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METHOD OF HEAT TREATING ALLOY STEEL ROTOR FORGINGS

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This invention relates to improvements in heat treating heavy alloy steel forgings and more particularly to forgings which are used in the production of large generator and turbine rotors.

Heretofore in the production of alloy steel forgings for generator and turbine rotors the heavy forgings, i.e. forgings over 30 inches in diameter have been subjected to very long and expensive heat treatment to develop required physical and mechanical properties. The steps in the heat treatment have been as follows:

(1) Slowly cooling after forging, usually from a temperature of about 1500° F., at a rate of about 10° F. per hour to about 600° F. and holding at this temperature for about 30 hours.

(2) *First austenitizing treatment.*—Reheating to an austenitizing temperature of from 1750 to 1850° F. and holding at this temperature for about 30 hours.

(3) *First normalizing treatment.*—Cooling (usually in air) to about 600° F. and holding at this temperature for about 30 hours.

(4) *Pretemper treatment (optional).*—Heating to a tempering temperature of from 1100 to 1275° F., holding at this temperature for about 30 hours and cooling usually in a furnace to room temperature.

(5) *Second austenitizing treatment.*—Reheating to an austenitizing temperature of from 1475 to 1750° F. and holding at this temperature for about 30 hours.

(6) *Second normalizing treatment.*—Cooling (in air, by fan, fog or spray) to about 300 to 600° F. and holding at this temperature for about 30 hours.

(7) Reheating to a tempering temperature of from about 1050 to 1275° F., holding at this temperature for about 30 hours and cooling at a rate of about 10° F. per hour to room temperature. Machining and testing is usually performed after steps 4 and 7 above.

We have discovered that the foregoing heat treatment time can be reduced from between 400 to 600 hours to between 150 to 300 hours for nickel-molybdenum-vanadium steels of the following composition, not only without impairment of the properties obtained but with actual improvements therein. The steel composition for which the treatment is effective is as follows:

Carbon	.15/.30%
Manganese	.15/.80
Silicon	.40 max.
Nickel	1.50/4.25
Chromium	2.00 max.
Molybdenum	.20/.70
Vanadium	.30 max.

balance iron and residual impurities and other elements such as copper, aluminum, nitrogen, etc. in small amounts which do not adversely affect the properties.

I have discovered that with such steel a heat treatment consisting of air cooling after forging, austenitizing and tempering will produce results as good or better than the prior art treatment. My treatment is as follows:

(1) Air cool the forging directly to room temperature after the forging operation.

(2) Heat to an austenitizing temperature of 1475 to 1525° F., i.e. about 1500° F. and hold at this temperature for at least about 30 hours (the only austenitizing treatment).

(3) Cool at an accelerated rate in air by fan, fog, or spray, or in water or oil to about 600° F. or lower, for example, room temperature is preferred, remove from the cooling environment, and allow to cool to ambient temperature in still air.

(4) Heat to a tempering temperature of 1025 to 1175° F., hold at this temperature for at least 30 hours, and furnace cool (i.e. slow cool at a rate less than 30° per hour) to room temperature. Machining and testing may be performed after steps 1 and 4.

Studies have been conducted on nickel-molybdenum-vanadium steels of the following chemical composition, percent.

Steel	C	Mn	P	S	Si	Ni	Cr	Mo	V
1	0.25	0.51	0.009	0.011	0.24	2.82	0.45	0.30	0.10
2	0.25	0.52	0.014	0.014	0.15	3.09	0.07	0.31	0.08
3	0.23	0.48	0.008	0.015	0.27	3.11	0.08	0.34	0.10

Specimens of these steels were heat treated in accordance with the method of this invention for heat treating heavy rotor forgings of the nickel-molybdenum-vanadium rotor steel as set forth in steps 1 to 4 above. In addition, two 40-inch octagon by 60-inch long test pieces of steels 2 and 3, were produced and processed with a double normalizing and tempering treatment (utilizing austenitizing temperatures of 1700 and 1475° F.) to provide a basis for comparison of the effect of single versus double normalizing treatment on the properties of these steels when all other factors were held constant.

