CLAIMS

1. A method of inspecting a turbomachine, the turbomachine comprising a rotor having at least one stage of rotor blades and a casing surrounding the rotor and at least one stage of rotor blades, each rotor blade comprising a platform portion and an aerofoil portion, the aerofoil portion having a leading edge, a trailing edge, a concave surface, a convex surface and a tip, the method comprising the steps of a) providing a plurality of boroscopes, b) inserting each boroscope through a respective one of a plurality of apertures in a casing of the turbomachine, at least one of the apertures in the casing being upstream of the rotor blades, at least one of the apertures in the casing being downstream of the rotor blades, c) rotating the rotor of the turbomachine, d) providing reference measurements of the rotor blades and/or reference measurements between the rotor blades and the boroscopes, e) viewing the leading edge and at least a portion of the concave surface or viewing the leading edge and at least a portion of the convex surface of each of the rotor blades of the turbomachine as the rotor is rotated using the boroscope in the at least one of the apertures in the casing upstream of the rotor blades and supplying the image of each of the rotor blades to the processor, f) viewing the trailing edge and at least a portion of the convex surface or viewing the trailing edge and at least a portion of the concave surface of each of the rotor blades of the turbomachine as the rotor is rotated using the boroscope in the at least one of the apertures in the casing downstream of the rotor blades and supplying the image of each of the rotor blades to the processor, and g) analysing the images of the rotor blades and using the reference measurements of the rotor blades and/or reference measurements between the rotor blades and the boroscopes to determine the position and size of any defect on any of the rotor blades.

2. A method as claimed in claim 1 wherein the reference measurements of the rotor blades are the measurement from the platform portion to the tip of the aerofoil portion of the rotor blade and/or the measurement from the leading edge to the trailing edge of the aerofoil portion of the rotor blade.

3. A method as claimed in claim 1 or claim 2 comprising providing a model of the rotor and the at least one stage of rotor blades.

4. A method as claimed in claim 3 comprising placing the image of the leading edge and at least a portion of the concave surface or placing the image of the leading edge and at least a portion of the convex surface of each of the rotor blades of the turbomachine onto corresponding positions of the model of the rotor and rotor blades and placing the image of the trailing edge and at least a portion of the convex surface or placing the image of the trailing edge and at least a portion of the concave surface of each of the rotor blades of the turbomachine onto corresponding positions of the model of the rotor and rotor blades.

5. A method as claimed in any of claims 1 to 4 wherein each boroscope comprises a rigid structure and at least one camera arranged at a predetermined longitudinal position, the at least one camera is arranged with a line of sight transverse to the longitudinal direction of the boroscope.

6. A method as claimed in any of claims 1 to 5 wherein at least one of the boroscopes comprises a plurality of cameras.

7. A method as claimed in claim 6 at least one of the boroscopes comprises a plurality of cameras at the predetermined longitudinal position and the cameras are arranged with lines of sight arranged at different angles.

8. A method as claimed in claim 6 or claim 7 wherein at least one of the boroscopes comprises a plurality of cameras at different longitudinal positions.

9. A method as claimed in claim 8 comprising supplying the image of each of the rotor blades from each of the cameras at the different longitudinal positions of the boroscope to the processor, the processor producing a composite image of each of the rotor blades from the images supplied by the plurality of cameras.

10. A method as claimed in claim 9 comprising placing the composite image of each of the rotor blades of the turbomachine onto corresponding positions of the model of the rotor and rotor blades.

11. A method as claimed in any of claims 6 to 10 wherein at least one of the boroscopes comprises at least one camera arranged with a line of sight directed in a downstream direction towards a stage of rotor blades and at least one camera arranged with a line of sight directed in an upstream direction towards a stage of rotor blades.

12. A method as claimed in any of claims 1 to 11 comprising providing a measurement of the angular position of the rotor relative to the boroscopes, supplying the measurement of the angular position of the rotor to the processor and relating the images of each of the rotor blades to the corresponding rotor blade on the rotor.

13. A method as claimed in any of claims 1 to 12 wherein the turbomachine comprises a stage of stator vanes upstream of the at least one stage of rotor blades and a stage of stator vanes downstream of the at least one stage of rotor blades, step b) comprising inserting a boroscope between two adjacent stator vanes of the stage of stator vanes upstream of the at least one stage of rotor blade and inserting a boroscope between two adjacent stator vanes of the stage of stator vanes downstream of the at least one stage of rotor blades.

