May 26, 1959 E. G. PEKAREK 2,888,244

FLUID DIRECTING MEMBER

Filed May 24, 1956 2 Sheets-Sheet 1

Fig. 1

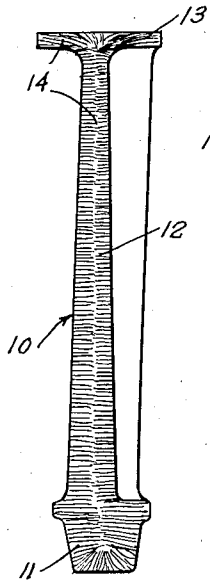


Fig. 2

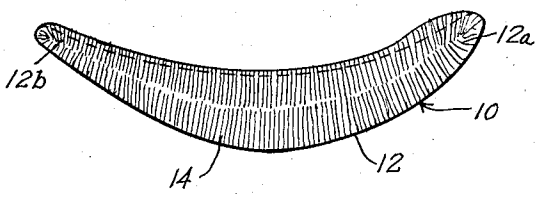


Fig. 3

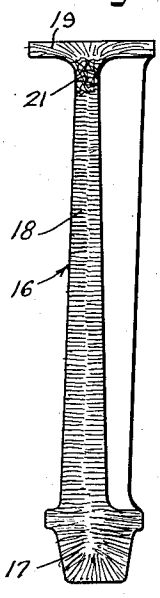


Fig. 4

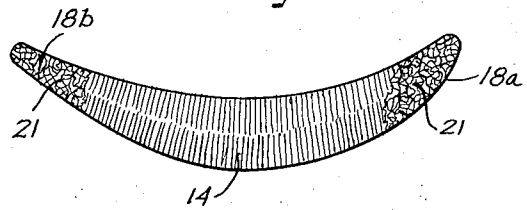


Fig. 5

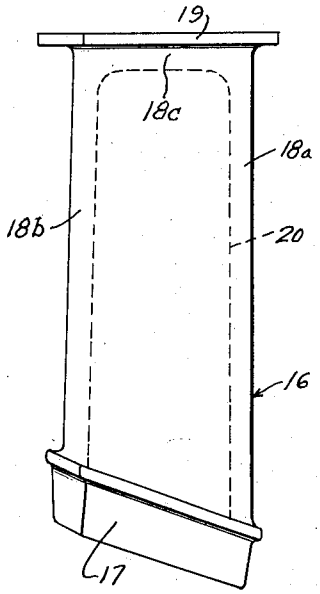


Fig. 6

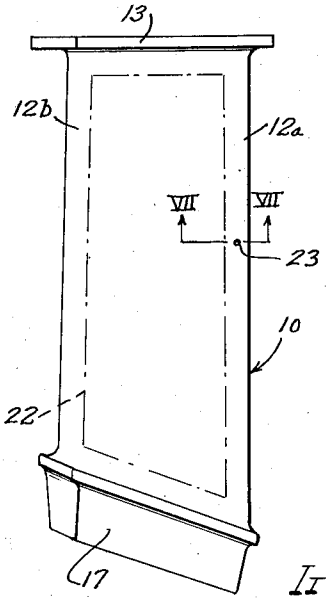


Fig. 7

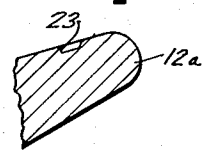
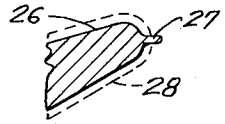


