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METHOD OF ADDING LEAD TO STEEL

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This invention relates to a method of adding lead to steel. It has to do primarily with that class of steel which is generally referred to as "free cutting," "free machining" or "screw-stock" steel. However, it is not necessarily limited to this class of steel and has to do with any type of steel which is to be subjected to machining operations.

As disclosed in my Patent No. 2,182,758, issued December 5, 1939, I have found that the introduction of lead into steel and the retention thereof in percentages ranging from .03 to 1.0 per cent greatly improves the machinability of the steel. This is particularly true when more than .10 per cent lead is retained in the steel. This is true whether or not the lead be introduced into the so called "free cutting" steels or whether it be used in other types of steels. When introduced into the free cutting steels in proper percentages, it results in an improved machinability over and above the free cutting characteristics imparted to the steel by the sulfur and, in addition, does not impair the mechanical characteristics of the steel. When used, in adequate percentages, with steels of relatively low sulfur content as, for instance, in steels containing less than .05 per cent sulfur, it imparts improved machinability characteristics and, in some instances, gives free cutting characteristics which compare favorably with machinability characteristics of some of the present commercial "free cutting" steels.

This application is a continuation in part of my copending applications Serial No. 205,364, filed April 30, 1938, and Serial No. 177,292, filed November 30, 1937.

In the pursuance of my development, lead has been added to steel by a number of methods and some of these will be discussed hereinafter. It has been found that certain methods of introduction are so much more effective that they constitute a marked advance over any prior art methods of introduction. The exact form in which the lead exists in the finished steel, when introduced in accordance with my invention, is not definitely known at this time. It is known, however, that the lead containing steels, produced in accordance with my invention, have certain micro-structures which can be brought out by metallographic technique and that these structures are characteristic of these lead-bearing steels of improved machinability.

In introducing lead into molten steel, it has been found that when lead is introduced on top of a bath of molten steel, in blocks of substantial size, the lead frequently settles directly to the bottom of the bath so that only a very small proportion thereof is dispersed throughout the bath and the major portion of the introduced lead is ultimately found on the bottom of the container. Likewise, if the lead is introduced in the form of "chunks" or particles which are unduly large, these chunks or particles either settle individually to the bottom of the container or they combine to form a more or less single mass which also settles to the bottom of the container. Similarly, if the lead is placed in a container, even though the lead is in particle form, and dropped into a molten bath of steel, it will immediately agglomerate and sink to the bottom of the container. Apparently, the lead, once having settled to the bottom of the container, remains there as a separate metal layer and is not materially distributed throughout the bath. As a result the steel ingot which is eventually formed from the bath shows such a slight recovery of lead dispersed therethrough as not to show favorable effects on machinability. Even if metallic lead is introduced in subdivided form into the molten bath of steel, it has been found that under some conditions, it is difficult to obtain adequate dispersion of the lead.

Because of these drawbacks, I have devised other methods of introducing lead into steel for the purpose of improving the machinability thereof and have found such methods to be highly advantageous. I have found that it is desirable to introduce the lead into the molten steel in the form of a lead compound or lead alloy in order to obtain adequate dispersion of the lead in the steel. The lead compound or alloy should consist of lead and at least one additional element which will volatilize or go into solution in the steel. Consequently, the additional element or elements should be either soluble in the steel or have a lower boiling point than the lead or both. I have found that with a compound or an alloy of the type indicated, higher initial dispersion of the lead is obtained than with metallic lead of a similar particle size and which is added under similar conditions. This apparently is due to the fact that when the compound or alloy is added to the molten steel, it is immediately decomposed so that the lead in its nascent or at least finely divided form is liberated and the additional element or elements either goes into solution in the molten steel or is liberated as a gas. When the particles of lead compound or lead alloy are broken up, as indicated, the remaining lead particles will be extremely small, will have a lower surface tension and will be easily and quickly dispersed. Furthermore, the lead compound or alloy will be of a lower specific gravity than metallic lead and will not have as much tendency to agglomerate and sink to the bottom of the container.

