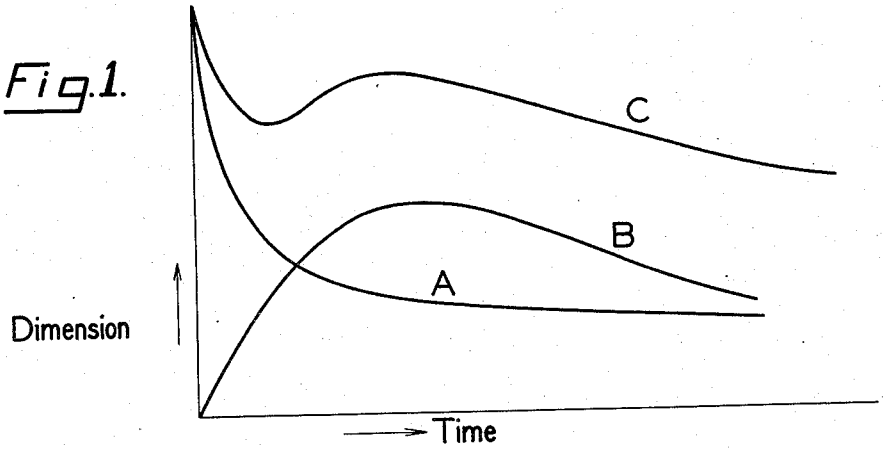
May 19, 1936. H. STYRI 2,041,649

THERMALLY TREATING QUENCHED AND HARDENED STEELS

Filed Aug. 24, 1934

Fig.1.



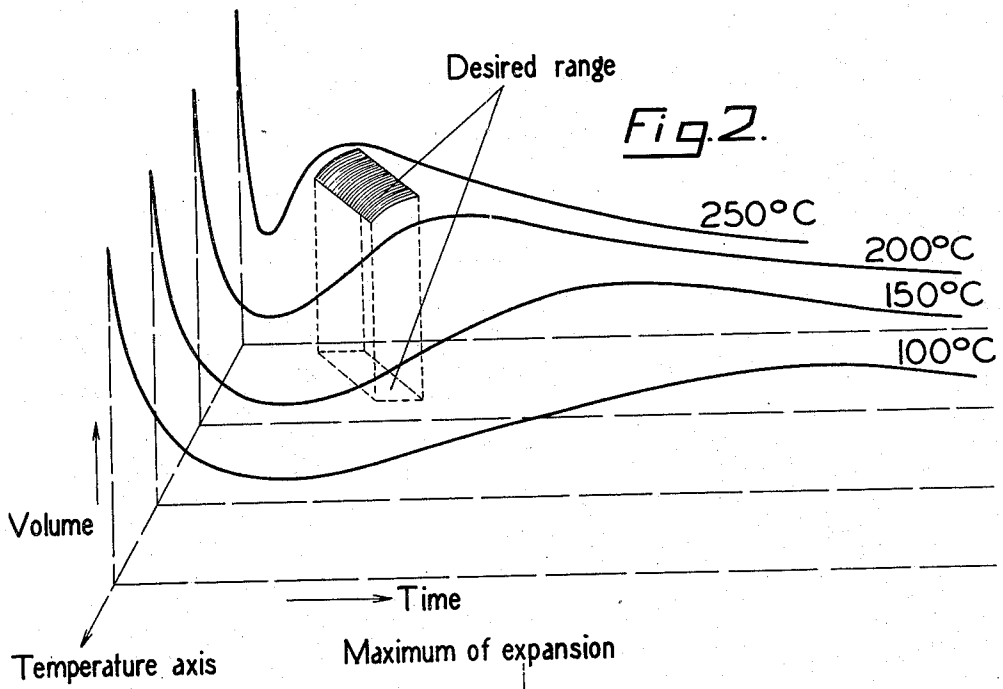


Fig.2.

Fig.3.

Complete treatment as maximum is being approached

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THERMALLY TREATING QUENCHED AND HARDENED STEELS

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This invention relates to the art of tempering steel and has for an object to minimize the occurrence of dimensional changes in quenched and tempered steel objects.

For assistance in describing the art or method upon which this application is based reference may be had to the accompanying sheet of drawing showing some graphs or charts in which

Figure 1 illustrates in three graphs the changes in volume of the constituents of a hardened steel during heating.

Figure 2 is a chart to illustrate volume changes in time, and

Figure 3 is an enlarged section of the portion of the uppermost curve of Figure 2 representing the approach of the volume of the article under treatment toward its maximum.

Metallurgists are in substantial agreement that the characteristic components in the microstructure of steel that has been hardened by rapid quenching from temperatures over the critical range are martensite and austenite. There are also other constituents present, particularly when the steel has not been completely hardened, but such constituents as troostite, sorbite, pearlite, cementite and ferrite are not considered characteristic for a steel that is fully hardened. They are, however, in the case of troostite and sorbite to be considered as transition products between the martensite and austenite which are the characteristic constituents of fully hardened steel and cementite and ferrite (granular pearlite) which are constituents of an annealed steel.