14. A method as claimed in any of claims 1 to 13 wherein step (b) comprises placing a boroscope upstream of each one of a plurality of stages of rotor blades and placing a boroscope downstream of each one of the plurality of stages of rotor blades, step d) comprises providing reference measurements of the rotor blades of each of the stages of rotor blades and/or reference measurements between the rotor blades of each of the stages of rotor blades and the corresponding boroscopes and step g) comprises analysing the images of the rotor blades of each of the stages of rotor blades and using the reference measurements of the rotor blades for each stage of rotor blades and/or reference measurements between the rotor blades of each stage of rotor blades and

the corresponding boroscopes to determine the position and size of any defect on any of the rotor blades.

15. A method as claimed in any of claims 1 to 14 wherein the rotor is a compressor rotor and the rotor blades are compressor blades.

16. A method as claimed in any of claims 1 to 14 wherein the rotor is a turbine rotor and the rotor blades are turbine blades.

17. A method as claimed in any of claims 1 to 16 wherein the turbomachine is a gas turbine engine.

18. A method as claimed in any of claims 1 to 14 wherein the turbomachine is a steam turbine or a water turbine.

19. A method of inspecting a turbomachine substantially as hereinbefore described with reference to the accompanying drawings.

20. An apparatus for inspecting a turbomachine, the turbomachine comprising a rotor having at least one stage of rotor blades and a casing surrounding the rotor and at least one stage of rotor blades, each rotor blade comprising a platform portion and an aerofoil portion, the aerofoil portion having a leading edge, a trailing edge, a concave surface, a convex surface and a tip, the casing of the turbomachine having a plurality of apertures, at least one of the apertures in the casing being upstream of the rotor blades and at least one of the apertures in the casing being downstream of the rotor blades,

the apparatus comprising a plurality of boroscopes, each boroscope being insertable through a respective one of the plurality of apertures in the casing of the turbomachine,

a device to rotate the rotor of the turbomachine,

a processor having reference measurements of the rotor blades and/or reference measurements between the rotor blades and the boroscopes,

at least one of the boroscopes inserted in at least one of the apertures in the casing upstream of the rotor blades being arranged to view the leading edge and at least a portion of the concave surface or being arranged to view the leading edge and at least a portion of the convex surface of each of the rotor blades of the turbomachine as the rotor is rotated,

the at least one of the boroscopes being arranged to supply the image of the leading edge and at least a portion of the concave surface or being arranged to supply the image of the leading edge and at least a portion of the convex surface of each of the rotor blades of the turbomachine as the rotor is rotated,

at least one of the boroscopes inserted in at least one of the apertures in the casing downstream of the rotor blades being arranged to view trailing edge and at least a portion of the convex surface or being arranged to view the trailing edge and at least a portion of the concave surface of each of the rotor blades of the turbomachine as the rotor is rotated,

the at least one of the boroscopes being arranged to supply the image of the trailing edge and at least a portion of the convex surface or being arranged to supply the image of the trailing edge and at least a portion of the concave surface of each of the rotor blades of the turbomachine as the rotor is rotated,

the processor being arranged to analyse the images of the rotor blades and to use the reference measurements of the rotor blades and/or reference measurements between the rotor blades and the boroscopes to determine the position and size of any defect on any of the rotor blades.

21. A boroscope comprising a rigid structure and a plurality of cameras, each camera is arranged at a predetermined longitudinal position, each camera is arranged with a line of sight transverse to the longitudinal direction of the boroscope.

22. A boroscope as claimed in claim 21 wherein the boroscope comprises a plurality of cameras at the predetermined longitudinal position and the cameras are arranged with lines of sight arranged at different angles.

23. A boroscope as claimed in claim 21 or claim 22 wherein the boroscope comprises a plurality of cameras at different longitudinal positions.

24. A boroscope as claimed in claim 21, claim 22 or claim 23 wherein the boroscope comprises at least one camera arranged with a line of sight directed in a first direction and at least one camera arranged with a line of sight directed in a second direction opposite to the first direction.

25. A boroscope as claimed in claim 24 wherein the boroscope comprises a plurality of cameras at different longitudinal positions arranged with a line of sight in the first direction and a plurality of cameras at different longitudinal positions arranged with a line of sight in the second direction.

