

Dec. 25, 1945.

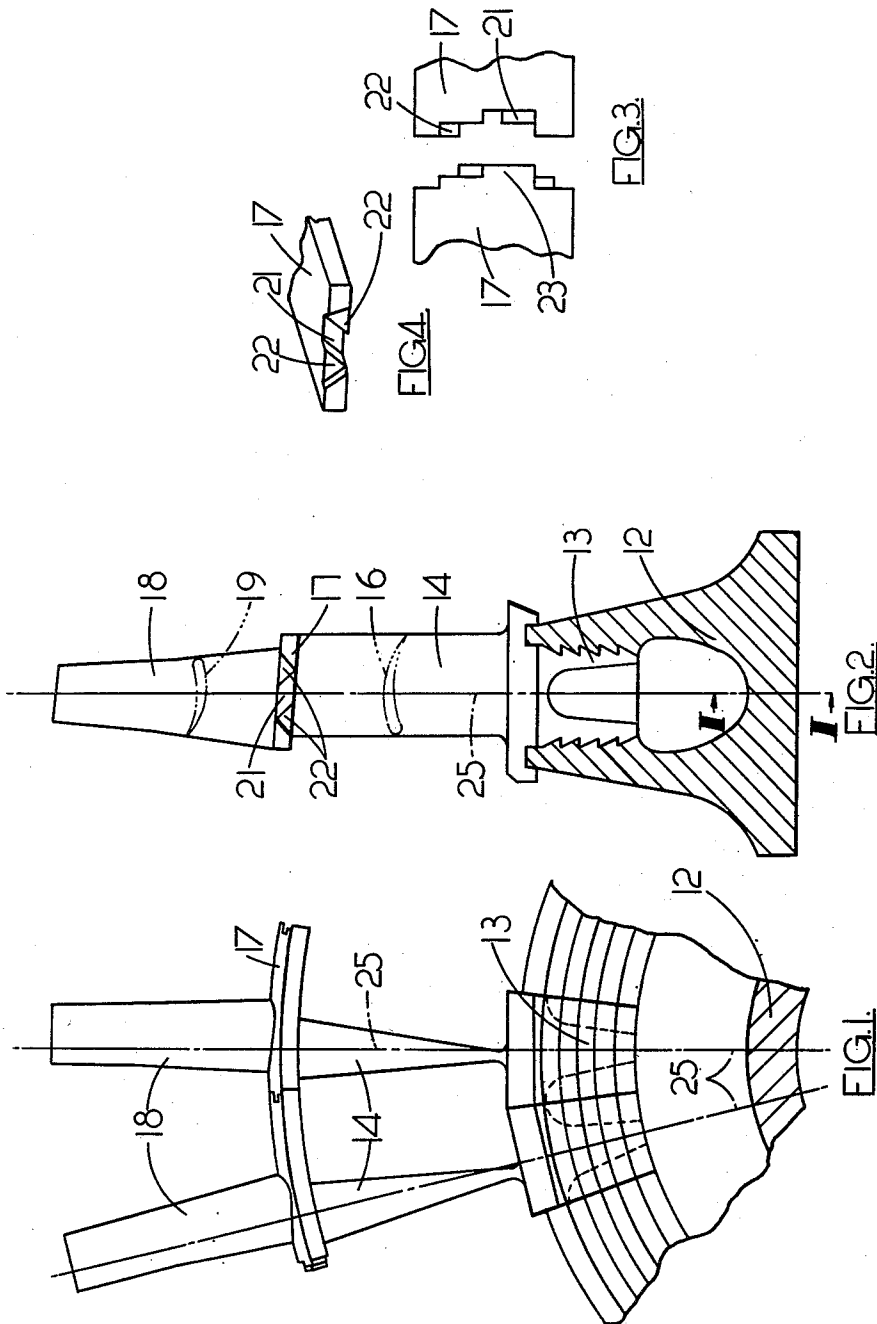
F. A. M. HEPPNER

2,391,623

BLADED ROTOR

Filed Aug. 11, 1944

2 Sheets-Sheet 1



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2 Sheets-Sheet 2

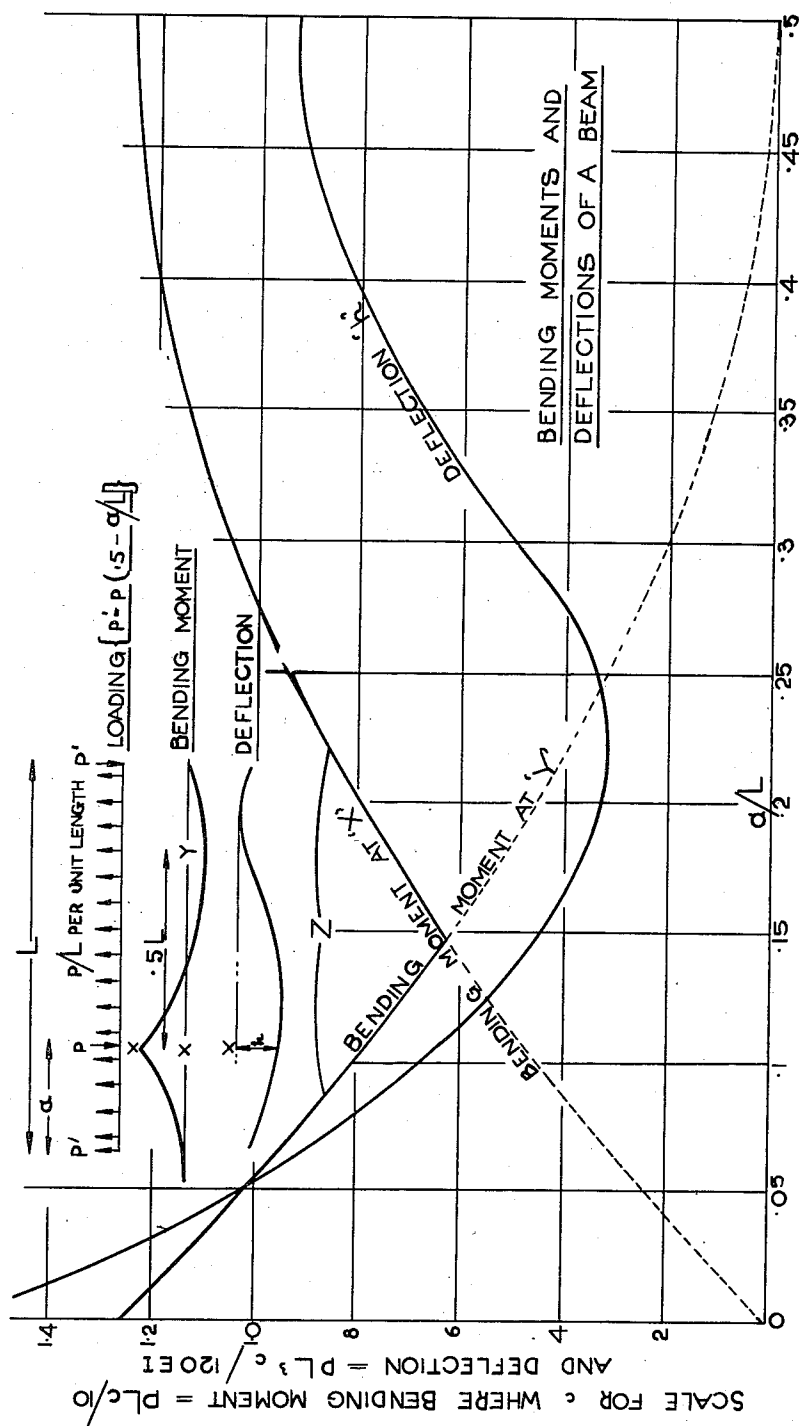


FIG. 5

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UNITED STATES PATENT OFFICE

2,391,623

BLADED ROTOR

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Application August 11, 1944, Serial No. 549,038
In Great Britain December 8, 1943

4 Claims. (Cl. 230-134)

This invention relates to a rotor having a peripheral row of blades, the latter carrying at their outer ends shrouds which form a ring and are interlocked against relative radial and lateral movement—for example, as disclosed in the specification of my co-pending U. S. Patent Application Serial No. 549,039 filed August 11, 1944.

My main object is to reduce the maximum deflection in a shroud due to centrifugal action.

In the accompanying sheets of drawings:

Figure 1 is a fragmentary, part-sectional, elevational view of a compound turbine rotor having shrouds according to the invention, only two shrouds with their associated blades being shown (and in elevation) whilst the portion of the rotor itself is shown as a section on the line I—I of Figure 2;

Figure 2 is an elevational view of one of the shrouds, with its associated blades, taken from the right of Figure 1, the portion of the rotor itself being in cross-section;

Figure 3 is a fragmentary plan of two shrouds when separated, and Figure 4 is a fragmentary perspective view of one of the shrouds, indicating a preferred form of interlock such as that disclosed in the specification aforesaid; and

Figure 5 is a diagram hereinafter described.

According to the invention the shrouds are offset in a circumferential direction relatively to the associated blades so as to reduce the maximum deflection in a shroud, due to centrifugal action, to a value lower than if the shrouds were centrally placed with respect to the associated blades. Preferably, each blade is connected to its associated shroud approximately mid-way between the centre of the shroud and one end, or preferably slightly nearer the said one end.

In this way, with a certain construction I can reduce the maximum deflection from three thousandths of an inch to one thousandth of an inch. This is an important consideration if the bladed rotor forms part of an internal combustion turbine plant in which, for example, the running clearance is only approximately 30 thousandths of an inch.

In the construction shown, 12 indicates a rotor in which are secured the roots 13 of compressor blades 14 (the cross-section of which is indicated by the chain lines 16) in the manner disclosed in the specification aforesaid, and 17 are relatively thin, flat shrouds carrying externally turbine blades 18, the cross-section of which is indicated by the chain lines 19.