Mechanical test results in the transverse test direction of the above-mentioned forgings are given in the following Table I.

These data show that none of the mechanical properties of these three nickel-molybdenum-vanadium rotor steels are significantly affected by single normalizing instead of double normalizing, by the elimination of the initial slow cooling from the forging operation, and by cooling to and holding at room temperature after the austenitizing treatment (steel 1 was not treated in this manner, it was held at about 600° F. for about 30 hours and then reheated to the tempering temperature). In fact, some of the mechanical properties are improved by this new method of heat treatment, for example, see the improved (lower) transition temperature of steels 2 and 3, which were cooled to room temperature after austenizing as compared to steel 1 which was held at 600° F. after austenitizing. In every respect, the properties of the single normalized and tempered steels are equivalent to the properties of the same steels double-normalized and tempered.

While I have shown and described several specific embodiments of my 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 my invention, as defined in the appended claims.

Table 1

Steel	Yield Strength, p.s.i.		Tensile Strength, p.s.i.	Elong. in 2", percent	Reduction of Area, percent	Charpy V-Notch, 50 Percent Shear Fracture Appearance Transition Temperatures	
	0.02% Offset	0.2% Offset				F	Ft.-lbs. at 50% Shear
1	73,940	80,800	102,250	20.0	59.4	130	ND
N & T [1]	78,700	85,960	107,200	20.0	57.4		
2	78,760	82,540	101,150	20.5	58.3	80	42
N & T [2]	79,130	83,370	101,600	21.0	58.6		
2	78,420	80,450	99,540	24.0	58.0	90	40
DN & T [3]	74,740	79,520	99,140	21.5	49.3		
3	79,950	84,270	102,600	21.5	59.0	85	38
N & T [2]	80,850	83,380	102,600	20.5	56.8		
3	79,590	83,370	101,050	18.0	52.5	70	41
DN & T [3]	77,150	81,730	100,300	19.5	51.0		

ND—Not determined.

[1] N & T—Normalize and temper as specified in procedure outlined above except that the forging was held at 600° F. for about 40 hours after cooling from austenitizing and then reheated to temper—temperatures used: 1,500° F. austenitize, 1,120° F. temper.

[2] N & T—Normalize and temper as specified in procedure outlined above—temperatures used: 1,475° F. austenitize, 1,140° F. temper.

[3] DN & T—Double normalize and temper, as specified in procedure outlined for normalize and temper except that an additional normalize (equivalent to Step 2) was added—temperatures used: 1,700° F. first austenitize, 1,475° F. second austenitize, 1,140° F. temper.

I claim:

1. A method of producing large rotor forgings comprising forging a rotor from steel containing essentially iron and

Carbon	.15/.30%
Manganese	.15/.80
Silicon	.40 max.
Nickel	1.50/4.25
Chromium	2.00 max.
Molybdenum	.20/.70
Vanadium	.30 max.

air cooling said forging after the forging operation, austenitizing it at a temperature of 1475 to 1525° F. and hold at such temperature for at least about 30 hours, cool to room temperature, temper at a temperature between 1025 and 1175° F. for at least about 30 hours and thereafter slow cool to room temperature.

2. A method of producing large rotor forgings comprising forging a rotor from steel consisting of

Carbon	.15/.30%
Manganese	.15/.80
Silicon	.40 max.
Nickel	1.50/4.25
Chromium	2.00 max.
Molybdenum	.20/.70
Vanadium	.30 max.

balance iron and residual impurities and other elements such as copper, aluminum, nitrogen, in small amounts which do not adversely affect the properties, air cooling the forging to room temperature, austenitizing it at about 1500° F. and hold at this temperature for at least about 30 hours, rapidly cool to at least 600° F. and thereafter air cool to room temperature, heat to a tempering temperature of between 1025 and 1175° F. and hold at this temperature for at least about 30 hours and then furnace cool to room temperature.

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