Sept. 12, 1972 E. A. THOMPSON 3,690,958

ROCKER ARM

Original Filed Feb. 24, 1966 2 Sheets-Sheet 1

FIG 1

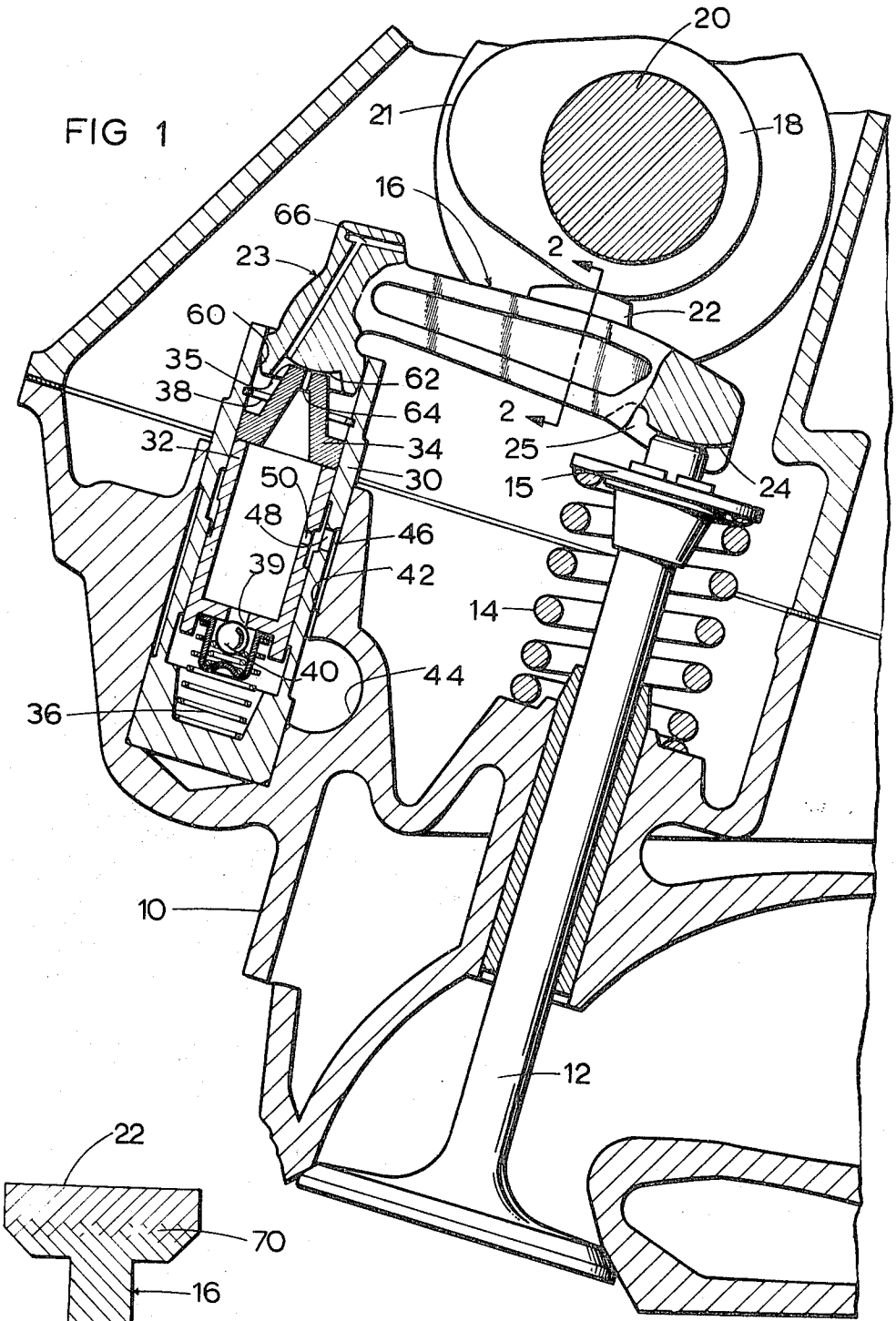


FIG 2

INVENTOR
EARL A THOMPSON

BY

J. L. Chisholm

ATTORNEY

ROCKER ARM

Original Filed Feb. 24, 1966 2 Sheets-Sheet 2



FIG 4 .0001



FIG 6 .0001



FIG 3 .0001

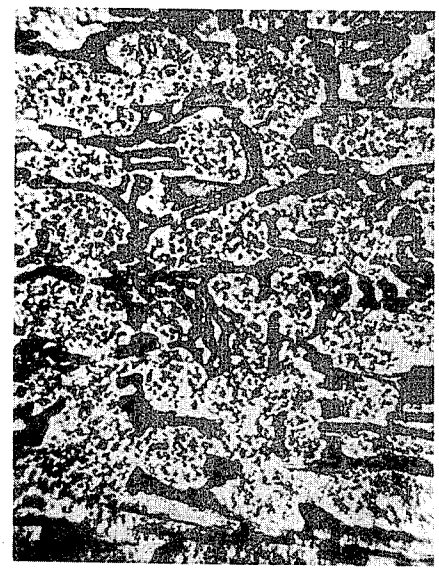


FIG 5 .0001

EARL A THOMPSON
By J. L. Chisholm
Attorney

United States Patent Office 3,690,958 Patented Sept. 12, 1972

3,690,958

ROCKER ARM

Earl A. Thompson, Bloomfield Hills, Mich., assignor to F. Jos. Lamb Company, Warren, Mich.

Original application Feb. 24, 1966, Ser. No. 529,829, now Patent No. 3,502,058, dated Mar. 24, 1970. Divided and this application Mar. 18, 1970, Ser. No. 20,516
Int. Cl. C22c *37/06*; F01l *1/18*
U.S. Cl. 148—3 5 Claims

ABSTRACT OF THE DISCLOSURE

A rocker arm for internal combustion engines made from an alloy containing from 1.3% to about 3.1% C, from about 15% to about 35% Cr with the remainder iron, with or without up to about 3.25% Si, Mn and other residuals. The alloy is cast, cooled so a relatively small number of relatively large primary chromium carbide particles are formed and widely dispersed in a matrix of austenite containing a solid solution of chromium and carbon. Then large numbers of relatively small particles of chromium carbides are precipitated from the matrix and distributed throughout the spaces between the large primary carbon particles leaving the remainder of the matrix containing carbon and susceptible to subsequent hardening. Then hardening the casting by heating and subsequently quenching to convert the matrix to substantially a martensitic structure without significantly changing the carbide particles.

