

May 22, 1956

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2,746,514

MACHINE FOR MAKING COMPRESSOR BLADES

Filed April 6, 1950

2 Sheets-Sheet 1

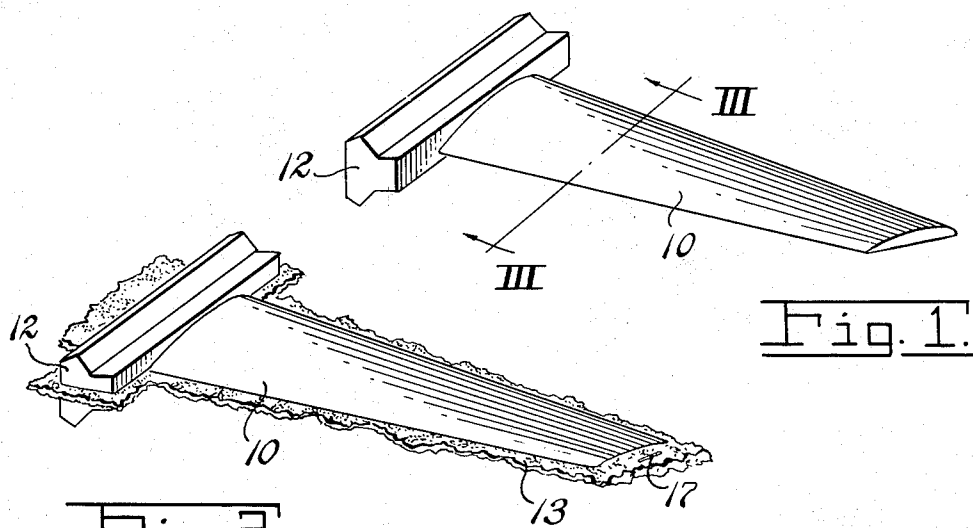


Fig. 2.

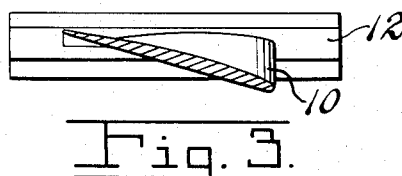


Fig. 3.

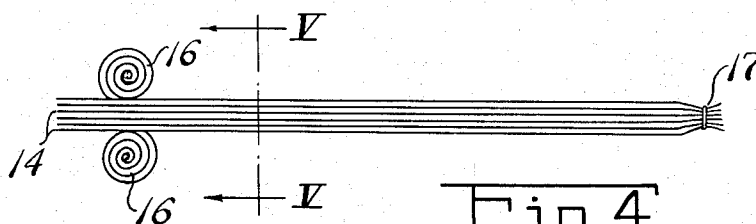


Fig. 4.

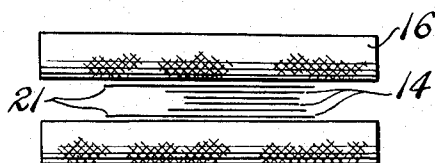


Fig. 5.

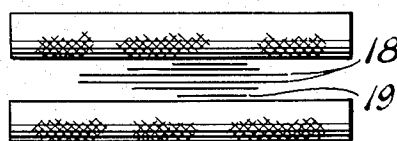


Fig. 6.

