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PROCESS OF TREATING STEEL

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This invention relates to the art of steel making, it being concerned particularly with new and improved steels which are normal in their character and which can be made either in Bessemer or in open hearth furnaces.

More specifically, the invention relates to new and improved steels which exhibit a machinability comparable with that of leaded steel without the use of lead in the analysis and the difficulties which are attendant, naturally, upon the addition of lead to a steel.

For a number of years steels have been classified as "normal" or "abnormal," depending upon the extent to which the grains are surrounded by the grain boundary material, i. e., cementite or ferrite. When the grain boundary material is well defined and substantially continuous around each grain, the steel is said to be normal, but when the grain boundary material is not substantially continuous, the steel is said to be abnormal, and the degree of abnormality depends upon the extent to which the boundary material is interrupted. A steel is classified as normal or grade A steel when it has a substantially continuous boundary of cementite or ferrite around each grain. Abnormal steels are classified in the trade (Dodge test) in grades B, C and D. In grade B, the boundary is slightly broken; in grade C it is considerably broken; and in grade D, it is more or less limited to one or possibly two sides of the grain.

For approximately the same length of time the steel industry has classified the sizes of grains in steel according to the standard chart of the Americal Society for Testing Materials. This chart extends from No. 1 for very coarse grains, to No. 8 for very fine grains.

The present invention relates particularly to normal steels which are classifiable in grade A, which have grains ranging in size between about Nos. 1 and 4 on the A. S. T. M. Standard scale, and which, although free from lead, have a machinability comparable to that of leaded steel.

Machinability is a somewhat controversial term to define; it may refer to the surface produced, to the number of pieces of work finished in a unit of time, to the tool life, or to chip formation. In the present description, machinability will be understood to embrace all of these factors. That is to say, in accordance with the present invention, the foregoing factors are balanced properly to produce more of a satisfactory product than has been possible heretofore.

It is well known that free-machining steels are produced frequently by adding lead in various amounts, such additions producing steels which machine at high production rates and with a long tool life.

The use of lead in steels has certain objections. First, there may be mentioned the ever-

present possibility of the operators becoming lead-poisoned. Additionally, the large quantities of lead employed in industrial applications such as the main component of bearing metal, electric cable sheaths, pigments, and a multitude of other uses place lead in the category of a strategic metal.

These, among other reasons, make the elimination of lead highly desirable.

In accordance with the present invention, there are provided steels of widely different composition in which there has been included sufficient nitrogen to render the addition of lead unnecessary. Such steel may be made by either the Bessemer process, or open hearth, and should have a composition within the following approximate ranges:

	Bessemer	Open hearth
	Per cent	Per cent
Carbon.....	0.05 -0.40	0.05 -0.40
Manganese.....	0.40 -1.30	0.40 -1.65
Phosphorus.....	0.10 -0.200	0.010-0.200
Sulphur.....	0.020-0.45	0.020-0.45
Nitrogen.....	0.010-0.020	0.005-0.020

Some silicon, copper, nickel, molybdenum in accidental or residual amounts may be present in the composition without materially influencing the machining properties of the improved steel of the present invention.

In accordance with the present invention, the nitrogen is introduced into the steel by using anhydrous ammonium sulphate which is mixed in the steel in the ladle.

The use of anhydrous ammonium sulphate possesses definite advantages over other nitrogen-bearing compounds because it avoids the intense combustion which results if inflammable materials, such as urea, for example, be employed; also it avoids the toxic hazard of cyanides, the carburizing action of organic compounds, and the contaminating action of metallic nitrogen salts. The low cost of ammonium sulphate also affords a definite economic advantage, since in any event a large excess of the nitrogen-bearing material must be employed in order to obtain the requisite nitrogen content in the metal. Thus, using ammonium sulphate as the nitrogen-bearing compound there should be used enough to contain about four times the amount of the nitrogen which it is desired to introduce into the steel. That is to say, the efficiency is about 25%, but this is inconsequential owing to the low cost of ammonium sulphate. It is necessary to use the anhydrous salt to avoid the explosive action resulting from the presence of water.

