(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 3 045 705 A1

(12) EUROPEAN PATENT APPLICATION

(43) Date of publication:
20.07.2016 Bulletin 2016/29

(51) Int Cl.:
F02G 1/043 *(2006.01)*

(21) Application number: **15405002.5**

(22) Date of filing: **13.01.2015**

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR
Designated Extension States:
BA ME

(71) Applicant: **Ecotech Engines AG**
7000 Chur (CH)

(72) Inventor: **Noskov, Alexander Victorovich**
CH-7000 Chur (CH)

(74) Representative: **Bohest AG Branch Ostschweiz**
Postfach
9471 Buchs (CH)

(54) **External heat engine**

(57) An external heat engine, in particular a Sterling engine, comprises a first cylinder (2) and a second cylinder (3), in which respective first and second working pistons (21, 31) may move up and down periodically. A conduit (4) connects the first and second cylinders (2, 3) and delimits a closed working volume for a working fluid, which in operation reciprocally exerts pressure on the first and second working pistons (21, 31). A regenerator (5) is arranged in the conduit (4) in the path of the working fluid, which separates the conduit (4) into a hot branch tube (41) and a cold branch tube (42). Each one of the first and second cylinders (2, 3) is provided with a bellows, which is located within the working volume and hermetically seals the working volume at a transition zone from the respective first or second cylinder (2, 3) to a respective first or second bellows housing (12, 13).

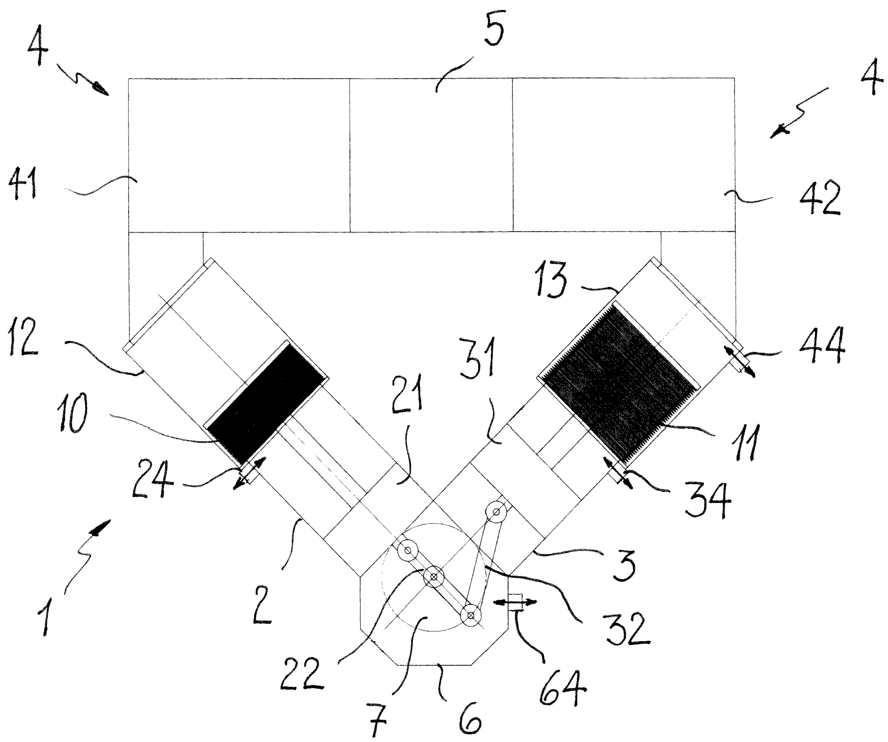

Fig. 1

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Description

[0001] The current invention relates to an external heat engine, in particular a Stirling engine, in accordance with the introductory clause of patent claim 1.

