 in which the steel is heated to a temperature less than 300° F. subsequent to the quench and prior to deformation.

8. The method as claimed in claim 1 which includes the step of tempering the steel after the deformation step.

9. The method of creating high strength in a steel article comprising the steps of advancing said article while the steel consists essentially of martensite through a die to cause deformation within the range of 0.25 to 10 percent whereby the tensile and yield strengths of said article are raised without significant loss of ductility.

10. A steel article produced by the method of claim 9.

11. The method of producing steels of high strength comprising the steps of advancing a steel consisting essentially of martensite through a die to effect reduction in cross-sectional area by an amount within the range of 0.25 to 10% while the steel consists essentially of martensite.

12. The method of producing steels of high strength comprising the step of rolling the steel which consists essentially of martensite to effect reduction in cross-sectional area by an amount within the range of 0.25 to 10% while the steel consists essentially of martensite.

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