This application is a division of my application Ser. No. 529,829 filed Feb. 24, 1966 now Patent 3,502,058 issued Mar. 24, 1970.

This invention relates to rocker arms for valve trains of internal combustion engines and particularly to rocker arms made of improved high-chromium, high-carbon iron alloys. It is particularly but not exclusively suited for rocker arms in engines with overhead camshafts, which are shown here only as one example of the invention.

In internal combustion engines, it is customary to have the camshaft operate the valves through pivoted rocker arms, each bearing on a valve. An example of such general arrangement is shown in U.S. Pat. 2,763,250 to Bensinger et al. dated Sept. 18, 1956. It is also customary to provide an automatic lash adjuster, called a hydraulic tappet, to take up lost motion in the valve train or valve actuating mechanism. Such a tappet customarily includes an assembly which is constantly urged to expand to take up slack when the valve is closed. When the valve is being opened, the tappet is urged to collapse by the force of the cam opening the valve against the force of the valve closing spring, but the collapse is retarded so that the tappet becomes substantially rigid, and the cam can be effective to open the valve.

An example of such lash adjuster is shown in my U.S. Pat. 2,935,059, May 3, 1960. Such devices often have a plunger sliding in a cup-shaped guide called the tappet body, a spring constantly urging the plunger out of the body and toward the pivot end of the rocket arm, and an oil trap between the plunger and the body to retard collapse. The plunger carries a fulcrum for supporting the pivot end of the rocker arm, variously called a push rod seat or a rocker arm seat.