It is desirable that the molten steel be agitated at or after the time of adding the lead in order to obtain effective dispersion of the lead. If a compound or alloy is used which is of such a nature that one or more of the elements volatilizes, the gases which are freed will produce agitation of the bath and tend to increase the dispersion of the lead. If the alloy or compound is of such a nature that one or more of the additional elements goes into solution in the steel, this provides a way for introducing an additional element or elements into the steel simultaneously with the introduction of lead into the steel. I have also found that when a compound or alloy is used instead of metallic lead, a relatively higher recovery of the lead is obtained.

I have tried a number of compounds and alloys of the type indicated above and have found them to work very well.

For example, I have found it quite desirable to introduce lead into the molten steel bath as a constituent of the mineral galena (BbS with approximately 86.6 per cent Pb and 13.4 per cent S). It is very desirable to use galena or other forms of lead sulfide for the purpose of introducing sulfur into the steel simultaneously with the introduction of the lead. When added to the steel galena or lead sulfide is decomposed by the iron into iron sulfide and lead. The sulfur going into solution in the iron leaves the lead in nascent form or at least finely divided form and in extremely intimate contact with the molten steel. Therefore, the lead will be quickly and effectively dispersed. The sulfur will be added to the steel and will cooperate with the lead in producing a steel having improved machining properties.

I may also introduce the lead in the form of litharge or lead oxide. It may be desirable to use lead oxide in introducing lead into steels where it is desired to keep the sulfur content low. When the lead oxide is added to the molten steel, it is immediately reduced and the remaining lead particles may be quickly and effectively dispersed.

I have also employed lead phosphate for introducing the lead into the molten steel. When the lead phosphate is added to the molten steel, the phosphorus goes into solution in the steel while the lead is freed. This provides a means for adding phosphorus to the steel.

Various other compounds may be used in introducing the lead into the steel. It is necessary that these compounds consist of lead and one or more additional elements which will either go into solution in the molten steel or will volatilize or both leaving the lead in the steel in its nascent or at least finely divided form so that it may be quickly and effectively dispersed therein.

I have also used many alloys for introducing the lead into the steel. Some of the alloys which have been used may be listed as follows:

Lead-tin antimony alloy	Ratio 1:1:1
Lead-tin alloy	60% Pb, 40% Sn
Lead-copper tin alloy	32% Pb, 66% Cu, 2% Sn
Lead-tin alloy	(1.5% Sn)
Lead calcium alloy	(.6% Ca)
Lead bismuth alloy	(3% Bi)
Lead arsenic alloy	(1.1% As)
Lead cadmium alloy	(.5% Cd and 1.6% Cd))
Lead tellurium alloy	(.1% Te)
Lead antimony alloy	(1.7% Sb)
Lead lithium alloy	(.1% Li)
Lead zinc alloy	(.3% Zn and .9% Zn)
Lead sodium alloy	(.3% Na)
Lead magnesium alloy	(.3% Mg)
Lead-manganese-iron alloy	(20% Pb, 46% Mn (33% Fe) plus impurities)

PbS, FeS (64% Pb 13% Fe 17% S).

Various other alloys may be used in introducing the lead into the steel. It is merely necessary that such alloys consist of lead and one or more additional elements which will be soluble in the steel or which will have a lower boiling point than the lead or both. If the alloy has these characteristics, the lead will be freed and will be in the form of very small particles in intimate contact with the molten steel so that they can be quickly and effectively dispersed.

The lead compound or alloy may be added to the molten steel in finely subdivided form or relatively small "chunks" or particles. The compound or alloy may be in the form of "buck" shot or "B. B." shot. It is preferably in finely divided form ranging from 10 to 50 mesh. As previously stated, it is preferably added to the molten steel and the steel is agitated at or after the time of adding it either by chemical means or by mechanical means, or both. The compound or alloy is added in an unconfined state and is gradually introduced into the molten steel.

