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ALLOY STEEL.

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The present invention relates to an alloy steel and more especially to an alloy steel particularly adapted for making dies and punches, which combines the desirable characteristics of (1) the capability for air or oil hardening, particularly air hardening, to a high degree of hardness; (2) the capability of being annealed soft enough for easy machining, and (3) a high resistance to abrasion. Dies which are used for blanking or forming sheet metal, as for example forming sheet metal body parts for automobiles, have to be made with a high degree of accuracy and also must be extremely hard to withstand wear. There is a tendency, particularly in large dies, for the die to warp slightly during the heating and quenching operation. When water or oil hardening are resorted to, it is difficult, and often impossible, to control this tendency to warp. Moreover, a relatively more expensive equipment is necessary for such oil hardening. On the other hand, if the die steel is an air hardening steel, the die may be put in clamps, usually water cooled clamps, which hold it accurately in shape during the air quenching or cooling, or the die may be laid upon a table and if any tendency to warp is observed during the air cooling, it may be counteracted by applying suitable pressure. It is therefore particularly advantageous in making dies of this character that the die steel be an air hardening steel. The dies are machined either from forged blocks, or from forged or rolled bars, and for this reason it is highly desirable, if not essential, that the steel be capable of being annealed to a sufficiently soft condition for easy machining. It is also essential that a good die shall have a high resistance to abrasion as otherwise it would have but a short life under the average conditions of use.

Ordinary die steels are usually made so that they can be annealed for ready machining. The metallurgical conditions required in the usual die steels to permit of a high degree of machinability have precluded air hardening so that oil or water quenching has been resorted to. High chromium steels have been used for air hardening dies, but when such steels have been given the capacity for air hardening to a high degree of hardness, they have not had the capacity for being annealed to a sufficiently soft condition for the best machining. The metallurgical conditions which have given the capability on the one hand for air hardening, and the capability on the other hand for annealing to a soft condition, have been generally regarded as mutually antagonistic, and either one has had to be sacrificed to attain the other. I have found that the alloy steel which is hereinafter described has these desirable capabilities, neither one being sacrificed for the other.

My steel is a chromium steel, usually having about the stainless steel ranges of chromium. Smaller percentages of vanadium and molybdenum are alloyed with the steel. The carbon is preferably somewhat below that of the plain high carbon high chrome die steels which attain the same hardness, the combination of the chromium, vanadium and molybdenum apparently allowing the carbon to be reduced without sacrifice of the necessary hardness. The lowered carbon content of my alloy permits the steel to be annealed to a softer condition than with higher carbon.

I will now describe in detail the preferred composition of my alloy steel and its physical characteristics, referring particularly to its use in making dies or punches. It will be understood that the steel may be used for other purposes.

The carbon may vary from 1.20 to 1.80%. The preferred carbon range is from 1.30 to 1.70%, usually from 1.40 to 1.60%. Within about the preferred limits, the steel may be readily air hardened, except in very large sizes, to a Brinnell hardness in excess of 600, and at the same time may be annealed to an easy machining softness of less than 200 Brinnell. It is difficult to set exact limits as to the carbon, as the carbon may be varied depending upon the hardness required, and the type of quenching and annealing employed. In general, toward the lower end of the carbon range, the material is more difficult to harden, particularly with air quenching, and toward the upper end of the carbon range the material becomes more difficult to machine when annealed.

The chromium may vary from 10 to 14%, although the preferred chromium range is from 11 to 13%, usually from 11.5 to 12.5%. The vanadium is used in considerably less amounts than chromium and may vary from about .75 to 1.25%.

The molybdenum content is in general about the same as that of the vanadium, although it may be somewhat less, the molybdenum varying from .50 to 1.25%, preferably from .75 to 1.25%. For economy, it is preferred to use not over about 1% of molybdenum, although the molybdenum may be used in excess of this without any particular advantage or disadvantage, especially where it is desirable to use the lower carbon ranges. The molybdenum serves as an energetic hardener and lowered carbon may be compensated for by increased molybdenum.

The manganese, silicon, phosphorus and sulphur are preferably within the usual ranges of good tool or die steel making practice, although under some conditions it may be desirable to increase the silicon up to about 3%.

