July 24, 1962 D. J. CLARKE ET AL 3,045,967

HOLLOW BLADES AND MANUFACTURE THEREOF

Original Filed April 12, 1952 2 Sheets-Sheet 1

FIG.-1

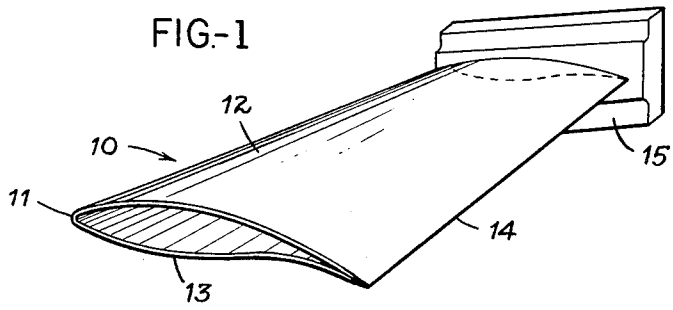


FIG.-2

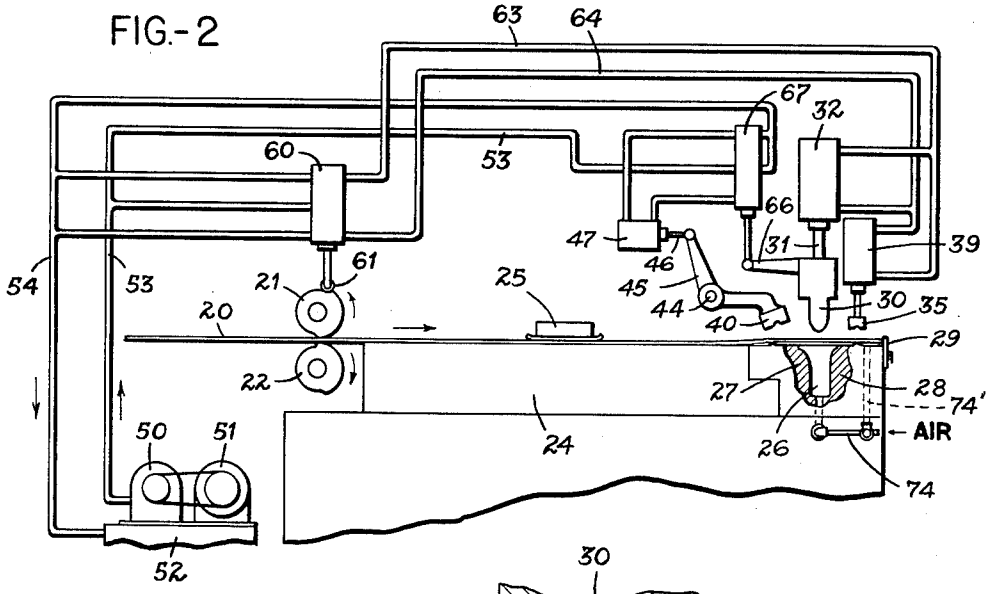


FIG.-3

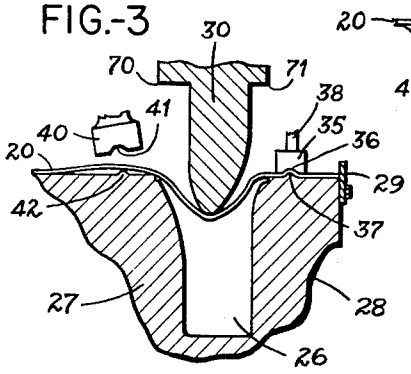
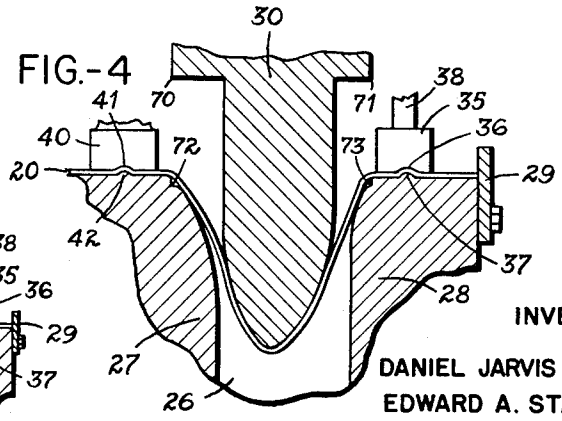


