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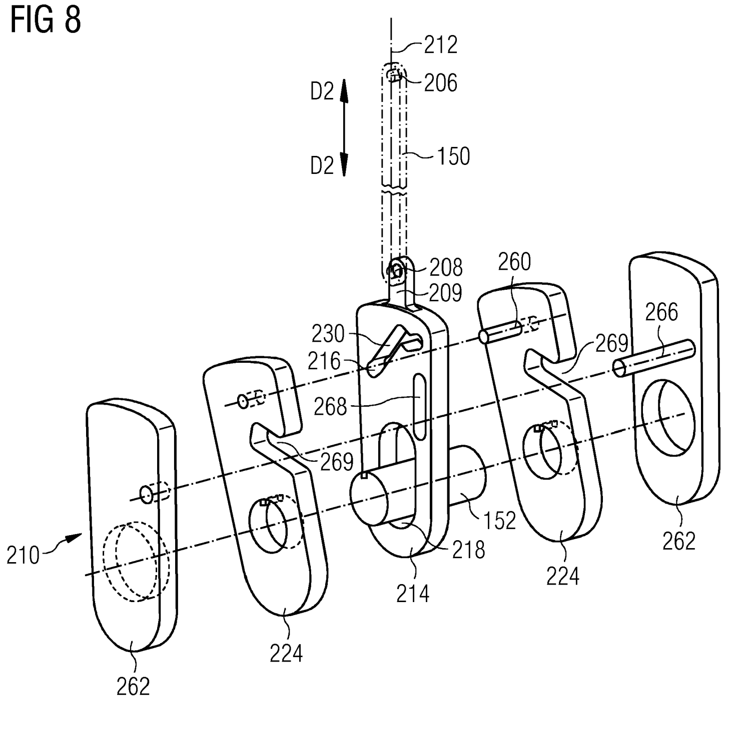
(54) **ADJUSTMENT LINKAGE**

(57) An adjustment linkage (200a) for a guide vane (8) of a compressor (14) for a gas turbine engine (10). The adjustment linkage (200a) comprises a push rod (150). A first end (206) of the push rod (150) is configured to be coupled to an adjustment ring (140) for actuation of a variable guide vane (8a). A second end (208) of the push rod (150) is configured to be coupled to an output (152) of an adjustment drive (154) via a cam mechanism (210) configured to modify the directional output (152) of the adjustment drive (154). The push rod has a longitudinal axis (212) which extends between its first end (206) and second end (208). The cam mechanism (210) configured to allow the push rod (150) to move in a direction along its longitudinal axis (212), and restrict the push rod (150) from moving in a direction at an angle to its longitudinal axis (212).

FIG 8



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Description

[0001] The present disclosure relates to an adjustment linkage.

[0002] In particular the disclosure is concerned with an adjustment linkage for a guide vane of a compressor for a gas turbine engine.

Background

[0003] A gas turbine comprises a turbine and a compressor driven by the turbine. A compressor may consist of multiple stages of stator vanes which are non-rotatable about the operational axis, and rotor blades which are rotatable about the operational axis. Commonly, the gas turbine is subjected to varying operating conditions resulting in different aerodynamic flow conditions within the compressor.

[0004] In order to adapt the compressor performance to different flow conditions, it is known to provide the compressor with variable guide vanes (VGV). The variable guide vanes are pivotable/rotatable about their longitudinal axis in order to adjust their angle relative to the operational axis of the engine (i.e. the axial flow direction through the compressor), and hence relative to rotor blades downstream.

[0005] Operational flow conditions may induce a stall condition during start-up and at off-design conditions. This may result in aerodynamic noise, loss of efficiency and excessive rotor vibration.

[0006] In order to avoid such deleterious behaviour, engines may be controlled to avoid combinations of conditions which will result in stall. For example, compressor stall may be reduced by rotating the variable guide vanes to increase the blade angle relative to the operational axis and reduce the compressor throat area, thus reducing the mass flow of air through the compressor.

[0007] Unfortunately restricting the operational conditions may have further consequences, for example having an impact on efficiency or power output.

[0008] Hence an arrangement or system which reduces the likelihood of unwanted aerodynamic behaviour, thus reducing the likelihood of damage to the engine, and at the same time allows the engine to operate over a wider range of conditions, is highly desirable.

Summary

[0009] According to the present disclosure there is provided an apparatus and system as set forth in the appended claims. Other features of the invention will be apparent from the dependent claims, and the description which follows.

[0010] Accordingly there may be provided an adjustment linkage (200a) for a guide vane (8) of a compressor (14) for a gas turbine engine (10). The compressor (14) may comprise a casing (50) which extends along, and is centred on, an operational axis (20). There may also be provided a variable guide vane (8) rotatably mounted at a first location (202) on the casing (50). There may also be provided a vane lever arm (20) coupled at one end to the variable guide vane (8), and coupled at its other end to an adjustment (unison) ring (140) coaxial with the casing operational axis (20). There may also be provided an adjustment drive (154) mounted to the casing (50) in a second location (204) spaced apart from the first location (202). The adjustment linkage (200a) may comprise a push rod (150) having a longitudinal axis (212) which extends between a first end (206) and a second end (208). The first end (206) of the push rod (150) may be configured to be coupled to the adjustment ring (140). The second end (208) of the push rod (150) may be configured to be coupled to an output (152) of the adjustment drive (154) via a cam mechanism (210) configured to vary the directional output of the adjustment drive (154). The cam mechanism (210) may be configured to allow the push rod (150) to move in a direction along its longitudinal axis (212) and restrict the push rod (150) from moving in a direction at an angle to its longitudinal axis (212).

[0011] There may also be provided an adjustment linkage (200a) for a guide vane (8) of a compressor (14) for a gas turbine engine (10). The adjustment linkage (200a) may comprise a push rod (150). A first end (206) of the push rod (150) may be configured to be coupled to an adjustment ring (140) for actuation of a variable guide vane (8a). A second end (208) of the push rod (150) may be configured to be coupled to an output (152) of an adjustment drive (154) via a cam mechanism (210) configured to convert a single direction rotational input from the adjustment drive to a reciprocating linear output. The push rod may have a longitudinal axis (212) which extends between its first end (206) and second end (208). The cam mechanism (210) may be configured to allow the push rod (150) to move in a direction along its longitudinal axis (212) and restrict the push rod (150) from moving in a direction at an angle to its longitudinal axis (212).

[0012] The output (152) of the adjustment drive (154) may comprise a distributor shaft (152).

[0013] The cam mechanism (210) may comprise a cam plate (214) configured to be coupled to the push rod (150), the cam plate (214) provided with a slot (216) which defines a cam guide path (230). The cam plate may be provided with an aperture (218) through which the distributor shaft (152) extends, such that the cam plate (214) is slideable relative to the distributor shaft (152).

[0014] The cam mechanism may also comprise a drive plate (224) from which extends a drive pin (260), the drive pin (260) extending through, and in slideable engagement with, the cam plate slot (216). The drive plate (224) may be drivingly engaged with the distributor shaft (152). The pivoting movement of the drive plate (224) with the distributor shaft (152) may cause the cam plate (214) to move relative to the distributor shaft (152), thereby acting on the push rod (150) to move in the direction along its longitudinal axis (212), and thereby turn the guide vane (8a).

[0015] The cam plate aperture (218) may be an elongate slot such that the cam plate (214) is linearly slideable relative to the distributor shaft (152).

[0016] The adjustment linkage (200a) may further comprise a fixed plate (262) from which extends a restraint pin (266) which extends into a clearance slot (268) in the cam plate (214), the cam plate clearance slot (268) being elongate and extending parallel to the cam plate aperture (218) to restrict motion of the cam plate (214) to the elongate direction of the cam plate clearance slot (268) and cam plate aperture (218).

[0017] The cam plate (214), drive plate (224) and fixed plate (262) may be configured to be arranged in series along the distributor shaft (152), the cam plate (214) spaced apart from the fixed plate (262) by the drive plate (224).

[0018] The cam mechanism (210) may further comprise a further fixed plate (262) spaced apart from the cam plate (214) by a further drive plate (224) configured to be arranged in series along the distributor shaft (152) with the cam plate (214) and fixed plate (262) and drive plate (224). The further fixed plate (262) and further drive plate (224) may be configured to be arranged on an opposite side of the cam plate (214) to the other fixed plate (262) and drive plate (224), the drive pin (260) engaged with, and extending between, the drive plates (224), and the restraint pin (266) engaged with, and extending between, the fixed plates (262).

[0019] The cam guide path (230) may comprise at least one inflexion (240) which, in use, defines a change in direction of travel of the cam plate (214) relative to the distributor shaft (152), and thus defines a change of direction of travel of the push rod (150) relative to the distributor shaft (152), thus defining a change of rotational direction of the guide vane (8).