Fig. 8



Fig. 9



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FLUID DIRECTING MEMBER

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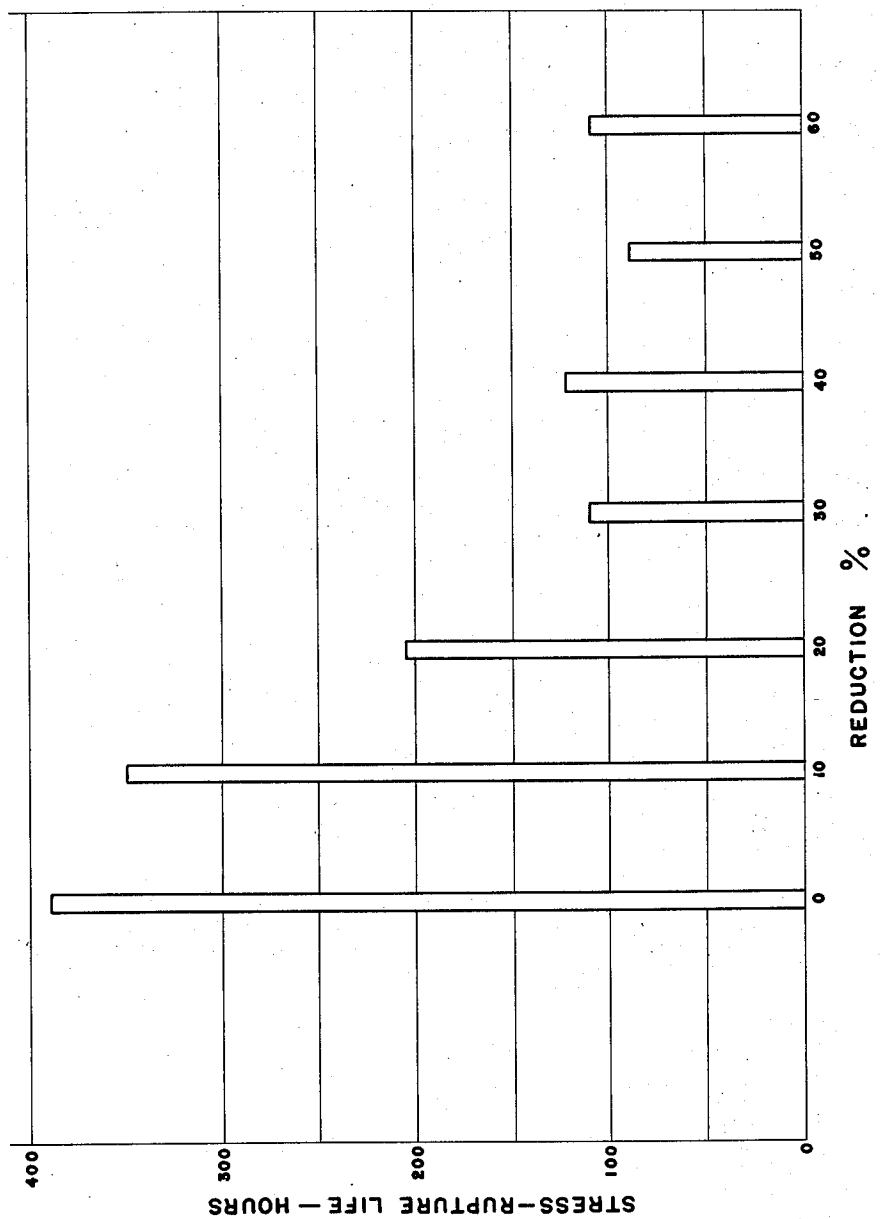


Fig. 10

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2,888,244

FLUID DIRECTING MEMBER

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Application May 24, 1956, Serial No. 586,995

5 Claims. (Cl. 253—77)

The present invention relates to improvements in fluid directing members and, in particular, deals with improvements in parts adapted for use in jet engines.

In the manufacture of parts such as turbine buckets, compressor blades, nozzle diaphragm vanes and the like, there is presented the problem of providing a complex shape to within very close tolerances. Coupled with this requirement is the necessity of employing a strong, creep resistant metal or alloy for the body of the element which is capable of withstanding a combination of complex, superimposed thermal fatigue and bending stresses. In many cases, suitable metals or alloys due to their refractory nature cannot be adapted to conventional forging practices without considerable difficulty, or they may require the employment of investment casting procedures to permit their fabrication into useful parts. Even with these modifications, however, the number of rejects was high and the processes were accordingly quite expensive.

The present invention overcomes these difficulties and provides a fluid directing member composed of an integral casting with portions thereof being selectively treated to permit those portions to resist more adequately the types of stresses to which they are subjected during operation.

An object of the present invention is to provide an improved fluid directing member which can be shaped by conventional hot-working procedures.

Another object of the invention is to provide a fluid directing member of the turbine blade type from an integral casting, with localized areas of said fluid directing member being treated to provide in the member localized areas capable of more adequately resisting the particular types of stresses to which those areas are subjected during operation.

Another object of the present invention is to provide a fluid directing member from alloys in the as cast condition, with selected portions thereof being in a wrought condition.

The fluid directing member of the present invention is particularly adapted to use in conditions of high temperatures and extreme stresses, such as exist in the operation of a jet turbine engine. Such fluid directing members may, for example, take the form of turbine buckets, compressor blades and nozzle diaphragm vanes each of which must be capable of resisting corrosion, and each of which has its own combination of working stresses which must be resisted adequately at the operating temperatures employed. A turbine bucket, for example, is subjected during use to various types of stresses. The turbine bucket is subjected to creep stresses in the root area of the bucket during operation due to the effects of centrifugal force. At the same time, the tip end of the vane, and the leading and trailing edges of the turbine bucket are subjected to fatigue stresses occasioned by vibration and thermal stresses due to rapid changes in temperature along the edges. In order to resist the stresses adequately, the metallurgical properties of the bucket, according to

the present invention, are varied in accordance with the type of stress to which the particular area involved is to be subjected.

