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SUSUMU GODA ETAL

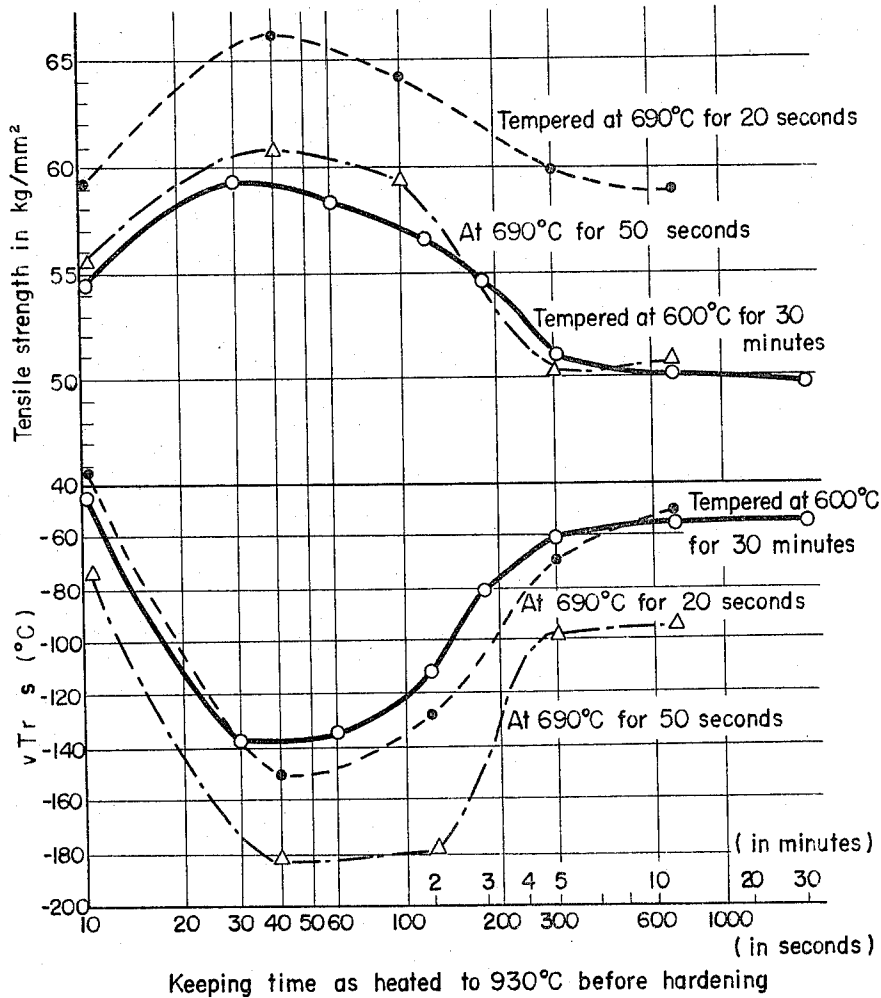
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SHORT-TIME HEAT-TREATING PROCESS FOR STEELS

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2 Sheets-Sheet 1

FIG. 1



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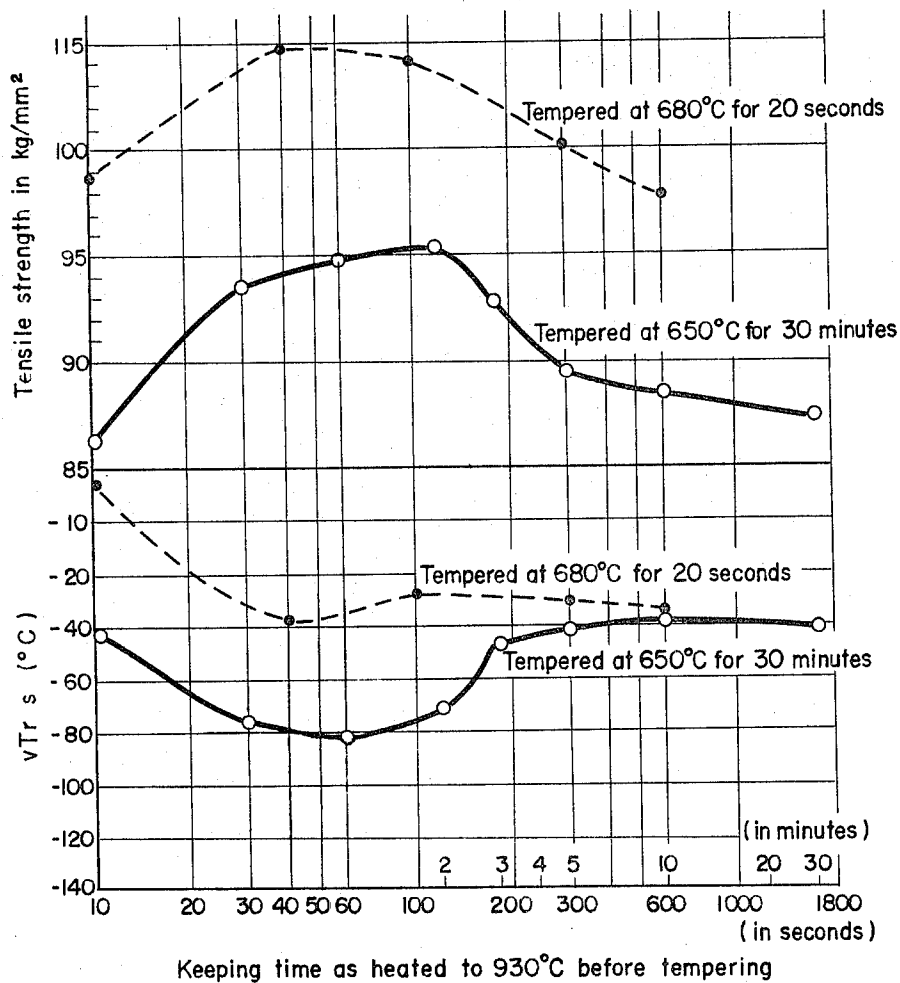
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FIG. 2