[0020] The cam guide path (230) may comprise two inflexions (240, 242), the first inflexion (240) defining a change in direction of travel of the cam plate (214) relative to the distributor shaft (152) from a first direction (D1) to a second direction (D2), thus defining a change of rotational direction of the guide vane (8) from a first rotational direction (R1) to a second rotational direction (R2). The second inflexion (240) may define a change in direction of cam plate (214) relative to the distributor shaft (152) from the second direction (D2) to the first direction (D1), thus defining a change of rotational direction of the guide vane (8a) from the second rotational direction (R2) to the first rotational direction (R1).

[0021] There may also be provided a compressor for a gas turbine engine comprising a casing (50) which extends along, and is centred on, an operational axis (20). It may comprise a rotatably mounted variable guide vane (8a) at a first location (202) on the casing (50). It may further comprise a vane lever arm (20) coupled at one end to the variable guide vane (8a), and coupled at its other end to an adjustment (unison) ring (140) coaxial with the casing operational axis (20). It may further comprise an adjustment drive (154) mounted to the casing (50) in a second location (204) and an adjustment linkage (200a) according to the present disclosure. A first end (206) of the adjustment linkage (200a) may be coupled to the adjustment ring (140) and a second end (208) of the adjustment linkage (200a) may be coupled to an output of the adjustment drive (154).

[0022] There may also be provided a compressor for a gas turbine engine comprising a casing (50) which extends along, and is centred on, an operational axis (20). It may further comprise a rotatably mounted variable guide vane (8a) at a first location (202) on the casing (50). It may further comprise a vane lever arm (20) coupled at one end to the variable guide vane (8a), and coupled at its other end to an adjustment ring (140) coaxial with the casing operational axis (20). It may further comprise an adjustment drive (154) mounted to the casing (50) in a second location (204), and an adjustment linkage (200a) according to the present disclosure. A first end (206) of the adjustment linkage (200a) may be coupled to the adjustment ring (140). A second end (208) of the adjustment linkage (200a) may be coupled to an output of the adjustment drive (154).

[0023] The variable guide vane may be one of an array of variable guide vanes arranged around the circumference of the casing (50) to form at least part of a first flow stage (46a). A second array of variable guide vanes (8b) may be arranged around the circumference of the casing (50) to form at least part of a second flow stage (46b) spaced apart from the first flow stage (46a) along the operational axis (20). A vane lever arm (20) may be coupled to, and extend from, at least some of the variable guide vanes (8b) of the second flow stage (46b) to a second flow stage adjustment (unison) ring (140) coaxial with the casing operational axis (20).The compressor may further comprise a second flow stage adjustment linkage (200a), a first end (206b) of the second flow stage adjustment linkage (200a) coupled to the adjustment ring (140); and a second end (208b) (distal to the first end (206b)) of the second flow stage adjustment linkage (200b) is coupled to the output (152) of the adjustment drive (154). The second flow stage adjustment linkage (200b), and the first flow stage adjustment linkage (200a) may be configured such that for a given output of the adjustment drive (154), the vanes (8b) of the second flow stage (46b) will move by a different amount and/or in a different direction to the variable vanes of the first flow stage (46a).

[0024] The variable guide vane may be one of an array of variable guide vanes arranged around the circumference of the casing (50) to form at least part of a first flow stage (46a). A second array of variable guide vanes (8b) may be arranged around the circumference of the casing (50) to form at least part of a second flow stage (46b) spaced apart from the first flow stage (46a) along the operational axis (20). There may also be provided a second flow stage adjustment ring (141) coaxial with the casing operational axis (20). There may also be provided a second flow stage adjustment linkage (200a); a first end (206b) of the second flow stage adjustment linkage (200a) coupled to the adjustment ring (140); and a second end (208b) of the second flow stage adjustment linkage (200b) is coupled to the output (152) of the adjustment drive (154); wherein the second flow stage adjustment linkage (200b), and the first flow stage adjustment linkage (200a) a may be configured such that for a given output of the adjustment drive (154), the vanes (8b) of the second flow stage (46b) will move by a different amount and/or in a different direction to the variable vanes of the first flow stage (46a).

[0025] The vanes (8b) of the second flow stage (46b) may move by a different amount and/or in a different direction to the variable vanes of the first flow stage (46a) at a predetermined flow condition in the compressor (14).

[0026] There may also be provided a gas turbine engine comprising a compressor according to the present disclosure wherein : the predetermined flow condition is in the range of 80% to 95% maximum engine speed.

[0027] Hence there is provided a mechanism which combines a cam and a constrained push rod in order to transpose rotating movement driving the cam to longitudinal movement of the push rod, where the cam mechanism is designed to induce one or several changes of direction of the push rod, and hence induce opening and closing of the variable guide vanes without changing the rotational direction of the cam. The mechanism is configured as to allow the push rod to operate substantially only along its longitudinal axis with little or no lateral movement.

[0028] The cam plate and push rod are coupled so that the angle of the variable vane stage to which they are connected can be varied differently to other variable guide vane stages (where provided) driven by the same actuator. This provides sufficient control to the air flow to avoid stall.

[0029] The rotatable parts of the cam mechanism may be fixed to a single distributor shaft, driven by a single actuator, which drives multiple stages of variable guide vanes (where provided). This is particularly advantageous as it reduces part count, cost, control complexity and maintenance.

Brief Description of the Drawings

[0030] Examples of the present disclosure will now be described with reference to the accompanying drawings, in which:

Figure 1 shows a schematic representation of an example of a turbomachine;

Figure 2 is a view of a compressor assembly according to the present disclosure;

Figure 3 shows an enlarged region of the compressor assembly shown in Figure 2;

Figure 4 shows another enlarged region of the compressor assembly shown in Figure 2;

Figure 5 shows an example of variable guide vane movement profiles;

Figures 6, 7, 8 show a cam mechanism in a side-on, end-on and exploded view respectively;

Figures 9a to 9d shows an example of the range of movement of the adjustment linkage shown in Figure 6, 7 and 8 with reference to Figure 5.

Detailed Description

[0031] The present disclosure relates to an adjustment linkage 200a for a guide vane 8 of a compressor 14 for use in a turbomachine, such as a gas turbine engine 10. Hence the present disclosure also relates to a compressor for a gas turbine engine comprising the linkage 200a, and a gas turbine engine comprising the compressor. By way of context, Figure 1 shows a known arrangement to which features of the present disclosure may be applied.

[0032] Figure 1 shows an example of a gas turbine engine 10 in a sectional view. The gas turbine engine 10 comprises, in flow series, an inlet 12, a compressor or compressor section 14, a combustor section 16 and a turbine section 18 which are generally arranged in flow series and generally about and in the direction of a rotational axis 20. The rotational axis may also be termed the "operational axis", the direction of flow through the compressor being generally aligned with the operational/rotational axis. The gas turbine engine 10 further comprises a shaft 22 which is rotatable about the rotational axis 20 and which extends longitudinally through the gas turbine engine 10. The shaft 22 drivingly connects the turbine section 18 to the compressor section 14.

[0033] In operation of the gas turbine engine 10, air 24, which is taken in through the air inlet 12 is compressed by the compressor 14 and delivered to the combustion section or burner section 16. The burner section 16 comprises a burner plenum 26, one or more combustion chambers 28 extending along a longitudinal axis 35 and at least one burner 30 fixed to each combustion chamber 28. The combustion chambers 28 and the burners 30 are located inside the burner plenum 26. The compressed air passing through the compressor 14 enters a diffuser 32 and is discharged from the diffuser 32 into the burner plenum 26 from where a portion of the air enters the burner 30 and is mixed with a gaseous or liquid fuel. The air/fuel mixture is then burned and the combustion gas 34 or working gas from the combustion is channelled through the combustion chamber 28 to the turbine section 18 via a transition duct 17.

[0034] This exemplary gas turbine engine 10 has a cannular combustor section arrangement 16, which is constituted by an annular array of combustor cans 19 each having the burner 30 and the combustion chamber 28, the transition duct 17 has a generally circular inlet that interfaces with the combustor chamber 28 and an outlet in the form of an annular segment. An annular array of transition duct outlets form an annulus for channelling the combustion gases to the turbine 18.

[0035] The turbine section 18 comprises a number of blade carrying discs 36 attached to the shaft 22. In the present example, two discs 36 each carry an annular array of turbine blades 38 are shown. However, the number of blade carrying discs could be different, i.e. only one disc or more than two discs. In addition, guiding vanes 40, which are fixed to a stator 42 of the gas turbine engine 10, are disposed between the stages of annular arrays of turbine blades 38. Between the exit of the combustion chamber 28 and the leading turbine blades 38 inlet guiding vanes 44 are provided and turn the flow of working gas onto the turbine blades 38.

[0036] The combustion gas 34 from the combustion chamber 28 enters the turbine section 18 and drives the turbine blades 38 which in turn rotate the shaft 22. The guiding vanes 40, 44 serve to optimise the angle of the combustion or working gas 34 on the turbine blades 38.

[0037] The turbine section 18 drives the compressor 14, i.e. particularly a compressor rotor, via the shaft 22.