[0002] An external heat engine, in particular a Stirling engine, is, in principle, a heat engine operating due to cyclic compression and expansion of a working fluid, such as, e.g., air, helium, hydrogen or other gases. Cyclic compression and expansion of the working fluid is performed at different temperature levels, so that there is a direct conversion of externally provided heat energy into mechanical work. It may also be designated a closed-cycle heat engine with a permanently working gaseous fluid. The term "closed-cycle" may be defined as a certain thermodynamic system in which the working fluid is permanently contained within the system. A major advantage of an external heat engine, in particular a Sterling engine, is that it may be operated with a continuous heat supply such as, e.g. solar energy, geothermic energy, or even heat from radioactive decay; thus, in operation a sterling engine is comparatively silent. The mechanical energy delivered by the engine may be used to generate electricity or it may be directly coupled to a load.

[0003] In order for an external heat engine, in particular a Sterling engine, to be competitive with known combustion engines or internal heat engines, in particular mechanical losses must be minimized. One source of losses is the piston rings on the hot side and on the cold side of the Sterling engine. Due to leakage at the piston rings working fluid may flow out of the working volume into the cylinders housing the pistons, thus reducing the mass of working fluid within the working volume of the engine. It has been suggested already to connect the cylinder volumes underneath the pistons on the hot side and on the cold side of the engine via a buffer tank for the working fluid. This, however, increases the dead-volume of the external heat engine and contributes to the losses of the engine. Needless to say, that due to the leakage of the working fluid, the external heat engine must be stopped from time to time, in order to refill lost working fluid into the working volume in order to reach the optimal working pressure again.

[0004] It is therefore an object of the invention to provide a remedy to the disadvantages of the external heat engines of the prior art. Power losses due to leakage of working fluid shall be reduced. A solution shall be provided, which has a simple and reliable configuration and is compatible with different kinds of external heat engines, in particular Sterling engines of the Alpha and Beta and Gamma type. An external heat engine shall be provided which has a high endurance and may be operated continuously without the need to refill the working fluid in order to maintain the optimal working pressure within the working volume of the engine.

[0005] These and still further objects in the context with the above subject matter are met by an external heat engine according to the invention which comprises the features listed in patent claim 1. Further improvements thereof and advantageous and preferred embodiments of the invention are subject of the dependent claims.

[0006] In accordance with the invention an external heat engine, in particular a Sterling engine, is provided which comprises a first cylinder and a second cylinder, in which respective first and second working pistons may move up and down periodically. The first and second working pistons are connected with respective first and second piston rods, which are attached to a coupling member for transmitting the kinetic energy of the first and second working pistons. A conduit connects the first and second cylinders and delimits a closed working volume for a working fluid, which in operation reciprocally exerts pressure on the first and second working pistons. A regenerator is arranged in the conduit in the path of the working fluid, which separates the conduit into a hot branch tube and a cold branch tube. Each one of the first and second cylinders is provided with a bellows, which is located within the working volume and hermetically seals the working volume at a transition zone from the respective cylinder to respective bellows housing.

[0007] The bellows constitutes a sealing element in addition to sealing piston rings which usually are provided in between the first and second pistons and the respective first and second cylinders. The piston rings must enable a sliding function of each piston within its respective cylinder, and therefore inevitably some leakage of working fluid into the cylinders will occur during operation of the external heat engine. The bellows, however, does not have to fulfil or support any kinematic function. Therefore, the bellows may be constructed such, that it constitutes a hermetic seal against any leakage of working fluid into the cylinders and against penetration of any lubricants used for the pistons into the working fluid. Thus, because the bellows fulfils the actual sealing function, the piston rings may be optimized with regard to enabling the sliding of the pistons within the cylinders, such that mechanical losses due to friction may be reduced. The bellows also constitutes a certain heat barrier, in particular at the hot branch tube of the engine. Thus, the piston rings are less exposed to heat stress and therefore, a greater selection of materials is available for the piston rings, which also fosters optimization thereof.

[0008] In accordance with another embodiment of the invention the first and second bellows housings may be arranged in axial extension of the respective first and second cylinders. This constructive approach is simple and easy to implement and results in a very homogeneous stress of the bellows, due to the pressure exerted by the working fluid.