FIG.-4



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HOLLOW BLADES AND MANUFACTURE THEREOF

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FIG-5

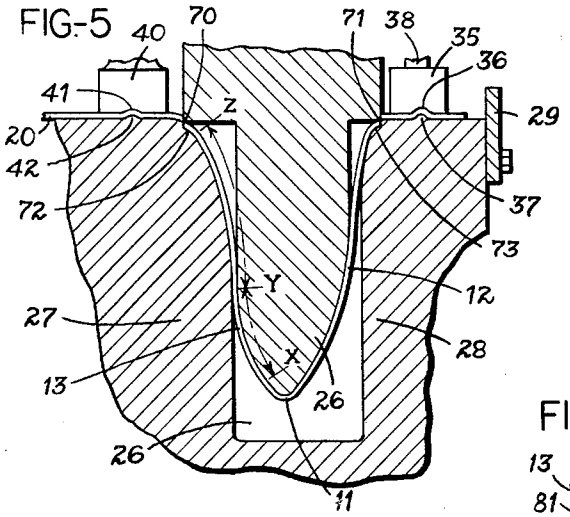


FIG-6

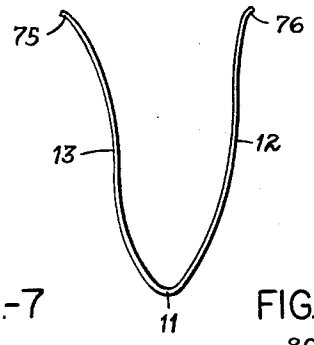


FIG-7

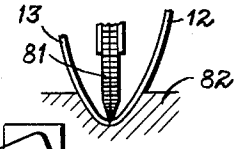


FIG-8



FIG-9

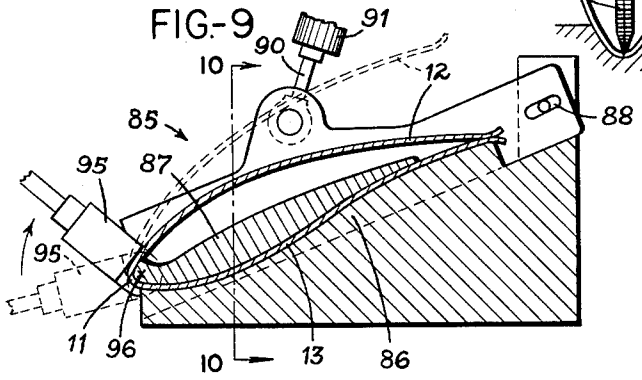


FIG-10

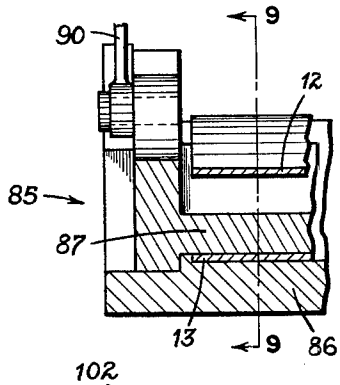


FIG-11

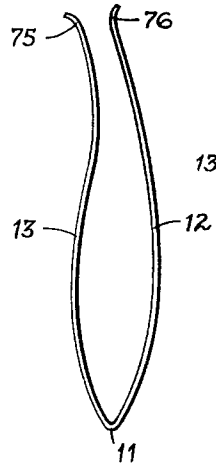


FIG-12

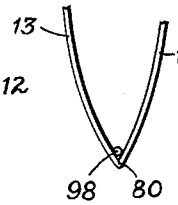


FIG-13

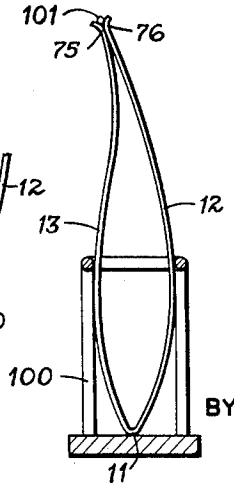
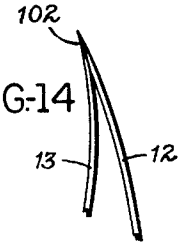


FIG-14



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3,045,967

Patented July 24, 1962

3,045,967

HOLLOW BLADES AND MANUFACTURE THEREOF

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Original application Apr. 12, 1952, Ser. No. 282,012. Divided and this application Apr. 17, 1957, Ser. No. 653,342

1 Claim. (Cl. 253—77)

This invention relates to hollow fluid turning blades for compressors, turbines and the like and to methods and apparatus for producing the same.

An object of the invention is to provide a hollow blade for compressors, turbines and the like which is formed of an integral piece of sheet metal and which is accurately formed throughout to the desired contour and which upon formation is substantially free of internal stress and tendency to deform under the conditions to which it is subjected in use.

A further object is to provide a process for producing hollow blades for this purpose by means of which the blade may be formed with the precise contour desired and in a manner which is both rapid and economical.

It is a further object to provide apparatus for so forming hollow blades of this character.

Other objects and advantages will be apparent from the following description, the accompanying drawings and the appended claim.

In the drawings—

FIG. 1 is a view in perspective of a form of hollow blade constructed in accordance with the present invention;

FIG. 2 is a view showing apparatus used in accordance with the invention in the formation of the blade;

FIGS. 3, 4 and 5 are sectional views on a different scale showing successive stages in the forming operations carried out in the forming press;

FIG. 6 is a view of a typical blade blank as formed in the press;

FIG. 7 is a detail view showing the method of cutting a groove in the nose of the blade to produce blades having a small radius in the leading edge;

FIG. 8 is a similar view of the grooved blade produced in the manner shown in FIG. 7;

