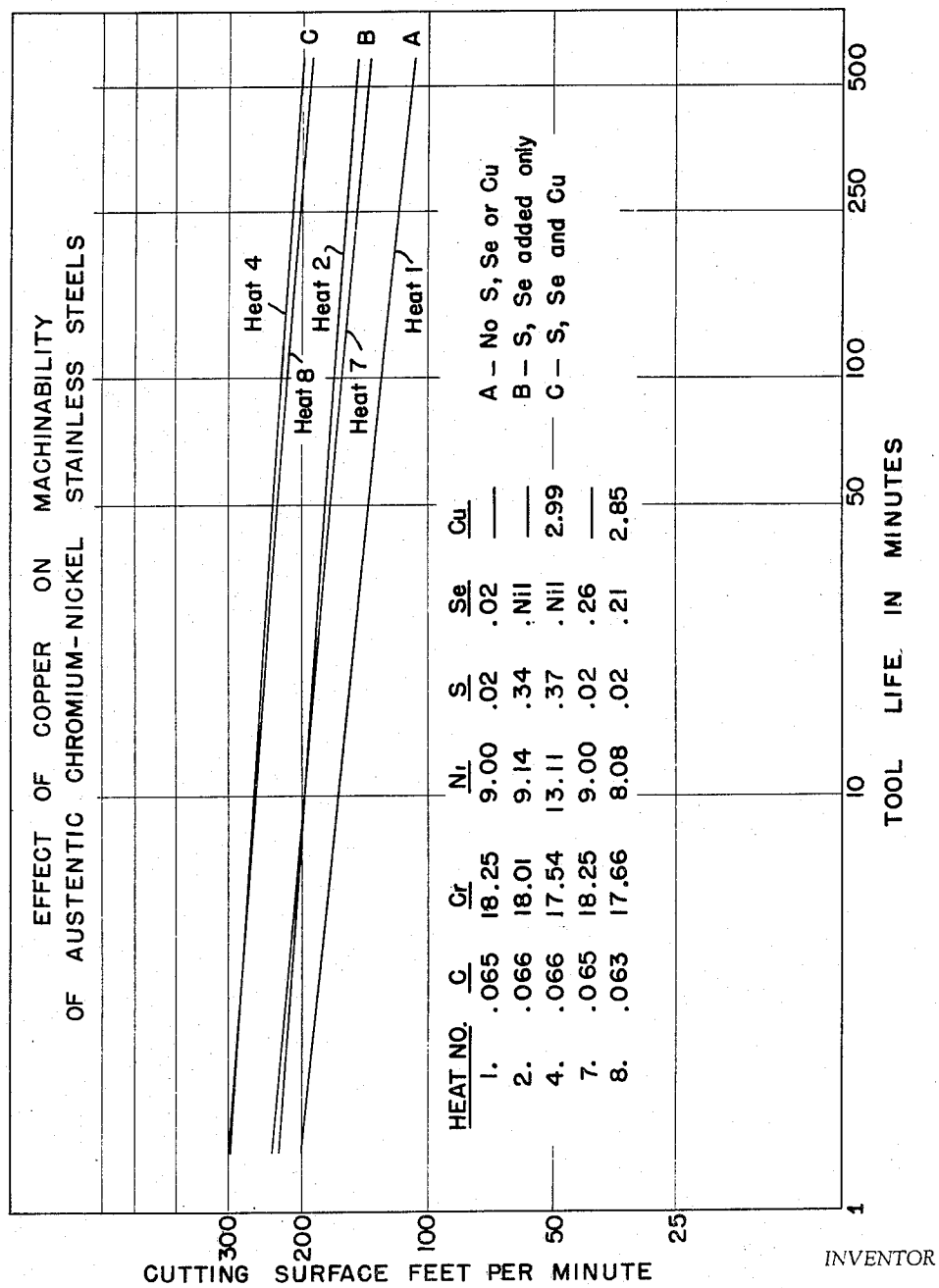
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FREE-MACHINING STAINLESS STEEL AND METHOD

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FREE-MACHINING STAINLESS STEEL AND METHOD

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My invention relates generally to chromium-nickel stainless steels, and more particularly concerns the production of stainless steels displaying free-machining qualities.

An object of my invention is to provide an austenitic chromium-nickel stainless steel which not only possesses all the advantageous properties characteristic thereof, but at the same time displays vastly improved machining qualities, responding favorably to standard tests, including tool life tests and drill tests, which qualities are imparted to the steel at minimum cost, in ready and simple manner.

Yet another object is to provide an austenitic chromium-nickel stainless steel displaying exceptional free-machining properties, with appreciably reduced work-hardening characteristics, together with reduced tendency to abrade the cutting tools, and with ready separation of chips from the metal.

