Aug. 7, 1945. A. W. MERRICK **2,381,459**

TURBINE BUCKET FOR EXHAUST TURBINE SUPERCHARGERS

Filed Dec. 10, 1941

Fig. 1.

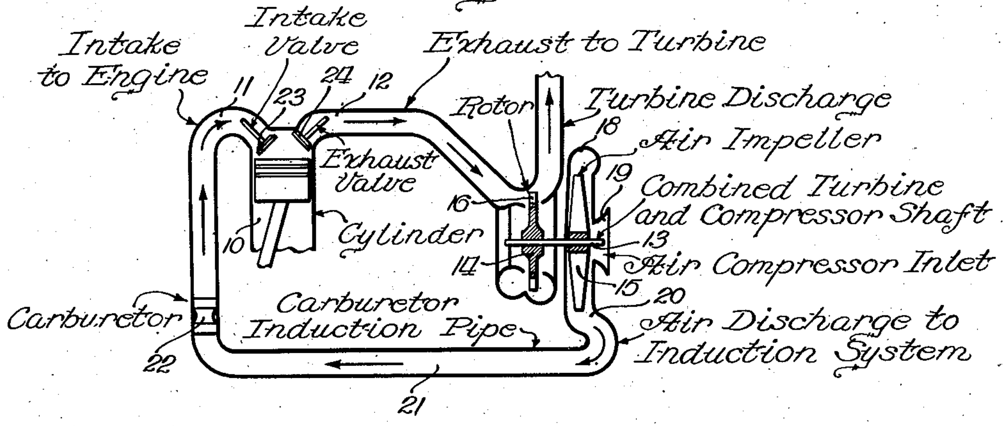


Fig. 2.

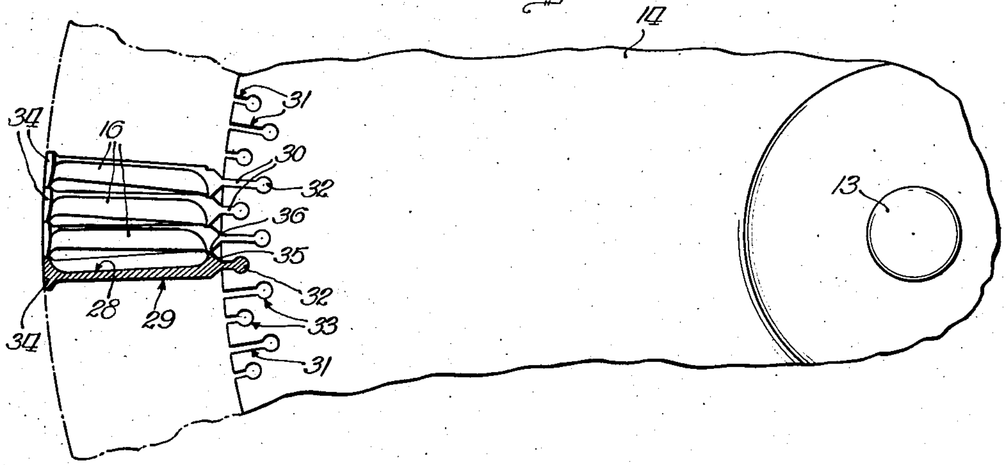


Fig. 3.

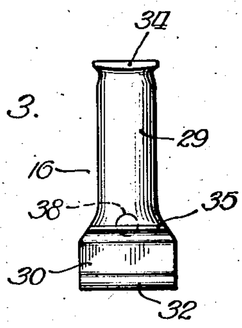


Fig. 4.

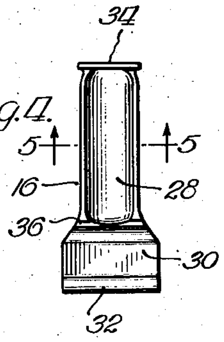
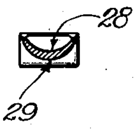


Fig. 5.



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TURBINE BUCKET FOR EXHAUST TURBINE SUPERCHARGERS

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5 Claims. (Cl. 253—77)

This invention relates, generally, to exhaust turbine superchargers for internal combustion engines, and it has particular relation to an improved turbine bucket for superchargers of the class described.

