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FREE MACHINING OPEN HEARTH STEEL

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This invention relates to a new free machining open hearth steel having properties not heretofore developed in such steels. In the lower carbon ranges, the new steel has the properties of a case hardening steel having high ductility and tensile strength. In the higher carbon ranges, the new steel is suitable for heat treatment. This application is a division of my copending application Serial No. 148,324, filed June 15, 1937 in which a process of manufacturing my new steel is described and claimed per se.

In the past, most open hearth and Bessemer free machining steels have been produced by increasing the sulphur and manganese content above that of the average commercial open hearth steel, the silicon and phosphorus content remaining about the same. For free machining case hardening steels the manganese content is often run as high as 1.20% and sometimes even to 1.50% with a sulphur content often of 0.20% and sometimes 0.30% as compared to manganese contents of 0.60% and 0.80% and sulphur content below 0.05% in ordinary steels. Such steels commonly carry a phosphorus content of about 0.04% and one commercial Bessemer steel of this type has a phosphorus range of from 0.09% to 0.13%. Their silicon content is usually in the range of ordinary steels and is not generally specified in the S. A. E. specifications since heretofore it has been considered of small importance. Such steels are free machining steels capable of case hardening but have the disadvantage of being non-uniform and sometimes brittle. This lack of uniformity and brittleness is caused by the formation of manganese sulphide in isolated masses known commercially as segregations and which weaken the bars at the points where they occur. Heretofore these segregations have been considered an inescapable evil accompanying the high sulphur and manganese content which has been found advantageous in producing a steel capable of machining at high speeds.

Heretofore the freest machining steels have been known as SAE X1112, SAE 1112 and SAE X1314 in the low carbon range and SAE 1040 in the higher carbon ranges. SAE X1112 and SAE 1112 have the best machining qualities but are rather brittle Bessemer steels having poor ductility and poor case hardening properties. SAE X1314 is fairly good from the standpoint of free machining and case hardening but has a low yield point. Its ductility, while better than X1112 and 1112, is still rather poor. As compared with these steels, the steel produced in accordance with this invention in the same carbon range has superior machinability, much better ductility, superior case hardening properties and a much higher yield point. In case hardening it produces a harder, deeper case in less time and with much less warpage.

In the higher carbon range, SAE 1040 has a good compensated ductility but is relatively poor from the standpoint of free machining. The new steel in this range has substantially the same ductility characteristics as SAE 1040 but has a machinability rating which compares favorably with that of the low carbon steels.

Heretofore no free machining steel having a high compensated ductility rating has been manufactured. Steel produced in accordance with this invention up to 0.55% carbon has a machinability rating of at least 80, compared to SAE 1112 taken as 100. In addition, its compensated ductility rating is higher than any other free machining steel. The compensated ductility of steels produced hereunder is above 28 and generally of the order of 31-33. Compensated ductility (hereinafter referred to as D-C rating) is calculated according to the following formula:

$$D-C \text{ rating} = E + 0.43C$$

and where E is the elongation percent in 2" for cold drawn material and C is the hundredths of percent of carbon.

The product likewise has a compensated machinability-strength rating considerably in excess of like steels. The compensated machinability-strength rating is calculated according to the following formula:

$$MCS \text{ rating} = \frac{T \times Y \times E \times M}{10^{11}} + C$$

where T is the ultimate tensile strength in pounds per square inch, Y the yield point in pounds per square inch, E the elongation percentage in 2", M the machinability based upon SAE 1112 as 100, and C is the carbon content of the steel expressing in hundredths of 1%. T, Y, E and M are based on cold drawn material.

My new steel has an MCS rating of at least 140 and normally about 150. This compares with an MCS rating of 113 for X1112, 89 for 1112 and 102 for X1314. Rigidly .15% carbon steel produced hereunder had an MCS rating of approximately 217.

My new steel has a yield point of at least 75,000 lbs. based on a 1" rod.

My invention contemplates a steel having sulphur and manganese contents sufficiently high to permit cutting speeds as high or higher than present steels but in which the excessive formation of manganese sulphide which produces segregation is reduced to a minimum. According to my invention, the sulphur is believed to form soluble iron sulphides which are uniformly distributed throughout the heat and in turn throughout the ingot, billet and bar and which add materially to the free machining quality of the steel. This result is accomplished by reducing the silicon and phosphorus content, which has heretofore

been considered unimportant, to a commercial minimum, by the method of control of the manganese and sulphur content hereinafter described, and by rolling the steel within critical temperature ranges. Each of these four factors contributes to the reduction of manganese sulphide segregations.

The preferred specification of my new steel is as follows:

	Per cent
10 Sulphur.....	0.18 to 0.30
Manganese.....	1.00 to 1.40
Phosphorus.....	0.02 maximum
Silicon.....	0.02 maximum

15 The steel may be made with carbon contents from 0.08 to 0.75% or higher, the lower carbon steel having excellent case hardening characteristics and the higher carbon steel having heat treating properties. Departure from these preferred specifications, within the usual commercial tolerances, may be made without extremely deleterious results.

20 It is important that the phosphorus and silicon content be kept as low as possible. More phosphorus or silicon than that specified above reduces the amount of sulphur and manganese which can be absorbed by the steel without producing segregations. Less silicon and phosphorus permits more manganese and sulphur to be used. 25 The manganese and sulphur contents should be in the ratio of about 5 to 1.

30 In the manufacture of the steel, the furnace is preferably charged with pig iron and scrap steel or with scrap steel alone, as may be desired.