In such devices the only useful force of the cam in opening the valve is that component of force which produces motion of the rocker arm in the direction of the axis of the valve stem. While the customary rotary cam does provide this motion of the rocker arm, it also provides an undesirable force. Because as the cam rotates,

its surface rubs along the length of the rocker arm, it applies thrust to the rocker arm back and forth in the direction of its length which is transverse to the direction of reciprocation of the plunger. Because the load between the cam and the rocker arm is periodically heavy, this thrust is large. This causes side thrust on the seat, which in turn produces side thrust between plunger and body, which in turn causes destructive wear of the plunger and body, which in turn causes destructive wear of the plunger or body or both. Even a small amount of such wear is serious because the fit, or clearance, between the plunger and body must be maintained within critical limits in order to control the rate of escape of oil from the oil trap, which controls the rate of collapse of the tappet, and thus controls the amount and timing of the valve opening.

I have heretofore proposed an improved rocker arm, of the form shown herein as one example of the invention, which prevents side thrust between the plunger and body of the tappet. Such rocker arms are particularly subject to wear of the spherical bearing surface in the tappet, and of the cam follower surface.

This invention is based in part on my discovery that greatly improved rocker arms can be cast of particular high-chromium, high-carbon iron alloys which can be treated to provide a surprisingly easily machinable rocker arm which article can be processed further to give it surprising hardness and resistance both to wear and to corrosion. The rocker arm during heat treatment is surprisingly stable as to dimension, so that it can be machined with customary cutting tools and ground precisely to finished size and shape, neither of which is significantly affected by subsequent hardening, for the purposes of my invention.

Accordingly one of the objects of the invention is to provide an improved rocker arm which is satisfactorily rigid and is easily machinable and highly resistant to wear and corrosion.

More specifically, another object is to provide a rocker arm which is made of an improved material which is extremely resistant both to corrosion and to wear.

Another object is to provide a rocker arm which can be economically made by conventional processes and which has improved dimensional stability.

Other objects and advantages of the invention will be understood from the following description and from the annexed drawings, in which

FIG. 1 is a transverse vertical section through a portion of an engine showing partly in section and partly in elevation a valve train including a rocker arm embodying one form of my invention.

FIG. 2 is a section on the line 2—2 of FIG. 1.

FIG. 3 is a photograph of a polished and etched section of a portion of a casting made of an alloy embodying one form of my invention. This photograph is of metal in the condition as cast, and is magnified about 1495 times. The scale line, approximately ⅛ of an inch long, at the bottom of the photographs, represents one ten thousandth of an inch (.0001).

FIG. 4 is a photographic corresponding to FIG. 4 of the same alloy after subsequent heat treatment.

FIG. 5 is a photograph corresponding to FIG. 4 of the same alloy after subsequent hardening.

FIG. 6 is a photograph corresponding to FIG. 4 of the same alloy after drawing following hardening.

Referring to FIG. 1, **10** is an engine head in which is mounted a valve **12** normally closed by a valve spring **14** acting on a spring retainer **15**. The valve is opened against the force of this spring by a rocker arm **16** when the rocker arm is depressed by the cam **18** fixed to a camshaft **20** mounted in the engine head. The rocker arm is

of I-shaped section, to combine rigidity with light weight, as shown in FIG. 2. The left hand end of the rocker arm is pivoted so that the right end swings down to open the valve when the lobe **21** of the cam engages the cam pad **22**. The rocker arm **16** is constantly urged counter-clockwise about its pivot end **23** by the valve spring **14** which pushes the valve stem **12** against a rocker bearing surface **24** in a pocket **25** in the right end of the rocker arm. The pivot end **23** of the rod is automatically urged upward, to hold the cam pad **22** against the face of the cam. This is accomplished by an automatic lash adjuster or hydraulic valve tappet of generally known arrangement.