One end of a shroud has machined in it transverse slots 21, 22 of which one, 21, is narrower

than and imposed upon the other. The mating edge of the adjacent shroud has complementary projections 23 formed thereon, all as disclosed in the specification aforesaid. In this way, when the shrouds are brought together in the form of a ring, they are interlocked against radial or lateral movement.

It is found that the centres of gravity of different sections of a blade, taken along the length of a blade, all lie substantially on a radial line such as that marked 25, this applying both to a compressor blade and to an associated turbine blade, such radial line passing centrally through the blade root. According to the invention it passes not through the centre of the shroud but to one side of the centre, and for preference, and as shown, it intersects the shroud at a distance which is approximately 0.22 of the length of the shroud from one edge of the shroud.

The reason for this will be apparent from a consideration of Figure 5, in which the problem considered is that of a uniformly-loaded beam of uniform section supported at an arbitrary point X where the load P is applied. There is also a load P' at each end of the beam, and a symmetry condition (that the beam shall be identical in loading and deflection to a similar one on either side) necessitates the loads P' at the two ends being equal and opposite, and the deflections, of the two ends from the point X where the load P is applied, equal. The support and the two ends are assumed to apply no bending moment to the beam. It is required to find the best position of the point of support in order to minimise either or both the stress and the deflection.

The equal and opposite loads (P') on the ends may be determined by the statical equilibrium of the beam for any fixed position of the point of support. The bending moment diagram (due to centrifugal forces) may then be constructed and the deflections calculated, as shown for a typical case in the small diagrams. Normally, the bending moment has two maximum values, one at the point of support X (at a distance a from one end) and one between the point of support and the end furthest away, and the distance between the two maximum bending moment points is $\frac{1}{2}L$, where L is the length of the beam. The former bending moment vanishes if the point of support is at one end, and the latter if it is exactly in the centre. The variation of the two for different positions of support is shown in the main diagram, marked Z. In this diagram the bending moments are represented by a dimensionless factor c by dividing by the total load and the length of the beam.

The small diagram of a typical deflection curve shows the deflection h , between the point of support and the point furthest away from it, in a direction perpendicular to the beam. This dimension is important in the case considered because the distorted shroud must move past an undistorted one (in the adjacent row of blades, which are stationary), and this distance must be added to the centrifugal expansion of the rotating compressor blade to give the minimum clearance. The main graph, marked "deflection h ," shows the variation of this deflection, represented again by a dimensionless factor, according to the position of the support.

The bending moment diagram Z shows that for a beam of uniform section the stresses are least when the point of support is 0.15 of the distance along the beam. This stress occurs at two places, and any change of position of the support would cause one of them to increase, although the other would decrease.

The minimum value of the deflection is seen to occur when the point of support is 0.22 of the distance along the beam. Thus according to whether stress of deflection is most critical, the optimum point of support will lie somewhere between these two values.

It should be understood that the shroud is stiffened up by the integral inner and outer blades the sections of which, at the shrouds, are inclined to one another, and this reduces the effective length of the beam and would, in point of fact, modify the shape of the curves shown.

What I claim as my invention and desire to secure by Letters Patent of the United States is:

1. A rotor having a peripheral row of blades, said blades carrying at their outer ends shrouds which form a ring and are interlocked against relative radial and lateral movement, an outer row of blades carried externally by said shrouds, the shrouds being offset in a circumferential direction relatively to the associated blades of the inner row so as to reduce the maximum deflec-

tion in a shroud due to centrifugal action to a value lower than if the shrouds were central with respect to the associated blades of the inner row.

2. A rotor having a peripheral row of blades, said blades carrying at their outer ends shrouds which form a ring and are interlocked against relative radial and lateral movement, an outer row of blades carried externally by said shrouds, the blades of each shroud being arranged so that the lines through the centres of gravity of different sections of the blades are coincident, the shrouds being offset in a circumferential direction relatively to the associated blades so as to reduce the maximum deflection in a shroud due to centrifugal action to a value lower than if the shrouds were central with respect to the associated blades.

3. A rotor having a peripheral row of blades, the latter being fast at their outer ends with shrouds which form a ring and are interlocked against relative radial and lateral movement, an outer row of blades which are individually fast with the shrouds and respectively aligned with the blades of the inner row, the shrouds being offset in a circumferential direction relatively to both the associated blades such that the line through the centres of gravity of different sections of each blade is approximately mid-way between the centre of the shroud and one end.

4. A rotor for an internal-combustion turbine plant having a peripheral row of compressor blades, the latter carrying at their outer ends shrouds which form a ring and are interlocked against relative radial and lateral movement, a row of turbine blades carried externally by the shrouds, the shrouds being offset in a circumferential direction relatively to the associated compressor blades such that the line through the centres of gravity of different sections of each compressor blade is at a distance from one end of the shroud which is between 0.2 and 0.25 of the circumferential length of the shroud.

FRITZ ALBERT MAX HEPPNER.