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SHORT-TIME HEAT-TREATING PROCESS
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4 Claims. (Cl. 148—143)

This invention relates to a heat-treating process for obtaining tough steels which takes only a short time, and more particularly to a heat-treating process applicable to ordinary steels or alloys containing C less than the eutectoid composition.

Generally, when a polycrystalline metal is heated to a high temperature, unstable fine grains grow to stable coarse grains. In the hardening process a steel material is heated above the A_3 transformation point for a certain time so as to be austenite throughout and is quenched by some proper method. However, at the high heating temperature before the quenching the austenite crystal grains rapidly become coarse, resulting in coarsening of the structure after the hardening and tempering and consequent deterioration of the material.

Also in the tempering process, if the time the steel material is kept at the tempering temperature is too long, carbide precipitations occur and ferrite structure grows, also resulting in coarsening of the structure.

As one method of making the structure fine, there has been practised a treatment for making grains fine by the use of Al, Ti, Zr or Nb or a two-step hardening process.

The present invention has as an object the provision of a new process for preventing the structure from coarsening due to such heat-treatment more perfectly than any other known methods.

The present invention is characterized by a method of quick heat treatment which does not give the material to be treated time for the coarsening of the structure. By this method a steel having a grain fineness of much higher degree than in any conventional fining treatment, that is, a tough steel, can be obtained.

That is to say, the present invention has as its object a method of producing a steel far tougher than any known product by a short duration hardening process wherein the material is heated quickly so that a complete austenitization may occur quickly and is kept there for such a short period of time that coarsening of the structure does not occur and there is produced a fine grain hardened structure.

Further, the present invention has as its object a method of improving the strength and toughness of a steel by a short duration tempering process, wherein the hardened material is also heated at a high speed and is also kept there for such a short time that the precipitation of carbide due to the decomposition of martensite in the course of tempering occurs much more quickly than the grain growth thereof.

The present invention will now be explained in detail in connection with the accompanying drawings, in which FIGS. 1 and 2 are graphs showing the tensile strength and impact fracture transition temperatures of steels treated according to the invention as compared to steels treated conventionally.

The steel material to be treated by the present invention must have a composition such that, on heating said material above the A_3 transformation point, carbide does not remain but is sufficiently dissolved and austenitization is performed completely.

That is to say, in the case of a carbon steel, the carbon

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content should be $\leq 0.83\%$ (subeutectoid steel). If carbon is present in an amount above this limit austenitization will be insufficient, a carbide will remain in the treated steel and accordingly the impact strength will be reduced.

In the case of alloy steels, the steel must be one in which the carbon content is $\leq 0.83\%$ as in the above mentioned carbon steel, if said alloy steel contains one or more elements which will form little or no carbide as, for example, Ni, Cu, Al, Si and Mn, but the carbon content should be ≤ 0.4 if said alloy contains any element which will form some carbide and the alloying components are Cr $\leq 5\%$, Mo $\leq 2\%$, W $\leq 4\%$, V $\leq 1.5\%$ and Nb $\leq 1.5\%$. When higher percentages of these elements are present, the carbide will not completely dissolve in and the austenitization will be insufficient.