26. A boroscope substantially as hereinbefore described with reference to and as shown in figures 3 and 4.

27. A boroscope substantially as hereinbefore described with reference to and as shown in figures 3 and 5.

28. A boroscope substantially as hereinbefore described with reference to and as shown in figure 6.

29. A boroscope substantially as hereinbefore described with reference to and as shown in figure 7.

CLAIMS

1. A method of inspecting a turbomachine, the turbomachine comprising a rotor having at least one stage of rotor blades and a casing surrounding the rotor and at least one stage of rotor blades, each rotor blade comprising a platform portion and an aerofoil portion, the aerofoil portion having a leading edge, a trailing edge, a concave surface, a convex surface and a tip, the method comprising the steps of a) providing a plurality of boroscopes, b) inserting each boroscope through a respective one of a plurality of apertures in a casing of the turbomachine, at least one of the apertures in the casing being upstream of the rotor blades, at least one of the apertures in the casing being downstream of the rotor blades, placing a boroscope upstream of each one of a plurality of stages of rotor blades and placing a boroscope downstream of each one of the plurality of stages of rotor blades, c) rotating the rotor of the turbomachine, d) providing reference measurements of the rotor blades and/or reference measurements between the rotor blades and the boroscopes, providing reference measurements of the rotor blades of each of the stages of rotor blades and/or reference measurements between the rotor blades of each of the stages of rotor blades and the corresponding boroscopes, e) viewing the leading edge and at least a portion of the concave surface or viewing the leading edge and at least a portion of the convex surface of each of the rotor blades of the turbomachine as the rotor is rotated using the boroscope in the at least one of the apertures in the casing upstream of the rotor blades and supplying the image of each of the rotor blades to a processor, f) viewing the trailing edge and at least a portion of the convex surface or viewing the trailing edge and at least a portion of the concave surface of each of the rotor blades of the turbomachine as the rotor is rotated using the boroscope in the at least one of the apertures in the casing downstream of the rotor blades and supplying the image of each of the rotor blades to the processor, and g) analysing the images of the rotor blades and using the reference measurements of the rotor blades and/or reference measurements between the rotor blades and the boroscopes to determine the position and size of any defect on any of the rotor blades, analysing the images of the rotor blades of each of the stages of rotor blades and using the reference measurements of the rotor blades for each stage of rotor blades and/or reference measurements between the rotor blades of each stage of

rotor blades and the corresponding boroscopes to determine the position and size of any defect on any of the rotor blades.

2. A method as claimed in claim 1 wherein the reference measurements of the rotor blades are the measurement from the platform portion to the tip of the aerofoil portion of the rotor blade and/or the measurement from the leading edge to the trailing edge of the aerofoil portion of the rotor blade.

3. A method as claimed in claim 1 or claim 2 comprising providing a model of the rotor and the at least one stage of rotor blades.

4. A method as claimed in claim 3 comprising placing the image of the leading edge and at least a portion of the concave surface or placing the image of the leading edge and at least a portion of the convex surface of each of the rotor blades of the turbomachine onto corresponding positions of the model of the rotor and rotor blades and placing the image of the trailing edge and at least a portion of the convex surface or placing the image of the trailing edge and at least a portion of the concave surface of each of the rotor blades of the turbomachine onto corresponding positions of the model of the rotor and rotor blades.

5. A method as claimed in any of claims 1 to 4 wherein each boroscope comprises a rigid structure and at least one camera arranged at a predetermined longitudinal position, the at least one camera is arranged with a line of sight transverse to the longitudinal direction of the boroscope.

6. A method as claimed in claim 5 wherein at least one of the boroscopes comprises a plurality of cameras.

7. A method as claimed in claim 6 wherein at least one of the boroscopes comprises a plurality of cameras at the predetermined longitudinal position and the cameras are arranged with lines of sight arranged at different angles.

8. A method as claimed in claim 5 or claim 6 wherein at least one of the boroscopes comprises a plurality of cameras at different longitudinal positions.

9. A method as claimed in claim 8 comprising supplying the image of each of the rotor blades from each of the cameras at the different longitudinal position of the boroscope to the processor, the processor producing a composite image of each of the rotor blades from the images supplied by the plurality of cameras.

10. A method as claimed in claim 9 comprising placing the composite image of each of the rotor blades of the turbomachine onto corresponding positions of the model of the rotor and rotor blades.

11. A method as claimed in any of claims 6 to 10 wherein at least one of the boroscopes comprises at least one camera arranged with a line of sight directed in a downstream direction towards a stage of rotor blades and at least one camera arranged with a line of sight directed in an upstream direction towards a stage of rotor blades.

12. A method as claimed in any of claims 1 to 11 comprising providing a measurement of the angular position of the rotor relative to the boroscopes, supplying the measurement of the angular position of the rotor to the processor and relating the images of each of the rotor blades to the corresponding rotor blade on the rotor.