The tappet or automatic valve lash adjuster may include a cup-shaped body or guide **30** closed at its lower end. Slidable in the tubular portion of the cup is a plunger **32** which supports at its upper end a rocker arm seat **34** having an upper surface **35** which acts as a fulcrum for the pivot end of the rocker arm. The plunger is constantly urged upward or out of the cup by a compression spring **36** and it is positively retained in the cup by a snap ring **38**. The body **30** is rigidly secured in a bore **42** in the engine head **10**. I prevent any lateral thrust from the cam on the plunger by a spherical pivot surface **60** which fits snugly in the upper end of the bore in the body **30**. This spherical surface allows the rocker arm to rock about the seat and transmits all of the lateral thrust from the cam directly to the engine head through the fixed cup or body **30**.

A rocking bearing surface **62**, preferably cylindrical, supports the rocker arm on the seat. As the cam alternately depresses and releases the rocker arm, the surface **62** rolls across the surface of the seat **34** while the spherical surface **60** slides in the upper end of the bore of the body **30** as the rocker arm pivots.

In order to lubricate and cool the surfaces **60** and **62** and the bearing between the cam and the rocker arm pad **22** I prefer to supply lubricant, which is also a coolant, to these surfaces at a substantially constant rate. This may be done through a lubricating passage **64** in the seat and a continuing conduit **66** formed in the pivot end of the rocker arm and discharging adjacent the cam. Oil under pressure is squirted onto the cam and rocker arm pad **22**, being supplied from the source of pressure **44** through annular chamber **46**, openings **48**, **50** and **64** and passage **66**.

The passage **66** must be drilled in the rocker arm, and the surfaces **22**, **24**, **60** and **62** must be accurately formed and must be hard to resist wear. This makes problems in manufacture which are solved by the particular alloys of my invention.

I cast the rocker arm, preferably of a high-carbon, high-chromium iron alloy containing about 2.20% carbon and about 22.5% chromium. This alloy may also contain about 1.60% silicon and about .90% manganese. The silicon may be added to make the alloy easier to pour. The manganese combines with any sulphur which may be present in the material of which the alloy is made. Also the manganese may improve the hardenability of the matrix of the alloy upon subsequent quenching. Ordinarily such alloys are made from available ingredients including scrap of uncertain analysis so that the resulting alloy may contain residual quantities of copper, nickel, molybdenum and other metals. As one example an analysis showed that one batch of my preferred alloy contained 2.20% carbon, 1.60% silicon, .90% manganese, 22.5% chromium, and residuals of .25% copper, .31% nickel and .17% molybdenum.

The silicon, manganese and the residuals amount to about 3.25% and I believe that these do not importantly affect the final metallurgical structure, for the purpose of my invention. Consequently alloys containing them come within my definition of an alloy having stated ranges of carbon and chromium, and having the remainder iron.

I have discovered that alloys of the composition mentioned above, or of the ranges of composition disclosed herein, can be given a new and improved metallurgical structure by cooling quickly after pouring, and that this new metallurgical structure can be treated to provide new, surprising and very desirable properties. As one example a melt having the proportions of ingredients to provide the alloy of the composition set forth above was poured at about 2750° F. This particular alloy has a liquidus temperature of about 2399° F. and a solidus temperature of about 2270° F., as determined by the Leeds and Northrup carbon determinator.

FIG. 3 is a photograph of a section of a part which has been cast according to my invention. The temperature of the metal has been reduced from the liquidus to the solidus so quickly that two things have happened. One is that the usual formation of primary chromium carbide particles has been arrested, so that the chromium carbide particles formed are fewer in number and smaller than they would be if the metal had cooled slowly. Evidence of this is that he matrix has remained essentially non-magnetic austenite. If the casting had cooled slowly, austenite would not be formed. The other thing that has happened is that the matrix contains large amounts of chromium and carbon in solid solution. Evidence of this is the subsequent formation of very fine chromium carbide particles during subsequent heat treatment. If the casting had cooled slowly the carbon and chromium now remaining in solution would have precipitated out as primary carbides. The primary chromium carbides shown in FIG. 3 are very small, much smaller than if the metal had cooled slowly, and they are more widely dispersed. The largest primary carbide particle visible in FIG. 3, measured in inches is about .00135 long, and in a representative area .001 square there are about 17 primary carbide particles. The large dark particles shown are what is generally called chromium carbides. Among such chromium carbides Cr_7C_3 and Cr_4C have been identified. It is also possible for iron to replace some of the chromium to form complex or mixed chromium iron carbides such as $(FeCr)_3C$. All of these come within the definition of chromium carbides as that term is generally understood and used herein. The spaces, relatively large with reference to the carbides, are austenite and substantially non-magnetic. The hardness of the alloy as cast is about 44 Rockwell C.