A further object is to provide a free-machining stainless steel demanding only reduced power requirements on drilling tests, displaying high cutting speeds with minimum necessity of regrinding and resharpening the tools, and this together with reduced burning of the cutting tools, more time for useful work on the part of the operator, and longer tool life, all with reduced investment in tools and in sharpening equipment.

Other objects and advantages in part will be obvious and in part pointed out hereinafter during the course of the following description, taken in the light of the accompanying drawings.

Accordingly, my invention may be seen to reside in the composition of ingredients and combination of elements, and in the art of producing the same, as well as in the combination of steps employed, the scope of the application of all of which is more fully set forth in the claims at the end of this specification.

In the drawing, I disclose a chart wherein the cutting speed in surface feet per minute is plotted against the tool life in minutes for the various types and grades of metal undergoing cutting tests.

As conducive to a more thorough understanding of certain features of my invention, it may be noted at this time that many of the highly advantageous qualities of chrome-nickel stainless steel alloys cannot presently be availed of, at least not readily, due to the high rate at which these steels work-harden during processing. Tool wear at high rate is observed, and necessity arises for frequent regrinding the tool or replacement. Both the duration of processing is prolonged, with attendant appreciably increased labor costs, and plant investment is increased. Particularly is the use curtailed where appreciable machining is required. Rapid tool wear is observed, and the metals must be operated at low surface speeds.

Now for economic utilization of labor, particularly at the high wage standards prevailing today, it has long been recognized that tools should be reground and resharpened only once for each working shift, this at the beginning of the shift. Again, it is found that the total time during which the tools are actually in use on an eight-hour shift averages about five hours. That means, of course, that given tools of standard composition, then for best results the metal to be machined must be operated at such surface speeds that the cutting tools will retain a proper cutting edge throughout a five hour life period, and will not require refinishing or regrinding until the completion of the work shift.

For a particular metal upon which the cutting operation is to be performed, therefore, it is essential that a surface speed, or cutting speed, be selected for that particular metal such that the wear of the cutting tool will be at such rate that the tool can be kept effectively in use throughout the five hour cutting period. As a matter of fact, these standards are employed in measuring free-machining qualities in standard testing practice, known as the five hour form tool life.

Another measure of the machining qualities of a metal is the time required to drill through a test specimen of the metal of a standard thickness with a test drill of standard composition and standard diameter under standard constant loading.

Heretofore it has been observed that the austenitic chromium-nickel stainless steels, with their high work-hardening rate, can be used only infrequently where subjected to considerable machining. Accordingly, much effort has been expended towards improving the free-machining qualities of these metals, while retaining the characteristic advantages thereof, including smooth lustrous finish, resistance to corrosion, non-magnetic qualities and the like.

It heretofore has been suggested to include an appreciable quantity of sulfur in the metal, thereby improving, in well-known manner, the chipping qualities of the metal, while also reducing somewhat the abrasive qualities of the metal against the tools. Expressed in other terms, under cold-operating conditions, some improvement in machining qualities is observed, as well as an improvement in drilling time, when sulfur is added to the stainless steels. Where desired, the sulfur may be substituted in whole or in part by selenium.

An important object of my invention, therefore, is to remove or diminish in appreciable respect the many disadvantages of prior practices, and at the same time produce an austenitic chromium-nickel stainless steel displaying free-machining qualities, which steel can be produced in ready, simple and direct manner, and which once produced, can be machined with minimum wear on the cutting tools, with high cutting speeds, and with improved rate of drilling and with the formation of small chips, the use of steel permitting more ready and complete utilization of the operator's time during the standard work shift.

Referring now to the practice of my invention, I find that a really noteworthy and marked improvement in machining qualities of the austenitic chromium-nickel stainless steels is achieved, with full retention of the usual advantageous characteristics of the steel, when an appreciable amount of copper is included in its composition. I prefer to include copper, preferably along with one or more of the ingredients sulfur, selenium, tellurium, bismuth, lead and silver in small amounts, these conveniently being referred to hereinafter as free-machining elements. Preferably I include either sulfur or selenium, or both, in broad analysis, substantially as follows: chromium 12% to 20%, nickel 6.5% to 15%, copper 1.5% to 5%, sulfur .1% to .5%, and/or selenium .1% to .4%, manganese up to 4%, carbon up to .15%, and remainder iron. Where a substantial amount of manganese is used, it is employed in a range of 1.75% to 3.75%. If desired, nitrogen may be added up to .15% in order to impart improved surface. So also phosphorus up to .50% likewise may be added to improve the surface.

Now, as to the broad composition range, I find that the addition of copper drastically reduces the work-hardening rate of the alloy. Moreover, I find that when manganese is present some improvement in machinability is had, particularly in the matter of tool life.