13. A method as claimed in any of claims 1 to 12 wherein the turbomachine comprises a stage of stator vanes upstream of the at least one stage of rotor blades and a stage of stator vanes downstream of the at least one stage of rotor blades, step b) comprising inserting a boroscope between two adjacent stator vanes of the stage of stator vanes upstream of the at least one stage of rotor blade and inserting a boroscope between two adjacent stator vanes of the stage of stator vanes downstream of the at least one stage of rotor blades.

14. A method as claimed in any of claims 1 to 13 wherein the rotor is a compressor rotor and the rotor blades are compressor blades.

15. A method as claimed in any of claims 1 to 13 wherein the rotor is a turbine rotor and the rotor blades are turbine blades.

16. A method as claimed in any of claims 1 to 15 wherein the turbomachine is a gas turbine engine.

17. A method as claimed in any of claims 1 to 13 wherein the turbomachine is a steam turbine or a water turbine.

18. An apparatus for inspecting a turbomachine, the turbomachine comprising a rotor having at least one stage of rotor blades and a casing surrounding the rotor and at least one stage of rotor blades, each rotor blade comprising a platform portion and an aerofoil portion, the aerofoil portion having a leading edge, a trailing edge, a concave surface, a convex surface and a tip, the casing of the turbomachine having a plurality of apertures, at least one of the apertures in the casing being upstream of the rotor blades and at least one of the apertures in the casing being downstream of the rotor blades,

the apparatus comprising a plurality of boroscopes, each boroscope being insertable through a respective one of the plurality of apertures in the casing of the turbomachine,

a device to rotate the rotor of the turbomachine,

a processor having reference measurements of the rotor blades and/or reference measurements between the rotor blades and the boroscopes, the processor having reference measurements of the rotor blades of each of the stages of rotor blades and/or reference measurements between the rotor blades of each of the stages of rotor blades and the corresponding boroscopes

at least one of the boroscopes inserted in at least one of the apertures in the casing upstream of the rotor blades being arranged to view the leading edge and at least a portion of the concave surface or being arranged to view the leading edge and

at least a portion of the convex surface of each of the rotor blades of the turbomachine as the rotor is rotated,

the at least one of the boroscopes being arranged to supply the image of the leading edge and at least a portion of the concave surface or being arranged to supply the image of the leading edge and at least a portion of the convex surface of each of the rotor blades of the turbomachine as the rotor is rotated,

at least one of the boroscopes inserted in at least one of the apertures in the casing downstream of the rotor blades being arranged to view the trailing edge and at least a portion of the convex surface or being arranged to view the trailing edge and at least a portion of the concave surface of each of the rotor blades of the turbomachine as the rotor is rotated,

the at least one of the boroscopes being arranged to supply the image of the trailing edge and at least a portion of the convex surface or being arranged to supply the image of the trailing edge and at least a portion of the concave surface of each of the rotor blades of the turbomachine as the rotor is rotated,

a boroscope inserted upstream of each one of a plurality of stages of rotor blades and a boroscope inserted downstream of each one of the plurality of stages of rotor blades,

the processor being arranged to analyse the images of the rotor blades and to use the reference measurements of the rotor blades and/or reference measurements between the rotor blades and the boroscopes to determine the position and size of any defect on any of the rotor blades, the processor being arranged to analyse the images of the rotor blades of each of the stages of rotor blades and to use the reference measurements of the rotor blades for each stage of rotor blades and/or reference measurements between the rotor blades of each stage of rotor blades and the corresponding boroscopes to determine the position and size of any defect on any of the rotor blades.

19. An apparatus as claimed in claim 18 wherein each boroscope comprises a rigid structure and at least one camera arranged at a predetermined longitudinal position, the at least one camera is arranged with a line of sight transverse to the longitudinal direction of the boroscope.

20. An apparatus as claimed in claim 19 wherein at least one of the boroscopes comprises a plurality of cameras.

21. An apparatus as claimed in claim 20 wherein at least one of the boroscopes comprises a plurality of cameras at the predetermined longitudinal position and the cameras are arranged with lines of sight arranged at different angles.

22. An apparatus as claimed in claim 20 or claim 21 wherein at least one of the boroscopes comprises a plurality of cameras at different longitudinal positions.

23. An apparatus as claimed in claim 22 wherein the apparatus is arranged to supply the image of each of the rotor blades from each of the cameras at the different longitudinal position of the boroscope to the processor, the processor being arranged to produce a composite image of each of the rotor blades from the images supplied by the plurality of cameras.