[0038] The compressor 14 comprises an axial series of vane stages 46, or guide vane stages 46, and rotor blade stages 48. The rotor blade stages 48 comprise a rotor disc supporting an annular array of blades. The compressor 14 also comprises a casing 50 that surrounds the rotor blade stages 48 and supports the guide vane stages 46. The casing 50 extends along, and is centred on, the operational axis 20. The guide vane stages 46 include an annular array of radially extending guide vanes 7 that are mounted to the casing 50. The guide vanes 7, hereinafter also referred to as the vanes 7, are provided to present gas flow at an optimal angle for the blades of the rotor blade stage 48 that is present adjacent to and downstream of, with respect to a flow direction of the air 24 along the compressor 14 at a given engine operational point.

[0039] The casing 50 defines a radially outer surface 52 of the passage 56 of the compressor 14. The guide vane stages 46 and the rotor blade stages 48 are arranged in the passage 56, generally alternately axially. The passage 56 defines a flow path for the air through the compressor 14 and is also referred to as an axial flow path 56 of the compressor 14. The air 24 coming from the inlet 12 flows over and around the guide vane stages 46 and the rotor blade stages 48. A radially inner surface 54 of the passage 56 is at least partly defined by a rotor drum 53 of the rotor which is partly defined by the annular array of blades.

[0040] Some of the guide vane stages 46 have variable guide vanes 8 (shown as vanes 8a, 8b, 8c, 8d), where the angle of the guide vanes 8, about their own longitudinal axis, can be adjusted for angle according to air flow characteristics that can occur at different engine operations conditions. Some of the other guide vane stages 46 have stationary guide vanes 9 where the angle of the guide vanes 9, about their own longitudinal axis, is fixed and thus not adjustable for angle.

[0041] The present system is described with reference to the above exemplary turbine engine having a single shaft or spool connecting a single, multi-stage compressor and a single, one or more stage turbine. However, it should be appreciated that the present system and method is equally applicable to two or three shaft engines and which can be used for industrial, aero or marine applications. Furthermore, the cannular combustor section arrangement 16 is also used for exemplary purposes and it should be appreciated that the present technique is equally applicable to gas turbine engines 10 having annular type and can type combustion chambers.

[0042] The terms axial, radial and circumferential are made with reference to the rotational axis 20 of the engine, unless otherwise stated.

[0043] As shown in Figure 2, the pitch or the angular offset for the individual stages of variable guide vanes 8a-d inside of the compressor wall 50 is controlled via a linkage mechanism 100 which is applied from the outside of the wall.

[0044] Each individual vane 8a (first stage 46a), 8b (second stage 46b), 8c (third stage 46c), 8d (fourth stage 46d) is mounted on a spindle 122 to allow angular movement of the vane 8a, 8b. Figure 3 shows an individual vane 8a of the first stage, e.g. the most upstream stage of the compressor and a corresponding lever 120.

[0045] As shown in Figure 2, the lever 120 connects the spindle 122 to a driving ring 140, provided as an adjustment ring, the so called unison ring. Each vane 8 of each stage 46 is connected to its respective unison ring via a lever 120. That is to say, the lever 120 connects the spindle 122 of each vane to a respective driving ring 140, 141, 142, 143.

[0046] All vanes 8 in a single stage are connected to the same ring so that all vanes 8 on one stage 46 are adjusted at the same time and with the same angle.

[0047] Each of the driving rings 140, 141, 142, 143 is rotated via a push rod 150, one per ring, from a common adjustment drive shaft 152 which is coupled to (and/or is the output shaft 152 of) a adjustment drive 154. The adjustment drive shaft 152 may be coupled to and be driven by the adjustment drive 154 in any suitable manner.

[0048] The adjustment drive may comprise only a single actuator (i.e. a drive). Hence a single drive may provide an input to act on all of the push rods 150, unison rings 140-143 and hence guide vanes.

[0049] The rotational movement of the driving rings 140, 141, 142, 143 (shown as arrows s1, s2, s3, s4) is applied via the lever 120 as a rotational movement as indicated via arrow m2 to the lever 120 of each vane 8a to 8d. Thus the movement of the adjustment drive shaft 152 results in a rotation of vanes 8a to 8d as indicated in Figures 3, 4.

[0050] In the present example the first stage 46a is operated in concert with the later stages 46bm 46c, 46d. However, stages 46b, 46c, 46d are in synchronisation with each other, where stage 46a is configured to open and close to a different schedule.

[0051] Put another way, the opening/closing of the stages 46b, 46c, 46d is synchronous in that they all open and close at the same time, whereas the opening/closing of the stage 46a is asynchronous relative to the other stages in that the first stage 46a may be opening when the other stages are closing, and may close at a different rate to the other stages.

[0052] This is best illustrated with reference to Figure 5 (and will be explained further with reference to Figures 9a, 9b, 9c, 9d.)

[0053] Figure 5 shows a plot of variable guide vane angle plotted against engine speed. As can be seen with reference to the profile schedule for vanes 8b, 8c, 8d, at low engine speed the vanes are disposed at a first angle relative to the operational axis 20 (and/or direction of flow through the compressor), and as engine speed increases the vanes are rotated relative to the operational axis 20 such that they are at their most "open" configuration at highest engine speed to allow maximum airflow.

[0054] The angle of the variable guide vane relative to the operational axis 20 may be considered in terms of the angle a chord line 123 which extends between the vane leading edge and trailing edge makes with the operational axis 20, for example as shown in Figure 4.

[0055] In a conventional compressor for a gas turbine engine the vanes 8a of the first stage 46a would follow the same pattern as the later stages, as indicated by the profile marked 8a' in Figure 6.

[0056] However the arrangement of the present disclosure, as the profile as shown for 8a. The asynchronous schedule is achieved by virtue of the cam mechanism shown in Figures 6 to 8, which may be provided on the first stage 46a of the compressor.

[0057] Figures 6, 7 show side and end on views of the cam mechanism 210. Figure 8 shows an exploded view of the cam mechanism 210. The cam mechanism 210 incorporates a closed cam 230 which can receive force from a drive pin 260 from either the lower cam surface or the upper cam surface. Hence, the variable stage of blades can be opened or closed by the same cam mechanism.

[0058] The linkage mechanism 100 includes several adjustment linkages 200a, 200b, 200c, 200d for control of vanes 8a (first stage 46a), 8b (second stage 46b), 8c (third stage 46c) and 8d (fourth stage 46d).

[0059] As shown in Figures 2, 3, the variable guide vane 8a is rotatably mounted at a first location 202 on the casing 50, the vane lever arm 120 coupled at one end to the variable guide vane 8a. The vane lever arm 120 is coupled at its other end to the adjustment (unison) ring 140 (see Figure 5) which is coaxial with the casing operational axis 20.

[0060] Hence the variable guide vane 8a pivotably coupled to the adjustment ring 140 via the lever arm 120.

[0061] As shown in Figure 2, the adjustment drive 154 is mounted to the casing 50 in a second location 204 spaced apart from the first location 202, the adjustment drive operable to actuate the adjustment ring 140 and hence rotate the vane(s) 8a via the adjustment linkage 200a.

[0062] As shown in Figure 5, the adjustment linkage 200a comprises a push rod 150. A first end 206 of the push rod 150 is configured to be pivotably coupled to the adjustment ring 140. A second end 208 of the push rod 150 is configured to be coupled to an output 152 (for example the shaft 152 coupled to the adjustment drive 154) of the adjustment drive 154 via a cam mechanism 210. A push rod attachment member 209 extends from the cam plate 214 for coupling by some suitable means (for example a pin which links the push rod 150 and cam plate 214 together. Hence the second end 208 of the push rod 150 is coupled to the cam plate 214 by a push rod attachment member 209. The cam mechanism 210 is configured to vary the directional output of the adjustment drive 154. That is to say, the cam mechanism 210 is configured to convert a single direction rotational input from the adjustment drive to a reciprocating linear output. The push rod has a longitudinal axis 212 which extends between its first end 206 and second end 208.

[0063] The cam mechanism 210 comprises a cam plate 214. The cam plate 214 is configured to be coupled to the push rod 150.

[0064] The cam plate 214 is provided with a slot 216 which defines a cam guide path 230. The cam plate 214 is also provided with an aperture 218 through which the distributor shaft 152 extends, configured such that the distributor shaft 152 is rotatable relative to the cam plate 214, and configured such that the cam plate 214 is slideable relative to the distributor shaft 152. The cam mechanism also comprises a drive plate 224 from which extends a drive pin 260. The drive pin 260 extends through and is in slideable engagement with, the cam plate slot 216. The drive plate 224 is engaged with, and driven by, the distributor shaft 152. Hence the drive plate 224 is moveable relative to the cam plate 214 such that rotating/pivoting movement of the drive plate 224 with the distributor shaft 152 causes the drive pin 260 to move along the slot 216 i.e. path 230, and thereby causes the cam plate 214 to move relative to the distributor shaft 152, thereby acting on the push rod 150 to move in the direction along its longitudinal axis 212, and thereby turning the guide vane 8a.

[0065] The cam plate aperture 218 is an elongate slot such that the cam plate 214 is linearly slideable relative to the distributor shaft 152. The distributor shaft 152 is rotatable relative to the cam plate 214.