The casting, a section of which is shown in FIG. 3, was cooled under the following conditions.

A test casting having a thickness of about .090 was poured in a silicon sand shell mold having a wall thickness of approximately one and one-half times the thickness of the casting. The mold was at room temperature. The metal was poured at about 2750° F. The cooling rate, under these conditions, dropped the temperature from the liquidus to the solidus so fast that the metallurgical structure shown in FIG. 3 and described above, was formed.

I have found that faster cooling forms even smaller and fewer primary chromium carbide particles and slower cooling forms more and larger primary carbides. The thickness of the metal influences the rate of cooling and this influences the metallurgical structure and properties of the cast metal, not only as cast, but in subsequent treatment. For example the thin center web section of the arm cools faster than the thick pivot end. There is an important and discernible difference in the appearance and properties of the metallurgical structures of these two portions as cast. Thin sections can also be drilled with a high speed tool steel drill more easily than thick sections after the subsequent heat treating step described below. Also after final hardening, as disclosed below, a thicker section (slowly cooled) is softer than a thinner section (quickly cooled). For example a test casting .190 thick as cast, cooled as described above, will have an ultimate hardness of about 60 Rockwell C, whereas a body having .160 thickness and cooled as described will have a final hardness of about 63 Rockwell C.

The important thing is that the temperature of the metal must be reduced from the liquidus to the solidus so quickly that only relatively small numbers of very small chromium carbides can form, and that they will be formed in an austenite matrix which has large inter-carbide spaces in which larger numbers of still smaller chromium carbides can be precipitated upon re-heating, while leaving the matrix containing carbon and in a condition which can be hardened. FIG. 3 shows a typical structure, which has properly cooled according to my invention.

I may affect the cooling in other ways. Since a thick section cools more slowly than a thin section it may be necessary to mold thicker sections in zircon sand, for example, which cools the casting faster than silicon sand. Alternatively chills may be placed in the mold to accelerate the cooling of thick parts of a casting, or I may use a permanent mold, water cooled. If the metal cools too slowly the casting will not only be too hard, but it cannot be satisfactorily heat treated so as to be machinable.

After cooling the casting was heat treated as follows. Its temperature was slowly raised from room temperature to about 1600° F. The time required was three hours. It was held at 1600° F. one hour. It was cooled to about 1400° F. during the next 40 minutes. It was cooled to about 1300° F. during the next hour. Total time 5⅔ hours.

FIG. 4 shows a casting after this treatment. It shows that the chromium carbides of FIG. 3 have not changed significantly. The interstices or inter-carbide spaces in the previously austenitic matrix are now substantially filled with a dispersion of very small precipitated chromium carbides, having a representative size of the order of about .000018 (18 millionths of an inch). In a representative area .0001 square there are about 13 of these very small particles, or about 1300 particles in the .001 square containing about 17 primary carbide particles. Thus although the primary chromium carbides in FIG. 3 are very small (a large one being of the order of a thousandth of an inch long) they are of the order of from 50 to 100 times as large as the smaller carbides formed in the re-heating process. The hardness after re-heating was from 27 to 33 Rockwell C.

I do not know the exact nature of the matrix after re-heating, shown in FIG. 4. It is magnetic. It contains carbon, so that it can be hardened by subsequent heat treatment which appears to convert the matrix essentially to martensite having properties typical of tool steel.

In the foregoing heat treatment the time required is a function of temperature, a lower temperature requiring a longer time. Also the time and temperature of this re-heating step influences the amount of carbon left in the matrix and so affects the subsequent hardenability of the alloy, when hardened as disclosed below.

