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(71) Applicant: **Weston Aerospace Limited**
Hampshire GU14 7PW (GB)

(72) Inventor: **DOBSON, Dean**
Farnborough, Hampshire GU14 7PW (GB)

(74) Representative: **Vleck, Jan Montagu**
Reddie & Grose LLP
The White Chapel Building
10 Whitechapel High Street
London E1 8QS (GB)

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(54) **SYSTEM FOR DETECTING ABNORMAL MOVEMENT OF A SHAFT IN A GAS TURBINE ENGINE**

(57) A system (10) for detecting abnormal movement resulting from breakage of a shaft in a gas turbine engine. The system comprises a detection circuit including a frangible and brittle fuse portion (12) made from a conductive ceramic and a plunger (18) connected to or adjacent the

frangible fuse portion, wherein the plunger may be displaced as a result of movement of the broken gas turbine shaft to break the frangible fuse portion (12) and thereby alter the detection circuit.

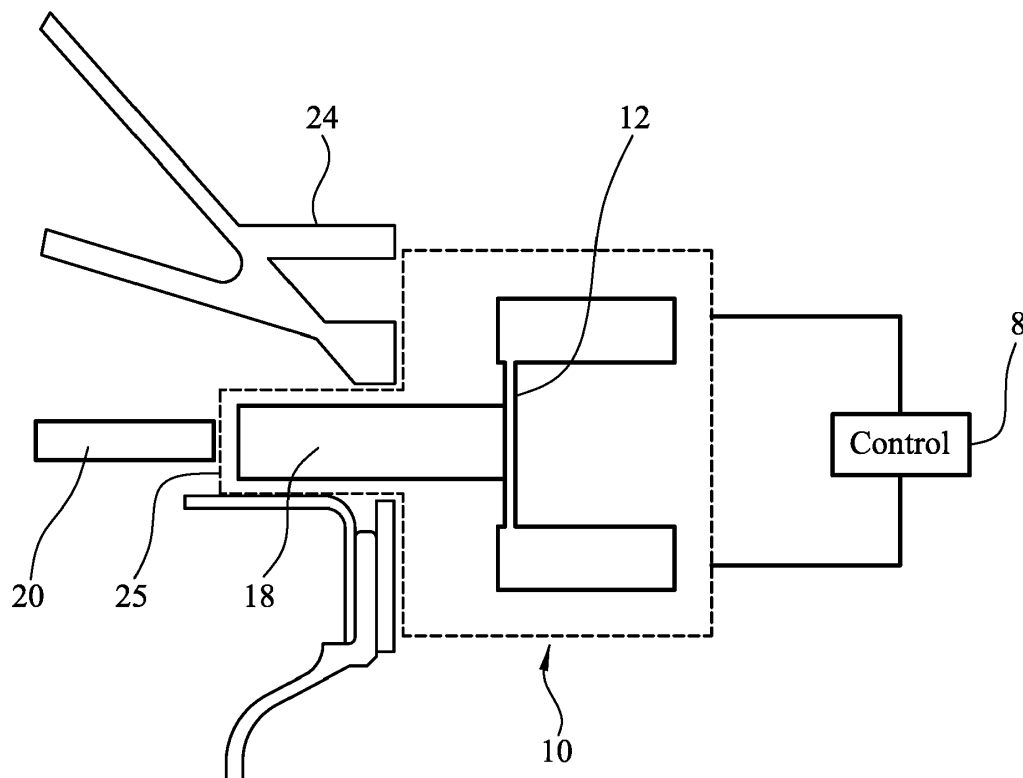


Figure 3

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Description

[0001] The present invention is concerned with a system for detecting a broken shaft in a gas turbine engine and a detector element for use in such a system. A broken shaft in a gas turbine engine results in the risk of so-called "turbine over-speed". When the shaft of, for example, a jet engine breaks, the compressor mass is lost to the rotating system so the shaft and turbine then rotates significantly more quickly. The movement of the turbine can be sufficiently fast to cause the turbine to fly apart and break.

