

[54] **PROCESS FOR A CONTINUOUS HEAT TREATMENT AND APPARATUS THEREFOR**

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1,127,072 2/1915 Morse 148/12.1

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[22] Filed: **Dec. 27, 1971**

[21] Appl. No.: **212,152**

[57]

ABSTRACT

[52] U.S. Cl. **148/16.5**, 148/146, 148/156, 219/10.57

[51] Int. Cl. **C21d 1/10**

[58] Field of Search. 148/16.5, 146, 156; 219/10.57

A heat treating process for a link chain or a similar article, characterized wherein a link chain or a similar article is conveyed through a high frequency induction coil and simultaneously heated at an elevated temperature, and is then cooled after a predetermined period of time.

[56] **References Cited**

UNITED STATES PATENTS

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6 Claims, 7 Drawing Figures

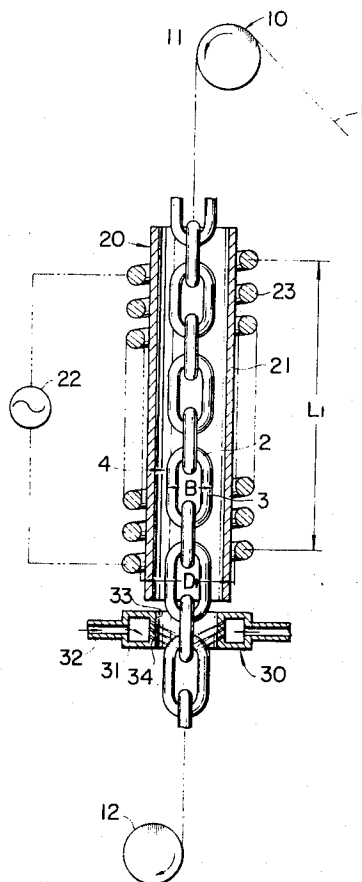


FIG. 1

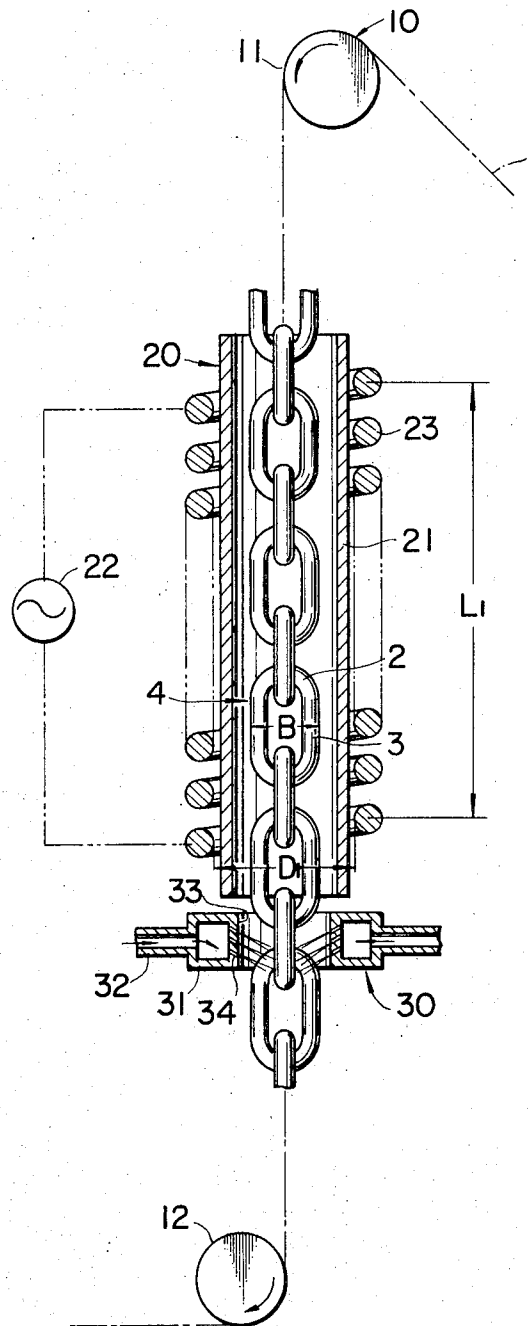


FIG. 2

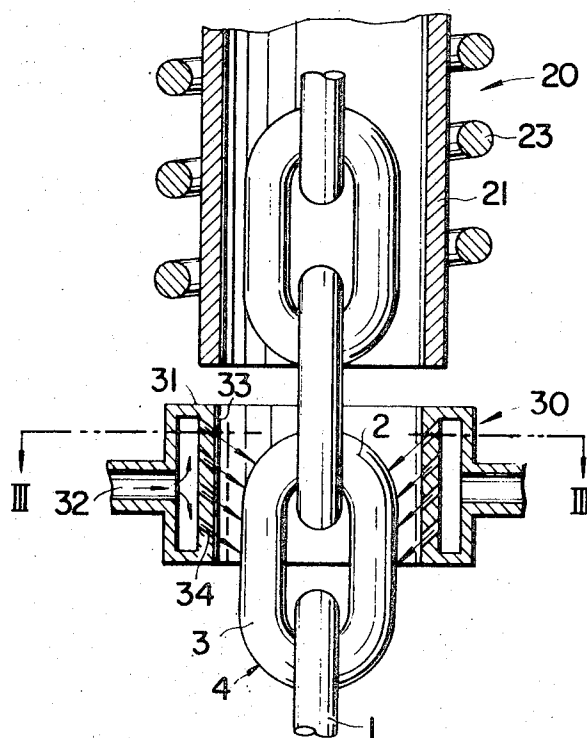


FIG. 3

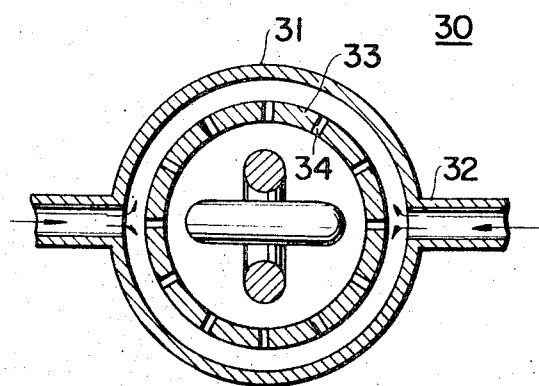


FIG. 4

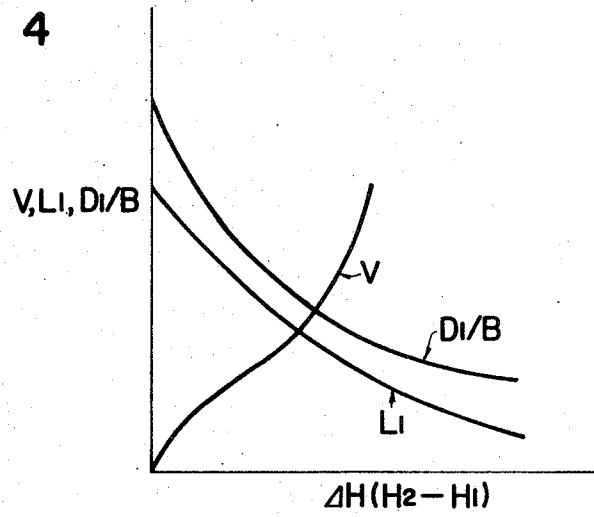


FIG. 6

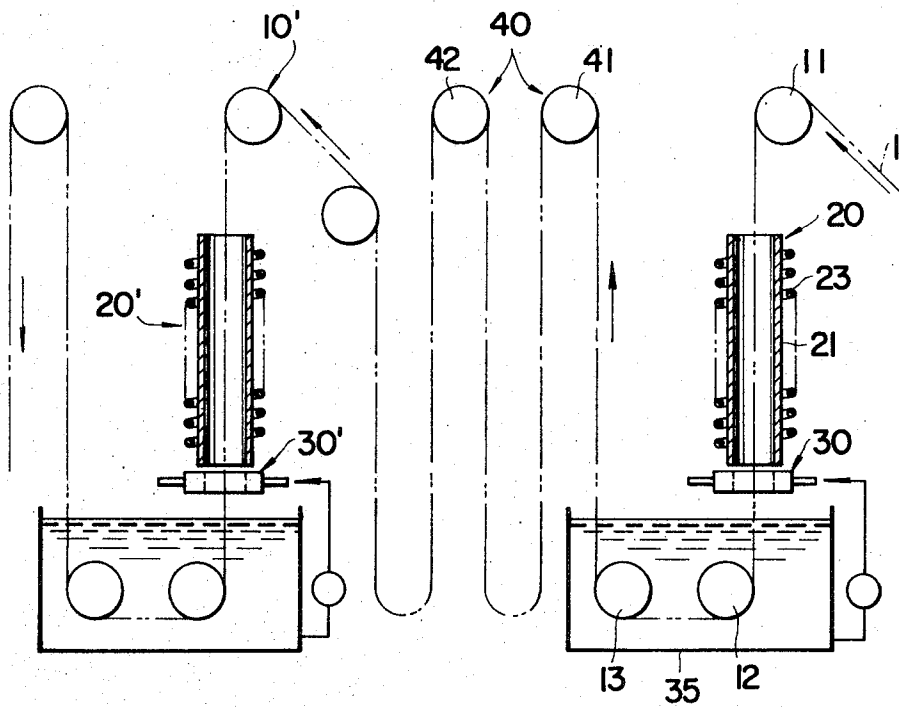


FIG. 5

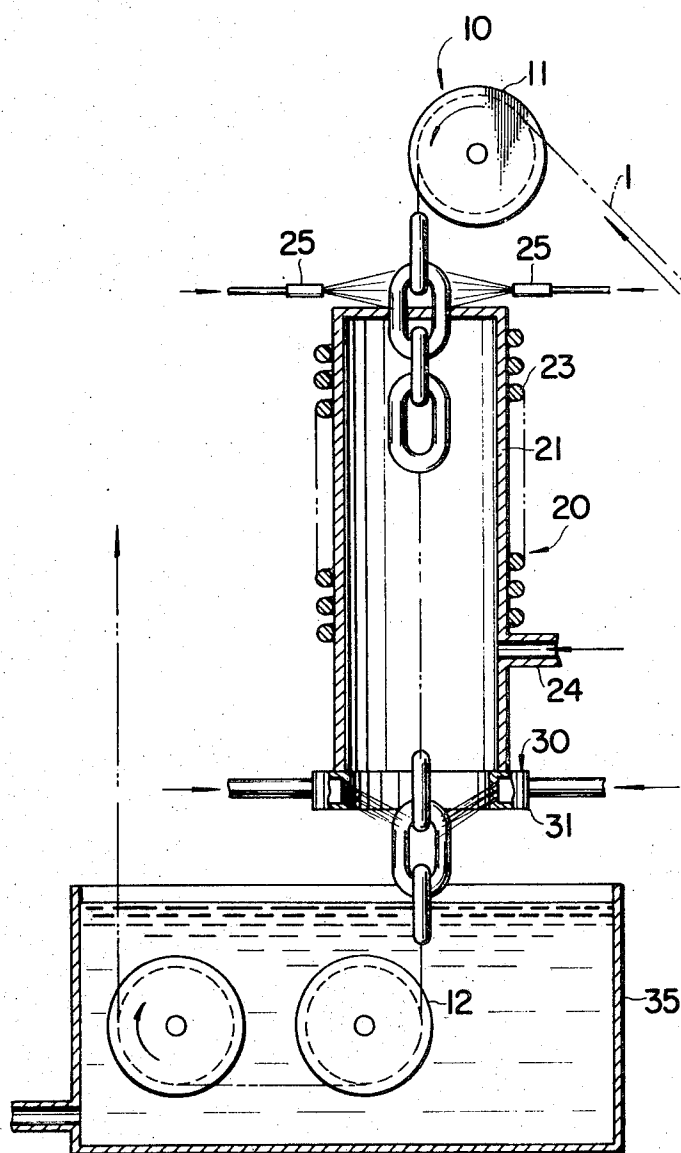
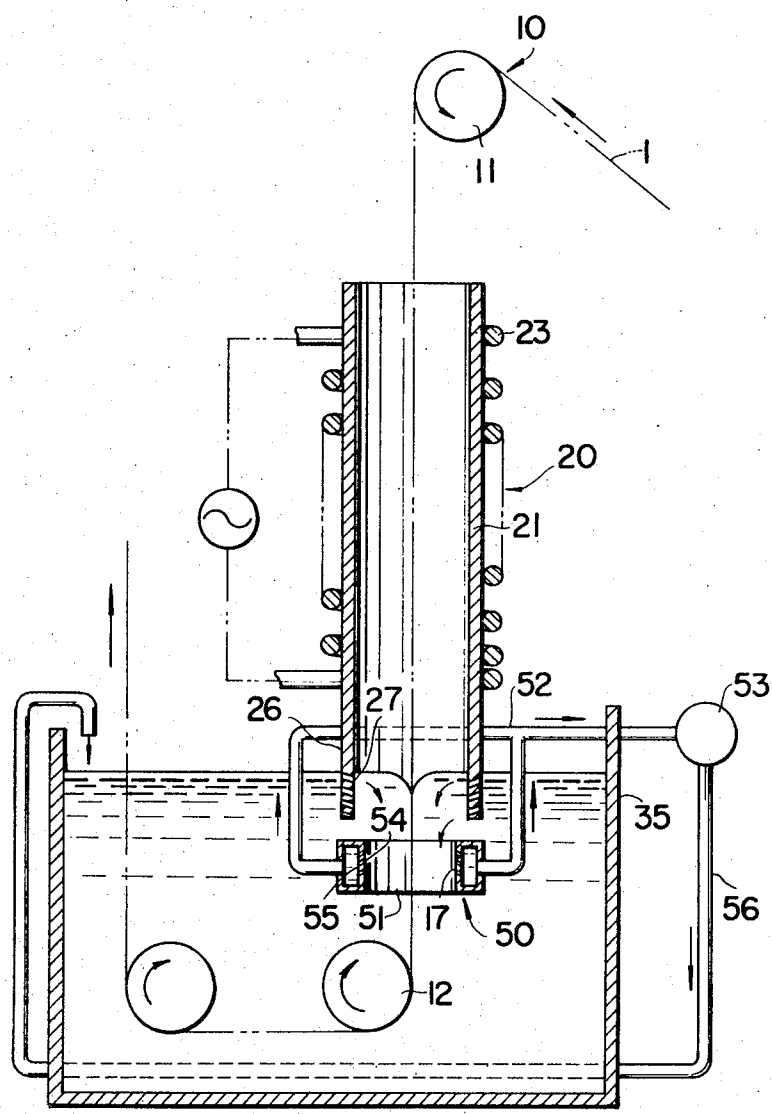


