Bar Stock

Cold Forge

Straighten Machine

Case Harden

Quench

Draw

Final Machine

Fig. 1

Fig. 2

Fig. 3

Fig. 4
METHOD OF MAKING ENGINE VALVE
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7 Claims. (C1—29—156.7)

The present invention relates to an improved method of making an engine valve and more particularly to an improved process for forming poppet-type valves of the type used in internal combustion engines employing a ductile low-carbon steel which facilitates the formation by cold forging and/or extrusion relatively intricate valve configurations followed by a subsequent preliminary machining and case hardening treatment and thereafter a final machining operation resulting in a valve having excellent performance characteristics and which is substantially simpler and more economical to manufacture.

Poppet-type valves for use in internal combustion engines, and particularly intake poppet valves of the type employed in automobile engines have hereetofore been made employing medium and high-carbon alloy steels by either cold or hot forging techniques. While this manufacturing technique has been satisfactory for most purposes, a continuing problem associated with these processes has been the difficulty and lack of versatility in forming intricate valve shapes under cold-forming conditions. In addition, medium and high-carbon alloy steels of the types conventionally employed necessitate more complex tooling and produce a greater tool wear rate resulting in increased tooling costs and in frequent down time for tool replacement. A further problem associated with the processes hereetofore known has been the limitation imposed by medium and high-carbon alloy steels on the rate of production of valves due to the difficulty of forming and machining the material. In addition to the problems associated with the manufacture of such valves by the processes hereetofore known, the valves themselves have been found to be of less than optimum fatigue life and wear resistance particularly in view of the increased design performance of modern internal combustion engines.

It is accordingly a principal object of the present invention to provide an improved method of making poppet-type engine valves and to an improved valve made by the process which overcomes the problems and disadvantages associated with these processes.

Another object of the present invention is to provide an improved process for the manufacture of poppet-type engine valves employing a low-carbon steel which provides for substantially increased versatility and flexibility in obtaining intricate configurations and forms at room temperatures while additionally providing for substantially increased production rates.

Still another object of the present invention is to provide an improved process for forming poppet-type engine valves employing a low-carbon steel which enables the use of simpler tooling and further reduces wear on the tools providing greater die life with corresponding reductions in production down time and improved manufacturing efficiency.

A further object of the present invention is to provide an improved process and an improved poppet-type engine valve employing a low-carbon steel which is more economical and simpler to manufacture, and which possess superior fatigue life and improved wear resistance over similar type valves made of medium and high-carbon alloy steels.

The foregoing and other objects and advantages of the present invention are achieved by a process employing a low-carbon steel which can be rapidly cold forged into any one of a variety of suitable shapes followed there-
0.5% maximum sulfur, and the balance iron. Typical properties of a fully annealed SAE 1018 steel are as follows:

**Physical properties**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yield strength, p.s.i.</td>
<td>30,000</td>
</tr>
<tr>
<td>Tensile strength, p.s.i.</td>
<td>55,000</td>
</tr>
<tr>
<td>Elongation (percent to inches)</td>
<td>45</td>
</tr>
<tr>
<td>Reduction of area, percent</td>
<td>70</td>
</tr>
<tr>
<td>Brinell hardness</td>
<td>100</td>
</tr>
</tbody>
</table>

In order to employ a steel blank having the requisite degree of ductility, it is frequently desirable to subject the raw bar stock material from which sheared blanks are cut to a complete, or partial spheroidization, or a simple subcritical annealing treatment prior to the cold-forming operation consistent with the composition of the steel, the degree of work hardenness to which it has been subjected in the rolling mill, and the degree of deformation to which it is to be subjected consistent with the configuration of the valve to be manufactured. Maximum ductility of a steel blank requires complete spheroidization. A partial spheroidization or a simple subcritical annealing treatment is frequently satisfactory while in many instances no annealing treatment at all can be employed to provide a steel blank of the requisite ductility.

With reference to FIGURE 1, a schematic flow sheet of the process steps are diagrammatically indicated wherein the bar stock as received can be sheared to the appropriate length forming blanks that can be directly cold forged or alternatively the bar stock either prior to or after shearing can be subjected to an intervening annealing treatment as indicated by the dotted lines in FIG. 1. The annealing treatment as indicated by the dotted lines in FIG. 1. The annealing treatment is to provide a valve blank slightly oversized from its finished dimensions or alternatively can be subjected to an intervening optional annealing treatment as indicated by the dotted lines in FIG. 1. The annealing treatment is desirable for the purpose of relieving some of the residual stresses inherent in the result of the cold-forming operation. While very high levels of residual stresses are permissible in the forged valve blank it is important that such stresses are symmetrically distributed so as to avoid warpage and dimensional distortion of the valve blank during subsequent case-hardening operations. Under situations where the valve blank has substantially symmetrical residual stresses therein and intervening annealing treatment between the cold forging and machining operation is not required. Since distortion of the valve blank during the case-hardening operation necessitates an increased degree of final machining of the case-hardened valve, it is desirable in many instances to subject the cold-forged valve blank to an annealing operation. The annealing treatment is performed for the purpose of assuring dimensional stability and freedom from warpage of the machined valve when subjected to the heat in the case-hardening such as carburizing or carbonitriding, for example.