[0002] Gas turbine engines (e.g. jet engines) include a rotating shaft having compressor and/or turbine blades mounted thereon and rotating therewith. Axial movement of the shaft relative to the remainder of the engine is considered to be an abnormal movement and indicative of engine failure (e.g. shaft breakage). Detection of axial movement of the shaft relative to the remainder of the engine can therefore be used to detect engine failure and used to prevent further damage to the engine by activating a shut off of the engine. A shaft links the turbine and compressor. If the shaft is broken, the turbine portion moves backwards because of the effect of combustion gases. The compressor elements would lose power and stop rotating.

[0003] It is known to detect abnormal movement of a gas turbine shaft relative to the engine casing by providing a circuit breaking element which is fixed to the shaft and moves therewith if and when the shaft moves in an axial direction to break a circuit and thereby produce a signal.

[0004] US 6,607,349 discloses a broken shaft detection system and a method which uses a detector assembly mounted downstream of a power turbine wheel of a gas turbine engine to detect rearward axial motion of the wheel and thereby a broken shaft event. The detector assembly has a plunger positioned to be axially displaced against a metal conductive wire fuse link connected in an electrical circuit. The metal wire link may be broken when the plunger is displaced thereby creating an open circuit that may be detected by a detection and test element. The breaking may be communicated to an over-speed circuit that controls a shut off switch that interrupts fuel flow to the engine. The metal wire link may be connected to the detection and test element by two pairs of parallel wires to facilitate monitoring of circuit function and to detect failures that are not broken shaft event failures. US 2003/0091430, GB 2,468,686 and WO 99/00585 disclose similar arrangements.

[0005] The system of US 6,607,349 has been used successfully in commercial engines. But it would be desirable to produce a system that improves on the system of US 6,607,349, in particular by reducing the variability in the force and distance of movement of the shaft required to detect a broken shaft.

[0006] The inventor of the subject application has realised arrangements such as those described in US

6,607,349 with a metal wire link forming a fuse element do not always break reliably. The inventor has recognised that the metallic wire element may fail in a ductile manner which decreases the likelihood of the circuit being broken when required. Furthermore it is known to support the metal wire link on an insulating ceramic medium by applying a metallic, electrically conductive track to a ceramic medium. This can create further reliability problems due to the differences in thermal expansion between the metal track and the ceramic on which it is laid. A gas turbine or jet engine is an extremely hot environment (with the temperature of the exhaust gases being perhaps 900 degrees Celsius) and those high temperatures and materials with differing rates of thermal expansion mean that the track may come loose from the supporting ceramic medium. Furthermore, the differential thermal expansion of the different materials mean that a relatively large shaft movement is necessary for breaking of the fuse. On the other hand shaft movement resulting from shaft breakage may be quite small (of the order of 5 to 7 mm). The claimed invention allows one to produce a more reliable fuse.

[0007] Reliable fuse performance is very important in a jet engine: accidental breaking of the fuse would cause the engine to switch off unnecessarily; the fuse not breaking on shaft breakage would cause the engine to explode.

[0008] EP 3 106 626 describes a system in which the fuse link is a solid metal link rather than a wire supported on a ceramic structure. This arrangement, however, continues to have a metal fuse link which will fail in a ductile manner when a breaking load is applied by the plunger. This ductile failure mode means that the fuse link is unlikely to break if subjected to a small displacement. Shaft movement resulting from shaft breakage can be quite small (of the order of 5 to 7 mm).

[0009] A further problem of metallic fuse links arises from the fact that gas turbines and jet engines, in use, shake and create environment vibration loads which the fuse link must be able to withstand. If the fuse link is metallic it is difficult to design a fuse link which will fail consistently under small plunger displacements but will still withstand the unavoidable environment vibration loads associated with a working gas turbine.

[0010] The present invention provides a system for detecting abnormal movement of a shaft in a gas turbine engine, the system comprising a detection circuit, the detection circuit including a frangible fuse portion and a plunger connected to or adjacent the frangible fuse portion, wherein the plunger may be displaced as a result of abnormal movement of the gas turbine shaft to break the frangible fuse portion and thereby alter the detection circuit, and wherein the frangible fuse is conductive ceramic.