[0066] The cam mechanism further comprises a non-rotatable fixed plate 262 from which extends a restraint pin 266 which extends through a cut out 269 provided in the drive plate 224 into a clearance slot 268 in the cam plate 214. The cut out 269 allows for the drive plate 224 to move relative to the restraint pin 266. The cam plate clearance slot 268 is elongate and extends parallel to the cam plate aperture 218. When assembled the slot 168 is aligned with longitudinal axis 212 of the push rod 150. The spacing and orientation of the slots 168 are configured to restrict motion of the cam plate 214 in the elongate direction of the cam plate clearance slot 268 and cam plate aperture 218.

[0067] As described above the fixed plates 262 are non-rotatable relative to the shaft 152 or casing 50, and are mounted/anchored to the casing 50, actuator drive housing or other non rotatable structure.

[0068] The cam plate 214, drive plate 224 and fixed plate 262 are configured to be arranged in series along the distributor shaft 152, the cam plate 214 spaced apart from the fixed plate 262 by the drive plate 224.

[0069] The cam mechanism 210 may further comprise a further fixed plate 262 spaced apart from the cam plate 214 by a further drive plate 224 configured to be arranged in series along the distributor shaft 152 with the cam plate 214 and fixed plate 262 and drive plate 224, the further fixed plate 262 and further drive plate 224 configured to be arranged on an opposite side of the cam plate 214 to the other fixed plate 262 and drive plate 224, the drive pin 260 engaged with, and extending between, the drive plates 224 and the restraint pin 266 engaged with, and extending between, the fixed plates 262.

[0070] The cam plate is engaged with, and hence rotatable by, the adjustment drive 154 (for example via the distributor shaft 152). Hence the adjustment drive 154 drives the drive shaft 152, which thus drives the drive plate 224 around an axis centred on the drive shaft 152.

[0071] The guide path 230 and pin 260 are configured such that the cam plate 214 is moveable relative to the drive shaft 152 in a lengthwise direction (indicated by arrow D1-D2 in Figure 6, 8), and such that the drive plate 224 is pivotable relative to the cam plate 214, for example in a widthwise direction (indicated by arrow W1-W2 in Figure 6) of the cam plate 214. That is to say, the guide path 230 allows for the cam plate 214 to move relative to the drive shaft 152 in a lengthwise D1-D2 direction and/or the drive plate 224 to move relative to the cam plate 214 in a widthwise direction W1-W2 of the cam plate 214, and so that the drive plate 224 can pivot relative to the cam plate 214.

[0072] As shown in Figures 6, 8, 9a to 9d, the guide path 230 comprises at least one inflexion 240, 242 which, in use, defines (and causes) a change in direction of travel D1, D2 of the push rod 150 and cam plate 214 relative to the distributor shaft 152 and thus defines a change of rotational direction R1, R2 of the guide vane 8a.

[0073] The cam mechanism in Figure 8 differs to the cam mechanism in Figure 9.

[0074] In the example shown in Figures 6, 7 and 8, the push rod attachment member 209 is spaced apart from the cam plate aperture 218 by the cam path 230. In the example in Figure 9 the push rod attachment member 209 is spaced apart from the cam path 230 by the cam plate aperture 218. However operation of both examples is essentially the same.

[0075] In the example shown the guide path 230 comprises two inflexions 240,242. The guide path comprises a first region 250 which extends from a start point 241 to the first inflexion 240. The first region 250 defines a direction of travel D1 of the push rod 150 and cam plate 214 relative to the drive shaft 152 as shown in Figures 5, 7a, and direction of rotation R1 of the vane 8, as shown in Figure 4. The second inflexion 242 is spaced apart from the first inflexion 240 along the guide path 230 by a second region 252. The first inflexion 240 defines a change in direction of the push rod 150 and cam plate 214 relative to the drive shaft 152 from the first direction D1 to the second direction D2 thus defining a change of rotational direction of the guide vane 8a from the first rotational direction R1 to the second rotational direction R2 (as shown in Figure 4). The second inflexion 241 defines a change in direction of the push rod 150 and cam plate 214 relative to the drive shaft 152 from the second direction D2 to the first direction D1, thus defining a change of rotational direction of the guide vane 8a from the second rotational direction R2 to the first rotational direction R1 (as shown in Figure 4). A third region 254 extends from the second inflexion to an end point 256, which defines a direction of travel D1, and direction of rotation R1.

[0076] As shown in Figures 5, 6, 8, 9a to 9d the first direction D1 is opposite to the second direction D2, and as shown in Figure 4 the first rotational direction R1 is opposite to the second rotational direction R2.

[0077] As described above, the variable guide vane 8a may be one of an array of variable guide vanes 8a arranged around the circumference of the casing 50 to form at least part of the first flow stage 46a.

[0078] As also described, there may also be provided a further arrays/stages 46b, 46c, 46d of variable guide vanes 8b, 8c, 8d respectively arranged around the circumference of the casing 50 to form at least part of a further flow stage 46b, 46c, 46d spaced apart from the first flow stage 46a along the operational axis 20.

[0079] Hence there may be provided a second (or more) array/stage 46b, 46c, 46d of variable guide vanes 8b, 8c, 8d arranged around the circumference of the casing 50 to form at least part of a second, third and/or fourth flow stage 46b spaced apart from the first flow stage 46a along the operational axis 20.

[0080] More than one of the stages 46a, 46b, 46c, 46d may be provided with an adjustment linkage as described in relation to the first stage 46a.

[0081] However, in the example shown, only the adjustment linkage 200a of the first stage 46a comprises a push rod 150 and cam mechanism 210 herein described. The remaining adjustment linkages 200b, 200c, 200d may be of a conventional kind, with push rods 150 coupled to the adjustment drive 154 such that an output from the displacement drive 154 is directly proportional to the direction of movement of the push rods 150 and vanes 8b, 8c, 8d.

[0082] Hence a first end 206b of a second flow stage adjustment linkage 200b is coupled to the second array 46b of variable guide vanes via the vane lever arm 120 and second flow stage adjustment ring 141 as described above generally and in relation to the first array 8a of variable guide vanes 8a.

[0083] Hence the second flow stage adjustment linkage 200b has a first end 206b of the second flow stage adjustment linkage 200b coupled to the adjustment ring. A second end 208b (distal to the first end 206b) of the second flow stage adjustment linkage 200a is coupled to the output 152 of the adjustment drive 154.

[0084] As described below, the second flow stage adjustment linkage 200b, and the first flow stage adjustment linkage 200a are configured such that for a given output of the adjustment drive 154, the vanes 8a of the second flow stage 46b will move by a different amount and/or in a different direction (R1, R2) to the variable vanes 8a of the first flow stage 46a.

[0085] When an axial compressor 14 with several stages is running the compression of the air passing through it is achieved progressively, with similar compression ratios at each stage, so the area of the gas path through the compressor is designed to reduce progressively. At very low speeds, encountered during starting and shutting down of the engine, the early stages variable guide vanes 8a, 8b do not provide sufficient compression to enable the air flow to pass through the rear (downstream) vane stages 46c, 46d which become "choked". When this occurs flow can separate from aerofoil surfaces causing "stall" and flow reversal in all stages of the compressor 14. As this occurs the high pressure air exiting the compressor flows back through the compressor 14 creating a pressure wave (called "surge"). Normally surges will occur repeatedly until the engine is stopped.

[0086] However, the arrangement of the present invention controls air flows to avoid the stall condition arising. Figure 5 illustrates the relative movements of the different the first stage 46a to later stages 46b, 46c, 46d in an arrangement according to the present disclosure which has been determined to affect air flows such that stall or other deleterious air flow conditions will be inhibited from occurring by virtue of a the first stage 46a being restricted compared to the other stages at predetermined engine conditions.

[0087] At low engine/flow speed the variable guide vanes are "closed" (restricting flow to their maximum extent) and as engine speed increases the variable guide vanes 8a to 8d are opened to their running position in order to pass more flow. As described, the variable guide vanes 8a, 8b, 8c, 8d are moved by the single actuator 152, with the mechanical linkage 100 enabling successive stages 46a, 46b, 46c, 46d to move by different amounts and in concert with each other.

[0088] In the present example the first stage 46a is operated in concert with the later stages 46b, 46c, 46d. However, stages 46b, 46c, 46d are in synchronisation with each other, where stage 46a is configured to open and close to a different schedule.

[0089] This is best understood with reference to Figures 5, Figure 9a to 9d.