In furtherance of the practice of my invention, I carried out a number of tests on samples of my steel to

ascertain its machinability. The results are shown in the following table:

Table

Heat No.	C	Cr	Ni	S	Se	Cu	5 Hr. Form Tool Life, S. F. M.	Drill Test Time, Secs.
1	.065	18.25	9.00	.020		Nil	115	[1] N. G.; [2] 90
2	.066	18.01	9.14	.341		Nil	155	
3	.058	18.39	9.05	.351		Nil		[1] 112
4	.066	17.54	13.11	.371		2.99	208	[1] 18
5	.065	18.25	9.00	.158		Nil	126	[2] 22
6	.057	17.84	9.09	.169		3.14	196	[2] 14
7	.065	18.25	9.00	low	.26	Nil	145	
8	.063	17.66	8.08	low	.21	2.85	198	[1] 23
9	.033	12.73	13.97	.293		3.00	238	

[1] 13/32" drill.
[2] 1/4" drill.
N. G. Drill would not penetrate.

These tests, generally as pointed out hereinbefore, are premised on the proposition that given the use of standard cutting tools a common measure of the machinability of those steels is the rate at which these tools wear while cutting the steels. In this connection it is to be noted, as already mentioned, that in machine shop practice it usually is desirable to grind or resharpen tools only once each shift, and this at the beginning of the shift. This means, in turn, that a tool is in actual cutting use on an average of five hours per shift, and the cutting speed which gives this tool life is used to express the machinability of a material.

Thus in the table, one test is the so-called five hour form tool life expressing the cutting speed in surface feet per minute.

Another test of the machining or free-cutting qualities of the metal is shown in the so-called drill test. In this test the number of seconds are measured which are required for a drill of given composition and temper, of fixed size, and under steady load conditions, to penetrate the metal to a certain distance. The more free-cutting is the steel undergoing test, the more rapid is the penetration of the drill into the test specimen. The drill test measures the ease with which chips are parted from the steel, or the amount of power required to cut it. It is because sulfur, and selenium as well, causes the chips to break off readily, without curling, that some improvement in drilling qualities are observed when sulfur or selenium are added to the melt.

It is to be noted that in the form tool life test, my practice is to employ a No. 4 Warner & Swasey turret lathe, using as a cutting fluid a sulfur base oil, Tycol 655, mixed with an equal amount of paraffin base oil. The forming tool bits are of a standard 18-4-1 type tool steel, and each tool bit is finished to a smooth surface with a standard wheel in a standard grinder. After failure, the tool is reground well below any evidence of burned metal.

The tests are carried out on a one-inch diameter bar of the metal undergoing test, and comprises taking a forming cut one-sixteenth of an inch wide at a feed of .0025 inch per revolution from the surface to the center of the bar, the tool being sharpened with a top rake of 8 degrees, a front clearance of 7 degrees, and a side clearance of 2 degrees. All forming cuts are made close to the collet of the machine. And with the machine speed adjusted to a predetermined value the tool is required to make successive cuts until tool failure occurs. This failure is determined by observing the burning and destructive abrasion of the nose of the tool.

In the drill penetration tests, there is required the use of a high speed 1/4 inch twist drill or 13/32 inch twist drill, together with a drill press, providing a spindle speed of 900 R. P. M., equipped to have a constant thrust of 90 pounds on the drilling spindle, and a method of measuring the depth of penetration of the other drill. The drill is sharpened to penetrate one-half inch of standard bar stock in sixteen seconds. The standard used in the laboratory is R12FM Heat 64376 analyzing, carbon .094%, manganese .44%, phosphorus .020%, sulfur .333%, silicon .32%, chromium 12.21% and nickel .46% tempered to a hardness of 207 Brinell. Under these standard conditions samples are drilled, noting the time required to drill a one-half inch hole or a one-quarter inch hole, as the case may be.

In studying the test results set forth in the table, it will be observed (Heat 1) that an austenitic 18–8 chromium-nickel stainless steel with no copper and with only low sulfur content, the steel has a maximum cutting speed for five hour tool life of but 115 surface feet per minute. Moreover, this steel could not be penetrated by a 13/32 inch drill loaded at 90 pounds, while a full 90 seconds was required for penetration with a 1/4 inch drill. Of course, the 1/4 inch drill tests are not quite as determinative, for the difference is less marked between test specimens with the use of the smaller drill, this latter not being as sensitive to variations in power requirements for chip removal.

With a substantial sulfur content (Heat 2) then with this 18–8 chromium-nickel stainless steel of low carbon content, the cutting speed is increased to 155 S. F. M., an improvement of about roughly 30%. From Heat 3, employing within practical limits, the same quantity of sulfur as in Heat 2, 112 seconds are required for penetration of a 1/4 inch test specimen with a 13/32 inch drill.