When a hardened steel is reheated to temperatures, usually over the boiling point of water and below red heat, which heating is called "tempering" by the trade, certain changes take place in the constituents of the microstructure. Martensite and austenite are unstable at these tempering temperatures and change gradually into more stable components. Martensite changes through troostite and sorbite to spheroidized cementite in ferrite. Simultaneously with this change of martensite there is a contraction in volume, more rapid a first and slowing up gradually and asymptotically until it reaches its final stable volume. This may be represented by the graph A in Figure 1. The rate at which such change takes place will increase with increase in temperature at which the steel is heated.

Austenite changes into martensite and this change is accompanied by an increase in volume as represented by B. This newly formed martensite is subjected simultaneously to change into troostite and sorbite with a contraction in volume, consequently the final result of tempering may be represented by graph C, which is the sum of graphs A and B. These changes, as just stated take place at a more rapid rate the higher the temperature at which steel is heated. For a temperature as low as 100° C., for instance, the total change to maximum expansion may cover a period of one or more years for a low alloy steel, depending on composition; at 150° C. the change may take place over a period of many months; at 200° C. the change may cover many days, and at 250° C. the change would cover several hours. A graph, not drawn to scale, shown in Figure 2 will probably make this more clear. For a high alloy steel for instance of the high speed steel type, it is necessary to increase the temperature to 500°–550° C. to obtain a reasonably rapid rate of change.

It will be noticed in graph C, which represents the resultant volume change in the steel held at certain temperature, that there is a contraction to a minimum, followed by expansion to a maximum again followed by a contraction. Experiments show that it takes a much shorter time to pass through the minimum than to pass through the maximum. In other words, when the steel has been subjected for a sufficiently long time to a selected temperature so as to pass the minimum and approach the maximum it will take a much longer time for it to pass the maximum and again begin to contract. When a steel, therefore, has been treated so that its volume is approaching the maximum it will be much more stable against further changes in volume when it is again held at this temperature. If the steel, after such stabilizing treatment, is cooled to room temperature in some suitable manner and is reheated and held at lower temperature than that used in the original treatment it is more sluggish in action and therefore more stable. The lower the temperature the more resistant to change. It is therefore desirable to end the treatment of the piece of steel as its volume is approaching the maximum.

The hardness which results after such stabilizing treatment depends both on the temperature and time used and is generally lower for the higher temperatures. The resulting hardness of low alloy high carbon steels varies between approximately 62 and 60 Rockwell "C", which are satisfactory for long endurance of material.

It will be understood that the maximum stability, combined with desired hardness may be reached either by treating at a relatively low temperature such as 100° C. for an excessively

long time, at 150 for a considerable time, at 200 for a shorter time and 250 for a short time. The higher temperature will cause somewhat softer material but has the advantage of treatment in much shorter time. Certain time and temperature combinations have been found by experiment to be commercially practical and to give satisfactory results.

What has been accomplished by the proposed treatment is a material with sufficient and satisfactory hardness for long endurance and with the characteristic of being better stabilized against changes in volume when exposed for long times to temperatures below the applied tempering temperature.

The making of blanking dies and other mating tools and the manufacture of ball and roller bearings where the parts have been hardened by quenching and have been tempered to temperatures hitherto commonly used in their manufacture may be mentioned as examples in applications of such knowledge of dimensional and physical properties to articles of manufacture.

In the case of ball bearings, it has been found that the dimensions of the races and of the balls, and of the rollers in roller bearings have been gradually changing in storage, and, more important, it has been found that the bearings change dimensions in actual industrial use when they have been operating under load at fairly high temperatures.

If a steel bar has been hardened by quenching and is compared in length with a standard bar in a differential measuring instrument, while both bars are subjected to the same temperature, the dimensional changes of the steel bar with time can be computed. As a general type of curve obtained, C of Figure 1, gives an illustration.

There is an initial contraction which rapidly decreases to a minimum, thereafter the specimen begins to expand slowly and the expansion increases at a more rapid rate for a while whereafter the rate of expansion decreases and a maximum of expansion is reached, then the specimen again begins to contract. The first part of this curve evidently is the contraction due to tempering of the martensite, the minimum corresponds to a balance of the contraction of martensite with the change in the austenite. The maximum rate of expansion corresponds with the maximum rate of change in the austenite constituent and the maximum dimension reached corresponds to a balance in the change in austenite with tempering of the transition products from austenite.

It has been found in these experiments that the temperature applied has a great influence on the rate at which these changes take place. They are extremely slow at temperatures around 100° C. and are still very slow at temperatures up to 150° C. The rate is increased considerably at 200° C. and is noticeably faster at 240 to 250° C. for low alloy steels. For higher alloy steels the rate of transformation is slower and for steels in the high speed steel class will not be fast enough to be utilized in practice below 500° C.