[0009] In yet another embodiment of the invention the first and second bellows housings and the respective first and second cylinders may be constructed integrally as one piece. Such a constructive variant facilitates the manufacture of the cylinders and the bellows housing as well as the assembly of the external heat engine.

[0010] The bellows at the cold branch tube suffers only minor temperature stress. The bellows as the hot branch tube, however, during operation may be exposed to considerably high temperatures. Therefore at least the bellows within the hot branch tube should be made from a material which is resistant to the temperatures within the hot branch tube. In another embodiment of the invention at least the bellows within the hot branch tube of the external heat engine may be made of metal. Metal not only withstands the temperatures which may be reached within the hot branch tube of the engine, but it also is wear resistant and provides the required mechanical stability to the bellows to withstand the pressures exerted by the working fluid during operation of the external heat engine.

[0011] In accordance with yet another embodiment of the invention each bellows may have a fixed axial end portion which is sealingly attached to an encasing wall of the bellows housing at the transition zone to the respective first or second cylinder. In case of a bellows which is made of metal the fixed axial end portion may e.g. be welded to the encasing wall of the bellows housing. It should be noted, however, that also alternative attachments which lead to a sealing connection of the fixed axial end portion of the bellows and the encasing wall may be established, such as, e.g., adhesive bonding, clamping within an annular groove, clamping in between the respective first or second cylinder and the respective first and second bellows housing, etc. The bellows further comprises an axially movable end-plate having an axial distance from the fixed axial end portion, which is rigidly connected with the respective first or second working piston. The connection in between the axially movable end-plate and the respective first or second working piston may e.g. be by means of a rod, which protrudes axially from a lead-face of the respective first or second piston and is connected with a back surface of the movable end-plate of the bellows. In operation the pressure exerted on the end plate of the bellows is transmitted to the respective first or second working piston which is rigidly connected with the end-plate of the bellows, thereby pushing the respective first or second working piston down within its respective first or second cylinder. When the working piston moves up again within the respective cylinder, due to the rigid connection in between the working piston and the end-plate of the bellows, the end plate follows the movement of the working piston and is advanced within the bellows housing. Thus, during operation of the external heat engine the bellows is collapsed and expanded periodically. In the completely expanded state of the bellows a maximum axial distance of the movable end-plate of the bellows from the fixed axial end portion amounts to the length of the piston stroke plus the height of the bellows in the collapsed state. The height of the bellows in the collapsed state depends on a wall thickness of an axially foldable jacket of the bellows.

[0012] During operation of the external heat engine the bellows is collapsed and expanded periodically. The periodic collapsing and expansion of the bellows, results in a considerable mechanical wear on the axially foldable jacket of the bellows. In order cushion the axial movement of the bellows in a still further embodiment of the invention a lower volume, which is delimited by the axially movable end-plate and a lead-face of the respective first or second working pistons is filled with a counter-balance fluid. The counter-balance fluid completely fills the lower volume including the inside of the bellows. During the collapse of the bellows the counter-balance fluid is forced out of the bellows into the space within the respective first or second cylinder, which is cleared by the retreating first or second working piston. Thus, the collapse of the bellows is cushioned by the counter-balance fluid, thus reducing the mechanical wear on the axially foldable jacket of the bellows.

[0013] In order to even better prohibit a loss of working fluid from the working volume of the external heat engine, according to yet another embodiment of the invention the counter-balance fluid within the lower volume, which is delimited by the axially movable end-plate and a lead-face of the respective first or second working pistons, is kept under a pressure which is at least as high as a maximum filling pressure of the working fluid within the working volume. By reducing a pressure gradient of the working fluid within the working volume to the counter-balance fluid within lower volume underneath the movable end-plate of the bellows the chance of eventual losses of working fluid may be further reduced.