FIG. 9 is a sectional view through a wrapping machine for completing the folding of the blade and the shaping of the nose thereof;

FIG. 10 is a partial sectional view through the wrapping machine of line 10—10 of FIG. 9;

FIG. 11 is a view showing the completed blade blank in end elevation;

FIG. 12 is a view showing a portion of the blade with a reduced radius leading edge in preparation for final processing;

FIG. 13 is a view showing the blade in a supporting fixture for completing the securing of the edges at the trailing edge of the blade; and

FIG. 14 is a detail view showing the finished shape of the trailing edge of the blade.

This application is a division of copending application Serial No. 282,012 filed April 12, 1952, now abandoned.

The invention relates to the making of hollow fluid turning blades such as those utilized in compressors, turbines and the like where the blades are necessarily subjected to severe conditions both as to the forces developed in operation and from the standpoint of the temperature and the wide variations thereof to which they are subject. It is difficult to form airfoil cross sections because of the continually varying radii of curvature along the chord and the twist along the span, and it is even more difficult to maintain a desired overall blade contour under the conditions encountered by the blade in use.

In accordance with the present invention the blade blank is stretched over dies to form accurately the upper and lower blade surface contours, these surfaces being joined by a leading edge portion also accurately defined and precisely related to the remaining portions of the blade. The blade is formed from a single sheet of metal which is stretched over cooperating male and female die surfaces to impart and produce the accurately shaped areas as desired and with the two portions of the blade forming the upper and lower surfaces respectively folded toward each other about the integral nose-forming portion. Subsequently the leading edge portion is additionally shaped to reduce the radius of curvature and to bring the trailing edges closer together, more accurately defining the correct contour for the leading edge portion. The trailing edges are then secured together without substantially changing the blade contour. The blade so formed is found to be capable of retaining its formed shape accurately and substantially without being effected by temperature changes or the mechanical forces to which it is subjected in use.

