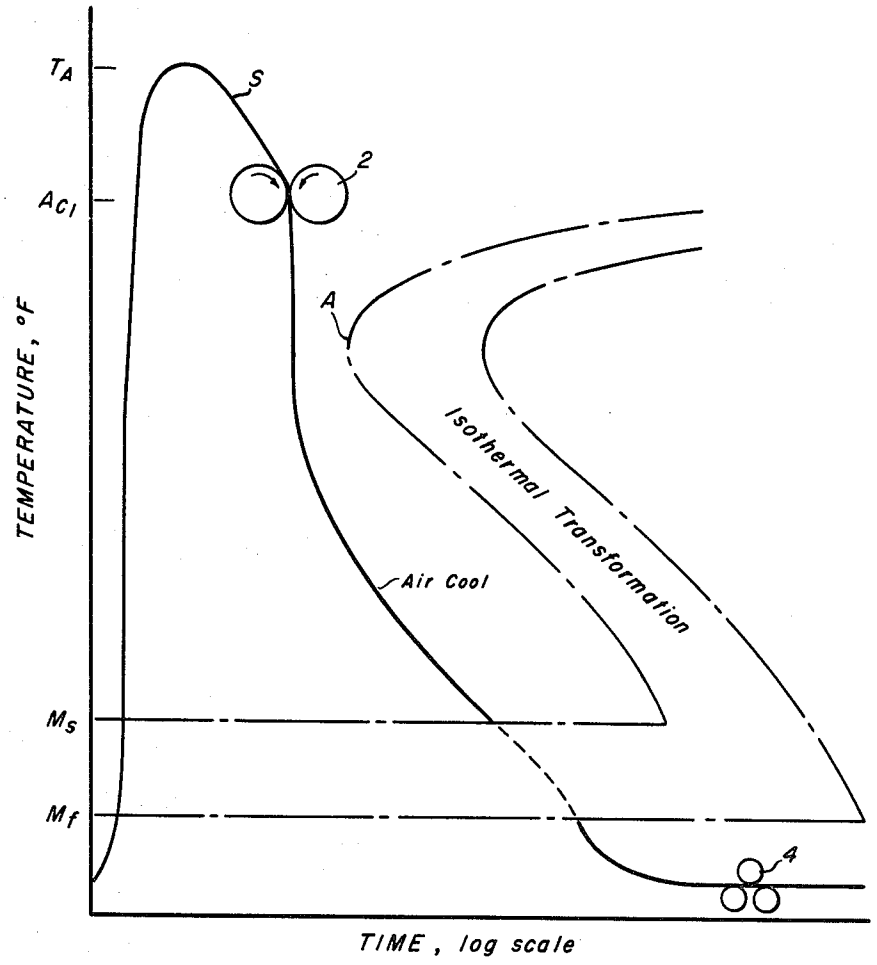
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METHOD OF PRODUCING HARDENED STEEL PRODUCTS

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METHOD OF PRODUCING HARDENED STEEL PRODUCTS

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This invention relates to improvements in the production of heat treatment hardened steel products and more particularly to the production of flat heat treatment hardened sheets.

In hardening steel products formed of steel hardenable by heat treatment which steel is normally ferritic at room temperature and austenitic at elevated temperatures, warping and distortion are a severe problem in products of thin cross section such as sheet product. Hardening by heat treatment involves quenching from an autenitizing temperature to transform the austenitic structure to the desired microstructure such as martensite. Dut to the non-uniform residual stresses arising from the rapid transformation of austenite to martensite, a wavy type of distortion results in sheet product. A variety of special techniques such as quenching between platens, hot straightening, austempering, or martempering among others, have been suggested or practiced to alleviate this problem. While minimizing the distortion to some extent, these are largely uneconomical to practice on a commercial scale and thus, despite the desirability of producing heat treatment hardened steel sheet product, it has not heretofore been produced on a large scale basis.

It is accordingly an object of this invention to produce heat treatment hardened flat sheets in an economical and efficient manner.

The foregoing and further objects will be apparent from the following specification when read in conjunction with the attached drawing wherein:

The single figure of the drawing is a schematic representation of the method of the invention.

We have discovered that flat heat treatment hardened steel strip S product can be continuously and rapidly produced by a combined rolling and hardening step as part of the heat treatment. Thus the strip is hot rolled slightly oversize prior to our hardening treatment and cooled to room temperature at any desired rate. In the treatment of this invention the steel can be heated in any convenient manner, preferably close to the Ac_3 temperature in the case of hypoeutectoid steels and the Ac_1 temperature of eutectoid or hypereutectoid steels to insure substantially complete austenitization. During heating, scaling should be minimized to insure subsequent good heat transfer between the strip and the work rolls when the strip is being worked thereby.

It is esssential that the temperature of the strip be controlled within close limits as it enters the work rolls. Thus the work enters the rolls at a temperature just barely high enough to preclude the possibility of austenite beginning to transform until after rolling is completed. The opposing objectives of minimum amount of heat in the work, but no transformation of austenite, limit the temperature to the vicinity of the lower equilibrium transformation temperature (Ac_1) of the steel. The precise temperature range for successful hardening depends, among other things, upon the transformation characteristics of the steel and the relative size of rolls and work. Generally, a temperature range of from 25° F. below to about 50° F. above Ac_1 will be satisfactory. With thin sheet and strip, conventional rolls used in hot rolling may produce satisfactory results by externally cooling the same by liquid sprays. Large diameter, water-cooled rolls and