[0014] In yet another embodiment of the invention the pressure of the counter-balance fluid within the lower volume, which is delimited by the axially movable end-plate and a lead-face of the respective first or second working piston, may be adjustable in accordance with a maximum pressure exerted on the axially movable end-plate of the bellows. For that purpose pressure sensors may be provided within the conduit which connects the first and second cylinders, in vicinity of the first and second bellows housings. Depending on a measured pressure in vicinity of the first or second bellows housing, the pressure of the counter-balance fluid within the respective lower volume underneath the end-plate of the respective bellows may be adjusted, and thereby even a local pressure gradient may be avoided.

[0015] For an easier control of the pressure of the counter-balance fluid within the lower volume the respective first and second cylinders may be provided with a control-valve for controlling the pressure of the counter-balance fluid. The control valves may be connected with a reservoir for the counter-balance fluid. As need may be, counter-balance fluid may then automatically or manually be added or removed from the respective lower volumes.

[0016] During operation of the external heat engine it may occur that counter-balance fluid flows into an engine housing, to which the first and second cylinders are attached and which accommodates the coupling member. The engine house too may be provided with a relief-valve through which the counter-balance fluid may be removed.

[0017] For maintaining the working fluid within the working volume under a constant filling pressure, in a yet further embodiment of the invention the conduit may also be equipped with a supply-valve for the working fluid. Depending on a filling pressure which may be measured when the external heat engine is not operative, or on measured working pressures within the hot branch tube or within the cold branch tube of the conduit and a deviation of the measured values from pre-defined maximum or minimum pressures additional working fluid may be introduced into the conduit.

[0018] In yet another embodiment of the invention the counter-balance fluid within the respective lower volumes matches the working fluid within the conduit. For the purpose of this invention the term "match" is defined as being physically and chemically at least very similar or being the same. Matching counter-balance fluids and working fluids facilitate the operation of the external heat engine. Any cross-contamination, as rarely as it may occur, will not impede the operation of the engine and will have practically no negative influence on the efficiency thereof.

[0019] In principle, the working fluid may be a liquid or a gas. For handling purposes and for the reasons of efficiency a gaseous working fluid is preferred. The gaseous working fluid may be a gas having a high heat capacity, such as, e.g., helium or hydrogen. In order to reduce the complexity of the sealing, which e.g. may be required for helium, and in order to observe the requirements on safety measures, in the case of hydrogen as the working fluid, air is the preferred working fluid.

[0020] The constructive solutions discussed hereinbefore may be applied in various kinds of external heat engines. In a preferred application of the various embodiments of the invention the construction of the external heat engine is that of a Stirling engine of the Alpha-type.

[0021] Further details and advantages of the present invention will become apparent from the following description of an exemplary embodiment thereof, reference being made to the schematic drawings, which are not to scale, in which:

Fig. 1 shows a sectional view of a Stirling engine of the alpha type;

Fig. 2 shows a cylinder including a bellows housing and a partially expanded bellows; and

Fig. 3 shows a cylinder including a bellows housing and a collapsed bellows.

[0022] Fig. 1 shows schematically a sectional view of an alpha type Sterling engine. Stirling engines are a well-known classical type of an external heat engine. The Stirling engine is generally designated with reference to numeral 1. The Stirling engine 1 of the alpha type configuration comprises a first cylinder 2 and a second cylinder 3, in which, in operation of the Sterling engine, respective first and second working pistons 21, 31 are move up and down periodically. The two cylinders 2, 3 are connected with one another via a conduit 4 for a working fluid. A regenerator 5 is arranged in the conduit 4 for the gaseous working fluid, which separates the conduit into a hot tube branch 41 and a cold branch tube 42. The cylinders 2, 3 and the conduit 4 together with the regenerator 5 constitute a closed system in which the working fluid, which is usually gaseous, is periodically transported from the first cylinder 2 to the second cylinder 3 and back again. The working fluid may, e.g., be helium, hydrogen or air. The two cylinders 2, 3 are mounted on an engine housing 6, in which a flywheel 7 is supported rotatable. The flywheel 7 is connected with the working pistons 21, 31 which reciprocate within their respective first and second cylinders 2, 3, via piston rods 22, 32.

