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ALLOY OF IRON, NICKEL AND MOLYBDENUM

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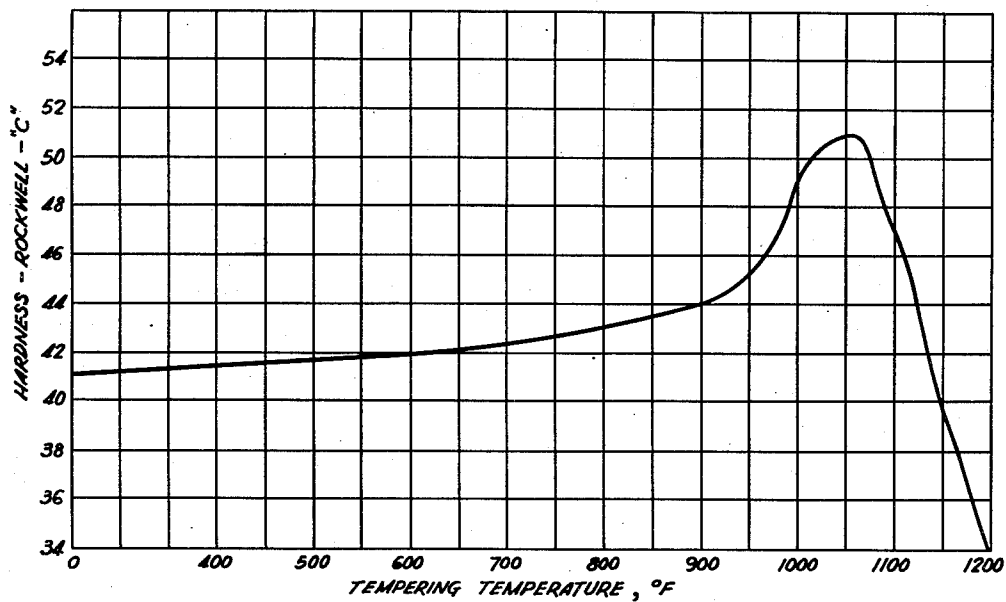


Fig. 1

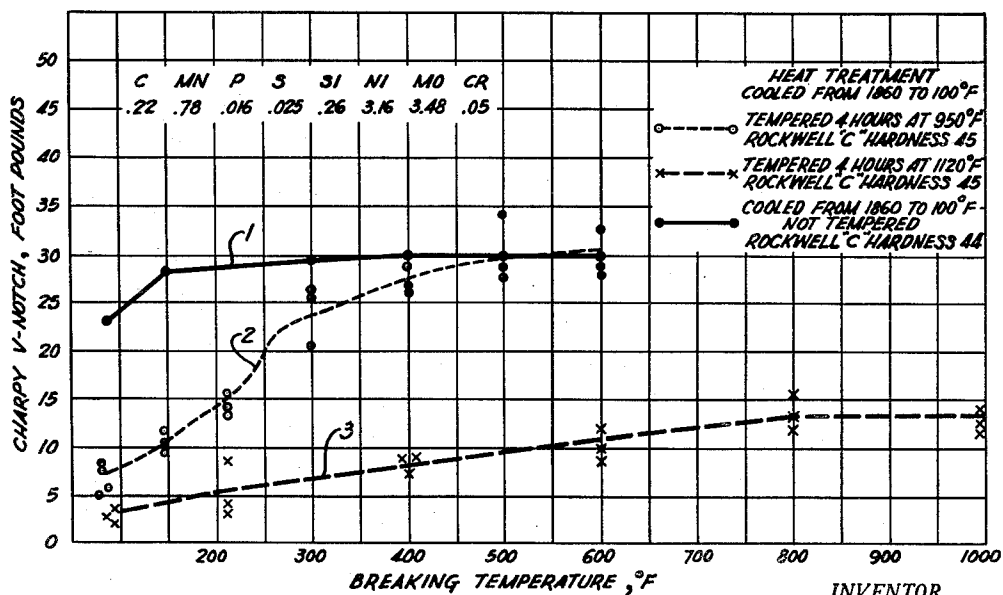


Fig. 2

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ALLOY OF IRON, NICKEL, AND MOLYBDENUM

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2 Claims. (Cl. 75-123)

This invention relates to hot work steels and steel articles for static pressure forming of hot stock, e. g., as hot upsetter dies, hot extrusion dies, and hot punches.