This particular combination of carbide particles and the characters of the matrix in the two conditions appear to make possible the machinability at one stage of my invention and the hardness at a subsequent stage, combined with the surprising dimensional stability and other properties I have observed.

After the foregoing re-heating treatment the rocker arm can be drilled and machined easily and economically with high speed steel tools and surprisingly the bearing surfaces can be ground to the exact final shape and desired dimensions.

Thereafter the part may be hardened by holding at a temperature above the critical temperature at which the matrix changes back into austenite and well below the melting point, followed by quenching. The time is a function of temperature, lower temperature requiring longer time. For example the part may be held at about 1750° F. for about twenty minutes, then oil quenched. FIG. 5 shows a casting which has been cooled, then re-heated, then hardened as above described. The Rockwell C hardness is about 63 to 65. The two sets of chromium carbide particles have remained unchanged. The matrix has been essentially converted to martensite. I find that this hardening step changes the size of the part so slightly that in the case of articles which are acceptable within tolerances as large as .0001 (one hundred millionths) of an inch, I can grind to final size before hardening. This is of great advantage in manufacturing.

After hardening, the part may be drawn by holding it at a temperature higher than it will ever work in service, for example of about 375° F., for about one hour. The hardness drops about 1 point Rockwell C and the structure is as shown in FIG. 6, with the alloy discussed above.

The advantages of the invention are realized while varying the proportions of the ingredients of the alloy within the limits stated herein. For example I may use carbon up to 2.35% and chromium up to 27.00% without significantly changing, for the purposes of the invention, the characteristics of the alloy from those of the preferred analysis given above.

Increasing the proportion of carbon within certain critical limits tends to increase the final hardness and hence wear resistance of the article. More carbon is required in articles having a thick section, because due to slower cooling, more carbon is combined with chromium, which has a very high affinity for carbon. If more carbon were not used, the matrix would be so depleted that it could not be hardened satisfactorily. More carbon than about 2.95% appears to render the article impractically difficult to machine although in some instances I can use up to about 3.10% carbon, particularly with high percentages of chromium. Increasing the proportion of chromium within a wider range of critical limits tends to increase the corrosion resistance and reduction of the chromium content below about 15% appears to reduce the corrosion resistance undesirably. Increasing the proportion of chromium beyond about 30% appears to have no important effect on either wear or corrosion resistance, except with very high carbon percentages (above 3.10% for example) and increase of chromium beyond about 35% appears to have no advantage and may even be undesirable. There is a desirable relationship between the amounts of carbon and chromium to have the desired effects because one part carbon will combine with about ten parts chromium. Therefore higher proportions of chromium require higher percentages of carbon so as to leave in the matrix, after the re-heating step, enough carbon not combined with chromium, to harden the matrix satisfactorily in the hardening step discussed above.

For example with my preferred alloy first mentioned, the processes described appear to leave about 1.10% of carbon in the matrix after the first re-heating step (in which the smaller carbide particles are formed). Then when the part is hardened as described, the matrix appears to contain no free carbon and is hardened to have properties resembling those of tool steel or 52100 steel. Measurements of properties of the cast and hardened alloy exceed those of steel. For example, a sample of the preferred alloy, cast and treated as above described showed a transverse bending stress of 693,000 pounds per square inch. From this the modulus of elasticity is calculated at 39,000,000. The modulus for steel is about 29,000,000.

Many of the advantages of the invention are present in a range of carbon between 1.70% and 2.85% while using a range of chromium between 15 and 27%.

In articles having different parts requiring different hardness, I find it of advantage to use an alloy having the general characteristics described above but being even harder and hence even more wear resistant. In such case I may use a carbon content of about 3.10% and may use this with a chromium content varying between about 30% and about 35%. This provides an extremely hard, wear resistant material. It is difficult to machine by cutting tools, and although it is difficult to grind I have found