FIG. 7



PROCESS FOR A CONTINUOUS HEAT TREATMENT AND APPARATUS THEREFOR

BACKGROUND OF THE INVENTION

This invention relates to a process for a continuous heat treatment and an apparatus therefor in which a link chain and a similar flexible and long steel article as a whole, are heated through a high frequency induction furnace at an elevated temperature and then cooled with a spray of a cooling medium.

BRIEF REVIEW OF THE PRIOR ART

A link chain is generally used to transfer power and to suspend a heavy article, and the constituent rings thereof must be uniformly heated. The prior art system now in use cannot achieve the establishing of an even hardness over different areas of an article having been heat treated, because the heat treatment of the prior art is carried out by means of an electric furnace or a heavy oil combustion furnace in which the articles to be treated are piled, one on another and overlapping portions would be heated to a lower temperature than other portions.

In addition, each constituent link of the chain comprises straight side portions and a shoulder portion in the shape of an circular arc with which the adjacent link is caught to form the link connection. In some cases, the shoulder portion should be hardened sufficiently so as to get good stiffness and wear resistance, and the straight portion having a lower hardness should show toughness to resist the deformation caused by tensile strength during operations. However, the prior art system cannot achieve a partial heat treatment which may result in a different hardness over different places of the treated article. Sometimes, the carburization is also accompanied with a special purpose heat treatment to surface-harden a portion where it is desired to have good wear resistance. However, such carburization results in some local excesses of carburization, because the link chain to be carburized is piled one link on another in a salt bath furnace or a gas-carburizing furnace. Bright heat treatment is also employed, together with said heat treatments, in order to minimize the oxidation or decarburization of the surface of an article to be treated. However, even in the case of bright heating, the bright heating gas cannot contact all surfaces of the articles to be treated, resulting in an uneven hardness over different places of the treated article, because the articles are piled one on another in a heating furnace. Particularly, in annealing, it takes a long time to cool the heated article within the furnace. This lowers the efficiency of the process. In some cases when an article as a whole, such as a link chain is to be quenched, it is necessary to temper the quenched article, and the tempering treatment sometimes causes cracking which should be eliminated by keeping it as it is for the given time, or conditioning it with another tempering treatment.

With the objective of eliminating such prior art disadvantages in the heat treatment of a long article as a whole, such as a link chain, we have studied the problem and unexpectedly found that we can produce the desired metallic structure in any portion of the long length article as a whole, such as a loop-like link, when we pass it, at a given rate, through a high frequency induction furnace to heat it and then cool the heated arti-

cle with a spray of a cooling medium, while adjusting the conveying rate of the article in connection with the inner diameter, length of the induction coil, cooling conditions, and time interval between the time when the heating is completed and the time when the cooling begins.

Thus, according to the present invention, a uniform metallic structure can be obtained resulting in even hardness over the article heat treated, or alternatively different metallic structures over different portions of the article can be obtained. That is, in the case of a link chain, the metallic structure of the arc-shaped shoulder portion can be changed to a structure that is different from that of the straight portion so that the hardness of the former portion is higher than that of the latter portion. In addition, the long length article as a whole, such as a link chain, is continuously passed into a heat-treating zone to establish a continuous treatment. Processing efficiency is thus improved. The high frequency induction furnace may also be filled with a carburization gas or a bright heating gas for the uniform heat treatment. Further, the continuous two-stage heat treatment can be established so that the quenching process is followed by the tempering treatment in a continuous manner, eliminating aging cracks.