[0023] In order to operate the Stirling engine 1 heat is introduced to the hot branch tube 41 of the conduit 4 on a hot side of the engine 1, while the cold branch tube 42 of the conduit is cooled on a cold side of the engine 1. Heating of the hot branch tube 41 of the conduit may be accomplished by any source of heat coming from both, conventional fuels, such as, e.g., gas, oil, petrol, etc. and alternative fuel sources, such as, e.g., solar power, geothermal power, etc. Heat may even be provided from radioactive decay. The cool branch tube 42 of the engine is kept cool by a heat sink, such as, e.g., by air circulating through cooling fins, which may e.g. be provided on the cool branch tube 42. The heating of the hot branch tube 41 and the cooling of the cold branch tube 42 may be accomplished directly inside the respective hot or cold branch tubes 41, 42. Alternatively or in addition the heating and cooling may be accomplished from outside of the respective hot and cold branch tubes 41, 42.

[0024] The Stirling cycle of the Stirling engine 1 can be thought of as comprising four different phases: expansion, transfer, contraction, and transfer. In the expansion phase most of the gaseous working fluid has been driven into the hot side of the Stirling engine 1. The heated working fluid expands and drives both pistons 21, 31 in the respective cylinders 2, 3 inwards, towards the bottom of the cylinders 2, 3. The axial motion of the moving working pistons 21, 31 is transferred via the piston rods 22, 32 to the flywheel 7 and is converted into rotational motion thereof. When the gaseous working fluid has fully expanded, the transfer phase is reached. The gaseous working fluid has expanded to e.g. about 2 to 5 times the volume as compared to its cold state. Most of the working fluid is initially still located at the hot side of the engine 1. The momentum of the flywheel 7 carries the piston rods 22, 32 the next 90°, whereby the working piston 21 of the first cylinder 2 on the hot side of the engine 1 is advanced away from the bottom of the first cylinder 2 and the working piston 31 in the second cylinder 3 on the cold side of the engine 1 is retracted further. By this motion the bulk of the gaseous working fluid is transferred from the hot branch tube 41 to the cold branch tube 42 of the engine 1. In the third phase, the contraction phase, nearly all of the working fluid is now on the cold side of the engine

1 and the cooling continues. As the working fluid cools it contracts thereby drawing both working pistons 21, 31 upwardly again, away from the bottoms of the respective first and second cylinders 2, 3. In the final transfer phase the contracted gaseous working fluid is still mainly located on the cold side of the engine 1, at the second cylinder 3. The momentum of the flywheel 7 carries the piston rod 32 another 90°, transferring the working fluid back again to the hot branch tube 41 towards the first cylinder 2 of the engine to complete the Sterling cycle.

[0025] On its way from the hot branch tube 41 on the hot side of the engine 1 to the cold branch tube 42 on the cold side of the engine 1, the gaseous working fluid passes through the regenerator 5. The regenerator 5 is constructed of a material that readily conducts heat, and usually of some metal. In order to improve heat transfer to and from the working fluid the regenerator preferably has a large surface area. When the hot working fluid is driven through the regenerator 5, a portion of the heat is deposited into the regenerator 5. When the cooled working fluid is transferred back through the regenerator 5, this heat is "reclaimed". Thus the regenerator 5 serves as an intermediate storage for heat and it precools and pre-heats the gaseous working fluid on its periodic travel through the regenerator 5. Using the regenerator 5, the efficiency of the Stirling engine may be improved considerably. The regenerator 5 may be constructed such, that as the working fluid passes through the regenerator 5, it is maintained under a generally constant pressure.