The invention is adapted particularly to dies for hot press forging, and may therefore be described with particular reference thereto. Experience over the years has demonstrated clearly that the forging press requires a die steel having greater heat resistant properties than are to be had with the die steels that are standard in the drop forging industry. This is due in large part to the longer contact time between the forging and the die in press forging than is the case with drop forging, combined with high static pressure. These factors combine to transfer more heat to the die surface in a press die, which cools between the forging steps. Thus the die surface is repeatedly exposed to a broad range of temperature reversals so that there is a greater tendency for severe heat checking of a press die than in the case of a drop forging die. The severity of the extremes of temperature to which the press die is exposed is furthermore increased, and also the tendency to heat check, when steam or liquid coolant is applied to the die surface.

A common measure of the life of a press die is the length of time required to develop heat checks inasmuch as they cause sticking of the forging and impairment of their surfaces, in consequence of which the die no longer has a useful life and must either be discarded or the impression machined to a larger size, which may not always be practical. Consequently, the development of press forging as a replacement for drop, hammer forging has been largely dependent upon the development of a steel that is more resistant to heat checking than the well known steels used in dropped forging dies. Additional requirements are that the dies will not be eroded unduly rapidly under the flow of metal within the die, will be themselves resistant to plastic flow, and will not break in service.

A variety of steels have been applied to such hot work purposes as hammer, or impact, forging, but for the reasons stated there is a need for steels giving better performance in press forging. Moreover, various of the steels used for drop forging dies, as well as those heretofore standard for press forging, require substantial amounts of presently critical metals, such as tungsten, and it would be desirable to have satisfactory hot static pressure elements to avoid the use of such critical metals.

The major object of the invention is to provide hot work steels and articles made therefrom that are especially adapted to static pressure use in hot forming operations, are of simple and relatively inexpensive composition, are easily heat treated, and possess exceptionally high resistance to heat checking, breakage in use, and erosion by the metal worked on.

A further object is to provide hot work elements for static pressure applications that may be put in use in the quenched and tempered condition and which in use develop surface secondary hardness through precipita-

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tion hardening that proceeds progressively as the surface is worn away or as the die impression is recut.

Other objects will appear from the following specification.

The accompanying drawings are graphs showing the variation of certain properties of the steels with temperature variations.

I have discovered, and the invention is in large part predicated upon this, that hot work articles of outstandingly superior quality for hot press forging and related static pressure uses are supplied by steels of substantially the following composition:

	Percent
Carbon	0.15 to 0.3
Manganese	0.6 to 0.8
Molybdenum	3.25 to 3.5
Nickel	3.0 to 3.25
Silicon	0.2 to 0.35

The steels should contain not over about 0.03 per cent each of phosphorus and sulfur. The remainder of the steels consists of iron together with impurities including incidental alloying elements, such as tungsten, chromium and vanadium, in amounts that do not detrimentally affect the unique characteristics of the steel of the work elements of this invention.

Hot work elements formed from steel of the foregoing composition have been proved to provide outstanding performance as hot press forming dies, and to be much superior for such use to dies made from all other die steels known to me. They are exceptionally resistant to heat checking, they possess good impact strength whereby breakage in use is suppressed, and they are resistant to plastic flow under the press stresses. Likewise, they develop and retain in use surface hardness adequate to minimize abrasion of the die opening under plastic flow of the metal being forged.