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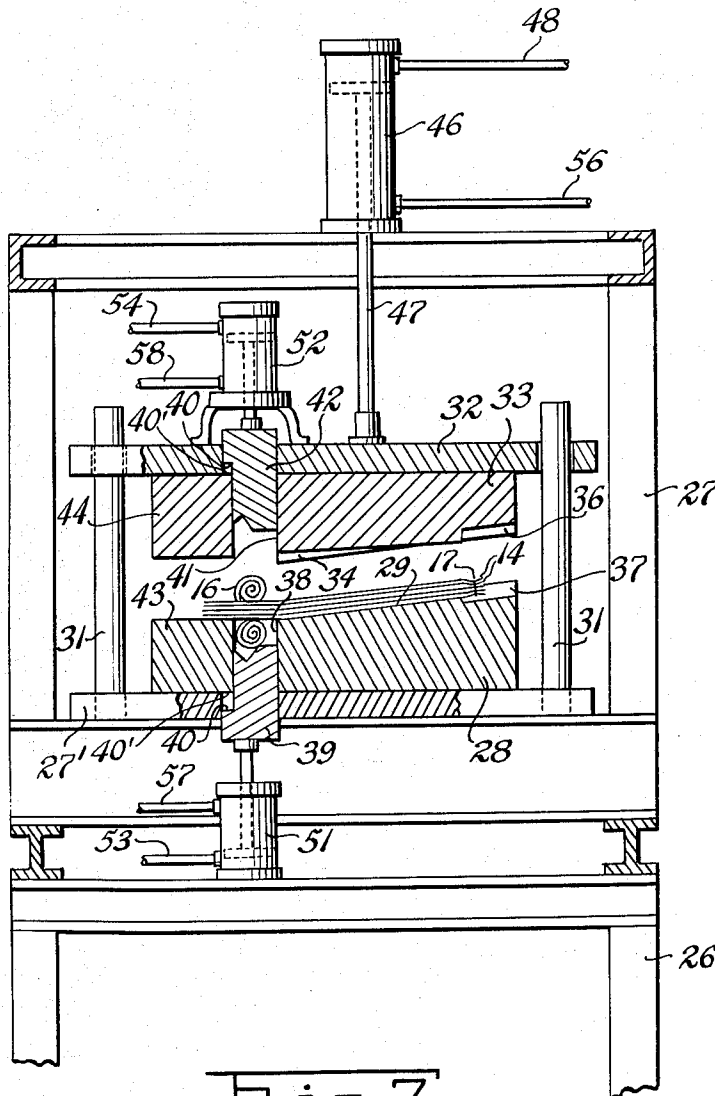


Fig. 7.

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MACHINE FOR MAKING COMPRESSOR BLADES

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Application April 6, 1950, Serial No. 154,333

1 Claim. (Cl. 154—1)

This invention relates to a blade for an axial flow compressor or the like. More particularly this invention relates to an impeller blade adapted for use in the compressor section of a jet type aircraft engine and to a machine for making such impeller blade.

Impeller blades have heretofore commonly been made of metal alloys such as alloy steels. Alloy steel blades are heavy, and, since impeller blades must travel at high speeds, only expensive and difficultly worked alloy steels may be employed in such blades. Accordingly, an object of this invention is to provide a compressor blade formed of relatively cheap readily worked material.

When alloy steel blades fail, parts thereof may be thrown by centrifugal force at high velocity like projectiles and may seriously damage the compressor housing and surrounding apparatus. Accordingly, a further object of this invention is to provide a blade which, if it fails, will disintegrate into more or less harmless particles and therefore not destroy the compressor housing.

A further object of this invention is to provide a lightweight, strong, laminated, resin-impregnated impeller blade for an axial flow air compressor.

Substantially elevated temperatures in the neighborhood of 450 degrees F. are produced in high speed air compressors. Accordingly, a further object of this invention is to provide a laminated resinous impeller blade capable of withstanding the temperatures encountered in a high speed axial flow air compressor without failure.

A further object of this invention is to provide a laminated resin-impregnated impeller blade in which the laminations of the blade proper are substantially flat and free of sharp bends or convolutions throughout their length.

A further object of this invention is to provide an inexpensive, readily formed, laminated, resin impregnated impeller blade having great strength and resistance to failure at high speed.

The above and other objects and features of the invention will in part be apparent and will in part be obvious from the following detailed description, and the drawings, in which:

Figure 1 is a perspective view showing a compressor blade constructed in accordance with an embodiment of this invention;

Fig. 2 is a perspective view showing the compressor blade illustrated in Fig. 1 prior to trimming to finished shape;

Fig. 3 is a sectional view taken along a line III—III in Fig. 1;

Fig. 4 is a diagrammatic view in side elevation showing the laminations of the blade prior to molding;

Fig. 5 is a diagrammatic sectional view taken along a line V—V in Fig. 4;

Fig. 6 is a view similar to Fig. 5 but showing a different arrangement of laminations; and

Fig. 7 is a view partly in side elevation and partly in vertical section of a machine for forming the compressor blade illustrated in Fig. 1.

In the following detailed description, and the drawings, like reference characters indicate like parts.

In Fig. 1, a compressor blade is shown which is constructed in accordance with this invention. The compressor blade includes a main or airfoil portion 10 and a root 12. Both main portion 10 and root 12 are formed from resin impregnated laminations of glass fibre cloth molded to the shape shown. When the blade is first removed from the mold, the blade has the appearance shown in Fig. 2 having irregular edges or flash 13 which may be trimmed away to form the completed blade shown in Fig. 1. The resin preferably is a phenol-formaldehyde resin.