The invention may be embodied in a wide variety of forms of turbine buckets for use with a wide variety of exhaust turbine superchargers. For purposes of illustration I shall refer more or less generally to a diagrammatically illustrated form of exhaust turbine supercharger and to an illustrative form of turbine bucket, but it is to be understood that the invention is not limited to use with the particular form of supercharger selected for illustration, nor to embodiment in the particular form of turbine bucket shown and described.

Superchargers are required for high power output and are desirable for aircraft engines, for example, for take-off power, and to compensate for the rare atmosphere at high altitudes. They are also desirable for automotive engines at high speeds, and for Diesel engines for increased output.

The rotors of these superchargers run at very high peripheral speeds—at substantially the speed of a rifle bullet—and the turbine buckets operate within the path of the exhaust gases where the temperatures are very high—of the order of from about 1400° F. to 1500° F. The turbine buckets, therefore, are subject to very severe conditions, particularly in regard to temperature and the high stresses to which they are subjected as the result of the action of centrifugal force.

Heretofore, forged and machined buckets have usually been employed, and these buckets have necessarily been formed of alloys which would permit the forging and machining operations.

With the improvement of aircraft and their engines, the necessity for better turbine buckets for exhaust turbine superchargers and better materials for such turbine buckets has become urgent.

The improvement of the present invention consists in forming the bucket by a casting process and of an alloy providing new and advantageous results not equalled by the alloys previously used in making such bucket, and which alloy it would be hopeless to consider for a forged and machined bucket on account of the hardness and difficulty of machining and impracticability of forging the same.

More specifically, the improvement of the present invention consists in providing a cast turbine bucket for exhaust turbine superchargers, such bucket being formed of a cobalt-chromium alloy, and, more particularly, formed of a cobalt, chromium, molybdenum alloy with the constituents combined and proportioned in a manner better to withstand the severe conditions to which such buckets are subjected.

Further and more specific features and advantages of the invention will appear from the following detailed description taken in connection with the accompanying drawing, in which:

Figure 1 is a diagram of one form of an exhaust turbine supercharger with which the turbine buckets of the present invention are adapted to be used;

Figure 2 is a fragmentary view showing one illustrative manner in which the turbine buckets may be attached to the periphery of the rotor or turbine wheel;

Figure 3 is a back view of one of the turbine buckets;

Figure 4 is a front view of the turbine bucket shown in Figure 3; and

Figure 5 is a transverse section taken on the line 5—5 of Figure 4.

In the diagrammatic showing in Figure 1, the internal combustion engine, which may be an aircraft engine, comprises a cylinder **10** having an intake **11** and an exhaust **12**.

The exhaust turbine supercharger comprises a combined turbine and compressor shaft **13** having fixed thereon the rotor or turbine wheel **14** and an air impeller **15**. The turbine buckets **16** are fastened, as will hereinafter appear, to the periphery of the rotor or turbine wheel **14** and operate within the path of the exhaust gases which serve as the motive fluid for turning the turbine wheel and thereby the shaft **13** and air impeller **15**. In aircraft engines, the exhaust gases will drive the turbine wheel at very high peripheral speed, commonly from seven to twelve times crankshaft speed, or at substantially the speed of a rifle bullet.

The air impeller **15** operates within the impeller housing **18** which has an air compressor inlet **19** and an air discharge **20** to the carburetor induction pipe **21**. The air impeller **15** forces air through the carburetor shown diagrammatically at **22**, and the explosive mixture is delivered from the carburetor through the intake **11** into the cylinders of the engine, one of which cylinders is shown. The carburetor may, of course, be located before the supercharger instead of after the same, as shown in the drawing. The intake into the cylinder of the engine is controlled by the usual or any suitable intake valve **23**, and the exhaust from the cylinder of the engine is controlled by the usual or any suitable exhaust valve **24**.

The turbine buckets **16** which, as already pointed out, operate in the exhaust pipe **12** where they are subjected to very severe conditions are preferably cast from an alloy whose essential or principal ingredients are cobalt and chromium. In the broader aspects of the invention, the cobalt is present as the principal ingredient, and more specifically, in amount more than 50%, and the chromium is present to the extent of from approximately 10% to approximately 40%.

For a full understanding of the various alloys from which I contemplate, within the broader aspects of the invention, casting or forming the turbine buckets **16**, attention is directed to the alloys more fully described in Charles H. Prange Reissue Patent No. 20,877, reissued October 4, 1938; also to Charles H. Prange Patent No. 2,135,600, patented November 8, 1938, and to Charles H. Prange Patent No. 2,180,549, patented November 21, 1939.

