Oct. 13, 1964 M. O. HOLOWATY 3,152,889

FREE MACHINING STEEL WITH LEAD AND TELLURIUM

Filed Oct. 31, 1961 2 Sheets-Sheet 1

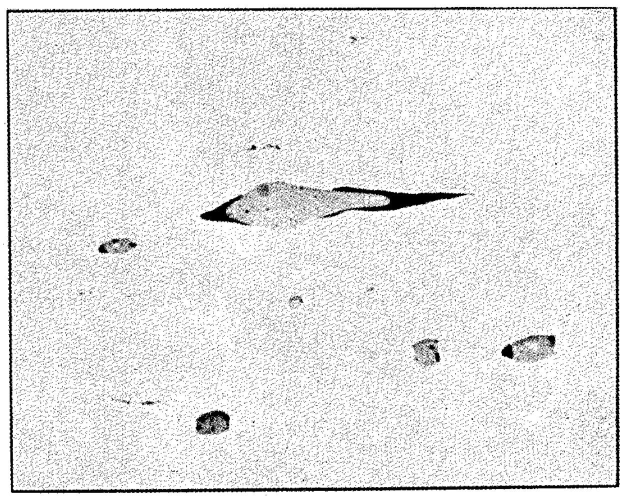

Fig. 1.

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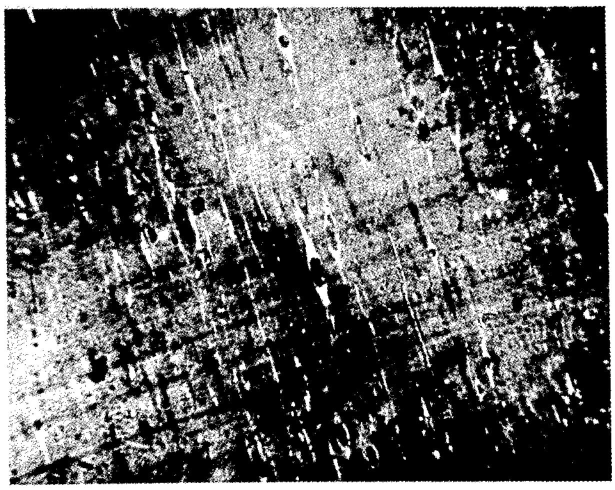

Fig. 2.

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FREE MACHINING STEEL WITH LEAD AND TELLURIUM

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The present invention relates generally to free machining steels and more particularly to a free machining steel having inclusions containing lead and tellurium, with all of the tellurium in inclusion form being associated with lead.

This is a continuation-in-part of the present inventor's application Serial No. 8,918, filed February 16, 1960, now abandoned, a continuation-in-part of application Serial No. 725,501, filed April 1, 1958, and now abandoned.

In the accompanying illustrations:

FIGURE 1 is a photomicrograph, at 500× magnification, showing the micro structure of a free machining steel containing lead and tellurium in accordance with the present invention; and

FIGURE 2 is an X-ray, at 100× magnification, of a 0.003-inch-thick specimen of the steel shown in FIGURE 1.

The machinability of steel has heretofore been improved by the addition of lead alone or of lead together with sulphur. In the microstructure of rolled steel, lead takes the form of elongated stringer-like inclusions (dark colored in FIGURE 1 and light colored in FIGURE 2), and sulphur, in inclusion form, is associated primarily with manganese (added to the steel to offset hot shortness otherwise imparted to the steel by sulphur in the absence of manganese) and appears as glob-like inclusions (light colored in FIGURE 1 and dark colored in FIGURE 2).

When the machinability of a steel is improved in accordance with the present invention, by an addition of lead and tellurium, the lead is found in the microstructure as elongated stringer-like inclusions; but, unlike sulphur, all of the tellurium in inclusion form is associated with the lead, and none of the tellurium is associated with the manganese. This has been confirmed by examining the microstructure with an electron beam microprobe. Increasing the manganese to sulphur ratio by lowering the sulphur content or raising the manganese content does not cause an association of tellurium with the additional manganese, the additional manganese merely going into solid solution in the matrix of the steel.

Thus, from the standpoint of the type of inclusion which they preferably form when added to steel together with lead, tellurium and sulphur are decidedly different. Unlike sulphur, tellurium in inclusion form is not found primarily in manganese-containing glob-like inclusions, but appears only in lead-containing elongated, stringer-like inclusions where the likelihood of intercepting a cutting tool is statistically much greater than if the tellurium were agglomerated in glob-like inclusions. Accordingly, when tellurium is added together with lead, both the tellurium and the lead are distributed in the most effective manner from the standpoint of frequently intercepting a cutting tool. In addition, the elongated stringer-like inclusions contain not only lead, but also intermetallic compounds of tellurium and lead which most likely impart a chip breaking property to the stringers already endowed with a lubricating property normally characteristic of stringers containing lead.