[0011] The inventor of the subject application has appreciated that using a conductive ceramic with its brittle failure mechanism is better able to meet the apparently conflicting requirements of a desire for a clear and complete failure or break with a short plunger displacement and an ability to withstand environment vibration. Ceram-

ic materials are usually made by the processing (often by sintering or firing) of powder pre-forms. This means that they also lend themselves easily to being shaped into a designed form which, for example, maximises the likelihood of failure when impacted by a moving plunger.

[0012] Preferably, the conductive ceramic is a silicon carbide ceramic or the like. The inventor has appreciated that a silicon carbide ceramic has particularly suitable material properties.

[0013] Preferably, the plunger is insulating ceramic. The inventor has appreciated that an insulating ceramic has particularly suitable material properties. It will also have a very similar rate of thermal expansion to the ceramic fuse link and thereby reduce the strains and stresses that might be created by differential thermal expansion of the adjacent fuse link and plunger components in the hot gas turbine working environment. Ceramic materials are usually made by the processing (often by sintering or firing) of powder pre-forms. This means that they also lend themselves easily to being shaped into a designed form which, for example, maximises the likelihood of failure when impacting a fuse link.

[0014] Preferably, the insulating ceramic is an alumina ceramic or the like. The inventor has appreciated that an alumina ceramic has particularly suitable material properties.

[0015] Preferably the fuse includes weakened portion or portions to facilitate breaking of the fuse at the weakened portion or portion. The ceramic fuse link can be formed into a shape or shapes which have points or lines of weakness which are designed to fail when impacted by the force of a moving plunger.

[0016] Preferably, the weakened portion or portions are surface notches or surface defects. Surface notches and surface defects are easy to introduce accurately into a ceramic component when it is formed. The surface defects might be other materials (e.g. thin wall tubes or other shapes) embedded in the fuse portion.

[0017] Preferably the weakened portion or portions are located in the middle and/or edges of the frangible fuse portion.

[0018] Preferably, the plunger is adjacent the frangible fuse and a plunger end portion adjacent the fuse is of narrower cross-section than the remainder of the plunger. Such an arrangement increases the pressure applied to the plunger and fuse link contact point or surface on the fuse link and thereby increases the breaking stress. The end of the plunger distal from the fuse link contact point must have a sufficiently large cross-section to be easily and accurately impacted and moved by the effect of a moving broken shaft. This arrangement allows the fuse link impact area to be reduced (and the impact pressure thereby increased).

[0019] Preferably, the plunger end portion is tapered. This a strong and easy to form structure with a narrowing of the plunger towards the fuse link impact point to achieve the advantages discussed above.

[0020] Alternatively, the plunger end portion is a pro-

trusion from a plunger body. This a strong and easy to form structure with a narrowing of the plunger towards the fuse link impact point to achieve the advantages discussed above.

[0021] Preferred embodiments of the present invention will now be described, by way of example only, with reference to the attached figures. The figures and following description are intended to exemplify the invention and it will be readily appreciated that alternative embodiments of the invention are envisaged and are covered by the scope of the claims.

Figure 1 is a schematic illustration of a gas turbine engine shaft showing where shaft breakage might occur;

Figure 2a is a schematic illustration of a system for detecting abnormal movement of a shaft in a gas turbine engine using a frangible fuse link;

Figure 2b is a schematic illustration of the system of Figure 1a with the frangible link broken;

Figure 3 is a schematic illustration of a system in accordance with the invention and for detecting abnormal movement of a shaft in a gas turbine engine using a frangible link;

Figure 4a is a schematic illustration of the electrical connections of a system such as that of figure 2;

Figure 4b is a schematic illustration of the system of Figure 1a with the frangible link broken; and

Figure 5 is a schematic illustration of the surface of a fuse link showing lines of weakness; and

Figure 6 is a schematic illustration of a plunger having a protrusion for impacting a fuse link.