[0026] In Fig. 1 it is shown that at each one of the first and second cylinders 2, 3 there is provided a bellows 10, 11, which bellows are received within respective first and second bellows housings 12, 13. The first and second bellows housings 12, 13 constitute extensions of the conduit 4, which connects the first and second cylinders 2, 3 of the Sterling engine 1. The bellows 10 within the first bellows housing 12 is shown in its collapsed state, while the bellows 11 within the second bellows housing 13 is shown in a partially expanded state. The bellows 10, 11 constitute seals against a loss of working fluid into the first and second cylinders 2, 3.

[0027] Fig. 2 shows a cylinder with a bellows within the bellows housing. It should be noted that the cylinder may be a first or a second cylinder. Likewise the respective bellows may be a first or a second bellows within a respective first or second bellows housing. To be in conformance with Fig. 1 the cylinder shown in Fig. 2 is a second cylinder 3. The bellows is designated with reference numeral 11 and is located within a second bellows housing 13. The second cylinder 3 and the second bellows housing 13 may e.g. be two separate parts, or they may be constructed integrally as one piece. Usually the second cylinder 3 and the second bellows housing 13 are made of metal. The second cylinder 3 and the second bellows housing 13 may have outside diameters which are distinct from each other or they may have the same outside diameters. The second working piston 31 within the second cylinder 3 is connected via the piston rod 32 with the flywheel 7, in order to convert the axial movement of the second working piston 31 into a rotational movement of the flywheel. The direction of rotation of the flywheel 7 is indicated by arrow R. The piston rod 32 is an articulated rod, which is hingedly connected with a rotation axis of the flywheel 7, with a joint at the circumference of the flywheel 7 and with the second working piston 31.This configuration of the piston rod 32 and its hinged connections with the second working piston 31 and the flywheel 7 ensure that the axial movement of the second working is converted into a rotational movement R of the flywheel 7.

[0028] The bellows 11 within the second bellows housing 13 is shown in a partially expanded state. The bellows 11 has a fixed end portion 14 which is sealingly connected with an encasing wall of the second bellows housing 13 at a transition zone to the second cylinder 3. The bellows may e.g. be made of metal. Thus, the fixed end portion 14 of the bellows 11 may e.g. be welded to the encasing wall of the bellows housing 13. It should be noted, however, that also alternative attachments which lead to a sealing connection of the fixed axial end portion 14 of the bellows 11 and the encasing wall of the second bellows housing 13 may be established, which include, but are not limited to e.g. adhesive bonding, clamping within an annular groove in the encasing wall of the housing, clamping in between the bellows housing and the respective cylinder, etc. The bellows 11 further comprises an axially movable end-plate 15 which is rigidly connected with the second working piston 31. The connection in between the axially movable end-plate 15 and the second working piston 31 may e.g. be by means of a rod 17, which protrudes axially from a lead-face 33 of the second piston and which is connected with a back surface of the movable end-plate 15 of the bellows 11. In operation the pressure exerted by the working fluid on the end plate 15 of the bellows 11 is transmitted to the second working piston 31, which is rigidly connected with the end-plate 15, thereby pushing the second working piston 31 down within the second cylinder 3. When the second working piston 31 moves up again within the second cylinder 3, due to the rigid connection in between the second working piston 31 and the movable end-plate 15, the movable end plate 15 follows the movement of the second working piston 31 and is advanced within the second bellows housing 13 towards an upper ending of the second bellows housing 13 which is attached to the conduit (reference numeral 4 in Fig. 1). Thus, during operation of the Sterling engine 1 the bellows 11 is collapsed and expanded periodically. In the completely expanded state of the bellows 11 the movable end-plate 15 of the bellows is located from the fixed end portion 14 an axial distance, which amounts to the length of the piston stroke plus an axial height of the bellows 11 in the collapsed state. The axial height of the bellows 11 in the collapsed state depends on a wall thickness of an axially foldable jacket 16 of the bellows 11.

[0029] In Fig. 3 in accordance with the drawing of Fig.