OBJECTS OF THE INVENTION

The primary object of the present invention is to provide a continuous heat treatment to produce the desired metallic structure in a long steel article as a whole, such as a link chain.

Another object of the present invention is to provide a continuous heat treatment to produce differing metallic structures over different areas of a long steel article as a whole, such as a link chain or the like.

Still another object of the present invention is to provide a continuous heat treatment to produce a different hardness over places of a long steel article as a whole, such as a link chain or the like.

A still further object of the present invention is to provide a continuous carburizing heat treatment to carburize a long steel article as a whole, such as a link chain or the like.

Yet another object of the present invention is to provide a continuous carburizing heat treatment to produce a localized carburized layer in a long steel article as a whole, such as a link chain or the like.

It is also an object of the present invention to provide a continuous bright heating process with which a continuous atmosphere heat treatment of a long steel article as a whole, such as a link chain can be achieved.

It is also still an object of the present invention to provide a continuous bright heating treatment to produce different metallic structures over different areas of a long steel article as a whole, such as a link chain or the like.

It is also further an object of the present invention to provide a continuous heat treatment apparatus for a long steel article as a whole, such as a link chain or the like.

It is yet further an object of the present invention to provide a cooling means in the heat treatment apparatus for a long steel article as a whole, such as a link chain, in which the spray of a cooling medium does not prevent efficient induction heating.

It is still further an object of the present invention to provide a continuous heat treatment apparatus which

continuously conducts quenching and subsequently, tempering of a long steel article as a whole, such as a link chain or the like.

The present invention also contemplates providing a continuous carburizing-quenching apparatus which conducts carburization and subsequent quenching of a long steel article as a whole, such as a link chain or the like.

The present invention further contemplates providing a continuous atmosphere heat treatment apparatus which conducts the continuous atmosphere heat treatment of a long steel article as a whole, such as a link chain or the like.

And yet another object of the present invention is to provide a continuous bright heat treatment apparatus which establishes a continuous bright heat of a long length steel article as a whole, such as a link chain or the like.

SUMMARY OF THE INVENTION

Broadly stated, the present invention contemplates a heat treating process for a link chain or a similar article, characterized wherein a link chain or a similar article is conveyed through a high frequency induction coil and simultaneously heated at an elevated temperature, and is then cooled after a predetermined period of time.

Further objects and advantages of the invention will be apparent to those skilled in the art from the following description of the present invention and the accompanying drawings, in which:

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a vertical section of an embodiment of the present invention, which comprises a heating means and a cooling means, to carry out the continuous quenching of a link chain, subsequently followed by the tempering;

FIG. 2 is an enlarged partial view of the cooling means in FIG. 1;

FIG. 3 is a cross section taken along lines III—III in FIG. 2;

FIG. 4 is a graph showing the relation between various heat treatment conditions of tempering applied to a link chain and the resulting surface hardness of the article;

FIG. 5 is a vertical section of an apparatus of the present invention, with which carburization or atmosphere heat treatment is carried out;

FIG. 6 is a vertical section of an apparatus of the present invention used to carry out the subsequent quenching and tempering treatments of a link chain; and,

FIG. 7 is a partial view of the cooling means in FIG. 6.

DETAILED DESCRIPTION OF THE INVENTION

Now, referring to the drawings which illustrate examples of the invention, FIG. 1 through FIG. 4 show typical embodiments of the present invention in which the heat treatments, such as quenching and tempering, are applied to produce an even or different hardness over portions of a long steel article as a whole, such as a link chain. In FIG. 1, the link chain 1 is continuously conveyed at a required rate through driving means 10 to high frequency induction heating furnace 20 which is designed to heat the article to different temperatures

over different areas of the article by means of electromagnetic induction heating. After the heating is completed, the heated article is cooled through cooling means 30, resulting in a desired metallic structure having a required hardness. In the example, the link chain 1 consists of a series of links 4 which have a shoulder portion 2 having a circular arc-shape with which the adjacent ring is connected and parallel straight portions 3. Driving means 10 comprises a driving chain wheel 11 and a guiding chain wheel 12 which are separately positioned at a required interval in the vertical direction. The link chain is fed to the furnace with rotation of the wheels 11 and 12 at the required rate.

The high frequency induction furnace 20 comprises a cylindrical furnace 21 made of a refractory non-conductive material, such as porcelain and quartz. High frequency induction coil 23 is a coil wound around the cylindrical furnace 21, leading to a high frequency generator 22. The term "high frequency" for the purpose of this application means of the order of 8 Hz. Link chain 1 introduced to furnace 21 is heated therein by eddy currents produced on the surface of the article with the desired frequency and power which is supplied from the high frequency generator 22 to the high frequency induction coil 23. The conveying rate of link chain 1, together with an inner diameter and a length of the coil 23, and the coil pitch is adjusted to heat the link chain to a uniform temperature through the overall areas, or alternatively to heat shoulder portion 2 of link 4 to a higher temperature than straight portion 3 and vice versa.