[0022] Referring to figure 1, a gas turbine 1 includes a shaft 2 to which are mounted compressor blades 3 and turbine blades 4. This is well-known and standard technology so will not be described in any detail. The system of the subject invention is intended to warn when the shaft 2 breaks. If the shaft were to break along line 5, the shaft will move to the right (in a rearwards direction through the gas turbine housing) as shown by arrow A in figure 1.

[0023] The system comprises a detector assembly 10 which forms part of a detection circuit or circuits. The detector assembly comprises an electrically conductive brittle fuse link 12 that connects two parallel sets of wires 14, 16. The brittle fuse link 12 is a conductive ceramic such as a silicon carbide ceramic (for example that available under the ROCAR registered trade mark). The parallel set of wires connect to a controller (not shown). The controller is able to determine if the electrically conduc-

tive ceramic link is intact, as shown in Figure 1a, or if the electrically conductive ceramic link is broken, as shown in Figure 2b, by monitoring the voltages or currents on the parallel wires. As shown in Figures 2a and 2b, the pairs of parallel wires 14, 16 may be split to connect to a second controller (not shown) to provide redundancy.

[0024] Referring to figure 3 (and as described in US 6,607,349), the electrically conductive ceramic link 12 is mounted in the gas turbine engine proximate to a plunger 18. The plunger 18 is mounted adjacent to a shaft disc 20 so that, if the shaft breaks and moves rearward in the engine the shaft disc 20 pushes the plunger 18 against the link 12 thereby breaking the link. The plunger 18 is formed from an electrically insulating ceramic such as an alumina ceramic. The plunger 18 should have a much lower conductivity than the fuse link 12 (perhaps 1/1000 of the fuse link conductivity).

[0025] The use of a brittle ceramic fuse link means that the fuse link 12 will break cleanly (i.e. total material fracture across a section so that electrical conductivity across the section no longer remains) with a small plunger displacement (1-5 mm of the plunger 18).

[0026] When the controller detects that the link is broken, it can communicate with an engine shut down circuit to ensure that the fuel supply to the engine is shut off and catastrophic engine over speed is prevented.

[0027] As shown in figure 3 the detector assembly 10 is fixed to the engine casing 24. The detector may be protected from the harsh environment of the interior of the gas turbine engine by a collapsible cap 25 over the plunger. A shaft disc 20 is illustrated adjacent the plunger 18, with the cover 25 interposed between them. When the shaft disc moves as a result of a shaft breakage, it drives the plunger against the link 12 and thereby breaks the frangible link 12 (see figures 4a and 4b). Also shown schematically in Figure 3 is a controller 8, that is connected to the detector and can determine when the frangible link 12 has been broken. The controller 8 can then send a signal to an engine shut down circuit as previously described.

[0028] In order to further improve the likelihood of an impact between the plunger 18 and brittle ceramic fuse link 12, the surface of the fuse link 12 may include surface defects such as the notches 13 shown in figure 5. Such notches 13 weaken the ceramic fuse link 12 and reduce the risk of a small movement not breaking the fuse link 12 and hence breaking the detection circuit. Weakened fuse link portions such as the notches 13 may be arranged such that the fuse link 12 is broken by plunger 18 into small pieces which can easily clear or fall away from the fuse area. The notches 13 (or alternative weakened fuse portions) may preferably be located in the middle and/or edges of the frangible fuse link 12.

[0029] Additionally or alternatively the likelihood of an impact between the plunger 18 and ceramic fuse link 12 resulting in breakage can be improved by having the impact end 19 of the plunger of a narrow cross-section (see figure 6). The narrower cross-section may be achieved

by, for example, having a plunger impact protrusion 17 on the plunger end surface 21 as shown in figure 6. Alternatives include a tapered or sharpened plunger end. It can be seen that a system and detector as described can be made in a simple and inexpensive manner and can provide significant reliability improvements over existing systems for detecting a broken shaft in a gas turbine engine.