that by confining this material to the cam pad **22**, for example, I can satisfactorily drill the oil passage in the pivot end and grind the exterior surface of the cam pad. This is partly due to my improved casting process which permits casting of two different metals within very small tolerances, and confines the extremely hard alloy to a small part, making it possible for me to make a rocker arm to finished size with minimum grinding. It is also due in part to the unusual dimensional stability of the material which makes it possible to grind to close tolerances and final size before the hardening step of the manufacturing process described above. An example of such article is a composite casting made by the process disclosed in my patent in Great Britain No. 991,513 published May 12, 1965, the disclosure of which is incorporated herein by reference with the same effect as if quoted completely herein. In such case the hard alloy containing about 3.10% carbon and about 27 to 30% chromium is cast in the mold first, to form the cam pad **22**. The remainder of the rocker arm may then be cast of any of the other alloys disclosed herein. The two alloys are autogenously joined along a bonding or juncture zone, or joint **70**.

I have successfully cast various articles having unusually high resistance to corrosion and wear and having exceptional dimensional stability of the alloys having the following analyses.

	C	Si	Cu	Mn	Cr	Ni	Mo
Example:							
I	2.20	1.60	.25	.90	22.5	.31	.17
II	1.70	.81	.09	.60	15.0	.19	.03
III	2.68	1.34	.13	.95	24.0	.30	.11
IV	2.85	1.47	.13	1.01	27.00	.37	.17
V	3.10	1.76	.59	1.29	25.7	.48	.34

I claim as my invention.

1. A rocker arm for an internal combustion engine having a pivot bearing surface, a valve operating surface, and a cam follower surface, said rocker arm being cast of an iron alloy consisting of from about 1.3% to about 3.10% carbon and from about 15% to about 35% chromium with the remainder iron, said alloy having a minimum hardness of about 61 Rockwell C and having a relatively small number of relatively large primary chromium carbide particles distributed in a matrix of martensite and having a relatively large number of relatively small precipitated chromium carbide particles distributed throughout the matrix between the large primary carbide particles.

2. A rocker arm as defined in claim **1** further characterized by a carbon content between about 1.7% and about 2.85% and a chromium content between about 15% and about 27%.

3. A rocker arm as defined in claim **1** further characterized by a carbon content between about 2.2% and about 2.35% and a chromium content between about 22% and about 27%.

4. A rocker arm as defined in claim **1** further characterized by a carbon content of about 2.2% and a chromium content of about 22.5%.

5. The method of making a rocker arm for an internal combustion engine which includes pouring a molten iron alloy consisting of from about 1.30% to about 3.10% carbon and from about 15% to about 35% chromium with the rest iron, rapidly reducing the temperature from the liquidus to the solidus at such a rate that a relatively small number of relatively large primary chromium carbide particles are formed and widely dispersed in a matrix of austenite containing a solid solution of chromium and carbon, then precipitating large numbers of relatively small particles of chromium carbides from the matrix and distributed throughout the spaces between the large primary carbide particles leaving the remainder of the matrix containing carbon and susceptible to subsequent hardening, then hardening the casting by heating and subsequent quenching, the last mentioned heating being at such temperature and for such time that the matrix is substantially converted to martensite without significantly changing the carbide particles.

References Cited

UNITED STATES PATENTS

2,763,250	9/1956	Bensinger et al.	123—90.44
2,051,415	8/1936	Payson	148—31
2,015,991	10/1935	Breeler	123—188 AA X
2,199,096	4/1940	Berglund	148—35 X
3,028,479	4/1962	Tauschek	123—188 AA X
2,127,245	8/1938	Breeler	123—188 AA X
1,245,552	11/1917	Becket	75—126
1,956,014	4/1934	Fink et al.	123—188
2,773,761	12/1956	Fuqua et al.	148—35 X
3,078,194	1/1963	Thompson	148—3 X

OTHER REFERENCES

Alloys of Iron and Chromium, vol. II, Kinzel et al., 1940, McGraw Hill Co., N.Y., pp. 182, 183, 230–235, 244–249 & 258.

Chromium in Cast Iron, Electro Metallurgical Co., 1939, pp. 29–37 and 42.

CHARLES N. LOVELL, Primary Examiner

U.S. Cl. X.R.

123—90.39, 90.40, 90.44; 148—2, 12.3, 35, 141