The blade is molded from a plurality of resin-impregnated laminations having resin carried to a B-stage or semi-cured state. The laminations are arranged in the manner illustrated in Figs. 4 and 5. As shown in Figs. 4 and 5, the main portion of the blade is formed from a plurality of substantially flat laminations 14 which are mounted one on top of the other in a pile. At the root end of the pile of flat laminations, a pair of convolutely wound laminations 16 are disposed on opposite sides thereof. As shown in Fig. 4, the convolutely wound laminations extend transversely of the flat laminations. When the blade is molded, the convolutely wound laminations 16 form root 12 of the blade, and the flat laminations form main portion 10 of the blade.

As shown in Fig. 5, the flat laminations vary in width, the inner laminations being somewhat narrower than the outer laminations so that there is a greater thickness of laminations near and slightly spaced from the center line of the blade than at the edges. The flat laminations may be held together by a staple 17 during molding. When the laminations are molded, the main portion is formed into an airfoil as shown in Fig. 3.

It is not necessary that the flat laminations be arranged precisely as shown in Fig. 5. An alternate arrangement of the flat laminations is shown in Fig. 6. In the arrangement shown in Fig. 6, central laminations 18 are somewhat wider than the outer laminations 19. However, the same effect is obtained as with the arrangement shown in Fig. 5 when the blade is molded, and the number of laminations adjacent the center line of the blade is greater than at the edges in both arrangements. The arrangement shown in Fig. 5 is the preferred arrangement in that a pair of wide laminations 21 cover all inner laminations, and the wide outer laminations cover the side edges of the inner laminations. Preferably, the outer laminations are formed from glass fibre cloth having a somewhat closer weave than the inner laminations. In a preferred form of this invention, the inner laminations may be cloth woven from glass fibres having 40×39 threads to the inch while outer or covering laminations 21 may have approximately 58×57 threads to the inch. In the preferred form, the cloth of the convolutely wound laminations 16 may have approximately 48×38 threads to the inch. In the drawings, for ease of illustration, only a few flat laminations are shown. However, it is to be understood that the number of flat laminations may be increased or decreased as required to form a blade of desired thickness. For example, a blade 1/8 inch thick may contain about 11 layers or laminations.

The assembly of laminations illustrated in Figs. 4 and 5 may be molded in a machine of the type illustrated in Fig. 7 to form the intermediate blade construction illustrated in Fig. 2. The machine illustrated in Fig. 7 includes a base 26 upon which a die support frame 27 is carried. Frame 27 supports a stationary press plate 27', on which is mounted a stationary die 28 having an upwardly facing die face 29. In addition, the plate 27' supports two pillars 31 at opposite ends of stationary die 28 which

form guides for a floating platen 32. The platen 32 carries a movable die 33 which is vertically reciprocable with platen 32 toward and away from die face 29. Movable die 33 has a lower die face 34 opposite die face 29, and die faces 29 and 34 are adapted to engage flat laminations 14 to form the flat laminations into the main or airfoil portion of the blade. The dies 28 and 33 are cut away at one end, as indicated at 36 and 37 respectively, to provide a slot into which the portion of the pile of laminations 14 which carries staple 17 may extend so that the ends of the laminations 14 to the right of die faces 29 and 34, as shown in Fig. 7, are exposed during the molding.

At the left hand end of die face 29 of stationary die 28, a vertical slot 38 is provided through which a lower, movable, root-forming die 39 is reciprocable. Opposite slot 38 main movable die 33 is cut away to form a slot 41 through which an upper movable, root-forming die 42 is vertically reciprocable. The root forming dies 39 and 42 have cooperating die faces which form the convolutely wound laminations into the root portion of the blade. The root forming dies are equipped with stop shoulders 40 which can engage cooperating stop shoulders 40' on the main dies for limiting the advance of the root-forming dies. The stops are arranged to prevent the root-forming dies from extending past the main die faces so that the root forming dies do not engage the flat laminations.

Stationary die 28 includes a gripping shoe 43 to the left of slot 38 (Fig. 7). Shoe 43 is disposed opposite a corresponding shoe 44 on main movable die 33. The shoes 43 and 44 grip and hold the left hand end of the pile of laminations 14 as die faces 29 and 34 mold the airfoil portion of the blade so that, when the root forming dies are advanced together upon the convolutely wound laminations 16, the flat laminations 14 are held flat and are not caused to fold or buckle as the root portion of the blade is formed.