Claims

1. A system (10) for detecting abnormal movement resulting from breakage of a shaft (2) in a gas turbine engine, the system comprising a detection circuit, the detection circuit including a frangible fuse portion (12) and a plunger (18) connected to or adjacent the frangible fuse portion (12), wherein the plunger (18) may be displaced as a result of movement of the broken gas turbine shaft (2) to break the frangible fuse portion (12) and thereby alter the detection circuit, wherein the frangible fuse portion (12) is conductive ceramic.
2. A system according to claim 1 wherein the conductive ceramic is a silicon carbide ceramic or the like.
3. A system according to any preceding claim wherein the plunger (18) is insulating ceramic.
4. A system according to claim 3 wherein the plunger conductivity is approximately 1/1000 of the fuse conductivity.
5. A system according to claim 3 wherein the insulating ceramic is an alumina ceramic or the like.
6. A system according to any preceding claim wherein the fuse portion (12) includes weakened portion or portions (13) to facilitate breaking of the fuse at the weakened portion or portion.
7. A system according to claim 6 wherein weakened portion or portions are surface notches (13) or surface defects.
8. A system according to any preceding claim wherein the plunger (18) is adjacent the frangible fuse portion (12) and a plunger end portion (17) adjacent the fuse is of narrower cross-section than the remainder of the plunger (18).
9. A system according to claim 8 wherein the plunger end portion (17) is tapered.
10. A system according to claim 8 or claim 9 wherein the plunger end portion is a protrusion (17) from a plunger body.