[0090] As indicated at location "A" at low engine speed the drive pin 260 is at the starting point 241 of the guide path 230 with the vanes 8a in their most "closed" orientation relative to the operational axis 20 (i.e. moved in the R2 direction to a predetermined extent). As the shaft 152 rotates the drive plate 224, the drive pin 260 moves along the cam path 230, which causes the cam plate 214 to move. Given the shape of the path 230 in the first region 250, and since the movement of the cam plate 214 is constrained by the restraint pin 266 in the restraint slot 268, the cam plate 214 may only move in first direction D1, as shown in Figure 9a. Hence the cam plate 214, linked to the push rod 150, draws the push rod 150 in the first direction D1 also to thereby open the vanes 8a in direction R1. This motion is indicated in the region between points "A" and "B" in Figure 5. As the shaft 152 and drive plate 224 rotate further in the same direction, the drive pin 260 moves further along the path 230 to reach the first inflexion 240, as shown in Figure 9b, and then start to travel towards the second inflexion 242, as shown in Figure 9c. The journey between the first inflexion 240 and second inflexion 242 causes the cam plate 214 (and hence the push rod 150) to change from moving in direction D1 and instead move in direction D2 as shown in Figure 9c to rotate and close the vanes 8a in direction R2. This is illustrated in the region between points "B" and "C" in Figure 5. When the shaft 152 and drive plate 224 rotate further in the same direction to move the drive pin 260 away from the second inflexion 242 towards the end point 256 of the path 230, the cam plate 214, and hence push rod 150, is drawn again in direction D1 and the vanes 8a are rotated in direction R1 to open them again. This is illustrated in the region between points "C" and "D" in Figure 5.

[0091] The reverse of this process, when the engine speed decreases during a deceleration, the shaft 152 and drive plate 224 are rotated in an opposite direction than during acceleration, and the relative movement of the push rod 150/cam plate 214 and drive plate 224/shaft 152 occurs in reverse to that described above.

[0092] Hence the second flow stage adjustment linkage 200b, and the first flow stage adjustment linkage 200a are configured such that for a given output (e.g. rotation of the shaft 152 between points "B" and "C") of the adjustment drive 154, the vanes 8b of the second flow stage 46b will move by a different amount and/or in a different direction (R1, R2) to the variable vanes 8a of the first flow stage 46a.

[0093] Additionally the second flow stage adjustment linkage 200b and the first flow stage adjustment linkage 200a are configured such that the vanes 8b of the second flow stage 46b will move by a different amount and/or in a different direction to the variable vanes of the first flow stage 46a at a predetermined flow condition in the compressor 14. The predetermined flow condition may be expressed in terms of engine speed. That is to say the cam mechanism 210 is configured such that point "B" is at a first % of maximum engine speed, and point C is a second % of maximum engine speed.

[0094] The cam mechanism 210 may be configured such that point "B" is in the range of 70% to 80% of maximum engine speed, and point C is in the range of 85% to 95% of maximum engine speed.

[0095] The cam mechanism 210 may be configured such that point "B" is at 80% of maximum engine speed, and point C is at 90% of maximum engine speed.

[0096] Alternatively the cam mechanism 210 may be configured such that point "B" is at 80% of maximum engine speed, and point C is at 95% of maximum engine speed.

[0097] Hence there is provided an arrangement which enables a "programmed" schedule (i.e. a predetermined movement profile) of operation for a variable guide vane stage to avoid stall and other potentially damaging air flow conditions. It also enables several variable guide vane stages to be operated to different predetermined opening/closing schedules to avoid stall and other potentially damaging air flow conditions.

[0098] The arrangement of the present disclosure also enables several variable guide vanes stages to be controlled using a single actuator, thus avoiding cost and reducing risk associated with using a separator actuator to control one or more stages.

[0099] Control using a single actuator for all of the guide vanes also simplifies the overall compressor structure, and obviates the need for reconfiguring engine components if the arrangement of the present disclosure is fitted retrospectively.

[0100] The combination of push rod 150 and cam mechanism (e.g. cam plate 214 with path 30 which guides a drive pin 260) configured to vary the directional output of the adjustment drive 154 (i.e. convert a single direction rotational input from the adjustment drive to a reciprocating linear output) provides a robust mechanical means of achieving the asynchronous scheduling of first stage 46a and other stages relative to one another.

[0101] Attention is directed to all papers and documents which are filed concurrently with or previous to this specification in connection with this application and which are open to public inspection with this specification, and the contents of all such papers and documents are incorporated herein by reference.

[0102] All of the features disclosed in this specification (including any accompanying claims, abstract and drawings), and/or all of the steps of any method or process so disclosed, may be combined in any combination, except combinations where at least some of such features and/or steps are mutually exclusive.

[0103] Each feature disclosed in this specification (including any accompanying claims, abstract and drawings) may be replaced by alternative features serving the same, equivalent or similar purpose, unless expressly stated otherwise. Thus, unless expressly stated otherwise, each feature disclosed is one example only of a generic series of equivalent or similar features.

[0104] The invention is not restricted to the details of the foregoing embodiment(s). The invention extends to any novel one, or any novel combination, of the features disclosed in this specification (including any accompanying claims, abstract and drawings), or to any novel one, or any novel combination, of the steps of any method or process so disclosed.

Claims

1. An adjustment linkage (200a) for a guide vane (8) of a compressor (14) for a gas turbine engine (10), the adjustment linkage (200a) comprising :

a push rod (150);

a first end (206) of the push rod (150) is configured to be coupled to an adjustment ring (140) for actuation of a variable guide vane (8a); and
a second end (208) of the push rod (150) is configured to be coupled to an output (152) of an adjustment drive (154) via

a cam mechanism (210)
configured to convert a single direction rotational input from the adjustment drive to a reciprocating linear output;
the push rod having a longitudinal axis (212) which extends between its first end (206) and second end (208);
the cam mechanism (210) configured to :

allow the push rod (150) to move in a direction along its longitudinal axis (212); and
restrict the push rod (150) from moving in a direction at an angle to its longitudinal axis (212).

2. An adjustment linkage (200a) as claimed in claim 1 wherein
the output (152) of the adjustment drive (154) comprises a distributor shaft (152); and
the cam mechanism (210) comprises :

a cam plate (214), configured to be coupled to the push rod (150);

the cam plate (214) provided with a slot (216) which defines a cam guide path (230); and
the cam plate provided with an aperture (218) through which the distributor shaft

(152) extends,
such that the cam plate (214) is slideable relative to the distributor shaft (152);

a drive plate (224) from which extends a drive pin (260),

the drive pin (260) extending through, and in slideable engagement with, the cam plate slot (216); and
the drive plate (224) drivingly engaged with the distributor shaft (152);

wherein pivoting movement of the drive plate (224) with the distributor shaft (152) causes the cam plate (214) to move relative to the distributor shaft (152),

thereby acting on the push rod (150) to move in the direction along its longitudinal axis (212); and
thereby turning the guide vane (8a).

3. An adjustment linkage (200a) as claimed in claim 2 wherein

the cam plate aperture (218) is an elongate slot such that the cam plate (214) is linearly slideable relative to the distributor shaft (152).

4. An adjustment linkage (200a) as claimed in claims 2, 3 further comprising
a fixed plate (262) from which extends a restraint pin (266)

which extends into a clearance slot (268) in the cam plate (214);
the cam plate clearance slot (268) being elongate and extending parallel to the cam plate aperture (218)
to restrict motion of the cam plate (214) to the elongate direction of the cam plate clearance slot (268) and cam plate aperture (218).

5. An adjustment linkage (200a) as claimed in claim 4 wherein
the cam plate (214), drive plate (224) and fixed plate (262) are configured to be arranged in series along the distributor shaft (152), the cam plate (214) spaced apart from the fixed plate (262) by the drive plate (224).

6. An adjustment linkage (200a) as claimed in claim 4, 5 wherein the cam mechanism (210) further comprises :

a further fixed plate (262) spaced apart from the cam plate (214) by a further drive plate (224) configured to be arranged in series along the distributor shaft (152) with the cam plate (214) and fixed plate (262) and drive plate (224),
the further fixed plate (262) and further drive plate (224) configured to be arranged on an opposite side of the cam plate (214) to the other fixed plate (262) and drive plate (224),
the drive pin (260) engaged with, and extending between, the drive plates (224) and
the restraint pin (266) engaged with, and extending between, the fixed plates (262).

7. An adjustment linkage (200a) as claimed in any one of claims 2 to 6 wherein

the cam guide path (230) comprises at least one inflexion (240) which, in use, defines a change in direction of travel of the cam plate (214) relative to the distributor shaft (152), and
thus defines a change of direction of travel of the push rod (150) relative to the distributor shaft (152),
thus defining a change of rotational direction of the guide vane (8).

8. An adjustment linkage (200a) as claimed in claim 7 wherein

the cam guide path (230) comprises two inflexions (240, 242),
the first inflexion (240) defining a change in direction of travel of the cam plate (214) relative to the distributor shaft (152) from a first direction (D1) to a second direction (D2);
thus defining a change of rotational direction of the guide vane (8) from a first rotational direction (R1) to a second rotational direction (R2);
the second inflexion (240) defining a change in direction of cam plate (214) relative to the distributor shaft (152) from the second direction (D2) to the first direction (D1),
thus defining a change of rotational direction of the guide vane (8a) from the second rotational direction (R2) to the first rotational direction (R1).