The machine illustrated in Fig. 7 is provided with hydraulically powered cylinders for operating the movable dies. An hydraulic cylinder 46 mounted on frame 27 has its piston and piston rod 47 connected to platen 32. The platen is moved downwardly when fluid under pressure is delivered into the upper end of the cylinder from a supply line 48. The platen 32 is raised when pressure is applied to the lower end of the cylinder by supply pipe 56. When platen 32 is moved downwardly it is forced toward stationary die 28 to apply pressure to the flat laminations and thereby mold and form them into the main or airfoil portion of the blade. As dies 28 and 33 mold the main or airfoil portion of the blade, shoes 43 and 44 squeeze and hold the left hand end of the pile of laminations so that the pile of flat laminations is held at both ends. While so held the root end of the pile lies between the root forming dies. The root forming dies are actuated by power cylinders 51 and 52. When the main movable die has been brought into engagement with the flat laminations, fluid under pressure is delivered into the lower and upper ends respectively of cylinders 51 and 52 through feed lines 53 and 54 whereby the piston rods thereof force the root forming dies into engagement with the convolutely wound laminations and form the root portion of the blade.

As shown in Fig. 7, cylinder 51 is attached to the stationary framework of the machine, while cylinder 54 is attached to and rides up and down with floating platen 32. The cylinders 51 and 52 are provided with pressure lines 57 and 58 respectively whereby fluid under pressure delivered to the cylinders causes return of the movable dies to the retracted positions shown in Fig. 7.

The operation of the machine in molding the laminations into a compressor blade will be clear from the foregoing detailed description and the drawings. The laminations are preferably assembled in the manner shown in Figs. 4 and 7. The convolutely wound lamina-

tions are preferably disposed as shown in Fig. 7 with the free lengthwise edges of the convolutely wound laminations abutting the outer laminations of the pile of flat laminations so that the free edges of the convolutely wound laminations are covered when the blade is molded. The flat laminations are gripped and formed by the main dies prior to molding of the root portion of the blade. Thereafter, the root forming dies are advanced toward each other to grip and mold the convolutely wound laminations 16 into the root of the blade. The dies may be heated to an appropriate temperature at which the resin impregnant can flow so that a firm lasting bond is provided at the root of the blade between the convolutely wound laminations and the flat laminations by appropriate heating means (not shown). When the blade has been molded, the dies are retracted, and the blade has the appearance shown in Fig. 2. The blade then can readily be finished by trimming and removing the flash 13 to form a finished blade as shown in Fig. 1.

The blade of the invention is substantially stronger per unit weight than a conventional steel alloy blade. Moreover, the blade does not fail by breaking or shearing off into large pieces. Test results have indicated that the blade of the present invention is superior in fatigue properties to a conventional alloy steel blade. Thus, it requires more protracted misuse of the present blade to cause its failure than is required to cause failure of a steel blade.

For high velocity axial flow air compressors such as are used in the compressor sections of jet-type aircraft engines, the blades of this invention are preferably formed of glass fibre cloth laminations impregnated with phenol-formaldehyde type resin. In other types of air compressors, blades of the same form may be constructed using other laminating fabrics and resins where the temperatures encountered are less extreme.

One form of compressor blade has been illustrated, but it is to be understood that compressor blades of other forms may be prepared in accordance with this invention and that the machine for forming the blades may be varied in structural details without departing from the spirit and scope of the appended claim.

Having described my invention what I claim as new and desire to secure by Letters Patent is:

A machine for molding a compressor blade having an elongated main portion of airfoil configuration and an enlarged root at one end thereof which comprises a pair of main dies, one of said main dies being movable relative to the other, means for moving said movable die, each of said main dies including a main portion and a root end portion, the main dies having elongated opposed die faces of airfoil configuration adapted to engage opposite sides of a pile of substantially flat resin-impregnated laminations to form said laminations into the main portion of the blade and gripping faces adjacent the root ends of said main dies, there being opposed slots between said gripping faces and the main die faces, whereby the die faces and gripping faces hold the laminations on opposite sides of the slots when the main portion of the blade is molded, a root-forming auxiliary die reciprocally mounted in each of said slots, said root-forming dies having opposed die faces of blade root shape adapted to engage opposite sides of root-forming laminations disposed in the slots and on both sides of the pile of laminations, means for moving said root-forming dies into engagement with opposite sides of the root-forming laminations to mold the enlarged root end of the blade while the elongated laminations are held by the main die, and stops on the root-forming dies, the back faces of the main dies having portions for engaging said stops, the length of each root-forming die from its stop to the root die face being less than the thickness of the main die associated there-

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with, whereby, when the dies are closed, cavities are formed in the slots, the bottoms of the cavities being defined by the root-forming die faces.

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