The resulting improvement in machinability due to the addition of lead and tellurium is unexpectedly greater than the machinability which would be predicted by adding the improvement due to the addition of lead alone to the improvement due to the addition of tellurium alone.

The following tabulations are the results of tests run to determine the improvement in machinability obtained by the addition of lead plus tellurium. In these tests, simulating the operation of automatic screw machines, a cut-off tool with a flat face enters a two and three-quarter-inch round test bar in a plane at a right angle to the axis of the bar and is fed toward the bar's axis to a cutting depth of one-half inch, using a feed of 0.009 inch per revolution.

The tools were made of 18–4–1 high speed steel with the following specifications:

10° positive back rake angle
15° front relief angle
3° side relief angle concave on top with 0.782 inch radius

Tests were run on a steel constituting a base with no lead or tellurium, a steel constituting the same base plus tellurium alone, a steel constituting the same base plus lead alone, and a steel constituting the same base plus lead and tellurium with the lead and tellurium being added in amounts similar to those used when lead alone or tellurium alone was added to the base. With each specimen of test material the test was run until tool failure or until the test material was exhausted, whichever happened first. The results are expressed, for the base, in terms of cubic inches of material removed until tool failure. The base is then given an index of 1 and the results for the steels constituting the base plus a machinability increasing addition are expressed in multiples of the base index.

Example I

The base had the following composition.

	Wt. percent
C	0.08
Mn	0.95
P	0.07
S	0.04
Si	0.05
Ni	0.2
Cu	0.19
Sn	0.08

Composition:	Machinability
Base	1=0.72 in.^{3} material removed till tool failure.
Base+0.045 wt. percent Te	61.
Base+0.21 wt. percent Pb	8.5.
Base+0.21 wt. percent Pb+0.045 wt. percent Te	200 (material exhausted; no tool failure).

The cutting speed for all the steels of Example I was 168 surface feet per minute or about 235 revolutions per minute for a two and three-quarter-inch bar which corresponds to the speed of commercial automatic screw machine operations. With reference to the above tabulation, the sum of the machinability indices of the base plus tellurium alone and the base plus lead alone is about 70. On the other hand, when similar amounts of lead and tellurium were added together to the base the machinability index was greater than 200, nearly three times the predictable machinability, and the tool had not yet failed when the test material was exhausted.

Example II

The composition of the base used in this example is substantially the same as that of Example I, except that the sulphur content was increased from 0.04 wt. percent to 0.11 wt. percent. The cutting speed for this example was about 230 surface feet per minute or about 320 revolutions per minute for a two and three-quarter inch bar.

Composition:	Machinability
Base	1=2.14 in.^{3} material removed till tool failure.
Base+0.2 wt. percent Pb	6.5.
Base+0.048 wt. percent Te	2.5.
Base+0.21 wt. percent Pb +0.042 wt. percent Te	32.5.

The sum of the machinability indices of the base plus lead alone and of the base plus tellurium alone is about 9, whereas the machinability index of the steel containing both the lead and the tellurium is 32.5, more than three times as great.

The present invention is applicable to non-stainless steels. The term "non-stainless" is used to refer to steels which are deficient in the alloying elements, particularly chromium, found in the well-known class of stainless steels in which the non-ferrous alloying elements exceed 10% and the concentration of chromium exceeds 5%. Thus, the steels to which the invention is applicable contain at least 90% iron, and preferably not less than 95% iron, and less than 5% chromium.

In accordance with the present invention, lead and tellurium may be added together to virtually any non-stainless steel which, as used herein, refers to an alloy having a matrix containing ferrite or austenite. A practical range for lead and tellurium when the two are added together is about 0.02 wt. percent to about 0.50 wt. percent lead and about 0.02 wt. percent to about 0.50 wt. percent tellurium. When used in conjunction with both tellurium and lead, the sulphur content is also suitably about 0.02%–0.50% and advisably about 0.3%–0.5%. Preferably, the tellurium need not exceed 0.20 wt. percent. For example, in the 1,000 series, 1100 series, and 1200 series of steels (A.I.S.I. numbers) a lead content of about 0.20 to 0.30 wt. percent together with a tellurium content of about 0.04 to 0.06 wt. percent has been found to constitute an ideal machinability increasing addition. Typical examples of steels of each of the above indicated A.I.S.I. series containing additions of lead and tellurium in accordance with the present invention are tabulated below.