9. A compressor for a gas turbine engine comprising :

a casing (50) which extends along, and is centred on, an operational axis (20);
a rotatably mounted variable guide vane (8a) at a first location (202) on the casing (50);
a vane lever arm (20) coupled at one end to the variable guide vane (8a), and coupled at its other end to
an adjustment ring (140) coaxial with the casing operational axis (20);
an adjustment drive (154) mounted to the casing (50) in a second location (204)

an adjustment linkage (200a), as claimed in any one of claims 1 to 8 , wherein

a first end (206) of the adjustment linkage (200a) is coupled to the adjustment ring (140); and
a second end (208) of the adjustment linkage (200a) is coupled to an output of the adjustment drive (154).

10. A compressor as claimed in claim 9 wherein :

the variable guide vane is one of an array of variable guide vanes arranged around the circumference of the casing (50) to form at least part of a first flow stage (46a);
the compressor further comprises :

a second array of variable guide vanes (8b) arranged around the circumference of the casing (50) to form at least part of a second flow stage (46b) spaced apart from the first flow stage (46a) along the operational axis (20),
a second flow stage adjustment ring (141) coaxial with the casing operational axis (20); and
a second flow stage adjustment linkage (200a);

a first end (206b) of the second flow stage adjustment linkage (200a) coupled to the adjustment ring (140); and
a second end (208b) of the second flow stage adjustment linkage (200b) is coupled to the output (152) of the adjustment drive (154);

wherein

the second flow stage adjustment linkage (200b), and
the first flow stage adjustment linkage (200a)
are configured such that for a given output of the adjustment drive (154), the vanes (8b) of the second flow stage (46b) will move by a different amount and/or in a different direction to the variable vanes of the first flow stage (46a).

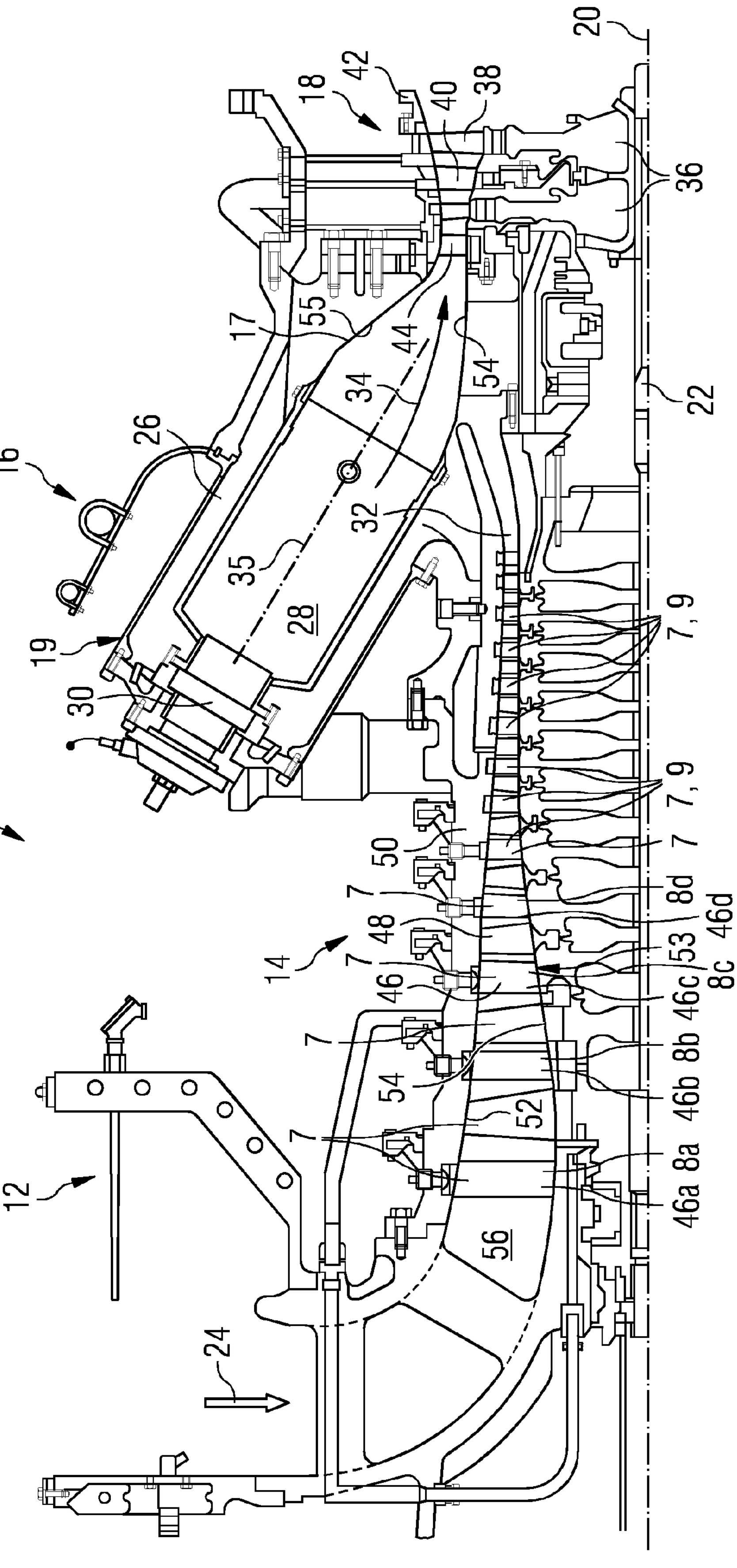
11. A compressor as claimed in claim 10 operable such that:

the vanes (8b) of the second flow stage (46b) will move by a different amount and/or in a different direction to the variable vanes of the first flow stage (46a) at a predetermined flow condition in the compressor (14).

12. A gas turbine engine comprising an compressor as claimed in claims 10, 11 wherein :

the predetermined flow condition is in the range of 80% to 95% maximum engine speed.

FIG 1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46
46a
46b
46c
46d
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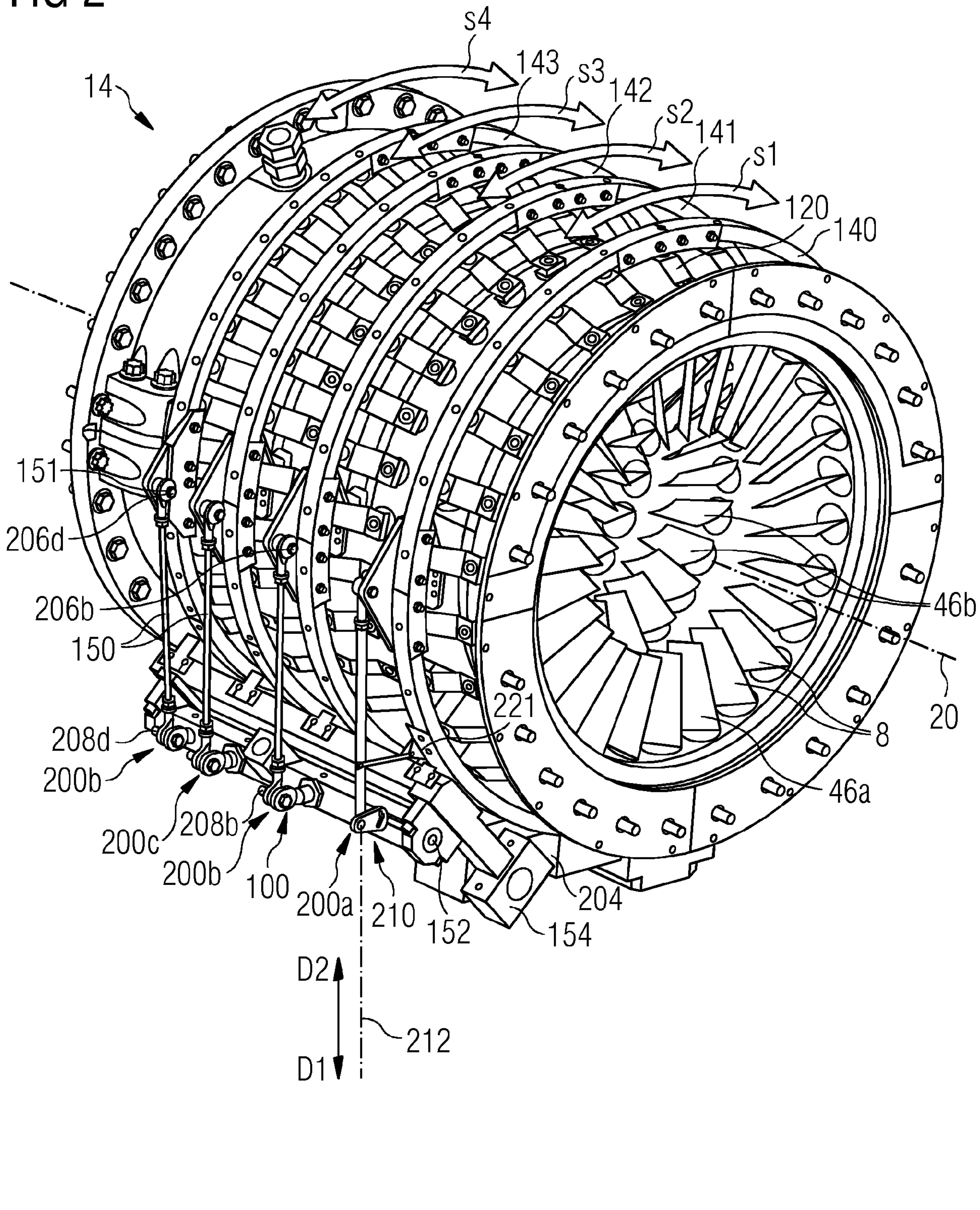
56
7
7, 9
8a
8b
8c
8d