The process for making the fluid directing members of the type described above may consist first in casting the metal or alloy under vacuum conditions to produce a relatively ductile preform. This preform is made somewhat oversize in selected degrees, so that after a subsequent working operation, such as coining, the finished part has the correct dimensions and the areas in which the excess metal appears in the preform are transformed into a wrought condition which is better able to resist fatigue stresses and thermal stresses.

The present invention may employ alloys which have heretofore been of limited utility in this field because of the difficulty of forging such alloys from bar stock or ingot form. Particularly good results have been obtained with nickel base, precipitation hardenable alloys containing from about 13 to 21% chromium, from 1.0 to 6.0% molybdenum, from 1.0 to 4.0% aluminum, from 1.5 to 3.5% titanium, a maximum of about 0.2% carbon, and in some cases, from about 10 to 35% cobalt, with the balance being substantially nickel. A particularly preferred alloy has the following composition:

C	0.1 to 0.2% by weight.
Mn	0.25 maximum.
Si	0.60 maximum.
Cr	14 to 17%.
Mo	4.5 to 6.0%.
Ti	1.5 to 2.5%.
Al	2.5 to 3.5%.
B	.025 to .07%.
Fe	8 to 12%.
Ni	Substantially the balance.

Another suitable alloy is that known commercially as "Waspaloy" having the following analysis:

C	0.1 maximum.
Cr	18.0 to 21.0%.
Co	12.0 to 15.0%.
Mo	3.5 to 5.0%.
Al	1.0 to 1.5%.
Ti	2.75 to 3.25%.
Ni	Substantially the balance.

The original casting is made under vacuum conditions in order to secure greater high temperature strength and a higher degree of ductility in the casting. In making the casting, pressures on the order of less than one millimeter of mercury and preferably not in excess of about 100 microns of mercury are appropriate. Satisfactory results can also be obtained by remelting a master melt previously made under vacuum conditions in an inert atmosphere.

The casting which results, particularly if cooled relatively slowly, is likely to exhibit a coarse crystalline structure characterized by the presence of dendrites. One of the features of the present invention resides in maintaining the as-cast structure in portions of the fluid directing member, particularly in the relatively massive root portion of a turbine blade and in the airfoil area adjacent to the root. Tests have indicated, for example, that the as-cast condition provides a better resistance to creep stresses than does a relatively fine crystalline structure typical of a hot-worked alloy composition.

A further description of the present invention will be made in conjunction with the attached sheets of drawings which illustrate the improved article of the present invention and a method for its preparation.

On the drawings:

Figure 1 is a cross sectional view of a preform used

in the manufacture of a turbine bucket according to the present invention;

Figure 2 is a greatly enlarged cross sectional view of the vane portion of the preform, illustrating its crystalline structure;

Figure 3 is a view similar to Fig. 1, but illustrating the grain structure of the turbine bucket after portions of the bucket have been converted to a wrought condition;

Figure 4 is a view similar to Fig. 2 illustrating the crystal structure of the vane portion existing in the turbine bucket of Fig. 3;

Figure 5 is a view in elevation of the completed turbine bucket;

Figure 6 is a view in elevation of a preform having a flaw therein;

Figure 7 is a greatly enlarged fragmentary view taken substantially along the line VII—VII of Fig. 6 to illustrate the flaws;

Figure 8 is a view similar to Fig. 7 but illustrates the condition of the preform after the flaw has been ground down;

Figure 9 is a view like Fig. 7 except that it illustrates the area of the flaw after the working operation; and

Figure 10 is a graph illustrating the effect that the amount of reduction has upon the stress rupture life of the alloy samples.

As shown on the drawings:

In Fig. 1, reference numeral **10** indicates generally a preform for the manufacture of a shrouded turbine bucket which includes a relatively massive base or root portion **11**, an arcuate twisted vane portion **12** and a relatively thin shroud **13**. As seen in both Figs. 1 and 2, the preform **10** is in the as cast condition, having been produced either by melting under vacuum conditions, or by remelting a master melt from a vacuum melting under inert conditions. If the preform is cooled slowly as in conventional investment casting practice, the metallurgical structure thereof will be characterized by a large number of coarse grained dendrites **14** as illustrated in Figs. 1 and 2.

As shown in Fig. 2, the van portion **12** of the preform **10** is made oversize, the amount of oversizing being greatest, as indicated by the dashed line which defines the ultimate shape of the vane portion, at the leading edge **12***a* and the trailing edge **12***b* of the preform **10**. The excess metal at these portions is provided so that subsequent hot working of the metal will be effective to reduce the oversize areas of the preform **10** to the desired dimensions and simultaneously provide a wrought condition in those areas of the turbine bucket.