An analysis which has been found to give satisfactory results had the alloying metals and the metalloids in approximately the following proportion:

	Per cent.
Carbon	1.60
Chromium	12.00
Vanadium	1.00
Molybdenum	.75
Manganese	.25
Silicon	.25
Sulphur	.02
Phosphorus	.02

The following are two specific analyses of the actual heats of the steel:—

	Per cent.	Per cent.
Carbon	1.58	1.52
Chromium	11.62	11.85
Vanadium	.91	1.21
Molybdenum	.73	.69
Manganese	.23	.31
Silicon	.20	.07
Sulphur	.025	.023
Phosphorus	.015	.017

The steel may be melted in any good steel making furnace, such as an electric furnace or crucible. The steel is poured into the usual ingots and is then worked by forging into the blocks or slabs from which the tools, such as dies, either forming or blanking dies, punches, shears and so forth, are to be made.

For the analyses given above I have found that the steel may be annealed sufficiently soft for easy machining by heating it to a temperature of about 1675° F. in an annealing furnace. The steel should be slowly heated up, held at heat for a sufficient time to allow of uniform annealing and then slowly cooled in the furnace. As a specific example, a five ton charge is brought up to heat in about six hours, held in the furnace heat of about 1675° F. for ten or twelve hours and then allowed to cool for about six hours in the furnace.

With the carbon within the preferred ranges, the steel may be annealed sufficiently soft for easy machining, the Brinnell hardness being reduced to below 210 or even as low as 170. The usual Brinnell hardness, after annealing the material, having the analyses given above, has been from about 180 to 190 which is considered practically dead soft for material of this type and can be readily machined. Such annealed steel is considerably softer than it has been possible to anneal the usual high carbon high chromium steels which have been used for dies, and it is softer than the standard high speed steels can be annealed.

After the dies or other articles have been machined they are hardened by heating and quenching. I have found that the steel should be heated from about 1600 to 1900 degrees F. For the usual practice I prefer to heat to about 1800° F., although the steel may be made a little harder by heating to 1850° F. In heating for the hardening operation, the articles are preferably rather slowly preheated to about 1400 to 1500° F. and held at this temperature for about an hour, and are then transferred to a furnace maintained at a temperature of about 1800° F. for the final heating before quenching.

After heating the dies or other articles, they are hardened by quenching. The quenching is preferably air quenching which may take place by laying the articles upon a table freely exposed to the air, or the articles may be held in suitable clamps, usually water cooled clamps, thus overcoming any tendency to warp during the quenching. The capability of air hardening is particularly important in the making of large dies since it permits any tendency to warp to be corrected either by clamping or by watching and manipulating the dies while cooling, whereas if the dies are oil or water quenched, they can not be so held or manipulated, and after hardening they are so brittle that they can not be pressed into shape.

The Brinnell hardness will vary depending upon the carbon, the size and the quenching conditions and may be from about 500 to 675 Brinnell. For good die making practice the Brinnell hardness should be over 600, which is readily attained by air hardening of the steel. The preferred Brinnell hardness is from about 600 to 650. Steels made in accordance with the typical specific analyses above given had average Brinnell hardness of about 620 to 650.

While I prefer to employ air quenching to harden the steel, the steel may be otherwise quenched, as for example by oil quenching. Water quenching may be resorted to, but is not preferred due to its tendency to crack the steel. If the carbon is toward the lower limits the more energetic quenching afforded by water or oil will give a greater hardness than air quenching. If oil quenching is used the steel is heated to about 50° lower than that for air quenching, and for water quenching is heated to about 100° lower than that for oil quenching.

After the articles have been quenched, they are preferably drawn at a temperature of about 300 to 400° F. to remove the quenching strains. Drawing to this temperature does not materially affect the hardness.

There is but very little tendency for the steel to warp during hardening and this can be readily counteracted by clamping and manipulating during the air quenching. The steel has a very high resistance to abrasion and is therefore particularly adapted for dies and punches, although the steel may be used for other purposes. The steel may be used for dies for cold work, such as dieing out and shaping sheets, or it may be used for forging dies for hot work. The steel has some tendency toward red hardness which adapts it for use in the working of hot metal.