FIG 2


s4
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s3
142
s2
141
s1
120
140
14
151
206d
206b
150
208d
200b
200c
208b
200b
100
200a
210
152
154
204
221
46b
20
8
46a
D2
212
D1

FIG 3

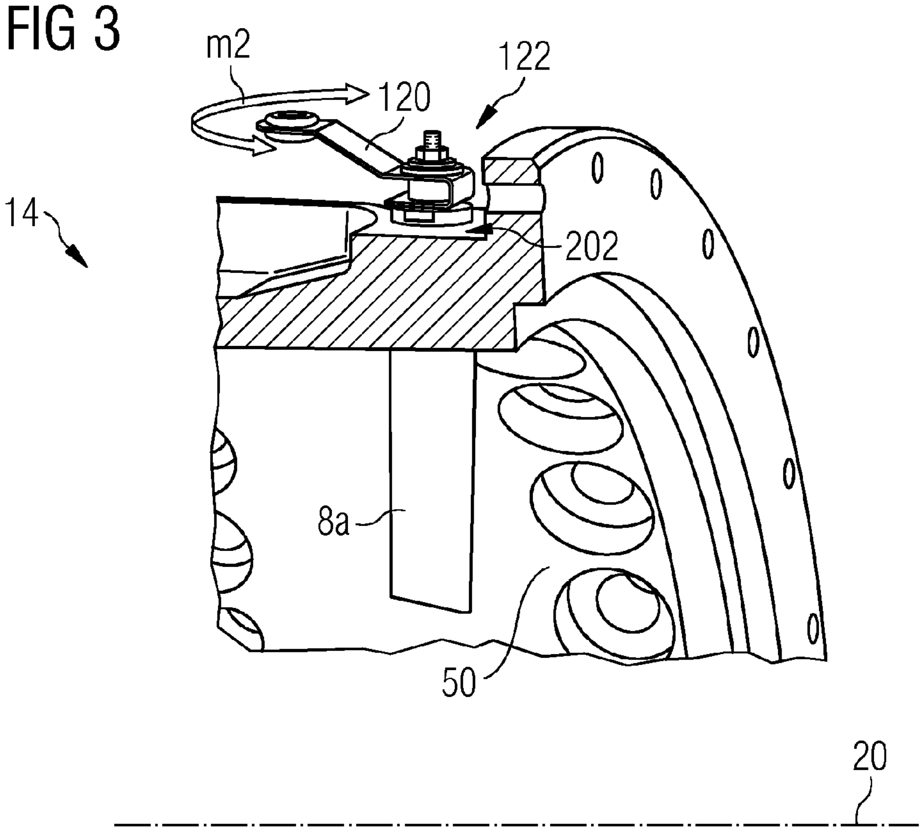


FIG 4

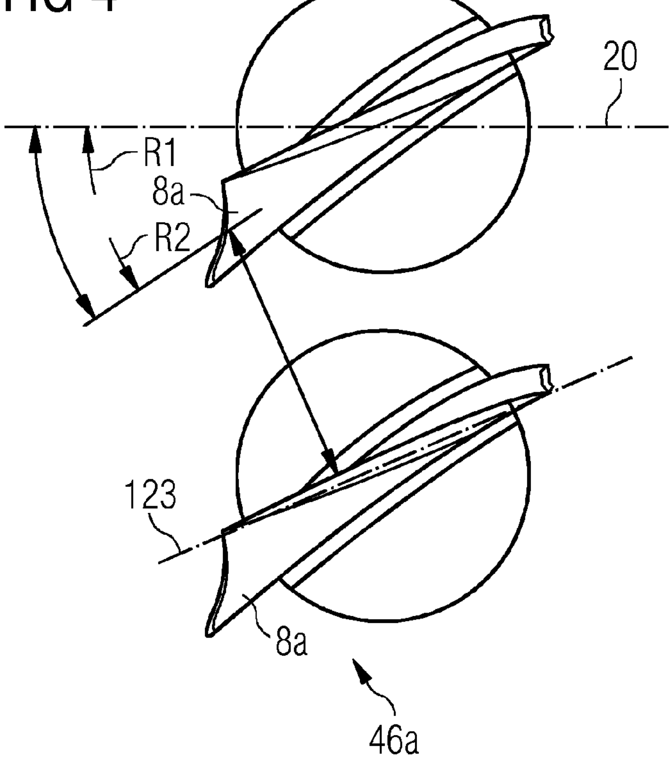


FIG 5

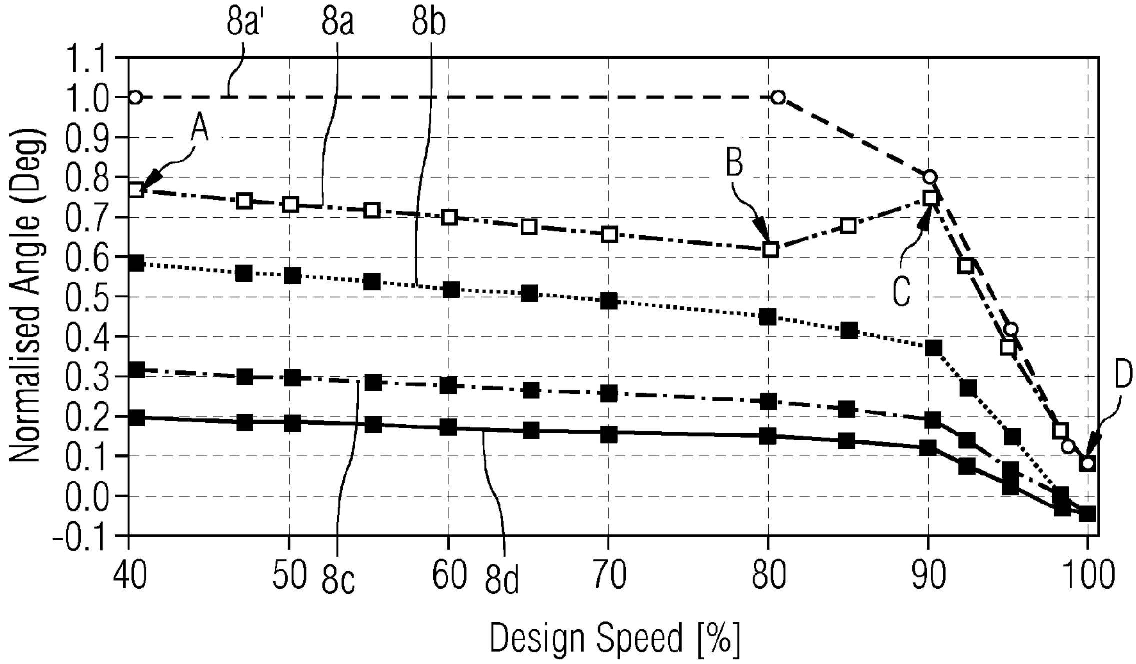


FIG 6

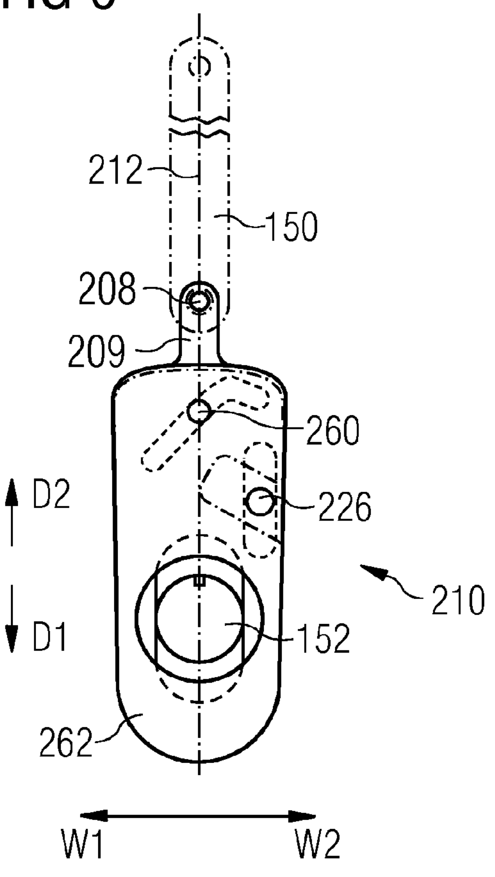


FIG 7

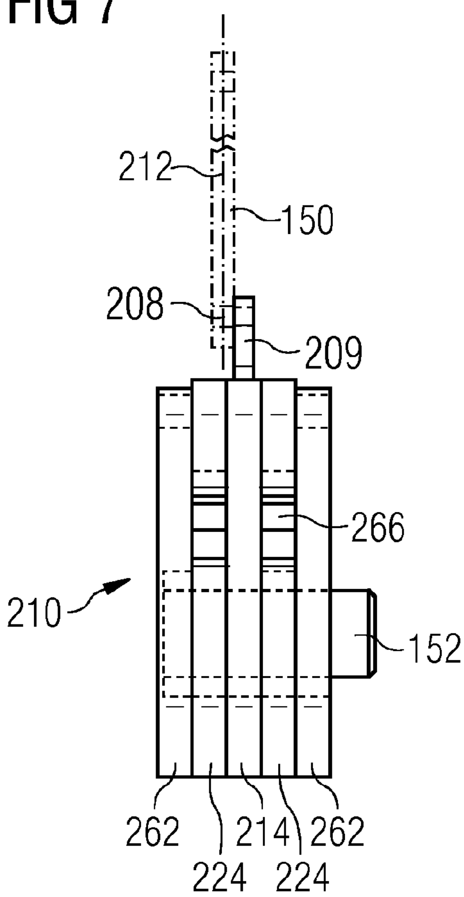
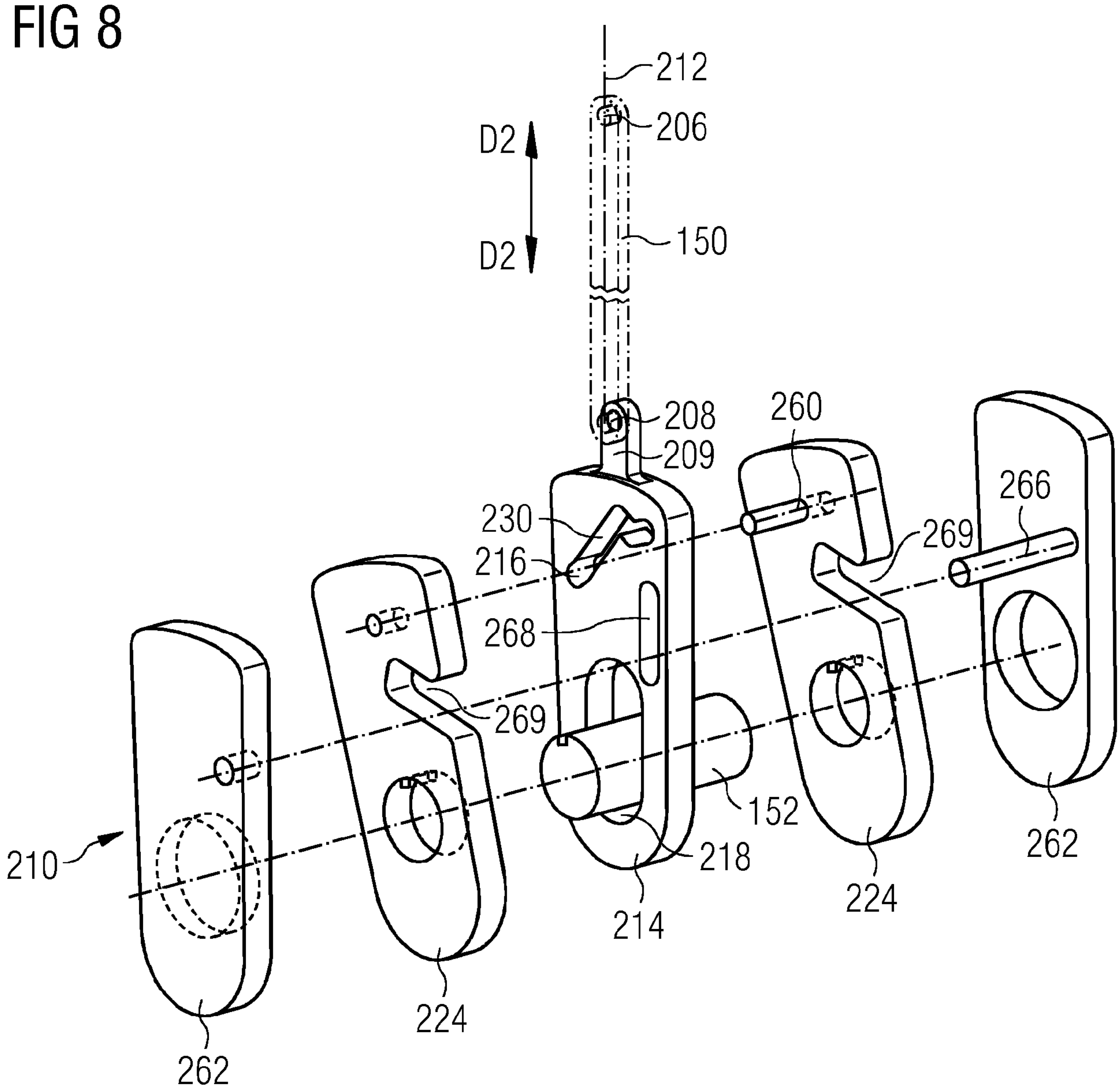


FIG 8



212
206
D2
D2
150
208
209
260
266
230
216