1 a first cylinder 2 with a first working piston 21 is shown. The first working piston 21 is attached to the flywheel 7 via a piston rod 22, which is configured as an articulated rod. The configuration of the piston rod 22 and its hinged attachments to the flywheel 7 and the first working piston 21 correspond to that described with regard to the second working piston 31 in Fig. 2. The first cylinder 2 is connected with a first bellows housing 12, which accommodated the bellows 10. The first cylinder 2 and the first bellows housing 12 may again e.g. be two separate parts, or they may be constructed integrally as one piece. Usually the first cylinder 2 and the first bellows housing 12 are made of metal. Again the first cylinder 2 and the first bellows housing 12 may have outside diameters which are distinct from each other or they may have the same outside diameters. Fig. 3 shows the bellows 10 in its completely collapsed state, with the first working piston 21 in its deepest end position. The movable end-plate 15 of the bellows 10 is again rigidly connected with the first working piston 21. The connection is established by means of a rod 17, which protrudes axially from a lead face 23 of the first working piston 21 and is attached with a back face of the movable end-plate 15. In the completely collapsed state of the bellows 10 the movable end-plate 15 has its minimum axial distance from the fixed end portion 14 of the bellows 10, corresponding to the axial height of the bellows 10.

[0030] In Figs. 2 and 3 the bellows and its collapsing and expanding have been described with reference to specific first and second bellows housings and first and second cylinders for first and second working pistons, it should be noted that the reference numerals in Figs. 2 and 3 could be substituted with each other. The bellows 10, 11 within the first and second bellows housings 12, 13 are of the same configuration and, in operation, perform the same axial movements. The only distinction between the two bellows 10, 11 is that the bellows 10 in vicinity of the hot branch tube (reference numeral 41 in Fig. 1) is subject to higher temperatures than the bellows 11 in vicinity of the cold branch tube (reference numeral 42 in Fig. 1) of the engine. Thus, while the bellows 10 in vicinity of the hot branch tube 41 must be made of a material which withstands the high temperatures, the bellows 11 in vicinity of the cold branch tube 42 could be constructed from a different material. Usually, however, the two bellows 10, 11 will be of the same construction and configuration. Making reference to the drawings in Figs. 1, 2 and 3, respectively, the axially movable end-plate 15 of the bellows 10, 11 and the respective lead-face 23, 33 of the respective first or second working piston 21, 31 in each case delimit a lower volume 18. Due to the rigid connection of the axially movable end-plate 15 and the respective first or second working piston 21, 31 the size of the lower volume 18 remains constant. The lower volume may be filled with a counter-balance fluid. The counter-balance fluid completely fills the lower volume including the inside of the bellows. During the collapse of the bellows 10, 11 the counter-balance fluid is forced out of the bellows into the space within the first or second cylinder 2, 3, which is cleared by the respective retreating working piston 21, 31. Thus, the collapse of the bellows 10, 11 is cushioned by the counter-balance fluid, thus reducing the mechanical wear on the axially foldable jacket 16 of the bellows 10, 11. The counter-balance fluid may be kept under a pressure which is at least as high as a maximum filling pressure of the working fluid within the working volume. By reducing a pressure gradient of the working fluid within the working volume to the counter-balance fluid within lower volume 18 underneath the movable end-plate 15 of the bellows 10, 11 the chance of eventual losses of working fluid may be further reduced. The pressure of the counter-balance fluid within the lower volume 18 may be adjustable in accordance with a maximum pressure exerted by the working fluid on the axially movable end-plate 15 of the bellows. For that purpose pressure sensors (not shown) may be provided within the conduit 4 in vicinity of the first and second housings 12, 13 for the bellows 10, 11. Depending on a measured pressure in vicinity of the first or second bellows housing 12, 13, the pressure of the counter-balance fluid within the respective lower volume 18 underneath the movable end-plate 18 of the respective bellows 10, 11 may be adjusted. For that purpose the respective first and second cylinders 2, 3 may be provided with control-valves 24, 34 (Fig. 1) for controlling the pressure of the counter-balance fluid. The control valves 24, 34 may be connected with a reservoir for the counter-balance fluid. As need may be, counter-balance fluid may then automatically or manually be added or removed from the respective lower volumes 18.

