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FREE MACHINING STEELS

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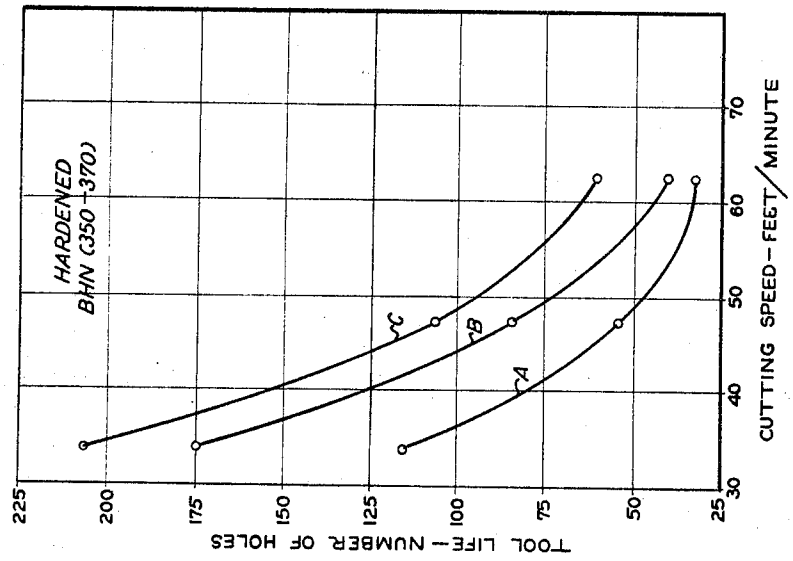


Fig. 2

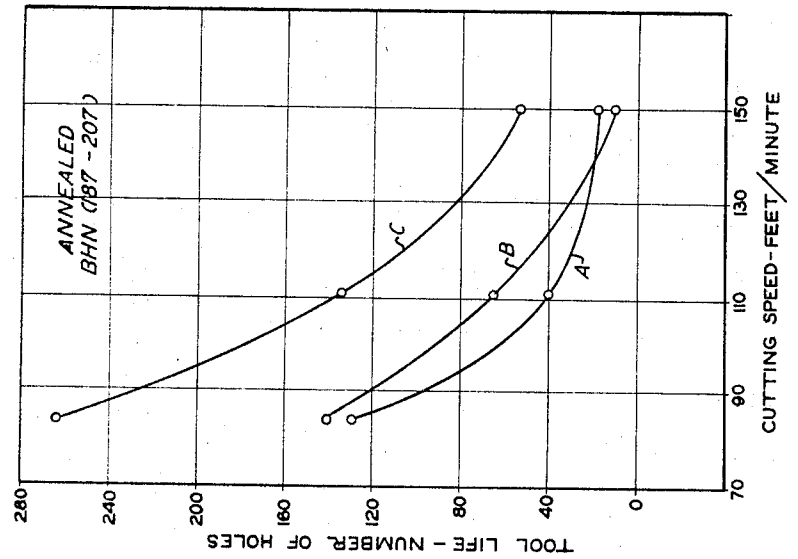


Fig. 1

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FREE MACHINING STEELS

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U.S. Cl. 75—123 4 Claims

Int. Cl. C22c *39/28, 39/52*

ABSTRACT OF THE DISCLOSURE

The machinability of fine-grain low alloy steel having about 0.13–0.65% C., 0.45–1.2% Mn, 0.04% P (max.), .05% S (max.), 0.1–0.5% Si, 2% Ni (max.), 1.5% Cr (max.), .05–0.6% Mo, the balance Fe is increased by incorporating therein about 0.01–0.15% of a deoxidizer from the group consisting of V, Nb and Ta and also about 0.05–0.35% Pb. The content of aluminum should be less than about 0.01%.

This application is a continuation-in-part of application Ser. No. 474,053 filed July 22, 1965, and now abandoned.

The present invention relates to free-machining, low alloy steels made according to fine-grain practice without the addition of aluminum. More particularly, the present invention relates to low alloy steels made according to fine-grain practice preferably with vanadium deoxidizer and lead addition to increase the machining characteristics of the steel.