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268
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152
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218
262
224
214
224
262

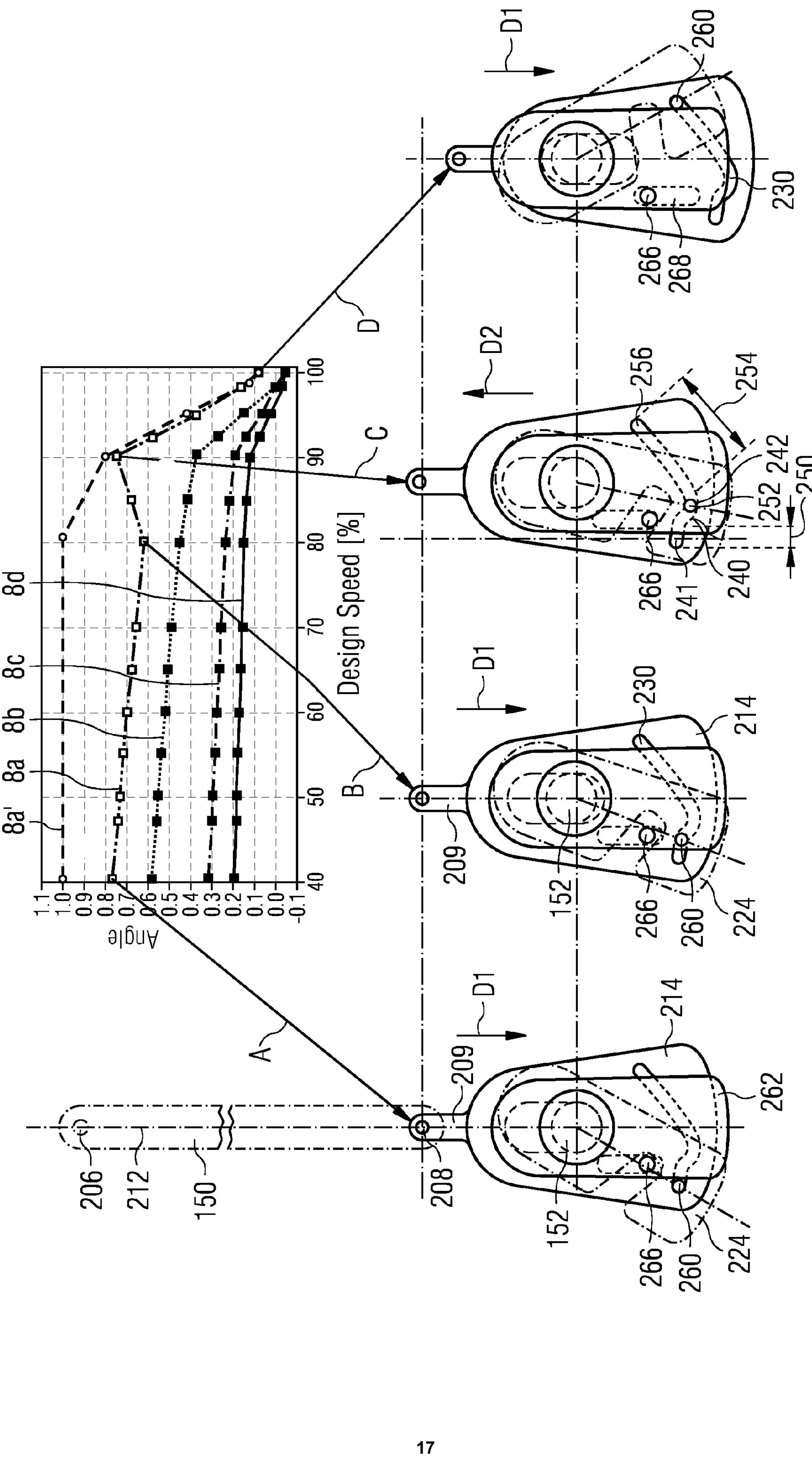

FIG 9A

FIG 9B

FIG 9C

FIG 9D

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EUROPEAN SEARCH REPORT

Application Number
EP 17 20 8563

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The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
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