If to the austenitic chromium-nickel stainless steel there be added more nickel, and copper in the amount of 2.99% (Heat 4), the cutting speed is increased to 205 S. F. M. for five hour tool life, while the time required for penetration of the 13/32 inch drill is reduced to 18 seconds. And with the nickel content high and the chromium content low (Heat 9) and about 3% copper and .3% sulfur, the cutting speed is even greater, namely, 238 S. F. M.

Similarly, with the 18–8 chromium-nickel steel with but 0.158% sulfur and no copper (Heat 5), the maximum cutting speed is 125 S. F. M. on five hour life test, while 22 seconds are required for penetration by the 1/4 inch drill. And that a like steel with .26% selenium substituted for sulfur and without copper (Heat 7) the cutting speed is 145 S. F. M., for five hour tool life.

With the copper addition of 3.14% (Heat 6) the cutting speed becomes 196 surface feet per minute and the time for drill penetration 14 seconds. And upon the addition of 2.85% copper to the steel with .21% selenium (Heat 8) the cutting speed is 198 surface feet per minute and the time for drill penetration 23 seconds.

It is apparent from the foregoing that radically improved results attend upon the addition of copper. Comparing the copper-bearing steels of Heats 4, 6, and 9 with the standard sulfur and selenium-bearing free-machining steels of Heats 2, 5, and 7, the average improvement comes to about 35%. And comparing my steel with the usual austenitic chromium-nickel steel (Heat 1) the improvement in machinability amounts to about 75%.

Further comparison of my steel with prior steels is graphically illustrated in the accompanying drawing. In this connection it is to be noted that when the logarithm of the cutting speed in surface feet per minute is plotted against the logarithm of the tool life in minutes, a straight line relationship is obtained. These data are extrapolated to five hour tool life, which figure is then used in the comparisons of the test stock. In my tests, upon extrapolating to 300 minutes or five hours, it will be seen that with the A group, involving Heat 1, and with no sulfur, selenium or copper, the cutting speed is about 115 surface feet per minute. With the B group, constituting the Heats 2 and 7, wherein sulfur and selenium, respectively, are the only additives, the average cutting speed is 150 surface feet per minute. While finally, for the C group, comprising Heats 4 and 8, wherein copper is added along with sulfur and selenium, respectively, the average cutting speed is slightly more than 200.

From the foregoing it is seen that given constant cutting speed, the tool life is greatly prolonged as a result of the addition of copper, and conversely, for given tool life, the cutting speed is appreciably increased. It is apparent, therefore, that by the addition of copper I have greatly increased the machinability of the austenitic chromium-nickel stainless steel. Moreover, longer tool life is observed, with less grinding or sharpening and with more time employed on useful work. A reduced investment in tools is required, and a smaller amount of grinding and resharpening equipment is employed, while such equipment as is provided is observed to display longer life.

Moreover, it is to be observed that the same phenome-

nom carries over to the drill test, and the more free-cutting be the steel, the more rapid is the penetration of the drill. This is due to the decrease in work-hardening and to the ease with which the chips are parted from the metal stock. With the ordinary 18–8 chromium-nickel steels, the 13/32 inch drill will not penetrate the steel at all under a 90 pound load, while the inclusion of sulfur alone, a ¼ inch drill will penetrate in 112 seconds. With sulfur and 3% copper, the same hole is drilled in 18 seconds evidencing the reduction in work-hardening. The same trend is observed when using a ¼ inch drill.

Thus in accordance with the practice of my invention I provide a chromium-nickel stainless steel displaying excellent free-machining qualities. With this steel improved tool life is had. This result, consistently obtained, ensures, vastly increased unit output. All these, as well as many other highly practical advantages, attend upon the practice of my invention.

It will be seen from the foregoing that once the broad aspects of my invention are disclosed, many embodiments thereof will readily suggest themselves to those skilled in the art, and as well, many modifications of the disclosed embodiment will likewise come to mind, all falling within the scope of my invention. Accordingly, I intend the foregoing description to be considered as merely illustrative, and not by limitation.

I claim as my invention:

1. Chromium-nickel stainless steels displaying free-machining qualities, together with reduced tool abrasion and free-chipping qualities comprising about 18% chromium, 8% nickel, 3% copper, a material selected from the group consisting of about .3% sulfur or .2% selenium, and the remainder iron.

2. Free-machining chromium-nickel stainless steels comprising about 18% chromium, 13% nickel, 3% copper, .2% to .5% sulfur, up to .15% carbon, and remainder iron.

3. Free-machining chromium-nickel stainless steels comprising about 13% chromium, 14% nickel, 3% copper, .3% sulfur, up to .15% carbon, and remainder iron.

4. A free-machining chromium-nickel stainless steel of improved surface finish comprising 12% to 20% chromium, 6.5% to 15% nickel, 2.5% to about 5.0% copper, and 0.1% to 0.5% material selected from the group consisting of sulfur and selenium, up to .5% phosphorus, and remainder iron.

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