Element	1,200 series	1,100 series	1,000 series
C	0.06–0.08	0.45–0.47	0.41–0.43
Mn	0.9 –1.10	1.52–1.60	1.45–1.55
P	0.06–0.07	0.03 max.	0.03 max.
Si	0.01–0.02	0.20–0.25	0.15–0.30
S	0.3 –0.33	0.29–0.33	0.035 max.
Te	0.04–0.06	0.05	0.05
Pb	0.20–0.30	0.20–0.30	0.20–0.30
Cu	—	0.17–0.20	0.19 max.
Ni	—	0.20 max.	—
Sn	—	0.08 max.	0.08 max.
Cr	—	0.12 max.	—
Mo	—	0.05 max.	—

FIGURES 1 and 2 illustrate the microstructure of the above 1200 series steel, which microstructure is typical of that containing lead and tellurium in accordance with the present invention. The 1200 series steel described above and illustrated in the figures contains no chromium. As seen in FIGURE 2, the lead-tellurium inclusions therein are widely and uniformly distributed, and elongated in the rolled condition.

Other examples of A.I.S.I. 1000, 1100 and 1200 series steels which may have their machinability increased in accordance with the present invention by adding 0.02–0.50 wt. percent lead and 0.02–0.20 wt. percent tellurium (0.04–0.06 wt. percent tellurium and 0.20–0.30 wt. percent lead, preferably) are listed on pages 817–18, in The Making, Shaping and Treating of Steel, seventh edition, United States Steel Corporation, Pittsburgh, Pennsylvania, 1957.

Before being modified in accordance with the present invention, these series of steels have a base composition, expressed in wt. percent ranges of constituent elements, as follows:

Element	1,000 series	1,100 series	1,200 series
C	0.08–1.03	0.08–0.55	up to 0.13
Mn	0.25–1.65	0.30–1.65	0.60–1.00
P	up to 0.12	up to 0.04	0.07–0.12
S	up to 0.06	up to 0.33	0.08–0.33
Si	up to 0.30	up to 0.30	—

While the invention applies to steel generally, it is particularly useful for improving the machinability of carbon steels containing up to 1% carbon. In addition to tellurium, lead, and sulphur, the steels of the invention can also contain small amounts of other elements such as manganese, phosphorus, silicon, nitrogen, nickel, copper, molybdenum, cobalt, chromium, etc., commonly found in steels of this type, provided that the amounts thereof do not adversely affect the improved machinability gained in accordance with the invention.

A steel containing lead and tellurium may exhibit the characteristic known as "hot shortness" or brittleness at read heat rolling temperatures. This characteristic is due to an overabundance of tellurium and/or sulphur in solid solution at the rolling temperature (about one-third of the tellurium forms inclusions, the rest going into solid solution). The brittleness can be alleviated by increasing the temperature range at which the steel is hot rolled or by increasing the manganese to sulphur ratio, the latter being accomplished either by increasing the manganese content (which is at least 0.6 wt. percent) or by decreasing the sulphur content. An increase in the manganese to sulphur ratio removes some of the sulphur from solid solution, thereby alleviating the hot shortness.

For example, a steel containing 0.07–0.09 wt. percent carbon, 0.95–1.05 manganese, 0.06–0.08 wt. percent phosphorus, 0.29–0.33 wt. percent sulphur, 0.10 silicon, and 0.2–0.3 wt. percent lead, with no tellurium, may be hot rolled at a temperature of about 2080° F. to 2120° F. without exhibiting hot shortness. When the machinability of this steel is improved by adding 0.04–0.06 wt. percent tellurium (in addition to the 0.2–0.3 wt. percent lead), the rolling temperature should be elevated to about 2100° F.–2140° F. to prevent hot shortness. In addition, it is advisable to increase the manganese content up to about 1.05–1.15 wt. percent while decreasing the sulphur content to about 0.28–0.32 wt. percent.

When the lead and tellurium inclusions are widely and uniformly distributed in the microstructure as shown in the figures (elongated stringer-like inclusions in the rolled condition), they are distributed in a manner most effective to intercept the cutting tool. In steel provided in accordance with the present invention, this distribution is assured by maintaining the chromium content at less than about 5.0 wt. percent. If the chromium content is higher, there is a likelihood that the lead and its associated tellurium will agglomerate into glob-like inclusions whose less dispersed distribution will be relatively less effective from a tool-intercepting standpoint than elongated stringer-like inclusions distributed as illustrated in the figures.

A steel containing lead and tellurium in accordance with the present invention may be made by adding the lead, preferably as metallic pellets, to the molten stream of steel as it is poured into the ladle, and by adding the tellurium preferably as metallic pellets either in the ladle, which is quickest and easiest, or in the ingot mold. The ladle addition of tellurium provides greater uniformity of tellurium content from ingot to ingot, but produces a smaller recovery of tellurium than when the tellurium is added to the ingot mold. When the tellurium is added to the ingot mold, bags containing one pound or more of metallic tellurium pellets are thrown directly into the center of the molten stream of steel being poured into the mold from the time the mold is about one-eighth full to a time when the mold is about five-eighths full.