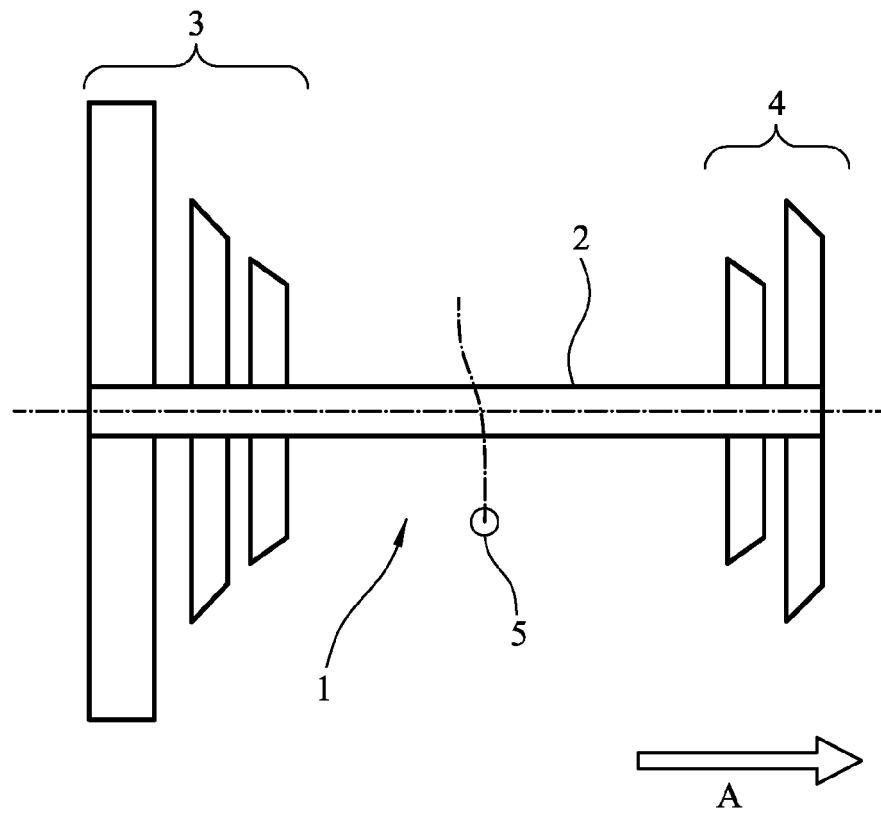


Figure 1

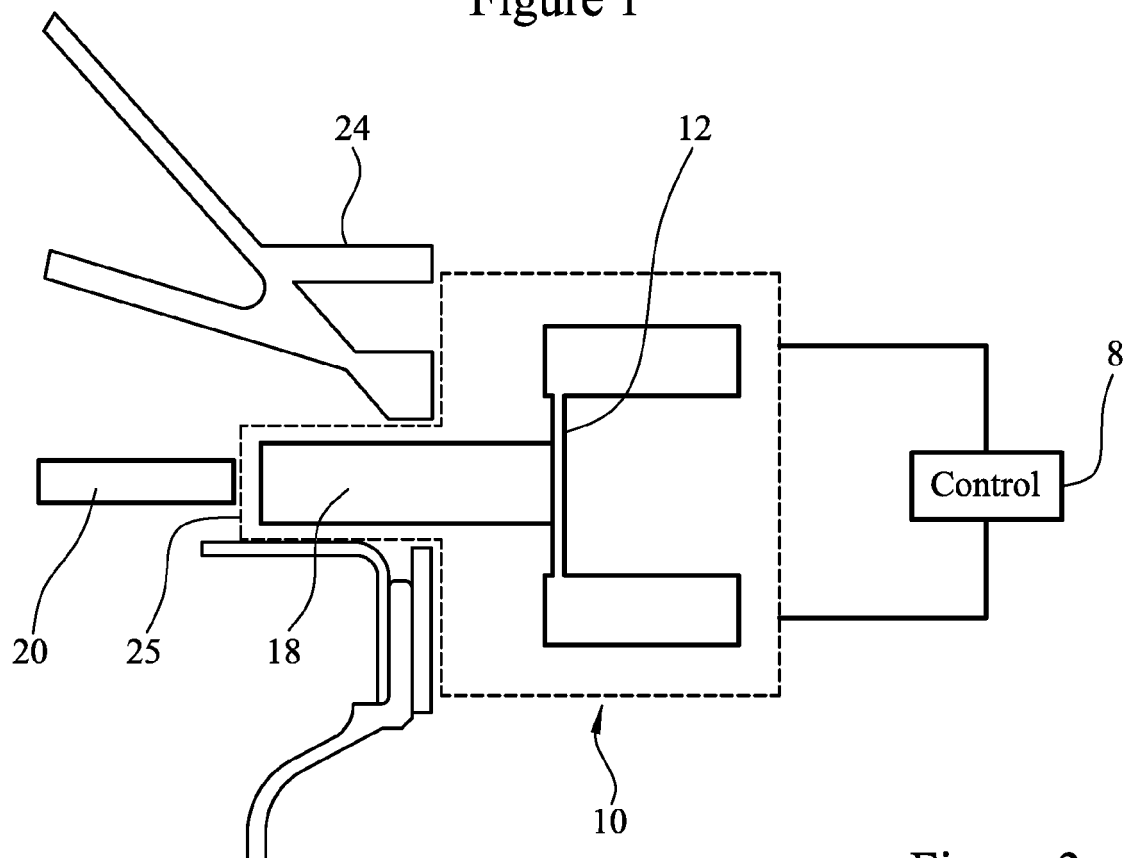


Figure 3

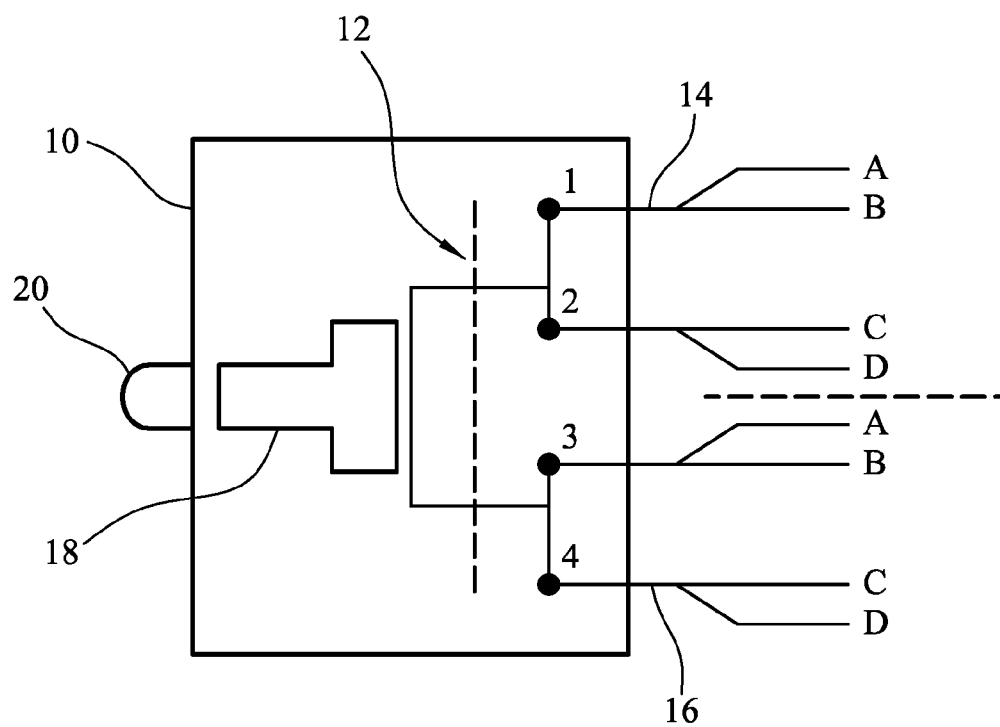


Figure 2a

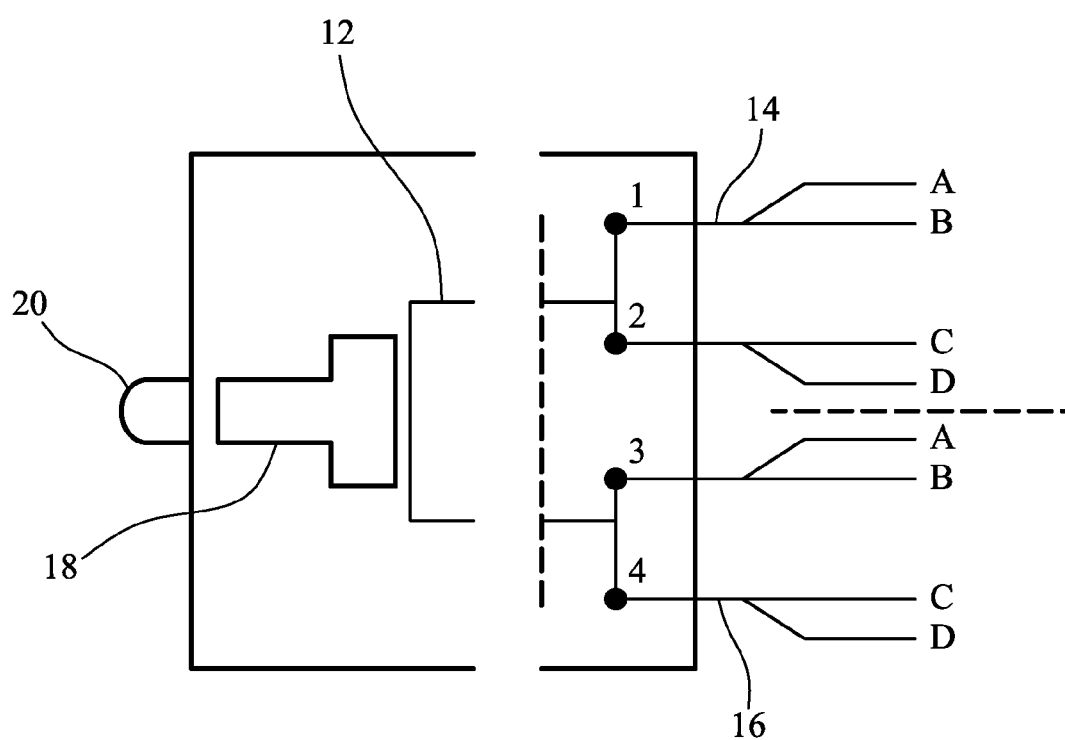


Figure 2b

Figure 4a

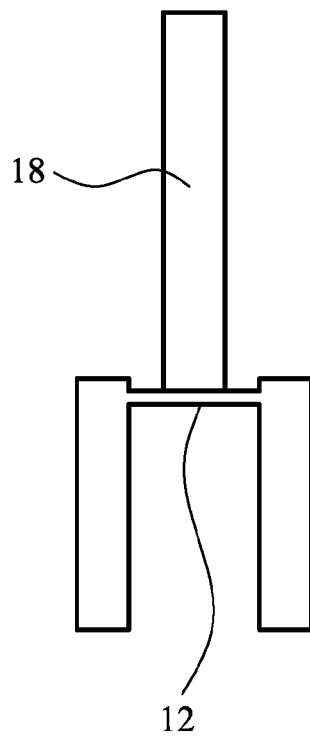


Figure 4b

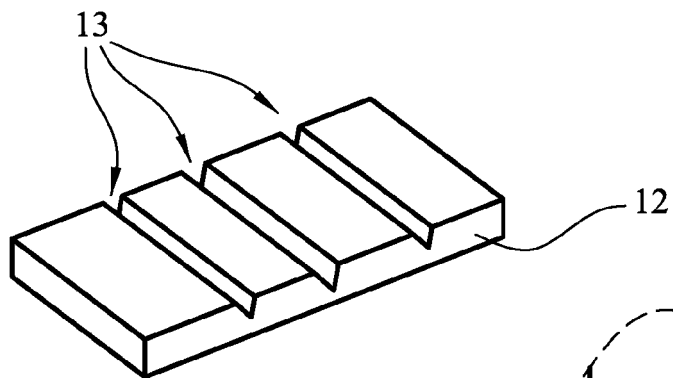
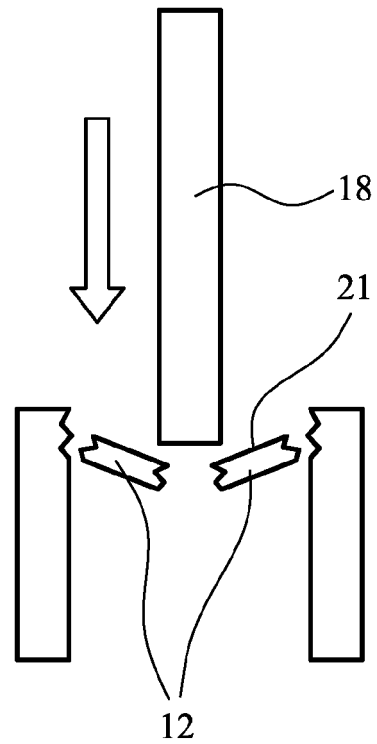


Figure 5