An outstanding characteristic is that when the hot work elements of this invention are properly heat treated they are soft enough for easy machining but when put into service they undergo precipitation hardening, or development of secondary hardness, at the surface under the influence of heat absorbed from the work, with development of high surface hardness. This phenomenon goes on progressively once the die is put in use and as the die surface is heated maximum hardness is developed. Thus press dies and other hot static work elements produced in accordance with this invention possess surface hardness that minimizes erosion, while the metal at and adjacent to the surface is backed by a ductile body which thus gives excellent shock resistance. Of major importance, however, is the exceptional resistance of these hot work elements to thermal, or heat, cracking.

These results are surprising metallurgically because it is known that nickel tends to make steels more susceptible to thermal rupture, and that it does not ordinarily tend to confer heat resistance, yet the performance of press dies in accordance with this invention is remarkable in resistance to heat checking in hot press forging.

For the best results the steels should be produced by electric induction melting. Preferably the ingots are cogged at about 2225° to 2250° F. after pre-soaking, and are then annealed by soaking at 1250° to 1300° F. followed by slow cooling to about 600° F., after which they may be air cooled. Finish forging is conducted in essentially the same way.

The die blocks thus produced are then given a solution, or austenitizing, treatment by heating them slowly to between 1800° and 1900° F., most suitably 1840° to 1860° F., and holding 15 to 20 minutes per inch of thickness, and then air cooled. In this condition the hardness is about 38 to 40 Rockwell C, and the blocks are of

relatively good machinability that permits satisfactory sinking of the die impression. In this untempered condition the dies may be put directly to use, and as a result of contact with the hot workpiece the metal at and immediately below the surface of the die impression will undergo precipitation hardening and development of hardness comparable to that produced by tempering as described hereinafter. Although this practice may be used successfully with large dies and those having deep impressions, it is less satisfactory where long life is desired from small dies and shallow impressions because the wash of the impression tends to be excessive before the surface has developed its full hardness, in which case the dies are placed in service at an initially higher hardness.

It is preferred, accordingly, for most purposes to quench the block, as just described, and then to temper at temperatures below, and preferably near, those which produce maximum aged hardness. In this condition, and despite being harder than in the as quenched state, the blocks are soft enough to permit machining of the die impressions. Without further treatment they are then put into service whereby contact of the die impression with the hot forging stock causes the block to progressively attain full hardness to a limited depth. This hardness increase and consequent wear resistance occur primarily near the surface of the impression because the temperature at an appreciable depth within the block is not sufficiently high to permit the aging reaction to proceed at an appreciable rate.

To these ends the steel is air or oil quenched from 1860° to 1875° F., the impression is then machined, and the die is then tempered. Fig. 1 is a graph representing the effect of the tempering temperature upon the hardness. As will be seen from it, precipitation hardening begins at relatively low temperatures but becomes progressively more rapid beginning at about 600° or 650° F., with maximum hardness attained at about 1050° F. This graph is characteristic of the steels of the present invention. For most purposes it is preferred to temper at about 950 to 1000° F., thus developing a hardness of from about 45 to 48 Rockwell C. When the die is placed in use it will, as described above, reach maximum hardness.

This treatment, i. e., tempering short of maximum hardness, gives the best results when all properties are considered. The impact resistance is adequate for the intended use, and tempering at a comparatively low temperature avoids scaling and decarburizing of the impression. As exemplifying the effect of tempering at various temperatures, the following data representing the properties of one inch square test bars normalized from 1860° F. and tempered at the temperatures stated are given:

Temp., Degrees F.	Ten. Str., p. s. i.	Yield, 0.2% p. s. i.	Elong., percent	R. A., percent	Impact-Izod, ft. lbs.
300	180,000	116,000	17.0	41.0	39
400	180,000	118,000	17.0	44.0	40
500	185,000	130,000	17.5	49.0	18
600	194,000	139,000	17.0	45.0	16
700	202,000	159,000	16.5	43.0	14
800	223,000	176,000	15.0	36.0	12
900	251,000	206,000	7.5	12.0	4
1,000	212,000	168,000	11.5	24.0	7

Fig. 2 consists of curves representative of the impact strength at various temperatures. Graph 1 represents the impact strengths at various breaking temperatures when normalized from 1860° F. and not tempered. Graph 2 shows the impact strengths at various temperatures for material normalized from 1860° F. and tempered four hours at 950° F. It will be observed from those two curves that although the impact strength of the normalized and untempered specimens varies little from about 150° to 600° F., the strength of the normalized but tempered specimens increases progressively

until it is equal to that of the untempered material. Graph 3 shows the effect of over-tempering, the specimens having been normalized and tempered four hours at 1120° F. The impact strength is obviously far below that of the specimens of curves 1 and 2.