One preferred form of alloy from which highly satisfactory turbine buckets have been made is substantially as follows:

	Per cent
Cobalt	63.0
Chromium	30.0
Molybdenum	6.0
Silicon	0.25
Manganese	0.50
Carbon	0.25

In addition, there are likely to be small quantities of iron and nickel, but these are simply impurities and are not introduced purposely.

As a commercial specification, substantially the following range of compositions would cover this latter alloy as it could be produced on a commercial basis:

	Per cent
Cobalt	60.0 to 65.0
Chromium	28.0 to 32.0
Molybdenum	5.0 to 7.0
Silicon	.10 to 1.0
Manganese	.20 to 1.0
Carbon	.00 to .50

The physical properties of the preferred form of turbine bucket alloy above set forth as exemplified by actual tensile tests are as follows:

Ultimate strength	lbs. per sq. inch	110,000	114,000	117,000
Yield point	do	68,000	71,000	72,000
Elongation	per cent	12.0	14.0	13.0
Reduction of area	do	14.0	12.0	15.0

The above tests are at room temperature. At 1500° F., the following properties are obtained:

Ultimate strength	lbs. sq. in	69,000	72,000
Elongation	per cent	17.0	16.0
Reduction of area	do	18.0	19.0

These figures show the excellent properties of the composition in the cast condition, the one set at room temperature and the other at 1500° F. This is illustrative of the excellence of the alloy for the high temperature conditions to which turbine buckets for exhaust turbine superchargers are subjected.

The mold and method for its production disclosed in Arthur B. Ray Patent No. 2,027,932, patented January 14, 1936, as well as the casting procedure disclosed in Charles H. Prange reissue patent Reissue No. 20,877, reissued October 4, 1938, and the casting investment material and process disclosed in Charles H. Prange Patent No. 2,180,549, patented November 21, 1939, are highly suitable and advantageous in the casting of the turbine buckets of the present invention, and reference is hereby incorporated herein for the further details of these casting investment materials and processes as casting investment materials and processes suitable for casting the turbine buckets of the present invention.

The founding apparatus and method disclosed in the present applicant's prior Patent No. 2,125,080, patented July 26, 1938, are also highly suitable and advantageous in the casting of the turbine buckets of the present invention, and reference to that patent is hereby incorporated herein for the further details of the founding apparatus and method as the same may be used in connection with the present invention.

I find that the characteristics of the alloy, when applied to turbine buckets for exhaust turbine superchargers for internal combustion engines, impart greatly desired properties not provided in the turbine buckets of the prior art.

Most alloys suffer a very marked reduction in strength at elevated temperatures, but a turbine bucket made from the alloy described herein retains a proportionately greater strength at such temperatures.

A further aspect is the matter of "creep" strength. This refers to the gradual stretching of a metal under stress at elevated temperatures which ultimately results in failure. It differs from the matter of "hot strength" in that the time element is involved. Turbine buckets formed of an alloy as herein disclosed have excellent resistance to "creep." This should not be confused with "red hardness" which is not the same as "hot strength."

Turbine buckets formed of an alloy as herein disclosed also have great resistance to oxidation and corrosion. The exhaust gases of an airplane engine are of high temperature and contain corrosive products such as sulphur compounds and possibly also anti-knock compounds. At any rate, turbine buckets of the class described are subjected to severe oxidizing and corroding conditions, and it has been found that buckets formed of an alloy as herein disclosed stand up excellently in this type of service. On tests, they have shown no deterioration other than a slight surface discoloration, whereas buckets made out of other alloys—for instance, nickel alloys—have shown definite deterioration.

As a further aspect, there is the matter of resistance to erosion by hot gases. Hot gases and vapors—as, for instance, steam, have a tendency to wear away metal by their mechanical action. In other words, they cause erosion. Where this is combined with the effect of corrosion and oxidation, as in turbine buckets of the class described, the effect may be quite severe. Buckets formed of an alloy as herein disclosed have excellent resistance to erosive influences.

There are also other important aspects—for instance, the matter of slight shrinkage upon solidifying—which enter into the making of sound turbine bucket castings.