Steel made according to fine-grain practice is oxidized when making the heat and then killed or deoxidized at high temperatures in the liquid state. The grain size of the steel would grow and greatly increase in size unless the deoxidization step is carried out. The usual practice is to make an aluminum addition to the heat so that the grain size is controlled and maintained relatively fine. Other deoxidizers, such as mixtures of ferrosilicon with aluminum, have been used in the past. Also, titanium and zirconium have been used for the same purpose.

Fine-grain steels are characterized by having improved toughness and shock resistance properties. Also, fine-grain steels have less tendency to crack during heat treatment. However, steels made according to coarse-grain practice are generally favored to make parts subject to intricate machining because fine-grain steels are hard and very resistant to cutting or shaping. The chief reason for the hardness of killed fine-grain steels is the presence of refractory aluminum oxide and nitride compounds. These hard oxides and nitrides tend to dull cutting edges of tools used to machine the low alloy steels.

In steels deoxidized with vanadium, the oxide and nitride are much less refractory in nature than the corresponding aluminum compounds. In some instances, lead or sulfur can be added to improve the machining characteristics of steel deoxidized with aluminum. The refractory characteristics of the oxides and nitrides of these elements still detract from the effects realized by the addition of lead. However, the use of lead, together with vanadium, has not previously been used and it has been found that this combination greatly increases the machining properties of killed, low-alloy steels made according to fine-grain practice.

Niobium and tantalum are deoxidizers which can be substituted for vanadium in some applications. Less niobium is required than vanadium for adequate grain refinement and for economic reasons niobium may be preferred, particularly in as-rolled steel. Vanadium is preferred in high strength, thick plates and for balanced normalized steel where impact properties are essential. Vanadium also contributes to precipitation hardening on normalizing which is not true with niobium.

Tantalum can also function as a deoxidizer and for as-rolled steel finished at low temperatures, tantalum is generally equivalent to niobium in the same amounts. Generally, less than about 0.06 tantalum or niobium is required. proportion of low-alloy steels are made according to The addition of combinations of vanadium with tantalum or niobium can be used and when employed with lead, the machinability of low-alloy steel is enhanced.

It is an object of the present invention to provide a free-machining, low-alloy steel that is produced according to fine-grain practice.

It is another object of the present invention to provide a free-machining, low-alloy steel that is produced to fine-grain practice deoxidized with vanadium or equivalent, and with lead addition.

These and other objects will be apparent from the following description.

Low alloy steels are supplied to minimum mechanical properties as high strength and wrought steels. Depending on the alloying elements used, these steels will vary in properties but the purpose of including small amounts of copper, nickel, chromium, molybdenum and other alloying elements is to impart strength, corrosion resistance, hardness and other characteristics to carbon steel. A large proportion of low-alloy steels are made according to fine-grain practice to increase toughness and other properties. When aluminum, and to a less extent, titanium, zirconium or mixtures thereof, are added to the heat to deoxidize steel, the machinability of killed low-alloy steel is impaired because of the formation of refractory oxides and nitrides. The addition of lead to killed steels has heretofore only resulted in minor improvement to the machining properties of the steel.

In the instant invention, it has been found that the machining characteristics of killed steel can be greatly improved by using lead and vanadium in combination. The amount of vanadium can vary between about 0.01–0.15%. When tantalum or niobium are substituted for vanadium, preferably 0.06% or less is used. The use of vanadium as a deoxidizer eliminates the highly refractory oxides and nitrides while lead provides some lubrication and improved control of chip breakage. Other elements, such as sulfur, selenium, tellurium, nitrogen or bismuth, can be added in minor amounts provided lead and vanadium or equivalent deoxidizers are present in the required amounts.

The increase in machinability is significant, as seen in FIGURES 1 and 2. FIGURE 1 is a graph comparing the machining properties of materials A, B and C hardened to certain B.H.N. values. FIGURE 2 is a similar graph with the same materials A, B, and C hardened to different B.H.N. values.

The chemical analysis of materials A, B, and C are as follows:

CHEMICAL ANALYSIS (LADLE)

Material	C	Mn	P	S	Si	Ni	Cr	Mo	Cu	V	Al	Pb
A	0.40	0.95	0 016	0.020	0.29	0.17	1.09	0.19	0.25	(1)	0.035	0.09
B	0.42	0.81	0.011	0.025	0.27	0.27	1.14	0.21	0.20	0.04	0.007	(1)
C	0.38	0.93	0.011	0.021	0.26	0.17	1.08	0.19	0.24	0.04	0.006	0.10

[1] Nil.