FIGS. 2 and 3 show in detail cooling medium spray means 30 which comprises the annular chamber 31 surrounding the passage of the article to be treated. The chamber is positioned apart from the discharging end of the furnace 21 in the downward direction. The heated link chain 1 is introduced to the hollow portion of the annular chamber 31. A plurality of nozzles 34 are provided on the inner wall 33 of the chamber, and are inclined inwardly through the inner wall 33. The nozzles are connected with the cooling medium spray means 32. After being heated to a uniform temperature or different temperatures over different areas of the article to be treated, the link chain is passed through the passage surrounding the rectangular chamber 31. A cooling medium is sprayed diagonally through the nozzles 34, so that uniform or different metallic structures over the areas can be established in the link chain. Since the cooling medium is sprayed diagonally on the moving link chain 1, a splash of the cooling medium from the shoulder portion 2 of the link chain being cooled does not penetrate into the inside portion of the furnace 21.

In the foregoing embodiment of the present invention, it is explained that the tempering operation can produce the different portions of the link 4, so that shoulder portion 2 will obtain stiffness and the straight portion 3 will obtain toughness. In such a process, the hardness difference ΔH between those of the shoulder portion and of the straight portion depends on the length L_1 of the coil 23, in connection with the ratio of the coil inner diameter D_1 to the outer diameter B of the link 4 and the feed speed of the link 4. This relationship is shown in FIG. 4. As apparent from FIG. 4, the hardness difference ΔH becomes larger when the coil length L_1 becomes smaller, or the ratio of the coil inner diameter D_1 to the link outer diameter B becomes

smaller, or the feed speed V of the link 4 becomes higher. Operators can use any desired conditions thereof.

Table 1 shows conditions of the heat treatment of a link chain, which is processed according to the present invention. In this table, shape and size of the link are as follows:

diameter:	9.5 mm
pitch:	28.6 mm
outer width:	31.3 mm
Chemical composition of the link is:	
C	0.23%
Si	0.21%
Mn	1.35%
P	0.021%
S	0.015%
Fe	balance

The link is previously quenched from 930° C with water. According to the present invention, after induction heating of the quenched link chain, it is cooled immediately using water.

TABLE 1

High frequency induction coil			Conditions of high frequency induction heating		Feed rate of link chain (mm/s)
Inner Diameter (mm)	length (mm)	Pitch (mm)	Frequency (KHz)	Power (KW)	
58	300	10	8	12	28

In this example, the shoulder portion 2 of the link chain 4 is heated at 550° C and the straight portion 3 at 450° C. Temperature difference is 100° C. The former portion shows the metallic structure of tempered martensite and the latter sorbite. The shoulder portion obtains a hardness of HRC 45 and the straight portion HRC 35.

Thus, according to the present invention, a desired metallic structure can be obtained with the continuous and simple single-stage treatment. When the article to be treated is heated at different temperatures over different portions thereof, different metallic structures over the different portions can be obtained. In addition, tempering can also achieve different hardnesses over different places on the article.

The high frequency induction furnace 21 may be placed horizontally or obliquely. The cooling medium spray means 30 may have an annular or rectangular structure surrounding the passage of the link chain.

FIG. 5 shows another embodiment of the present invention, in which carburization or atmosphere heat treatment is carried out. As shown in FIG. 5, the link chain is introduced into the high frequency induction heating furnace 20 by driving means 10 and is therein heated in a gas atmosphere charged with a gas supply means, so that carburizing heat treatment or atmosphere heat treatment may be applied to the link chain. By way of a gas charging means, a gas inlet 24 is provided with the furnace 21 in the high frequency induction furnace 20. A plurality of gas curtain producing means 25 directing gas to the center are provided at the discharging end for the link chain 1, so as to prevent leakage of the gas. In addition, in order to avoid leakage of the gas and to cool the heated link chain, the

chamber 31 of the cooling medium is connected directly with the discharging end of the furnace 21.

In this carburizing treatment, a carburizing gas is supplied to the furnace 21 in the high frequency induction furnace 20. A gas curtain, such as of propane, hydrogen, argon or nitrogen and the like, which is produced through the gas curtain producing means 25, prevents the carburizing gas from leaking out of the furnace 21.

Link chain 1 is continuously introduced into the high frequency induction furnace by the driving means 10. The link chain is herein heated in the carburizing gas by means of the high frequency induction coil, and is cooled through the cooling spray means 30, resulting in a uniform carburized layer over the article, or different carburized layers over the different portions thereof.