Moreover, the alloy bucket as herein disclosed has a very high degree of resistance to repeated stresses. In other words, it is highly resistant to fatigue failure. This is important in a turbine bucket of the class described which is highly stressed and operates at extremely high rates of speed, and which may be subject to vibrations, synchronous or otherwise. Probably the resistance to fatigue breakage is related to the favorable damping characteristics of the alloy in its cast form. In this connection it will be noted that, in general, cast metals have a greater damping effect than forged or machined metals.

Referring to the bucket as a cast product, it is important to note that cast buckets which have been made have proved to be sound, in general, whereas the forged buckets have given a great deal of trouble due to internal defects, such as forging cracks which are hard to discover by X-ray. The alloys which are suitable for turbine buckets on account of their strength and hardness at high temperatures are generally hard to handle by forging. Consequently, there is a great likelihood of cracks in forged and machined buckets.

Buckets made in accordance with the present invention have been tested by X-ray and have been found to be uniformly sound and reliable. Forged buckets, on the other hand, sometimes have concealed defects which are difficult to discover, even by X-ray, such as internal cracks resulting from the forging operations. In an article, such as a turbine bucket for exhaust turbine superchargers, this, of course, is a very serious objection.

As a result of the casting method, the accuracy of the bucket is such that machining and grinding are reduced to an extremely small amount.

With the low carbon content as set forth in connection with the preferred forms of alloy, tough cast buckets are produced. With this low carbon content the molybdenum content is believed to make up the necessary strength and stiffness. Toughness and cold ductility are highly advantageous properties in buckets of the class described.

With the low carbon content as set forth in connection with the preferred forms of alloy, the resulting buckets appear to be better on account of there being less likelihood of internal structural changes under the conditions of service to which such buckets are put.

I am unable to state with certanty all considerations in connection with the present invention, and therefore I reserve the right to supplement and correct any considerations herein set forth. For example, it is conceivable that with higher carbon content, carbide precipiation may occur through the action of high temperature and time which would result in embrittlement of the bucket.

As will appear from Charles H. Prange Patent No. 2,135,600, molybdenum may be substituted for carbon, and a substantially carbonless alloy of high strength and corrosion resistance may be made by increasing the percentage of molybdenum. As indicated in the last mentioned patent, molybdenum, to excess, will cause both brittleness and high melting points.

There are other considerations in connection with carbon about which I am not fully aware. For instance, it is conceivable that a composition having a substantially zero carbon content might not be stable when exposed to exhaust gases which contain carbon monoxide and carbon dioxide at high temperatures. In short, a carburizing effect may occur, so that the carbonless alloy would take up carbon gradually and become brittle. It is possible in this connection that the preferred forms of alloy—and particularly the alloy containing about .25% carbon—is an exceptionally favorable one for the purposes of the present invention in that having some carbon in it, it would be less likely to take up more carbon and thereby become brittle.

It is to be understood that tungsten may operate in a similar role to molybdenum as replacing carbon, increasing amounts adding strength and stiffness, and, of course, there is the limitation as expressed in the patents hereinbefore identified that excesses of tungsten will produce brittleness and difficult melting.

As between molybdenum and tungsten, it is felt that molybdenum is preferable. With it, it is possible to retain a greater degree of toughness or ductility while at the same time attaining strength and stiffness. Furthermore, it is found that the molybdenum alloy has somewhat great corrosion resistance than the tungsten alloy.

The resulting buckets have not only accuracy and the other properties herein set forth, but they are smooth of surface. This results mainly from the character of the alloy and the method of spraying on a thin coat of investment over the wax pattern before investing it. The investment herein referred to is inert so that no carburization or decarburization or sulphidization occurs.

Referring again to the drawing, the cast buckets **16** selected for illustration have concave front or leading surfaces **28** arcuate in transverse section as shown in Figure 5 and extending radially from the periphery of the rotor or turbine wheel **14** when the buckets are applied thereto. The back surface **29** of the bucket follows generally the contour of the concave front surface **28**. The inner end of the bucket has an enlarged flattened neck or tongue **30** adapted to enter a transverse slot **31** in the periphery of the turbine wheel **14**. Extending transversely along the inner end of the neck or tongue **30** is an integral rounded head or enlargement **32** which enters a corresponding enlargement **33** at the inner end of the slot **31** for fastening the blade or bucket in place on the periphery of the wheel **14**. Alternate buckets **16** preferably have long and short necks **30** as shown in Figure 2, in order to avoid weakening of the wheel **14**, a continuous circle of the buckets **16** being mounted around the periphery of the wheel as shown.