The qualities of the steel are uniform throughout fairly large sections. Especially, the hardness is substantially uniform throughout a relatively large die. When a die is quenched, and particularly when air quenched, there is a tendency in most die steels for the corners, which are more quickly cooled than the body of the metal, to have a greater hardness. I have found that with my steel, a die of fairly large dimensions may be air hardened and the hardness will be substantially uniform and high, not only at the corners of the die but also on the faces within the die cavity. This is important, particularly in shaping dies, because the die faces which shape the metal are subjected to hard wear and abrasion. As an example of the ability of my steel for uniform air hardening, I may cite tests made with cubes of the material. The cubes of one, two, three and four inches were machined from the steel and heated to a temperature of about 1800° F. and quenched by setting them on a table or floor exposed to the air. When most die steels are subjected to such air quenching, there is a considerable difference between the hardness of the corners, which are more rapidly cooled, and the centers of the faces of the cubes. However, I have found that with cubes up to three and four inches in thickness, the Brinnell hardness is substantially as great in the center of the cube face as it is at the corners of the face, there being usually a difference between the center and the corners of the face not over about twenty points in the Brinnell scale. This ability for uniform air hardening in relatively large sections is of particular importance in the making of large dies where the high wearing qualities are desired on the faces as well as the corners of the die.

While I have described the fabrication and treatment of my steel with particular reference to the manufacture of dies, it should be understood that the steel may be used for other purposes, particularly where great hardness and resistance to abrasion are desired in the finished article, combined with easy machining of the annealed material.

I prefer to use molybdenum, although the tungsten may be substituted for the molybdenum with fair but not as good results. Tungsten has a tendency to stiffen the steel and prevent the annealing to ready machinability which is one of the characteristics of my steel. While tungsten is commonly regarded as an equivalent for molybdenum, it is not a true equivalent in my steel, because I have found that an amount of tungsten which will give the equivalent hardening effect of the molybdenum employed will tend to prevent the annealing or easy machinability. When tungsten is substituted for molybdenum, the range would be from about 1 to 2.00%, which is not the usual substituted ratio for these alloys. Even this range of tungsten does not give as good a balance between a hardness on air quenching and softness upon annealing as is given by the use of molybdenum.

While I have set forth specific examples of my alloy steel and its preferred heat treatment, it is to be understood that the invention is not so limited, but may be otherwise embodied within the scope of the following claims.

I claim:—

1. An alloy steel containing carbon about 1.20 to 1.80%, chromium about 10 to 14%, vanadium about .75 to 1.25%, and molybdenum about .50 to 1.25%, and having the capability for air hardening even in fairly large sections and the capability for being annealed sufficiently soft for easy machining.

2. An alloy steel containing carbon about 1.20 to 1.80%, chromium about 10 to 14%, vanadium about .75% to 1.25%, and molybdenum about .50 to 1.25% or tungsten about 1 to 2.00%, and having the capability for air hardening even in fairly large sections and the capability for being annealed sufficiently soft for easy machining.

3. An alloy steel containing carbon about 1.30 to 1.70%, chromium about 11 to 13%, vanadium about .75 to 1.25% and molybdenum about .75 to 1.25%, and having the capability for air hardening even in fairly large sections to over 600 Brinnell and the capability for being annealed to a softness below 210 Brinnell.

4. An alloy steel containing carbon about 1.40 to 1.60%, chromium about 11.5 to 12.5%, vanadium about .75 to 1.25%, molybdenum

about .75 to 1.25%, and having the capability for air hardening even in fairly large sections to over 600 Brinnell and the capability for being annealed to a softness below 210 Brinnell.

5. An alloy steel containing carbon about 1.20 to 1.80%, chromium about 10 to 14%, vanadium about .75 to 1.25% and molybdenum about .50 to 1.25% or tungsten about 1 to 2%, and having the capabilities for hardening and for annealing characteristic of such a composition.

In testimony whereof I have hereunto set my hand.

GREGORY J. COMSTOCK.