The anhydrous ammonium sulphate preferably is added after addition of ferro-manganese and ferro-silicon to the ladle. The heats in an open

hearth furnace are tapped without addition of ferro-manganese or ferro-silicon to the furnace prior to tapping, and little or no aluminum is added to the ladle. In any event, either a mechanically capped or semi-killed steel is employed, and any aluminum used to deoxidize is added in amounts only sufficient to form some aluminum oxide, but not enough to combine with any of the nitrogen.

A further advantage of the use of ammonium sulphate resides in the introduction of sulphur in the steel along with the nitrogen, the sulphur also enhancing the free machining of the steel, up to the point of rendering the steel hot-short. Since insufficient sulphur may be present in the steel even after the addition of ferro-manganese, ferro-silicon and ammonium sulphate for introducing nitrogen into the steel, any deficiencies in the sulphur content may be made up by adding elemental sulphur to the steel in the ladle.

It is observed also that the desirable properties imparted by the nitrogen are enhanced by phosphorus, appreciable beneficiation beginning with a phosphorus content of about 0.010%, and extending through the range of from about 0.010% to about 0.2%. Under normal practice in cold drawing, very beneficial effects are obtained at about 0.1% phosphorus.

This phosphorus content is present normally in Bessemer steels; but in the case of open hearth steels, rephosphorizing with ferro-phosphorus added to the ladle may be employed to bring the phosphorus content in the metal to its preferred value.

The improved effects of the present invention are illustrated by the following data, wherein the steels referred to have the following normal composition range:

Type of steel	Tool life, hr., min.	Surface finish	Tool life, hr., min.	Surface finish	Tool life, hr., min.	Surface finish
SAE 1120 plain	3'55"	Fair			Would not run	
Open hearth						
C Mn P S N						
.18 .82 .014 .142 .003						
SAE 1120 open hearth	5'30"	Fair	1'40"	Fair	do.	
Plus N						
C Mn P S N						
.18 .80 .012 .151 .012						
SAE 1120 open hearth			7'55"	Good	5'45"	Good.
Plus N and P						
C Mn P S N						
.16 .72 .047 .148 .010						
SAE 1120 plus lead			6'05"	Fair	6'00"	Fair.
C Mn P S N Pb						
.18 .82 .011 .120 .003 .16						
SAE 1120 plus lead					5'30"	Good.
Not given.						

SAEX-1112 as a Bessemer steel

C	0.08%—0.16%
Mn	0.60%—0.90%
P	0.09%—0.13%
S	0.20%—0.30%

SAE-1120 as an open hearth steel

C	0.15%—0.25%
Mn	0.60%—0.90%
P	0.045% maximum
S	0.075%—0.15%

EXAMPLE 1

Machinability test run on standard part cold drawn specimens

Revolutions per minute	2110	2333
Feed (depth of cut, inches)	0.007	0.0085
No. pieces per hr.	974	1200

TYPE OF STEEL

SAEX-1112

NOT NITROGEN TREATED

	C	Mn	P	S	N	Tool life	
						Hrs.	Minutes
5	0.12	0.72	0.101	0.268	-----	3	10
10	0.11	0.83	0.109	0.286	0.009	0	42
	0.11	1.07	0.106	0.332	0.011	8.	55

NITROGEN TREATED

15	0.10	0.88	0.108	0.292	0.013	5	55
	0.09	0.85	0.111	0.310	0.014	10	46
						9	09
						8	27
						10	29
	0.10	0.81	0.099	0.288	0.015	4	37
						9	21
20	0.12	0.92	0.119	0.330	0.016	9	00
	0.09	0.91	0.108	0.260	0.018	3	30
						5	00
						7	36
						9	20

Leaded steel, standard analyses.....

From the foregoing, it will be seen that the nitrogen-bearing Bessemer steel containing from 0.013% nitrogen to about 0.016% nitrogen gives very satisfactory tool life, and is in fact comparable to leaded steel in machining qualities. This improvement is noted in nitrogen contents up to approximately 0.020%.