rolls made of a highly conductive metal such as copper alloy are all conducive to faster heat extraction and are preferred especially for thicker material where greater heat extraction is required. The aim in rolling is twofold. First, to reduce the work to desired thickness and, second, to extract sufficient heat to insure hardening on subsequent air cooling. The amount of deformation need be only enough to insure good contact between the surfaces of the work and the rolls. A large amount of deformation is, in fact, undesirable because of the heating effect thereof. Thus, a percentage reduction in thickness in the range 1 to 20% is preferred. The essential requirement in rolling is that the temperature of the steel fall a hundred or more degrees by rapid transfer of heat to the rolls. As indicated in the drawing, this rapidly lowers the temperature of the work to below the "nose" A of its isothermal transformation curve. Thereafter, on air cooling, the steel is made to transform in a relatively low-temperature range to a hard martensitic or bainitic product or mixtures thereof. Under optimum conditions, this product will be martensite, as indicated in the drawing. Cooling in air through the temperature range of matensite formation (M_s–M_f) is relatively slow, which is advantageous because it minimizes distortion just as in martempering. A flat, undistorted product results from our processing method because of the relatively slow and uniform cooling through the M_s–M_f range. To insure retaining maximum flatness, tension should be maintained in the strip as by a drive bridle 4 or the like from the start of transformation and at least until transformation is completed.

As a specific example of our process, results obtained for modified SAE 10120 high-carbon steel containing 1.26% carbon, 0.36% manganese, 0.008% phosporus, 0.025% sulphur, 0.18% silicon and 0.25% chromium are as follows: Starting with such steel in the form of annealed 0.075" thick strip it was first rolled to 0.050" thick, a 33⅓% reduction. The structure changed greatly but hardness increased only from 317 to 331 D.P.H. Failure to harden appreciably in this instance is explained by the fact that for the size and type of rolls used, the thickness was too great to permit sufficient heat extraction for full hardening.

However, when the cycle was repeated with 0.050" thick strip rolled this time to 0.035" thick, a 30% reduction, hardness increases to 450 D.P.H. Although not fully hardened, the strip is now hard enough for use as certain types of springs and cutting tools. Repeating the cycle a third time and rolling from 0.035" to 0.028" thick, a 20% reduction, results in only a small additional increase in hardness to 466 D.P.H. because heat extraction by the rolls was still insufficient to develop a martensitic matrix. A fourth cycle, starting with 0.028" thick strip and rolling to 0.025" thick, an 11% reduction, resulted in full hardening to 946 D.P.H. and a microstructure which compares favorably with that developed by conventional heat treatment. The fully hardened strip is substantially flat and undistorted and after tempering to any desired lower hardness level is suitable for most commercial uses.

Although multi-cycle hardening treatments such as described above would not normally be employed, this example was chosen to demonstrate the possibility of developing various degrees of hardening directly on air cooling from rolling. Some of the structures developed have useful properties in the as-rolled condition and not even a subsequent temper need be given. For example, a slicing knife was made by merely mounting in a handle and grinding a piece of the strip following the third step above described wherein the strip was hardened only to 466 D.P.H. In this condition, the strip could be bent, drilled, sheared, and even cold-rolled without undue difficulty and yet was hard enough for some kinds of springs and cutting tools.

The type of product most amenable to our process is the one discussed thus far, namely, strip of high-carbon, i.e. over .9% carbon steel having a gauge less than 0.1 inch produced by rolling. However, there is no inherent limitation to such a product. Forging dies, for example, can under suitable circumstances extract heat just as do rolls. Thus, in accordance with the principle of this invention disclosure, a variety of forged products can be produced which are hard as forged and require no subsequent heat treatment except possibly a temper.

Thus, we have described a method of incorporating a deformation process into the final heat treatment so as to harden steel with a minimum of distortion. This involves the combination of the rolling and heat treatment processes along with the requirements that steel be rolled at the lowest temperature which preserves the austenite state during deformation and that the amount of reduction be small so as to maximize the transfer of heat from the work to the rolls so that the steel is rapidly cooled to below the nose of the isothermal transformation curve during the reduction and thus insure hardening on subsequent air cooling without substantial distortion.

While we have shown and described several specific embodiments of our invention, it will be understood that these embodiments are merely for the purpose of illustration and description and that various other forms may be devised within the scope of our invention, as defined in the appended claims.

We claim:

1. A method of producing flat heat treatment hardened steel sheets comprising hot rolling such steel strip to within 1 and 20% of the desired finished gauge, thereafter heating the hot rolled strip to just substantially the lowest temperature at which the microstructure is stable austenite, reducing the gauge thereof between 1 and 20% to the desired final gauge and simultaneously quenching the strip to a temperature below the nose of its isothermal transformation curve and then cooling it at a rate to produce the desired microstructure therein.

2. The method of claim 1 wherein the strip is maintained under tension while transformation occurs.

3. A method of producing flat heat treatment hardened steel sheets comprising hot rolling strip composed of steel which is hardenable by heat treatment which is ferritic at room temperature and austenitic at elevated temperatures to between 1 and 20% of the finished gauge desired, thereafter heating the hot rolled strip to between 25° below and 50° F. above its Ac_1 temperature and at which the microstructure of the steel is stable autenite, passing said strip between a pair of rolls to simultaneously reduce the temperature thereof at least 100° F. to below the nose of the isothermal transformation curve of the steel and to reduce the gauge of the strip between 1 and 20% before any transformation occurs and then air cooling said strip through the range of martensite formation to produce a martensitic microstructure in the strip which is in a substantially flat condition.

4. The method of claim 3 wherein the strip is maintained under tension while transforming to martensite.

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