As illustrated in Figs. 3 and 4, the preform **10** after hot working, such as by a coining operation, is converted to the finished turbine bucket **16** having a relatively massive root portion **17**, an arcuate, contoured vane portion **18** and a shroud **19**. The areas adjacent the leading edge **18***a*, the trailing edge **18***b*, and the area immediately below the shroud **19**, designated by **18***c* (Fig. 5) are all worked to the extent of providing a wrought structure in those portions of the bucket. The dashed line labeled **20** in Fig. 5 outlines the worked areas on the vane portion.

As best illustrated in Figs. 3 and 4, the wrought structure is characterized by a large number of relatively small grains **21** in the worked areas, leaving the dendrites **14** centrally of the turbine bucket (and also in the root portion **17**). With this type of structure, the portions of the bucket which are most likely to be subjected to fatigue stresses contain the fine grained structure while those portions of the bucket which must resist centrifugal forces tending to produce creep stresses remain in the as cast condition in which the crystalline form is relatively coarse.

The temperature of hot working may vary considerably, depending upon the composition, but ordinarily temperatures on the order of about 1950 to 2150° F. are appropriate for nickel base alloys.

One of the advantages of providing an oversized preform according to the process described is the ability to correct minor surface defects in the turbine bucket during the final hot working operation. Ordinarily, minor surface defects may be tolerated in the central portion of the vane but not in the portions of the bucket adjacent the leading and trailing edges, and adjacent the shroud or root. The inner outline of these critical areas has been designated in Fig. 6 of the drawings by the dashed line labeled **22**.

Such surface defects are most likely to occur in the relatively thin leading edge or trailing edge portions and one such defect, identified at numeral **23**, has been indicated in Figs. 6 and 7 of the drawings. To eliminate this defect, the flaw **23** is ground down to produce a relatively shallow depression **24** as illustrated in Fig. 8 of the drawings and then the preform **10** is subjected to the coining operation. The flow of metal which results during the coining operation due to the excess of metal located in the areas of the leading edge **12***a* fills up the void created by the depression **24** and creates a substantially smooth contour as indicated at numeral **26** in Fig. 9. The flow of metal during coining also produces a flash **27** which can easily be trimmed off the coined article. The dotted line **28** in Fig. 9 indicates the original dimensions of the preform.

The substantial improvement in stress rupture life of an as cast specimen as compared to a wrought specimen is best illustrated in the graph of Fig. 10. After a reduction of about 30%, the stress rupture life of the sample alloy levels off at about 100 hours, whereas in the unreduced or as cast condition, the stress rupture life of the same alloy was in the neighborhood of 400 hours. These differences in stress rupture life are directly related to the ability of the alloy to resist creep at elevated temperatures. On the other hand, it has been demonstrated that fine grained wrought material has greater fatigue strength than large grained castings.

From the foregoing, it will be evident that the fluid directing member of the present invention provides a single integral structure with localized areas particularly adapted to resist those stresses which they encounter in normal operation. It will also be evident that various modifications can be made to the described embodiments without departing from the scope of the present invention.

I claim as my invention:

1. A fluid directing member subject to creep stresses and fatigue stresses during use comprising a relatively massive root portion and a relatively thin vane portion, said root portion and said vane portion being composed of an integral metal casting, said root portion being characterized by a relatively coarse crystalline structure, and the leading and trailing edges of said vane being characterized by a relatively fine grained crystalline structure.

2. A fluid directing member comprising a relatively massive root portion and a relatively thin vane portion, said root portion and said vane portion being composed of an integral metal casting, said root portion being characterized by a relatively coarse crystalline structure including dendrites and the leading and trailing edges of said vane being characterized by a relatively fine grained crystalline structure.

3. A fluid directing member subject to creep stresses and fatigue stresses during use comprising a relatively massive root portion and a relatively thin vane portion, said root portion and said vane portion being composed of an integral metal casting consisting essentially of a nickel base precipitation hardenable alloy, said root portion being characterized by a relatively coarse crystalline structure, and the leading and trailing edges of said vane

being characterized by a relatively fine grained crystalline structure.

4. A fluid directing member subject to creep stresses and fatigue stresses during use comprising a relatively massive root portion, a relatively thin vane portion, and an outwardly flared shroud, said root portion and said vane portion being composed of an integral metal casting, said root portion and said shroud being characterized by a relatively coarse crystalline structure, and said vane portion having a leading edge and a trailing edge, both characterized by a relatively fine grained crystalline structure.

5. A turbine bucket comprising a relatively massive root portion and a relatively thin vane portion, said root portion and said vane portion being composed of an integral metal casting, said root portion being characterized by a relatively coarse crystalline structure and the airfoil edges of said vane being characterized by a relatively fine grained crystalline structure.

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