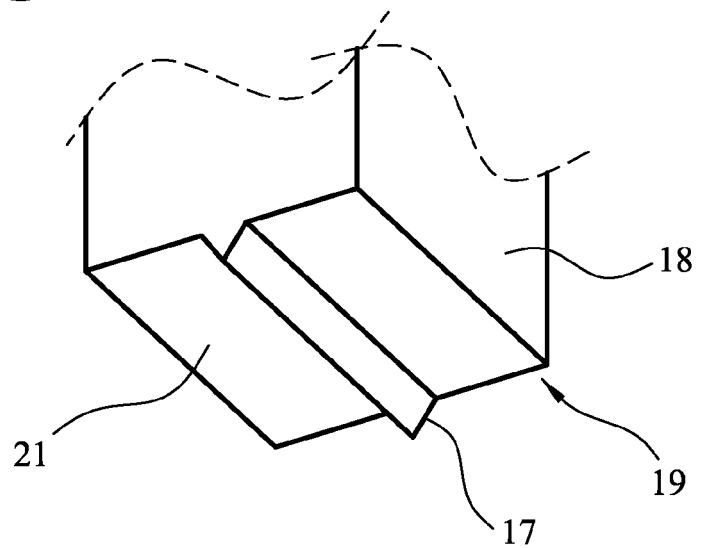


Figure 6



EUROPEAN SEARCH REPORT

 Application Number
 EP 20 16 5374

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EPO FORM 1503 03.82 (P04C01)

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			TECHNICAL FIELDS SEARCHED (IPC)
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The present search report has been drawn up for all claims			
Place of search Munich		Date of completion of the search 18 June 2020	Examiner Avramidis, Pavlos
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document		T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document	

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5 This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
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