35 A basic flux is used, lime in the proportion of about 8% of the charge being the preferred flux. This is found sufficient to reduce the phosphorus and silicon contents to the desired minimum. The carbon content is controlled by standard 40 open hearth practice. Sufficient ferro-manganese is added in the furnace to give about 70% of the final desired manganese and sulphur contents for a steel having a final manganese content of 1.20 to 1.30%, standard open hearth 45 practice being followed in this respect. The amount of manganese added to this point should not be sufficient to cause appreciable segregations of manganese sulphide. Ordinarily the amount of manganese present in the furnace is 50 well below 1%—say .84 to .91%.

The charge is preferably poured from the furnace at the usual pouring temperature of approximately 2850° F. and is allowed to stand in the ladle until it has cooled approximately 100° F. 55 or more. In the case of a charge sufficient to pour 175 tons of ingots this cooling requires approximately 30 minutes. At the end of the desired cooling time, a further addition of ferro-manganese is made sufficient to bring the final manganese content to the desired amount. 60 Free sulphur is also added at the same time if the sulphur contents of the original charge and the added ferro-manganese does not give the desired final sulphur contents.

65 The additions in the ladle still further lower the temperature of the heat but not sufficiently to permit solidification before pouring of the ingots can be completed.

70 The addition of the last portion of manganese and sulphur at a reduced temperature as in the ladle appears to be an extremely important factor in reducing the formation of manganese sulphide segregations. Apparently at this reduced temperature, the reaction forming manganese sulphide does not take place to so great a degree as

at the higher temperature, if at all. Furthermore, the time required to solidify from the lower temperature is so much less than from the higher temperature that such manganese sulphide as may possibly be formed does not have sufficient time to segregate before the charge has solidified in the ingot mold.

After the ingots have solidified, the molds are stripped and the ingots placed in the soaking pit and held at about 2460° F. until ready to roll. 10 The rolling from ingot to billet is done with the least possible temperature drop. The billets, cut to proper length, are then reheated for the rolling from the billet to bar.

In the rolling of bars of the low carbon steel from the billets, the starting temperature is about 2400° F. and the finishing temperature is kept as high as possible. Preferably at about 1860° F. to 1880° F. Below this finishing temperature it is found that cracks, seams and segregations occur which destroy in a large degree the desirable properties of the steel. For the high carbon steel the critical rolling temperatures are much lower, the preferable starting temperature being below 2100° F. Higher rolling temperatures for the high carbon steel produce a porous steel having incorrect density and excessive scale. 25

When used for case hardening, the new steel carburizes to the same depth in less time and gives a harder case and tougher core than other carburizing steels, and is uniform and free from brittleness. One of its most important characteristics is its freedom from excessive warpage. This characteristic is so marked that it may be used for parts, such as relatively long pins with ground journals on each end, which cannot be made from other case hardening steels. This property is due in a large measure to the uniformity of the material. 35

The following table indicates the relative properties of the new steel and certain other steels, referring only to those steels in the cold drawn state: 40

	A	B	C	D	E	F	G
SAE X1112.....	200 to 235	120 to 130	85,000	68,000	14	---	---
SAE 1112.....	150	100	80,000	64,000	15	---	---
SAE X1314.....	135	94	79,500	62,000	19	---	---
SAE 1040.....	115	60	94,000	83,000	16	---	---
Ridgely 0.18 carbon.....	190 to 210	120	85,000	80,000	26	5	60
Ridgely 0.39 carbon.....	150	100	105,750	81,000	16.5	4	48-56
Ridgely 0.47 carbon.....	140 to 150	90	112,200	82,940	13	2.5	56-65

Column A—Machining speeds in ft. per min.
Column B—Machinability rating.
Column C—Tensile strength, pounds per sq. in.
Column D—Yield point, pounds per sq. in.
Column E—Percent elongation in 2".
Column F—Torsion tests, 360° turns in 12".
Column G—Impact test, ft.-lbs.

The figures given for Ridgely steels are conservative averages. 55

The new steel not only machines more readily than comparable steel, but machines in an entirely different manner. Instead of producing chips in the ordinary form, long spirals of material are produced which may be several feet in length. Machine surfaces in the new steel have a smoother appearance and texture than surfaces machined in the same manner with other steels. 60

Another important result of the new steel is increased tool life. It has been found in practice that tools used in machining the new steel may be used several times as long as with other free machining steels notwithstanding greater cutting speeds. 70

While the invention is particularly applicable to steels having no other metallic contents than heretofore mentioned, it may be used with steels containing small amounts of other metallic elements such as nickel, chromium, molybdenum, vanadium, etc. When so used, it produces a steel having superior machinability to steels of the same class.

The term "free machining" as used in the claims means a machinability rating of the order of 80 or better for steels having 0.55% carbon or less and correspondingly lower ratings for the higher carbon steels.

The invention claimed is:

1. An alloy steel having an approximate composition as follows:

	Per cent
Sulphur.....	.18 to .30
Manganese.....	1.00 to 1.50
Phosphorus.....	.02 maximum
Silicon.....	.02 maximum
Carbon.....	.08 to 0.75

and the balance being substantially all iron, said

steel being sufficiently free from segregations of manganese sulphide to have a relatively high ductility, and a compensated machinability-strength rating of at least 140 based on cold drawn material.

2. An alloy steel having an approximate composition as follows:

	Per cent
Sulphur.....	.18 to .30
Manganese.....	1.00 to 1.50
Carbon.....	.08 to 0.75
Silicon in a percentage of commercial minimum	
Phosphorus in a percentage of commercial minimum	

the balance being substantially all iron, and such of the manganese and sulphur as may be present in the form of manganese sulphide being sufficient finely divided and in sufficiently small quantity to produce a steel having a relatively high ductility and a compensated machinability-strength rating of at least 140 based on cold drawn material.

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