Referring to the drawings, a typical blade **10** is shown in FIG. 1 of airfoil section having a leading edge or nose portion **11**, an upper generally convex blade contour **12**, a lower blade contour **13** having both a convex and a concave portion with the junction point between the convex and concave portions located approximately midway of the chord of the blade, a trailing edge **14**, and a base **15**. The airfoil cross section may vary throughout the span and the twist of the blade may likewise be made to conform with whatever shape is desired for the finished product.

The blade is produced from either separate lengths or from a continuous strip of sheet metal or suitable material illustrated at **20** in FIG. 2. The sheet has a length sufficient to form the chord of both upper and lower surfaces and a width sufficient to form the span of the blade. A pair of feed members **21, 22**, one above and one below the sheet have raised face portions which engage the sheet to feed the same forwardly over a supporting table **24** having lateral guides **25**. The sheet advances into a press which embodies a recess **26** having female dies **27, 28** on opposite side walls thereof. The die **27** has a shape corresponding to the major portion of the lower blade surface **13** beginning somewhat rearwardly from the nose and die **28** similarly corresponds with the shape of upper blade surface **12**. The sheet may be fed into a fixed position adjacent a stop **29**.

The cooperating or male die is shown at **30** and is carried by a plunger **31** actuated from hydraulic cylinder **32**. It is rounded about a radius usually greater than but corresponding generally to the nose of the blade. The sheet is arranged to be gripped on its forward side by means of a clamp or grip member **35** which has a recess **36** opposite a rib **37** in the base of the press in order to provide for a firm and secure gripping of the sheet throughout the width thereof or for allowing some localized slippling when the clamping pressure is less to supply more material to parts of the die which due to their shape require more material. The clamp **35** is carried on a plunger **38** and is operated from hydraulic cylinder **39**.

A second clamp or gripping member **40** is located on the opposite or rearward side of the recess, and is similarly grooved at **41** for cooperative engagement of the sheet against a rib **42**, similarly extending throughout the length of the machine and hence gripping the sheet across its width to secure the same firmly or to allow localized slipping and prevent local distortions or uneven stretching as described above. Gripping member **40** is arranged on a pivot **44** and is actuated through arm **45** from plunger **46** of hydraulic cylinder **47**.

Hydraulic pressure is supplied by pump **50** driven by

motor 51 and pumping fluid from the reservoir 52. The pressure line is shown at 53 and the return line at 54.

In order to provide for proper control of the press operation in the forming of a sheet of material, a reversing valve 60 is arranged to be actuated by the feed roller 21, the valve having a follower 61 which is lifted by the high section of the roller 21 at the proper point in the cycle when the forward feeding of a length of sheet material against stop 29 has been completed. This condition is shown in FIG. 2, the continued movement of roll 21 resulting in the actuation of valve 60 to supply pressure fluid from line 53 through lines 63 and 64 which supply the operating cylinders 32 and 39 respectively. In response to such actuation the male die 30 which is directly above recess 26 moves toward the sheet and clamp 35 grips the forward edge of the sheet at one side of the recess, this latter action being completed before the male die actually engages the sheet. As the die 30 engages the sheet, it begins to form the sheet by pressing it into recess 26 and against the two female die surfaces 27, 28, the clamp 40 at the rearward side of the recess at this time being released and the sheet being allowed to slip into the recess to an intermediate position. Such intermediate position is illustrated in FIG. 4, at which time the male die 30 has moved downwardly over a predetermined part of its stroke, and in so doing has operated through arm 66 to actuate valve 67 which then supplies pressure from line 53 into the actuating cylinder 47 to thereby cause engagement of rearward clamp 40. Thus as shown in FIG. 4 both clamps are engaged and the sheet is therefore held securely on each side of the recess throughout its entire width, the force being controlled to provide for some predetermined amount of slipping. Thus it has been found that the slip may be so controlled that a total stretch of about 12 to 13% is produced, such amount being satisfactory for example with 1010 steel. This is a relatively low carbon steel and it is found desirable to reduce the stretch somewhat when using alloy steels such as stainless steel, light metals, and the like.