There has thus been described a free machining steel containing both lead and tellurium with all the tellurium in inclusion form being associated with lead in widespread, uniformly distributed inclusions, elongated and stringer-like in the rolled condition, said steel having a machinability much greater than the sum of the machinability of a similar steel having an equal amount of tellurium alone and of a similar steel having an equal amount of lead alone. The foregoing detailed description has been given for clearness of understanding only, and no unnecessary limitations should be understood therefrom, as modifications will be obvious to those skilled in the art.

What is claimed is:

1. A free machining steel consisting essentially of:
0.02–0.50 wt. percent tellurium;
0.02–0.50 wt. percent sulphur;
0.02–0.50 wt. percent lead;
less than 5 wt. percent chromium;
up to 1 wt. percent carbon;
and a balance consisting essentially of iron.

2. A free machining steel as recited in claim 1 wherein said chromium content is zero.

3. A free machining steel consisting essentially of:
0.02–0.50 wt. percent tellurium;
0.02–0.50 wt. percent sulphur;
0.02–0.50 wt. percent lead;
less than 5 wt. percent chromium;
up to about 1 wt. percent carbon;
0.60–1.65 wt. percent manganese;
up to 0.12 wt. percent phosphorus;
up to 0.30 wt. percent silicon;
and the balance consisting essentially of iron constituting at least 90 wt. percent of said steel.

4. A free machining steel as recited in claim 1 and containing 0.60–1.65 wt. percent manganese.

5. A free machining steel as recited in claim 3 wherein:
said iron is at least 95 wt. percent.

6. A free machining steel as recited in claim 3 wherein said tellurium is no greater than 0.20 wt. percent.

7. A free machining steel as recited in claim 3 wherein:
said tellurium is 0.04–0.06 wt. percent;
and said lead is 0.20–0.30 wt. percent.

8. A free machining steel as recited in claim 7 wherein said sulphur is about 0.3–0.5 wt. percent.

9. A free machining steel as recited in claim 3 wherein said chromium content is zero.

10. A free machining steel consisting essentially of, by wt. percent:

0.08–1.03 carbon;
0.60–1.65 manganese;
up to 0.12 phosphorous;
up to 0.06 sulphur;
up to 0.30 silicon;
0.02–0.20 tellurium;
0.02–0.50 lead;
less than 5 chromium;
and the balance iron.

11. A free machining steel as recited in claim 10 wherein:

said tellurium is 0.04–0.06 wt. percent;
and said lead is 0.20–0.30 wt. percent.

12. A free machining steel consisting essentially of, by wt. percent:

0.08–0.55 carbon;
0.60–1.65 manganese;
up to 0.04 phosphorous;
up to 0.33 sulphur;
up to 0.30 silicon;
0.02–0.50 tellurium;
0.02–0.50 lead;
less than 5 chromium;
and the balance iron.

13. A free machining steel as recited in claim 12 wherein:

said tellurium is .04–0.06 wt. percent;
and said lead is 0.20–0.30 wt. percent.

14. A free machining steel consisting essentially of, by wt. percent:

up to 0.13 carbon;
0.60–1.00 manganese;
0.07–0.12 phosphorous;
0.08–0.33 sulphur;
0.02–0.020 tellurium;
0.02–0.50 lead;
less than 5 chromium;
and the balance iron.

15. A free machining steel as recited in claim 14 wherein:

said tellurium is 0.04–0.06 wt. percent;
and said lead is 0.20–0.30 wt. percent.

16. In steel containing less than 5 wt. percent chromium, machinability-increasing constituents consisting essentially of, by wt. percent:

0.02–0.50 tellurium;
0.02–0.50 lead;
and 0.02–0.50 sulphur.

17. In steel as recited in claim 16 wherein:

said tellurium is 0.04–0.06 wt. percent;
and said lead is 0.20–0.30 wt. percent.

References Cited in the file of this patent

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UNITED STATES PATENT OFFICE

CERTIFICATE OF CORRECTION

Patent No. 3,152,889 October 13, 1964

Michael O. Holowaty

It is hereby certified that error appears in the above numbered patent requiring correction and that the said Letters Patent should read as corrected below.

Column 6, line 34, for "0.02-0.020 tellurium" read -- 0.02-0.20 tellurium --.

Signed and sealed this 9th day of March 1965.

(SEAL)
Attest:

ERNEST W. SWIDER
Attesting Officer

EDWARD J. BRENNER
Commissioner of Patents