To illustrate this relationship, it is, for instance, found that a quenched steel of the SAE–52100 class will reach a minimum at 150° C. in one day, the maximum in about 80 days. At 200° C. the minimum is reached in about an hour, the maximum in about 125 hours, and at 250° C. the minimum is reached in a few minutes and the maximum in about two hours.

A chrome-molybdenum steel with about

	Percent
Carbon	1
Chromium	1
Molybdenum	.30

will show somewhat faster rates of reaction while the chrome-manganese steel of the type:

	Percent
Carbon	1
Chromium	1
Manganese	1

will show a slower rate of reaction, so that for the latter steel both the minimum and the maximum occur later. As a consequence of this relationship, it will be clear that in order to reach a maximum in approximately the same time, it would be necessary to temper the chrome-molybdenum steel at slightly lower temperature and the chrome-manganese at a higher temperature than the 52100.

A tool steel of the high speed steel class, for instance, having the well known composition:

	Percent
Tungsten	18
Chromium	4
Vanadium	1
Carbon	.7

may need several hours at 600° C.

For the practical use of this information it is necessary to consider how the hardness of the steel changes with the time of tempering at various temperatures. It may be stated in general that after quenching the hardness in tempering at any definite temperature will first drop quite rapidly, then slow up materially and remain almost constant for a considerable period before it will again increase the rate of softening. For instance, 52100 steel quenched in oil, may have about 64 to 65 Rockwell "C" and drop to about 61½ in one hour tempered at 200° C., and drop down to about 61 in the next 30 to 50 hours, and stay almost constant for the next 100 hours, while the same steel similarly quenched may drop to about 60½ the first half hour tempered at 240° C. and to about 60 in the next 100 hours and then somewhat more at still longer times. For higher alloy steels the hardness may, depending on tempering temperature used, first decrease and thereafter increase to higher values than the initial and go through a maximum and again decrease.

It is found that if the hardness has dropped noticeably below 59 the endurance of such material to repeated alternate stress will be considerably lowered. It is, therefore, of great practical importance to so combine the tempering temperature and tempering time for certain applications that there is very little change in dimension when operating at elevated temperature for considerable periods while high endurance quality is maintained.

As applied to ball bearings, this may be illustrated with the following specifications:

Tempering treatment for chrome-molybdenum steel—a temperature between 210° C. and 240° C. for time between 20 hours and 2 hours, the choice depending on the need of maintaining the greatest hardness or the need of having the least change in volume.

For SAE-52100 steel, tempering temperature of 220 to 250° C. for a time, 20 to 2 hours, and for a chrome-manganese steel of 230 to 260° C. for similar time periods.

Influencing the choice of tempering temperature and time will be variations in alloy content so that a lower alloy will demand the lower temperature and shorter time, whereas the higher alloy content will claim higher temperatures and/or longer time. It must, further, be considered how the various elements influence the relative amount of martensite and austenite formed. For instance, manganese, nickel and chromium will cause a greater amount of austenite while molybdenum, tungsten and vanadium will have considerably less influence on the formation of austenite.

The lower alloy steels referred to under this subject are of the tool steel class with:

Carbon	.80–1.10%
Chromium	2% maximum
Manganese	2 maximum
Nickel	3 maximum
Molybdenum	.75 maximum
Tungsten	1.5 maximum
Vanadium	.3 maximum

One or more of these elements may be present and when more than one element is present the proportion must be selected to suit the conditions.

The three specific types of analyses given above are suitable for ball and roller bearings of different dimensions.

Having thus described my invention, I claim and desire to secure by Letters Patent:

1. The art of stabilizing steels against dimensional changes which consists in applying tempering heat to a piece of steel hardened by quenching from above the critical range, and maintaining such tempering heat during a period covering the first contraction in volume of the steel and almost the entire period of its succeeding increase in volume, and then lowering the heat shortly before the steel reaches its maximum of increase in volume.

2. The art of stabilizing steels against dimensional changes which consists in applying to low alloy steel of the tool steel class, which has been hardened by quenching from above the critical range, a tempering heat of between 210° to 260° C. for approximately from 2 to 20 hours, and then lowering the heat just prior to the steel reaching its maximum of increase in volume.

3. The art of stabilizing steels against dimensional changes which consists in applying to steel of the SAE-52100 class, which has been hardened by quenching from above the critical range, a tempering heat of 200° C. for approximately 125 hours, and then lowering the heat just prior to the steel reaching its maximum of increase in volume.

4. The art of stabilizing steels against dimensional changes which consists in applying to steel of the SAE-52100 class, which has been hardened by quenching from above the critical range, a tempering heat of 250° C. for approximately 2 hours, and then lowering the heat just prior to the steel reaching its maximum of increase in volume.

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