Forward travel of the male die member continues and this operation as will be evident results in the stretching of the sheet metal against the respective die surfaces. This stretching thus occurs uniformly within both the upper and lower blade surfaces and in a direction which is generally chordwise of the finished blade, the stretch being effected throughout the entire chord and span of the blade. The controlled gripping of the blank on both sides prevents local unevenness or tearing. As shown in FIG. 5 the metal is stretched partly against the inner or male die, on the portion forming the leading edge and the forward part of the upper and lower surface contours. This produces a convex curvature in these portions of the blank. The shaping of the dies is such that this section of the sheet is tangent to the corresponding sections against which the sheet is worked on the female die portions, the latter dies forming the rearward sections of the upper and lower blade contours. While these sections may have contours as desired, it is seen that each of the latter or female dies cooperates with the convex male die to form the entire surface from one to the other, each female die separately cooperating with the male die to develop selectively a concave or a convex curvature as desired. FIG. 5 is marked with the letters X, Y and Z indicating the different portions of the final shape of the lower blade surface 13 formed between respective dies. That is, the portion from point X to point Y is formed entirely by the male die member while the portions from point Y to point Z which includes the concave part of the lower blade is formed by the female die 27. It will be understood that the final precise shape of the leading edge of the blade and of the trailing edge is determined in the subsequent operation. Likewise it will be evident that a different but corresponding shaping of the convex upper blade surface 12 is produced by the male and female die portions 30 and 28 respectively.

In the final step of its movement, the blank is nicked or cut by the edges 70, 71 of the base of the die 30 which work against the metal and into grooves 72, 73 on opposite sides of the recess. This results in the breaking or shearing of the partially formed blank from the sheet, and the blank and scrap may then be suitably ejected by an air blast supplied through lines 74 and 74' leading respectively into the bottom of the recess and to a point adjacent stop 29.

The separated blade blank is then in substantially the form shown in FIG. 6. The nose portion 11 is curved about a somewhat longer radius than usually desired, but the upper and lower surface contours 12 and 13 respectively are essentially in their final desired shape. The edges of the blank shown at 75, 76 are curved outwardly away from each other, resulting from the final shape of the female dies 27 and 28 and the shearing cutters operating to cut the blank from the sheet. Also it will be noted that the two portions of the blank are not folded fully upon each other but stand apart from each other.

In some cases where a blade of especially small radius at the leading edge is desired the blank at this stage may be subjected to a further operation comprising forming a groove 80 extending partly through the thickness of the metal along the leading edge 11. For example the groove may have a width of about 0.02 inch and a depth of 0.01 inch where the metal is 24 gage. This groove is shown in FIG. 8 and may be formed by operating a suitable milling cutter 81 into the interior of the blade while it is held in a support 82. The open character of the blank at this stage facilitates entry of such cutter and the removal of the material in a groove extending along the blade nose make it possible in the subsequent operation to form as small a radius at the leading edge as desired.

The blank is next placed in a wrapping or folding device 85 shown in FIGS. 9 and 10. Such device embodies a lower die 86 shaped to conform with the lower blade surface 13. It likewise embodies a mandrel 87 hinged by a sliding pin and slot connection 88 to the base. An operating plunger 90 actuated by hydraulic cylinder 91 provides for the forceable clamping of the blade between die 86 and the mandrel 87 in the manner shown in FIG. 9. At this point the upper blade portion 12 occupies substantially the dotted line position as shown in this figure.