The valve blank whether or not subjected to an intervening annealing treatment is thereafter subjected to a straightening operation so as to position the valve head substantially perpendicular to the axis of the stem followed by a machining operation in which the stem, tip, head, and face of the valve are machined to within several thousands above the finished dimension of the valve. At the completion of the straightening and machining operation the valve is thereafter subjected to a case-hardening treatment to provide a hard surface layer on the surfaces thereof to increase its wear resistance. The depth of the hardened case can be varied consistent with the intended end use of the valve and the amount of metal that must be removed during the final machining operation to provide a valve of the desired finish dimensions. Conventionally for intake valves employed in automobile internal combustion engines, a case-hardening depth in the finished valve of about 0.010 inch provides for satisfactory operation whereas a medium depth case hardening of about 0.030 inch is preferred. Case hardening of the valve to a depth greater than about 0.30 inch does not detrimentally effect the performance and operating life of the valve and generally is not necessary due to the added cost of providing increased case depth. The presence of a controlled case-hardened surface of a depth of at least 0.010 inch around the ductile core comprising a low carbon or low alloy steel of the type hereinbefore set forth provides for valve performance characteristics superior to those heretofore obtained from valves of medium and high carbon alloy steels.

The type of case hardening and the degree of case hardening achieved will also vary consistent with the intended end use of the valves. In many cases it is necessary that only the valve tip indicated at 16 in FIG. 4 be fully hardened to a martensitic structure while unhardened pearlitic structures may be suitable to provide suitable stem and seat abrasion resistance in conventional automobile internal combustion engine use. For most engine applications, a valve made in accordance with the present process having a Rockwell hardness on the C-scale (RC) on the valve tip of about 50 or more and on the other surfaces of valve of about 20 Rc or more provides for satisfactory operation and high resistance to wear. Since a full martensitic structure has a hardness in the range of about 50 to about 60 Rc units, a hardness in the valve tip of at least about 50 Rc can be achieved either during the primary case hardening operation or during a secondary or localized case hardening operation as for example by subjecting it to a flame-hardening treatment step as schematically illustrated in FIG. 1. Intake valves made from a type 1018 steel in accordance with the present invention having a case depth ranging from about 0.015 to 0.020 inch of a hardness of about Rc
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These blanks were thereafter subjected to a spheroidizing annealing treatment at 1400° F for a period of one hour and at 1250° F. for a period of 16 hours after which the blanks were furnace cooled to 1,000° F. and thereafter air cooled. The annealed blanks were thereafter descaled and provided with a phosphate coating on the surfaces thereof which was impregnated with a lubricant and subjected to a two-hold cold forging operation. A resultant valve blank of the general configuration shown in FIGURE 4 was produced which thereafter was roll straightened to orient the head substantially perpendicular to the stem.

The valve blanks thereafter were subjected to a preliminary machining operation wherein the stems were ground to about 0.006 to about 0.007 inch over finish diameter and the heads and seats were turned to about 0.008 to about 0.009 inch over finish dimensions. The length of the valve blanks were ground 0.002 inch over the finish dimension. The machined valve blanks were thereafter heat treated and subjected to carbonitriding at a temperature of 1580° F. for one hour and forty-five minutes having an ammonia atmosphere of from 5 to 6% and a dew point of 30° F. The carbonitrided valve blanks were thereafter further cooled to 800° F. and oil quenched to room temperature. The resultant carbonitrided valve blanks had a case hardness of about 25 Rc and were thereafter subjected to a second machining operation wherein the stem was semi-finish ground and the tip was flame hardened with acetylene to a hardness in the range of about 55 to 60 Rc. At the completion of the flame hardening treatment, the stem end, the seat and the stem of the valve were finish ground to the final finish dimensions.

Valves made in accordance with the process as described in the specification and as illustrated in the example have been found to provide very satisfactory operating conditions in conventional commercial automobile internal combustion engines and have been found moreover to provide for a substantial improvement in the simplicity and in the economy of valve manufacture over techniques heretofore known in the art.

While it will be apparent that the preferred embodiments herein illustrated are well calculated to fulfill the objects above stated, it will be appreciated that the invention is susceptible to modification, variation and change without departing from the proper scope or fair meaning of the subjoined claims.