Next is an example of the carburizing-quenching treatment which is carried out under the conditions indicated in Table 2. In this example, a carburized layer of a uniform depth is produced on the surface of the article. The shape and size of the link 4 in this example is the same as shown in Table 1, and the chemical composition is:

C	0.23%
Si	0.15%
Mn	1.32%
P	0.0015%
S	0.026%
Fe	balance

Carburizing gas employed is modified gas of the endothermic type, comprising:

H ₂	40%
CO	20%
N ₂	40%

C₃H₈ is added to the modified gas in the ratio of 13:1.

TABLE 2

Gas supply (m ³ /hr)	High frequency induction heating		Feed rate of the link chain (mm/s)	Cooling medium
	Frequency (KHz)	Power (KW)		
0.6	8	40	15	oil

The treated article is uniformly heated at a quenching temperature 950° C. The carburized layer having a surface hardness above Hv 700 is formed on the surface thereof.

In the case of an atmosphere heat treatment, the atmosphere heating gas is supplied to furnace 21 in the high frequency induction heating furnace 20. Curtain producing means 25 provides a gas curtain preventing the air from penetrating into the furnace 21. The link chain is introduced into the high frequency induction furnace 20 by the driving means 10 and is heated in the atmosphere gas. The heated article is cooled by the cooling medium spray means after a given time interval to establish the heat treatment.

Table 3 shows the conditions under which the atmosphere heat treatment of this invention is carried out. In this example, the shape and size of the link chain to be treated is the same as indicated in Table 1. The chemical composition is:

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C	0.21%
Si	0.15%
Mn	1.51%
P	0.021%
S	0.015%
Fe	balance

The following table shows the gas composition, etc., in this example.

Test No.	Gas composition of conversion gas	Conversion gas: C ₃ H ₈	Coil inner diameter (mm)	Cooling medium
1	N ₂	—	40	oil
2	H ₂ 40%, Co 20%, N ₂ 40%	12:1.5:1	70	Do.
3	do.	do.	40	Do.
4	do.	do.	40	Do.

TABLE 3

Test No.	Gas supply (m ³ /hr)	Induction heating		Feed rate of the link chain (mm/s)	Time between heating and cooling (sec.)	Remarks
		Frequency (KHC)	Power (KW)			
1	1	8	40	20	4	Bright heating
2	0.8	8	37	10	5	Carburizing and nitriding
3	0.8	8	37	19	3	Do.
4	0.8	8	37	10	120	Do.

In the example of test No. 1, the link chain is uniformly heated at the quenching temperature 850° C, and bright heating of the surface is established with non-oxidation and non-decarburization. The same effect may be obtained when H₂ or Ar is employed in the place of N₂. In the example of test Nos. 2 and 4, the quenching temperature of 850° C is obtained, and the

means 10, high frequency induction furnace 20, cooling medium spray means 30, and a similar tempering heat treatment apparatus comprising driving means 10', high frequency induction furnace 20' and cooling medium spray means 30'. Between these two apparatuses is provided a means for adjusting the accumulation of the link chain, which comprises a guide weight wheel 13 for the link chain 1, and weight wheels 41 and 42 for accumulating the link chain. Thus, the link chain 10 is heated at a quenching temperature in the high frequency induction furnace 20, and is also heated at a temperature in another high frequency induction furnace 20'. Since these temperatures should be different from each other, the high frequency induction coil inner diameter of the furnace 20' must be lower than the latter. In this heat treatment, either a uniform hard-

ness or a different hardness over the different portions can be obtained.

Table 4 shows conditions under which a continuous quenching-tempering treatment is carried out according to one embodiment of the present invention. In this example, the shape and size of the link 4 and the chemical composition of the link is the same as in Table 1.

TABLE 4

High frequency coil			Induction heating		Feed rate of the link chain (mm/s)	Remarks
Inner diameter (mm)	Length (mm)	Pitch (mm)	Frequency (KHz)	Power (KW)		
40	300	10	8	40	20	Quenching Tempering
58	300	10	8	12	28	

carburization layer of 0.15 mm in depth is formed. In addition, in the example of test No. 3, the shoulder portion 2 of the link chain 4 is heated at 900° C and the straight portion 3 at 800° C. The carburized-nitrided layers of 0.3 mm and 0.1 mm in depth are formed at the shoulder and straight portions, respectively.