It has been demonstrated that lead can be added to steel by all of the above addition agents, and recoveries in the range of 15 to 64 per cent have been obtained. The recovery depends upon a number of factors. Increasing the holding time between the lead addition and pouring the steel seems to increase recovery of lead in the steel, especially if there is agitation or circulation of the metal. The percentage recovery was better when relatively small additions such as 0.40 per cent were made than when larger additions were made, such as 1.5 per cent. The chemical composition of the steel may have some influence on the amount of lead retained in the steel but this relation has not been determined in a definite way. As will be shown hereinafter, lead has been added to steels of quite a range in chemical composition.

The solubility of lead in molten and in solid steel is not definitely known but a steel containing 0.53 per cent lead with practically all the lead completely dispersed therein has been obtained and it has been found that up to this amount increasing the lead content continued to improve machinability. When lead is added in such amounts as 0.80 to 1.5 per cent it has been noted that there is a tendency for some of the lead to settle to the bottom of the containing vessel because of its high specific gravity. It is very probable, however, that by long holding at steel making temperature and by the optimum method of adding the lead the lead retained in the steel can be materially increased above the value of 0.53 per cent mentioned above.

The addition of lead to relatively high sulfur steel of about 0.20 per cent sulfur and relatively low sulfur steel of about 0.03 per cent sulfur has also been studied and it appears that there is no essential difference in the amount of lead retained in the steel or in the relative amount recovered. It was found that the addition of lead to steels containing either a low percentage or a high percentage of sulfur definitely improved the machinability.

Lead has been added to steels of 0.80 and 1.35 per cent manganese contents and essentially the same recoveries and the same improvements in machinability obtained. Likewise, lead has been added to steels of 0.05 and 0.25 per cent silicon contents with no apparent differences in the amount of lead recovered or in its effect on machinability.

My researches have shown that the lead may be added at different stages in the making of the steel.

Lead in compound or alloy form has been added to the molten charge in a high frequency induction furnace which results in some agitation of the bath. It has also been added to the ladle as the steel was tapped from the furnace or from a larger ladle. While the lead might be added with the charge to the open hearth furnace, for example, it is not preferred to add it in this way because of the danger of the lead melting early and attacking the refractory materials of the furnace. After the steel is melted, the lead may be added with less danger of attacking the refractories of the furnace.

Preferred methods of adding the lead are:

To add a compound of lead or a lead alloy to the molten steel charge just before tapping, or

To add a compound of lead or a lead alloy in the ladle as the molten steel is tapped into the ladle.

It will be apparent from the above description that I have devised a method of introducing lead into steel which has many advantages.

It has been shown that it is particularly advantageous to use lead compounds or lead alloys in introducing the lead into the steel. It is merely necessary that the lead alloy or the lead compound be of such a nature that the element or elements in addition to the lead will volatilize or will go into solution in the molten steel or both.

The use of galena is very advantageous inasmuch as it results in getting both lead and sulfur in the steel simultaneously. This is particularly desirable when using electric furnaces of the induction type or other electric furnaces when small ingots are being produced since it would be difficult to add the lead and sulfur in the small ingot mold. Also it is desirable to use other lead compounds and/or lead alloys when producing steel with an electric furnace and in other instances.

Various other advantages will be apparent from the preceding description and the following claims.

Having thus described my invention, what I claim is:

1. A method of introducing lead into steel so that it will be retained therein in a dispersed condition which comprises introducing into a molten bath of the steel, a material in finely divided particle form, the particles of which consist of lead and at least one element which will separate from the lead upon addition to the molten steel so as to free the lead from the particles to facilitate dispersion thereof.

2. A method of introducing lead into steel so that it will be retained therein in a dispersed condition which comprises introducing into a molten bath of the steel a lead alloy in finely divided particle form, the particles of which consist of lead and at least one element which will separate from the lead upon addition to the molten steel so as to free the lead from the particles to facilitate dispersion thereof.

3. A method of introducing lead into steel so that it will be retained therein in a dispersed condition which comprises introducing into a molten bath of the steel a chemical compound of lead in finely divided particle form, the particles of which consist of lead and at least one element which will separate from the lead upon addition to the molten steel so as to free the lead from the particles to facilitate dispersion thereof.

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