What is claimed is:

1. A process for making a poppet-type engine valve which comprises the steps of providing a blank of a metal selected from the group consisting of carbon steel and low-alloy steel containing from about 0.03% to about 0.60% carbon and up to about 5% of intentional alloying constituents, said steel further characterized as being susceptible to case hardening and having a degree of ductility enabling cold forming thereof, cold forming said blanks into a valve blank comprising a head portion and a stem portion, machining said valve blank to a configuration and size slightly greater than the final finish dimension, case hardening said valve blank to a depth providing a finish valve surface hardness of at least about 20 Rc on the surfaces of the finished valve and a hardness of at least about 50 Rc on the tip of said stem, and thereafter finish machining said valve blank to the final dimension.

2. A process for making a poppet-type engine valve which comprises the steps of providing a blank of a metal selected from the group consisting of carbon steel and low-alloy steel containing from about 0.08% to about 0.25% carbon and up to about 5% of intentional alloying constituents, said steel further characterized as being susceptible to case hardening and having a degree of ductility enabling cold forming thereof, cold forming said blanks into a valve blank comprising a head portion and a stem portion, machining said valve blank to a configuration and size slightly greater than the final finish dimension.
dimension, case hardening said valve blank to a depth to provide valve surface hardness of at least about 20 Rc on the surfaces of the finished valve and a hardness of at least about 50 Rc on the tip of said stem, and thereafter finish machining said valve blank to the final dimension.

3. A process for making a poppet-type engine valve which comprises the steps of providing a blank of a metal selected from the group consisting of carbon steel and low-alloy steel containing from about 0.03% to about 0.60% carbon and up to about 5% of intentional alloying constituents, and further characterized as being susceptible to case hardening, annealing said blank to provide a degree of ductility enabling cold forming thereof, cold forming said blank into a valve blank comprising a head portion and a stem portion, machining said valve blank to a configuration and size slightly greater than the final finish dimension, case hardening said valve blank to a depth to provide a finish valve surface hardness of at least about 20 Rc on the surfaces of the valve and a hardness of at least about 50 Rc on the tip of said stem, and thereafter finish machining the said valve blank to the final dimensions.

4. A process for making a poppet-type engine valve which comprises the steps of providing a blank of a metal selected from the group consisting of carbon steel and low-alloy steel containing from about 0.03% to about 0.60% carbon and up to about 5% of intentional alloying constituents, and further characterized as being susceptible to case hardening and having a degree of ductility enabling cold forming thereof, cold forming said blanks into a valve blank comprising a head portion and a stem portion, annealing said valve blank to relieve the residual stresses therein, machining said valve blank to a configuration and size slightly greater than the final finish dimension, case hardening said valve blank to a depth to provide a finish valve surface hardness of at least about 20 Rc on the surfaces of the finished valve and a hardness of at least about 50 Rc on the tip of said stem, and thereafter finish machining said valve blank to the final dimension.

5. A process for making a poppet-type engine valve which comprises the steps of providing a blank of a metal selected from the group consisting of carbon steel and low-alloy steel containing from about 0.03% to about 0.60% carbon and up to about 5% of intentional alloying constituents, and further characterized as being susceptible to case hardening and having a degree of ductility enabling cold forming thereof, cold forming said blanks into a valve blank comprising a head portion and a stem portion, machining said valve blank to a configuration and size slightly greater than the final finish dimension, case hardening said valve blank to a depth to provide a finish valve surface hardness of at least about 20 Rc on the surfaces of the finished valve, case hardening the tip of said stem to provide a hardness of at least about 20 Rc on the finish surface of said tip, and thereafter finish machining said valve blank to the final dimension.

6. A process for making a poppet-type engine valve which comprises the steps of providing a blank of a metal selected from the group consisting of carbon steel and low-alloy steel containing from about 0.03% to about 0.60% carbon and up to about 5% of intentional alloying constituents, and further characterized as being susceptible to case hardening and having a degree of ductility enabling cold forming thereof, cold forming said blanks into a valve blank comprising a head portion and a stem portion, machining said valve blank to a configuration and size slightly greater than the final finish dimension, case hardening said valve blank to a depth to provide a finish valve surface hardness of at least about 20 Rc on the surfaces of the finished valve, flame hardening the tip of said stem to provide a hardness of at least about 20 Rc on the finish surface of said tip, and thereafter finish machining said valve blank to the final dimension.

7. A process for making a poppet-type engine valve which comprises the steps of providing a blank of a type 1018 steel, said steel further characterized as being susceptible to case hardening and having a degree of ductility enabling cold forming thereof, cold forming said blanks into a valve blank comprising a head portion and a stem portion, machining said valve blank to a configuration and size slightly greater than the final finish dimension, case hardening said valve blank to a depth to provide a finish valve surface hardness of at least about 20 Rc on the surfaces of the finished valve and a hardness of at least about 50 Rc on the tip of said stem, and thereafter finish machining said valve blank to the final dimension.

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