The heat-treatment shall now be described. The austenite grain size depends on the components contained, precipitation phase, heating temperature and heating time and the like. In such case, if the velocity of producing austenite nuclei from the ferrite by transformation is increased by increasing the heating velocity, many fine crystals will be produced. For attaining this object, the heating time should be as short as possible. Preferably the intended temperature should be reached within 100 seconds. The holding temperature and time are above the A_3 transformation point for 20 seconds to 3 minutes. The optimum conditions are a temperature from the A_3 transformation point to 1000°C . for 30 seconds to 2 minutes. With a time less than 20 seconds, the hardening will be insufficient. With a time more than 3 minutes, the grains will become as coarse as in any conventional steel and the object will not be attained. The cooling velocity is the same as in ordinary hardening and is determined in accordance with the composition. That is to say, if the cooling velocity is too high, the material will crack and residual austenite will be produced. If the cooling velocity is too low, the hardening will be insufficient. The cooling should be continued at least to below the M_s point. Further, even with air-cooling the material will be seen to improve.

In the tempering process it is necessary that the precipitation of a carbide be carefully performed. It is essential to select a heating velocity and holding time so that the carbide precipitation occur with no appreciable grain growth.

Therefore, the present invention has succeeded in making the tempered structure fine grained by making the heating time less than 100 seconds, the holding time 20 seconds to 5 minutes or preferably 20 seconds to 3 minutes and the holding temperature up to the A_1 transformation point temperature plus 30°C . Further, in case the amount of carbide is small, even if the holding time is made less than 20 seconds, the object can be attained.

In comparison with the above mentioned conditions of heat treatments in the method according to the present invention the following conditions of a conventional heat treatment are to be noted for reference. The heating temperature before the quenching is generally above the A_3 transformation point as in the present invention. But the time it takes to heat to that temperature is more than 10 minutes, while it is only 100 seconds in the present invention, and the holding time is 5 minutes to 2 hours according to the kind of materials to be treated, while it is 20 seconds to 3 minutes in the method of the present invention. In the conventional tempering process, the time it takes to heat up to tempering temperature is generally above 10 minutes and the holding time more than 30 minutes.

In summary, the method according to the present invention for making a steel of high strength and tough-

ness is characterized by a short duration hardening and short duration tempering, and the short duration hardening comprises the steps of heating a steel material containing carbon in an amount less than the eutectoid composition to a temperature from the A_{c3} transformation point to $1,000^{\circ}\text{C}$. within 100 seconds so that complete austenitization occurs quickly, keeping it there for a time of from 20 seconds to 3 minutes so that coarsening of grains does not occur, and cooling it at a conventional speed, and the short duration tempering comprises the steps of heating the hardened material to a temperature below the A_{c1} transformation point temperature $+30^{\circ}\text{C}$. within 100 seconds and keeping it there for a time of from 20 seconds to 5 minutes so that carbide precipitations occur with no appreciable grain growth in order to produce fine grained steel.

Example

The samples A, B, C, D, E, F, G and H having the composition as shown in the Table I have been treated according to the present invention. The results of the test are shown in FIGURES 1 and 2 and Table II.

TABLE I

Samples	C	Si	Mn	Ni	Cr	Mo	V	Al
A-----	0.10	0.32	1.13	-----	-----	-----	-----	-----
B-----	0.12	0.24	0.70	0.91	0.35	0.45	0.07	0.04
C-----	0.78	0.21	0.54	-----	-----	-----	-----	-----
xD-----	0.86	0.18	0.62	-----	-----	-----	-----	-----
E-----	0.33	0.35	0.68	-----	4.6	-----	-----	-----
xF-----	0.30	0.42	0.53	-----	5.5	-----	-----	-----
G-----	0.29	0.22	0.51	-----	-----	1.5	-----	-----
xH-----	0.30	0.27	0.55	-----	-----	2.3	-----	-----

NOTE.—The samples marked with x have other steel compositions than those which can be treated by the method of the present invention.

FIGURES 1 and 2 show tensile strength (kg./mm.²) and impact fracture transition temperature (VTs) of the samples A and B treated under the following conditions respectively:

For the sample A:

Heating temperature for hardening: 930°C .
Heating velocity: 60 seconds up to 930°C .
Holding time: variable.

Heating temperature for tempering: Holding time
 690°C .-----seconds-- 20
 690°C .-----do----- 50
 600°C .¹-----minutes-- 30

¹ 600°C .—30 minutes are the conditions according to the conventional method.

For the sample B:

Heating temperature for hardening: 930°C .
Heating velocity: 50 seconds up to 930°C .
Holding time: variable.

Heating temperature for tempering: Holding time
 600°C .-----seconds-- 20
 650°C .¹-----minutes-- 30

¹ 600°C .—30 minutes are the conditions according to the conventional method.

It is seen from these figures that, when the holding time before hardening was less than 3 minutes but more than 20 seconds, the strength and toughness were far higher than in the conventional case of tempering for 30 minutes. With the short duration heating for less than 20 seconds, the austenitization was insufficient, only the surface was hardened, both strength and toughness in the interior deteriorated and the object of the present invention was not attained. If above 3 minutes, the coarsening of the structure began as in the conventional method.