In order to reduce the radius of curvature at the nose of the blade and to form the nose accurately to the desired contour, a wrapping bar 95 is pivotally supported upon base member 85, the pivot axis indicated at 96 substantially corresponding with the center of curvature desired for the nose of the blade. Such wrapping bar is then raised from the dotted line position toward the full line position of FIG. 9, either manually or under suitable power operation, thereby forming the nose of the blank to the precise shape determined by the nose of the mandrel. Mandrels of different nose radius are provided as desired, those of smaller radius being utilized in conjunction with the blank with the groove therein as described above.

The trailing edges 75, 76 are thus brought into face-to-face contact as shown in full lines in FIG. 9. They may be sprung apart sufficiently to provide for withdrawal of the mandrel 87 either through the trailing end or spanwise of the blade as desired without impairing the shape of any portion of the blade. The blade in this condition is illustrated in FIG. 11, and may if desired be spot welded adjacent the trailing edge sections 75, 76 to retain the same together for completion of the operation. Likewise where a grooved blade is embodied any remaining portion of the groove may be filled by means of solder, brazing material or the like indicated in 98 in FIG. 12 which is placed along the groove before the closing of the trailing edge of the blade is completed.

The blade is then placed in a suitable fixture shown at 100 in FIG. 13 and similar solder or brazing material 101 is placed in the groove formed by outturned portions

75, 76 of the trailing edge. Suitable heating in a furnace, hydrogen atmosphere or the like follows with the soldering material 98 and 101 filling the grooves and forming a secure bond and retaining the trailing edges of the blade together. The final operation involves the deburring, grinding and smoothing of the trailing edge to the condition shown at 102 in FIG. 14 where it may be given as sharp a section as desired. The formed hollow blade may be attached to or mounted upon a suitable base 15 by a similar process of solder, brazing or the like, in order to provide for mounting the blades in a rotor or stator structure, as may be desired.

The invention thus provides a simple and accurate process and apparatus for forming hollow blades reliably and economically. The blade contours are determined accurately by the dies, and the remaining operation is performed without destroying these accurately developed contours. The blades so formed are thus of precisely the airfoil shape desired, and are integral and substantially free of internal stress normal to the plane thereof because of the stretching in the forming operation. Thus the blade as formed is substantially free of internal distortion-producing stress and may be said to be in a controlled stress condition. The subsequent brazing or soldering does not distort the blades, and they may be passed through a brazing furnace merely resting against a support as shown in FIG. 13, thus avoiding the necessity for any special fixture. Even without such fixtures tolerances of ± 0.005 inch on the contour are readily met. The blades likewise remain substantially free of distortion in their subsequent use, where they are subjected to high centrifugal and other forces as well as to wide variations of temperature. The stretch-forming operation so performed causes a working of the metal of the blade walls over substantially the entire extent of the blade from its leading to its trailing edge which has a stabilizing effect on the internal structure providing walls having work-formed contours with a stabilized internal structure substantially free of internal stresses of a nature which would distort the contours under heating during brazing or under the heat encountered in use, and with a characteristic modified crystalline structure which can be determined by metallography or X-ray examination.

Cross reference is made to application Serial No. 282,011 filed concurrently with said copending application.

While the forms of apparatus, process and product herein described constitute preferred embodiments of the invention, it is to be understood that the invention is not limited to these precise forms of apparatus, process and product, and that changes may be made therein without departing from the scope of the invention which is defined in the appended claim.

What is claimed is:

A hollow integral blade envelope for use in high speed axial flow compressors, turbines and the like and formed from a single relatively thin metal sheet, said blade comprising upper and lower blade walls each work-formed from the leading to the trailing edge of the blade to a predetermined blade wall contour in such manner and to such a degree that it maintains said walls in the completed blade substantially free from internal distortion producing stress and in controlled stress condition and dimensionally stable such that under high temperatures and centrifugal force encountered in use the blade is capable of mounting in close running clearance with a casing, a nose portion on said blade formed as an integral spanwise connection between said walls and including a short radius bent portion restricted to a narrow zone forward of said walls, and a trailing edge portion formed as a permanently brazed joint along the span of the blade completing the blade envelope and maintaining said stress-free blade walls in proper relation to each other.

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