The outer ends of the buckets **16** have generally rectangular end walls **34** which cooperate, as shown in Figure 2, when the buckets are in place on the wheel. Transverse ribs **35**, one integral with the back of each bucket, seat in and interlock with transverse grooves **36**, one in the front of each bucket when the buckets are in place in the periphery of the wheel.

The circle shown in dotted lines at **38** in Figure 3 indicates the position of small circular projections which are the remains of the sprues where they have been cut off. These small circular projections are preferably ground off or removed, and, therefore, are not shown in Figure 2.

The embodiment of the invention shown in the drawing is for illustrative purposes only, and it is to be expressly understood that said drawing and the accompanying specification are not to be construed as a definition of the limits or scope of the invention, reference being had to the appended claims for that purpose.

For example, different designs of buckets attached to the wheel by various types of welding, both fusion and resistance, are contemplated within the scope of the present invention. As a matter of fact, the alloys herein disclosed are favorable for welded construction because they are not subject to carbide precipitation and consequent embrittlement and lowered corrosion resistance, as is the case with certain other alloys, as, for instance, stainless steel.

Attempts have been made to make turbine buckets by powder-metallurgy—that is, by pressing and sintering. So far, these attempts have not been successful because they have not been able to get the required properties. The alloy herein disclosed in cast form is stronger and does not have the minute porosity found in articles molded from powder. One disadvantage of this porosity is a decreased thermal conductivity which may be important in an air-cooled bucket—that is, one having an internal cooling passage.

I also contemplate, within the scope of the appended claims, casting the whole turbine wheel in one piece, that is, casting the wheel and the bucket as an integral or unitary construction.

I claim:

1. As a new article of manufacture, a turbine bucket for a turbine wheel in which the bucket is directly exposed to a high temperature high velocity stream of combustion gases for driving the wheel at high peripheral speed, said bucket being cast of a cobalt-chromium alloy containing cobalt 50% to 70%, chromium 20% to 40%, molybdenum 3% to 7%, and carbon up to 0.5%, said alloy bucket being practically incapable of being machined and worked and having high tensile strength and high resistance to corrosion and erosion by the combustion gases at temperatures on the order of 1500° F.

2. As a new article of manufacture, a turbine bucket for a turbine wheel in which the bucket is directly exposed to a high temperature high velocity stream of combustion gases for driving the wheel at high peripheral speed, said bucket being cast of a cobalt-chromium alloy containing cobalt 50% to 70%, chromium 20% to 40%, metal from the group consisting of molybdenum and tungsten 3% to 7%, and carbon up to 0.5%, said alloy bucket being practically incapable of being machined and worked and having high tensile strength and high resistance to corrosion and erosion by the combustion gases at temperatures on the order of 1500° F.

3. As a new article of manufacture, a turbine bucket for a turbine wheel in which the bucket is directly exposed to a high temperature high velocity stream of combustion gases for driving the wheel at high peripheral speed, said bucket being composed of an alloy containing cobalt 60% to 70%, chromium 23% to 32%, molybdenum up to 7%, and carbon up to 0.5%, said alloy bucket being resistant to the high temperatures and accompanying high stresses at the periphery of the turbine wheel.

4. As a new article of manufacture, a turbine bucket for a turbine wheel in which the bucket is directly exposed to a high temperature high velocity stream of combustion gases for driving the wheel at high peripheral speed, said bucket being cast of an alloy containing cobalt 60% to 70%, chromium 23% to 32%, molybdenum up to 7%, and carbon up to 0.5%, said alloy bucket being resistant to the high temperatures and accompanying high stresses at the periphery of the turbine wheel.

5. A turbine bucket for a turbine wheel in which the bucket is directly exposed to a high temperature high velocity stream of combustion gases for driving the wheel at high peripheral speed, said bucket being composed of an alloy containing cobalt approximately 65%, chromium approximately 27.5%, molybdenum 5% to 6%, and carbon approximately 0.25%, said alloy bucket being resistant to the high temperatures and accompanying high stresses at the periphery of the turbine wheel.

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