The samples C, D, E, F, G and H in Table 1 were hardened at 850°C . for 40 seconds and then tempered at 600°C . for 50 seconds. The results are shown in Table 2. It is seen therein that the impact values of

the steel compositions other than those of the present invention were far lower.

TABLE 2

	C	xD	E	xF	G	xH
Tensile strength in kg./mm. ²	112.4	93.2	87.4	80.8	83.2	78.8
Impact value at -70°C . in kg.-m./cm. ²	23.1	1.8	28.2	3.0	30.3	3.8

Table 3 shows the effect of heating velocity, that is, sample C heated up to 850°C . for 100 seconds has superior characteristics to the same sample heated to the same temperature for 120 seconds. However, the latter has a rather better impact value, which is due to short time tempering.

TABLE 3

Quench	Heating time, sec.	Temper, $^{\circ}\text{C}/\text{sec}$.	Tensile strength in kg./mm. ²	Impact value at -70°C . in kg.-m./cm. ²
850°C -----	100	600/50	110.5	22.7
850°C -----	120	600/50	85.2	6.7

Microphotographs of the metals treated according to the present invention show that they have a fine grained structure far beyond that obtained by the conventional method, and that the increase in the strength and toughness of steel is caused by this fine structure. The short duration heat treatments according to the present invention can be successfully applied to a steel plate below 30 mm. thick.

What is claimed is:

1. A heat treating process for steels comprising heating a steel taken from the group consisting of fully hardenable substantially normal carbon steel having less than .83% carbon, alloy steel containing non-carbide forming elements and having less than .83% carbon, and alloy steel containing at least one alloying element taken from the group consisting of Cr up to 5%, Mo up to 2%, W up to 4%, V up to 1.5% and Nb up to 1.5% and less than .4% carbon to a temperature between the A_3 transformation point and 1000°C . in a heating time less than 100 seconds, holding said steel at said temperature for from 20 seconds to 3 minutes, then quenching it so as to produce a fine grain hardened structure, then heating it to a tempering temperature below a temperature equal to the A_1 transformation temperature $+30^{\circ}\text{C}$., holding said steel at said tempering temperature for from 20 seconds to 5 minutes so that carbide precipitations occur with no appreciable grain growth, and then cooling said steel.

2. A heat treating process for steels comprising heating fully hardenable substantially normal carbon steel containing less than 0.83% carbon to a temperature between the A_3 transformation point and 1000°C . in a heating time less than 100 seconds, holding said steel at said temperature for from 20 seconds to 3 minutes, then quenching it so as to produce a fine grain hardened structure, then heating it to a tempering temperature below a temperature equal to the A_1 transformation temperature $+30^{\circ}\text{C}$., holding said steel at said tempering temperature for from 20 seconds to 5 minutes so that a carbide may precipitate more quickly than the carbide precipitations grow, and then cooling said steel.

3. A heat treating process for steels comprising heating a fully hardenable alloy steel containing at least one alloying element taken from the group consisting of Cr up to 5%, Mo up to 2%, W up to 4%, V up to 1.5% and Nb up to 1.5% and less than 0.4% carbon to a temperature between the A_3 transformation point and 1000°C . in a heating time less than 100 seconds, holding said steel at said temperature for from 20 seconds to 3 minutes, then quenching it so as to produce a fine grain hardened structure, then heating it to a tempering tem-

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perature below a temperature equal to the A_1 transformation temperature $+30^\circ\text{C}$., holding said steel at said tempering temperature for from 20 seconds to 5 minutes so that carbide precipitations occur with no appreciable grain growth, and then cooling said steel.

4. A heat treating process for steels comprising heating quickly a steel containing 0.10% C., 0.32% Si, 1.13% Mn the rest being Fe and the usual impurities to a temperature of 930°C . in a heating time of less than 100 seconds, holding said steel at said temperature for from 30 seconds to 2 minutes, quenching it so as to produce a fine grain hardened structure, than again heating quickly said steel to a temperature of from 600 to 690°C . in a heating time of 100 seconds, holding it at said temperature for from 20 seconds to 3 minutes so that carbide precipitations occur with no appreciable grain growth, and then cooling said steel.

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References Cited by the Examiner

UNITED STATES PATENTS

2,326,674	8/1943	Pavitt	148—150
2,374,634	4/1945	Wile	148—143
2,424,794	7/1947	Brown	148—150
2,441,628	5/1948	Griffiths et al.	148—143
2,730,472	1/1956	Osborn	148—150
2,831,788	4/1958	Bridge et al.	148—150

OTHER REFERENCES

Metals Handbook: 1948 ed., published by the A.S.M., pages 280—282 relied on.

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