EXAMPLE 2

Machinability test run on standard part open hearth steel

35	Revolutions per minute	2110	2333	2110
	Feed	.0055"	.0055"	.0070"
30	No. of pcs. per hour	818	857	974

From the foregoing, it will be seen that an open hearth steel containing 0.012% of phosphorus and a like percentage of nitrogen showed definite improvements over the same steel in which the nitrogen was substantially absent.

However, when the steel was phosphorized to bring the phosphorus content up to 0.047%, and a nitrogen content of 0.01% substantially better results were obtained. It will be seen from the foregoing data that with 974 pieces machined per hour with 2,110 revolutions per minute and a cut of 0.007" in depth, the tool would not run on the steel containing 0.012% phosphorus and 0.012% nitrogen, the tool burning immediately, whereas a tool life of five hours and 45 minutes was obtained with an increase of phosphorus to 0.047%. On the other hand, the open hearth steel containing 0.012% nitrogen behaved substantially better than did the same steel with nitrogen sub-

stantially absent, the tool life for the nitrogen-containing steel being shown as five hours and 30 minutes with 818 pieces per hour machined at a depth cut of 0.0055" and 2110 revolutions per minute, whereas the steel which was substantially free from nitrogen giving only a tool life of three hours and 55 minutes, under these same conditions.

When the output was increased to 857 pieces per hour, the nitrogen-bearing steel gave a tool life of one hour and 45 minutes while this same steel with a phosphorus content of 0.047% gave a tool life of seven hours and 55 minutes.

The same steel with low phosphorus and substantially nitrogen-free but with a lead content of 0.16% which is the customary lead content of free-machining steels gave only a tool life of six hours and 5 minutes, with an output of 857 pieces per hour and this leaded steel showed substantially the same tool life at an output of 974 pieces per hour as did the higher phosphorus steel containing nitrogen under the same conditions. The surface finish of the nitrogen-bearing steel containing phosphorus of 0.047% gave a better surface finish than did the low phosphorus substantially nitrogen-free steel containing the lead.

The explanation of the improved results obtained by the addition of nitrogen to high-phosphorus steels is not known, and there is no intention nor desire to be bound by any explanatory theory. However, it may be that the nitrogen increases machinability because of the possibility that the nitrogen may dissolve in the ferrite and affect the plasticity of the ferrite. The steels as processed in accordance with the present invention are machined usually in the cold-drawn condition and a large amount of mechanically produced slip has occurred already before the machine tool acts upon the steel. The ma-

chining may embrittle the ferrite for there is a certain amount of cold work done ahead of the cutting tool by action of the tool, causing a precipitation of nitrides to occur and, therefore, providing a steel making a more brittle chip. It has been observed that when the nitrogen exceeds a maximum value the machining properties deteriorate.

I claim:

1. The process of treating steel to improve machinability thereof which comprises adding sulphur and nitrogen to molten steel contained in a ladle by incorporating in the steel ammonium sulphate in sufficient quantities to contain approximately 4 times the amount of nitrogen that is to be included in the steel.

2. The process of treating steel to improve machinability thereof which comprises adding ammonium sulphate to molten steel contained in a ladle in quantities sufficient to impart a nitrogen content to the steel of not more than approximately 0.020% but more than 0.003%.

3. The process of improving machinability of steel which comprises adding ammonium sulphate to molten steel in quantities sufficient to impart a nitrogen content to the steel of not more than 0.020% but more than 0.003%, the said nitrogen being imparted to the steel in the presence of from about 0.010% to about 0.2% phosphorus.

4. The process of improving machinability of steel which comprises adding ammonium sulphate to molten steel in quantities sufficient to impart to the steel up to about 0.020% nitrogen but more than 0.003%, the said nitrogen being imparted to the steel in the presence of about 0.010% to about 0.2% phosphorus and from about 0.1% to about 0.300% of sulphur.

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