As described hereinabove, according to the present invention, a link chain can be continuously carburized and atmosphere-heated in a simple processing step and in particular, is treated with the carburizing-quenching or bright heat quenching, resulting in a carburized layer of a uniform depth, or alternatively, the link chain can be carburized and nitrided to form a uniform or different carburized and nitrided layers over different portions of the link chain. Since the link 4 of the link chain 1 is processed one by one, a uniform heat treatment through the extensively long link chain can be obtained.

FIG. 6 illustrates an embodiment of the present invention, in which the link chain is continuously and subsequently quenched and tempered. In FIG. 6, a tempering heat treatment apparatus comprising driving

In this example, at the stage of quenching, the shoulder portion of the link 4 can be heated at 900° C and the straight portion at 850° C, and at the stage of tempering the former at 480° C and the latter at 550° C. The final hardness of the shoulder portion is HRC 42 and the straight portion HRC 35.

Thus, according to the present invention, subsequent quenching and tempering processes are continuously effected by means of two separate heat treatment apparatuses independently adjustable with respect to temperature, etc. In addition, the means 40 for adjusting the accumulation of the link chain can achieve continuous and smooth processing, even if one of the apparatuses is stopped by accident.

FIG. 7 shows another embodiment of the cooling device of the present invention, in which a stream of the cooling medium is produced by enforced stream producer 50. As shown in FIG. 7, a cylindrical cooling zone 26 is provided with the discharging end of the furnace 21 of the induction heating furnace 20, and is

dipped into a cooling medium, such as water and oil, which is contained in tank 35. A plurality of passages inclining downwardly are provided with the lower portion of the cooling device positioned below the level of the cooling medium. Annular chamber 51 having a shape like a doughnut is positioned under the cooling medium. The annular chamber is connected through suction pipe 52 to suction pump 53. A plurality of suction holes inclining upwardly in the inward direction are provided through the inner wall of the chamber. The discharging side of the pump is connected through discharging pipe 56 to tank 53. Thus, by the aid of the suction pump, the cooling medium is cycled from the region around the cooling zone to chamber 51 through the passages 27 and the gap between the cooling zone 26 and the annular chamber 51 to form the stream of the cooling medium. The stream of the cooling medium cools the heated article which is discharged from the furnace.

Thus, in this example, the cooling medium cannot penetrate into the heating furnace 20 of the high frequency induction furnace 21, so a continuous cooling of the link chain 1 is obtained. The stream-producing mechanism can also be applied to the heat treatment apparatus hereinbefore described so as to avoid the leakage of the supplied gas.

I claim:

1. In a heat treating process for a link chain article wherein the article is conveyed through a high frequency coil and simultaneously heated at an elevated temperature, and is then cooled after a predetermined period of time, the improvement therein, wherein the treated article is heated at different temperatures over different portions of the article, and is cooled after a predetermined period of time, resulting in different metallic structures over different portions of the article.

2. In a heat treating process for a link chain article wherein the article is conveyed through a high frequency coil and simultaneously heated at an elevated temperature, and is then cooled after a predetermined period of time, the improvement therein wherein the treated article is heated at different tempering temperatures over different portions of the article, and is cooled after a predetermined period of time, resulting in the different hardness over different areas of the article.

3. In a heat treating process for a link chain article wherein the article is conveyed through a high frequency coil and simultaneously heated at an elevated temperature, and is then cooled after a predetermined period of time, the improvement therein wherein the process is carried out in a carburization atmosphere and the treated article is simultaneously heated at an elevated temperature, and is cooled after a predetermined period of time, resulting in formation of the desired carburized layer in said article.

4. In a heat treating process for a link chain article wherein the article is conveyed through a high frequency coil and simultaneously heated at an elevated temperature, and is then cooled after a predetermined period of time, the improvement therein wherein the process is carried out in a carburizing atmosphere and the treated article is simultaneously heated at different temperatures over different areas of the article, and is cooled after a predetermined period of time, resulting in the formation of different carburized layers over different areas of the article.

5. In a heat treating process for a link chain article wherein the article is conveyed through a high frequency coil and simultaneously heated at an elevated temperature, and is then cooled after a predetermined period of time, the improvement therein wherein the process is carried out in a heat treatment gas atmosphere and the treated article is simultaneously heated at an elevated temperature, and is cooled after a predetermined period of time, resulting in the establishment of atmosphere heat treatment on the surface of said article.

6. In a heat treating process for a link chain article wherein the article is conveyed through a high frequency coil and simultaneously heated at an elevated temperature, and is then cooled after a predetermined period of time, the improvement therein wherein the process is carried out in the presence of a non-oxidizing and bright heating gas and the treated article is simultaneously heated at different temperatures over different portions of the article, and is cooled after a predetermined period of time, resulting in the formation of the different metallic structures over different portions of the article as well as the establishment of non-oxidation and non-decarburization of the surface of said article.

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