Precise dilatometric measurements of the steels of this invention have shown that they undergo, in contrast to most alloy steels, no substantial dimensional change during the heating, cooling and aging cycles. This characteristic adapts these steels to any of the applications where dimensional stability is required and is consequently no doubt responsible for the exceptional resistance to heat checking that characterizes the hot work articles of this invention.

Although the invention has been described in detail with reference to dies for hot press forging, it is equally applicable to other hot work elements for static pressure hot forming operations such, for example, as extrusion dies, shear knives, centrifugal casting dies, upsetter dies, punches, and the like.

As evidencing the outstanding performance to be had from the practice of this invention the following examples compare dies in accordance with this invention with other types of hot work steels used in the same operations.

1. *Axle shaft flanges forged on an upsetting machine.*—5 per cent chromium steels gave limited production due to the development of deep cracks in the impression which prevented resinking. A nickel-chromium-molybdenum type die steel with 0.5 per cent of carbon produced only 10,000 pieces. A die according to this invention produced 20,000 forgings and was still suitable for further resinking due to the absence of heat checks.

2. *Press forged connecting rod caps made with 3-impression die.*—5 per cent chromium type die steel produced 40,000 forgings. Dies according to this invention produced 77,800 forgings.

3. *Upset forging of rail clamps.*—Previous average production was 50,000 pieces; dies according to this invention produced 80,000 pieces.

4. *Press forged automotive ring gears using four die stages.*—Low carbon 12 per cent chromium type die steel produced 18,000 forgings and the die failed by cracking due to water cooling. Dies according to this invention average 25,000 forgings and although water cooled did not exhibit cracking.

In heat treatment the elements might be quenched below 1800° F. although that is less effective than when they are quenched between 1800° and 1900° F. Also, they might be quenched at above 1900° F. but that is not ordinarily desirable because there is the danger of grain growth.

This application is a continuation-in-part of my co-pending application filed March 18, 1950, Serial No. 150,403, now abandoned.

According to the provisions of the patent statutes I have explained the principle of my invention and have illustrated and described what I now consider to represent its best embodiment. However, I desire to have it understood that, within the scope of the appended claims, the invention may be practiced otherwise than as specifically illustrated and described.

I claim:

1. Steel adapted for hot press forging and related static pressure hot forming, characterized when normalized from between 1840° and 1860° F. and tempered below 1100° F. of undergoing precipitation hardening in hot forming use, and formed from substantially the composition: 0.15 to 0.3 per cent of carbon, 0.6 to 0.8 per cent of manganese, 3.25 to 3.5 per cent of molybdenum, 3.0 to 3.25 per cent of nickel, 0.2 to 0.35 per cent of silicon, and the remainder iron containing impurities in amounts not detrimentally affecting the said properties.

2. A hot forged and heat treated hot work article for hot press forging and related forming operations, charac-

terized as normalized from 1840° to 1860° F. and tempered below 1100° F. of undergoing precipitation hardening in use, and by high resistance to thermal cracking combined with resistance to plastic flow under static pressure and to erosion by the forging stock, said article being formed from steel of substantially the composition: 0.15 to 0.3 per cent of carbon, 0.6 to 0.8 per cent of manganese, 3.25 to 3.5 per cent of molybdenum, 3.0 to 3.25 per cent to nickel, 0.2 to 0.35 per cent of silicon, and the remainder iron containing impurities in amounts not detrimentally affecting the said properties.

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