The amount of aluminum should be less than 0.01 and even lower if possible.

The drilling test details are as follows:

Material.—S.A.E. 4140. Hardness (see below).

Drill.—M–1 HSS, ½" dia. x 2½" stub length screw machine.

Point Angle.—118°. Point type: Plain.

Clearance.—7°.

Cutting fluid.—Soluble oil (1:20).

Feed.—0.007 inch/rev. (FIG. 1) 0.005 inch/rev. (FIG. 2).

Depth of hole.—1.0" through.

Drill life end point.—0.015" Wearland or drill breakage.

The test results and Brinell Hardness Numbers (BHN) of the materials tested are listed in the table below:

DRILL LIFE, NUMBER OF HOLES

Cutting speed (feet/minute)	Material A (197–207 BHN)	Material B (197–207 BHN)	Material C (187–207 BHN)
83	130	138	265
111	40	67	140
150	20	16	60
	(350–370 BHN)	(350–370 BHN)	(357–363 BHN)
3			
44	115	175	208
67	55	85	105
3	32	40	61

All parts listed herein are percentages by weight unless otherwise indicated.

The preferred low alloys are hardened to Brinell Hardness Number (BHN) values less than about 500.

Machineability tests were carried out on deoxidized A.I.S.I. 4140 steel but other low-alloy steels can be vanadium-deoxidized with lead addition to show improved machineability. It will, also, be appreciated that the use of other additives can be made, provided the required amounts of vanadium and lead are present in the alloy combination.

In addition to the machineability data outlined above in connection with drilling tests, the following milling tests were conducted with results as reported below:

MILLING TEST

Material.—S.A.E. 4140, Hardness (see below).

Milling cutter.—6" dia. single tooth face mill with T–1 H55 insert.

GEOMETRY

Axial rake.—10°. E.C.E.A.: 5°.

Radial rake.—10°. Peripheral clearance: 5°.

Corner angle.—45°. End clearance: 5°.

Corner radius.—0.020".

Feed.—0.010 in./tooth. Dept of cut: 0.100".

Width.—3½".

Cutting fluid.—Soluble oil (1–20).

Tool life end point.—0.060" Wearland or tool failure.

Cutting speed (feet/minute)	Tool life (inches/tooth)	
	Material A (200 BHN)	Material C (187 BHN)
74	132	144
92	108	102
114	60	84
	Material A (341 BHN)	Material C (341 BHN)
47	168	
59	96	132
74	48	84
92		54

The steels used in the foregoing tests are typical of a range of steels having a composition range of carbon 0.13–0.65%; manganese 0.45–1.20%; phosphorus 0.04% max.; sulfur 0.05% max.; silicon 0.10–0.40%; nickel 2.00% max.; chromium 1.50% max.; and molybdenum 0.05–0.6%; remainder, iron and incidental impurities. For steels having the foregoing analysis, 0.01–0.15% vanadium and 0.05–0.35% lead included therein to replace a like amount of iron improves the machineability thereof as indicated in the specific alloys set forth above.

The foregoing detailed description has been given for clearness of understanding only, and no unnecessary limitations should be understood therefrom, for modifications will be obvious to those skilled in the art.

Having thus described our invention, what we claim as new and desire to secure by Letters Patent of the United States is:

1. A free machining, low-alloy steel with a fine grain structure having about 0.13–0.65% C, 0.45–1.2% Mn, 0.04% P (max.), 0.05% S (max.), 0.1–0.4% Si, 2.0% Ni (max.), 1.5% Cr (max.), and 0.05–0.6% Mo, said steel also having about 0.01–0.15% of a deoxidizer selected from the group consisting of vanadium, niobium, and tantalum and about 0.05–0.35% Pb, the remainder being Fe and incidental impurities, said steel having less than about 0.01% Al.

2. The steel of claim **1** wherein the deoxidizer is present in the amount of about 0.03–0.06% and the amount of Pb is about 0.08–0.15%.

3. The steel of claim **1** wherein the deoxidizer is vanadium and the B.H.N. is less than about 500.

4. The steel of claim **3** wherein the vanadium content is about 0.03–0.06% and the amount of Pb is about 0.08–0.15%.

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CHARLES N. LOVELL, *Primary Examiner.*

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