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FORGED STEEL ROLL AND METHOD OF PRODUCTION

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This invention relates to steel forgings, and finds practical application in the formation of rolls for rolling-mills. Its greatest value is realized in the formation of rolls for cold-rolling, which have to withstand the heaviest service strains, and in rolls of largest size, whose successful production is most difficult. The invention consists, first, in a new formula in the composition of the refined steel, attained in appropriate manner; second, in improvements of method, and, finally, in a roll of new characteristics, with the consequence and effect that production is simplified; the time factor in production is very substantially and advantageously shortened; the loss of articles found in the course of fabrication to be defective (in the present practice a very considerable and serious matter) is reduced to the point of disappearance; the danger to life and limb, consequent upon explosion of rolls, existent both during fabrication and during use, is substantially eliminated; and the durability of the roll in service is very considerably increased.

In the refining of steel preparatory to the production of forged rolls, it is the universal practice so to proportion the ingredients and so to conduct and control the refining operation that the steel shall be hypereutectoidal; that is to say, shall have a carbon content substantially exceeding the eutectoidal value of 0.9%. Specifically, the carbon content ranges from 0.95 to 1.2%. Additionally, and in order to gain hardness and toughness, chromium is included, in association with another alloying metal, ordinarily molybdenum, or, alternatively, vanadium or tungsten. The chromium is present in an amount exceeding 1.85% and within the range of 1.85–2.25; and with it molybdenum, for example, may be present in an amount ranging from 0.15 to 0.2%. The accepted typical formula for the refined steel for forged rolls is—

	Percent
Carbon	0.95–1.2
Manganese	0.25–0.35
Phosphorus, under	0.03
Sulphur, under	0.03
Silicon	0.15–0.25
Chromium	1.85–2.25
Molybdenum	0.15–0.2
Remainder, iron.	

I have discovered that by reducing the carbon content of the refined steel to eutectoidal value, or even less; by reducing the chromium content to less than 1.85%; and by omitting other such alloying metals as vanadium and tungsten that heretofore have been included to afford increased hardness and toughness, I realize large and unanticipated gain and advantage, both in fabrication and in service; and that by improved methods of procedure incident to and forming part of the fabricating operation superior results are realized.

The formula of my invention is—

	Percent
Carbon	0.75–0.95
Manganese	0.2 –0.3
Phosphorus, under	0.03
Sulphur, under	0.03
Silicon	0.2 –0.35
Chromium	1.3 –1.8
Remainder, iron.	

Following are the new and distinguishing features of fabrication, and the gains and advantages in method and product:

In the usual procedure, beginning with a steel of the composition typically given in the first formula above, it is customary, before pouring the metal into the mold, to add a small quantity of aluminum, or of that combination of aluminum, silicon, and iron, known as alsifer; in my improved practice, using the second formula given above, I find such an addition unnecessary. I reject a small quantity of metal at the beginning of the pour, because this is likely to be contaminated; but, thereafter, I pour into the mold. In the usual practice counterboring is frequently necessary, in order to remove defects in the casting; in my improved practice there are no such defects, and counterboring is in no case requisite.

In the practice now prevalent the ingot is stripped from the mold at relatively high temperature (typically 1550° F.—I shall throughout use the Fahrenheit scale), charged into the forge furnace, and brought as rapidly as possible to the forging temperature. I have found, with the steel of my improved formula, that advantageously the casting may continue in the mold until a very much lower temperature is attained (1000° or less); and that thereafter, in the forge furnace the casting may advantageously be brought very slowly to the forging temperature.

In the practice now prevalent, employing the hypereutectoidal steel with its alloy content as defined above, the forging temperature is 2400° and upward. With my improved eutectoidal or approximately eutectoidal steel, modified as specified with respect to alloy content, I find that a forging temperature of 2090° need never be exceeded. The economy of this variation in procedure is manifest; and the structure of the steel of the forged article I find to be, not inferior, but superior rather to that of prevalent practice.

The heat treatment of the forged roll of the usual practice includes, first, normalizing to a peak temperature of 1650–1700° and rapid cooling again to about 800°; second, spheroidizing to a peak temperature of about 1550°–1560°; followed by slow cooling in the furnace; third, oil-hardening, by heating to a peak of about 1600°, followed by cooling in oil; and, finally, a tempering of the roll before machining. I find that the heat-treatment of my forging of essentially euctectoidal character may advantageously be reduced to the single operation of heating to a peak temperature of 1490°, followed by slow cooling in the furnace. As always in heat-treating, the time during which the article is held at peak temperature varies, according to the mass of the article; and I find that in the heat-treatment my roll should be held at the peak for one hour for every inch of roll diameter. My roll, cooled after the single heat-treatment, is ready, without any intervening tempering step, for machining.

The roll of prevalent practice, heat-treated and tempered, when it is being machined, is relatively hard, the turnings are hard and brittle; the roll of my invention, when being machined, is relatively soft, the turnings are tough and "gummy," with tendency to curl, rather than to break into small pieces.

After machining, the roll is hardened, by raising to high temperature and cooling again under a water spray. In the prevailing practice the peak temperature of this hardening step is relatively high and varies widely, according to the size of the roll (typically, 1550°–1590°); in my improved procedure the peak temperature is lower, and is the same for all rolls, regardless of size (1475°–1500°).

The hardened roll of my improved procedure has a scleroscope hardness of 104–110, and that is somewhat greater than that of the roll of the usual practice (100–103); in consequence, the ultimate tempering step of my improved procedure involves a much higher peak temperature: 425°, as compared with 290°–300° of the usual procedure.

The superiority of my invention is found in the following features:

1. Great saving of time in the roll-making procedure, with consequent increase in possible rate of production.

2. Spalling and breaking of rolls in the course of production is overcome. Instead of the necessity of proceeding with the production of three or four rolls, in order to be reasonably assured of getting a finished pair, the roll-maker can proceed to produce two and no more.

The roll produced has the desired ultimate hardness (95–100); it is superior in homogeneity, in the uniformity of its physical characteristics; it will not spall, and the reason for this is that, while possessing the requisite hardness, it possesses superior toughness; it is less liable to breakage under the stress of mill operation; it is less liable to burning when in service, and on that account it may be re-ground with relative ease; the quality of hardness penetrates deeply, and the life of the roll is correspondingly long; since a roll when in service may not safely be allowed to attain the temperature of its ultimate tempering, and since in my improved procedure the temperature of ultimate tempering is much higher than is usual, it follows and is practically true that the roll of my invention is serviceable in a larger way. It need not be so carefully tended, lest it grow too hot in service; and the speed of mill operation as a whole, relieved of this embarrassment, may be accelerated.

I claim as my invention:

1. The method herein described of forming a forged roll from a steel whose carbon content approximates and does not substantially exceed the eutectoid value, and ranges from 0.75 to 0.95%, and in which a hardening and toughening content of chromium alone ranging in value from 1.3 to 1.8% is found, which consists in casting, forging, heat-treating in a single elevation of temperature to a peak of substantially 1490° F., followed by slow reduction of temperature, machining, hardening, and tempering.

2. The method herein described of forming a forged roll from a steel whose carbon content approximates and does not substantially exceed the eutectoid value, and ranges from 0.75 to 0.95%, and in which a hardening and toughening content of chromium alone ranging in value from 1.3 to 1.8% is found, which consists in casting, forging, heat-treating, and machining, hardening the machined roll by heating to a temperature not exceeding 1500° F. and cooling again under water spray, and tempering by heating to substantially 425° F. and cooling again.

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