[0031] In Fig. 1 it is further indicated that the engine housing 6 may be provided with a relief-valve 64. The relief-valve 64 permits the removal of counter-balance fluid 6, in case that it eventually reaches the engine housing 6, in spite of sealing piston rings on the first and second working pistons 21, 31. For maintaining the working fluid within the working volume under a constant filling pressure the conduit 4 may also be equipped with a supply-valve 44 for the working fluid. Depending on a filling pressure which may be measured when the Sterling engine 1 is not operative, or on measured working pressures within the hot branch tube 41 or within the cold branch tube 42 of the conduit 4 and a deviation of the measured values from pre-defined maximum or minimum pressures additional working fluid may be introduced into the conduit 4.

[0032] It has been mentioned before, that the working fluid may be gaseous, e.g. helium, hydrogen or air. The counter-balance fluid within the respective lower volumes 18 should match the working fluid within the conduit 4. For the purpose of this invention the term "match" is defined as being physically and chemically at least very similar or being the same. Thus, preferably the working fluid is also gaseous, and consists e.g. of helium, hydrogen or air. Any cross-contamination, as rarely as it may occur, will not impede the operation of the engine and will have practically no negative influence on the efficiency thereof.

[0033] Although the invention has been described with the reference to a specific embodiment, it is evident to the person skilled in the art that this embodiment stands only by way of example for the general inventive concept, and that various changes and modifications are conceivable without departing from the teaching underlying the invention. Therefore, the invention is not intended to be limited by the embodiment described, but rather is defined by the appended claims.

Claims

1. External heat engine, in particular a Sterling engine, comprising a first cylinder (2) and a second cylinder (3), in which respective first and second working pistons (21, 31) may move up and down periodically, the first and second working pistons (21, 31) being connected with respective first and second piston rods (22, 32), which are attached to a coupling member (7) for transmitting kinetic energy of the first and second working pistons (21, 31), a conduit (4) connecting the first and second cylinders (2, 3) and delimiting a closed working volume for a working fluid, which in operation reciprocally exerts pressure on the first and second working pistons (21, 31), a regenerator (5) which is arranged in the conduit (4) in the path of the working fluid and which separates the conduit (4) into a hot branch tube (41) and a cold branch tube (42), wherein each one of the first and second cylinders (2, 3) is provided with a bellows (10, 11), which is located within the working volume and hermetically seals the working volume at a transition zone from the respective first or second cylinder (2, 3) to a respective first or second bellows housing (12, 13).

2. External heat engine according to claim 1, wherein the first and second bellows housings (12, 13) are arranged in axial extension of the respective first and second cylinders (2, 3).

3. External heat engine according to claim 1 or claim 2, wherein the first and second bellows housings (12, 13) and the respective first and second cylinders (2, 3) are constructed integrally as one piece.

4. External heat engine according to any one of claims 1 to 3, wherein at least the bellows (10) within the hot branch tube (41) is made from a material which is resistant to the temperatures within the hot branch tube (41).

5. External heat engine according to claim 4, wherein at least the bellows (10) within the hot branch tube (41) is made of metal.

6. External heat engine according to any one of the preceding claims, wherein each bellows (10, 11) has a fixed axial end portion (14) which is sealingly attached to an encasing wall of the bellows housing (12, 13) at the transition zone to the respective first or second cylinder (2, 3) and an axially movable end-plate (15), having an axial distance from the fixed end portion (14), which is rigidly connected with the respective first or second working piston (21, 31).

7. External heat engine according to claim 6, wherein a lower volume (18), which is delimited by the axially movable end-plate (15) and a lead-face (23, 33) of the respective first or second working piston (21, 31) is filled with a counter-balance fluid.

8. External heat engine according to claim 7, wherein the counter-balance fluid is maintained under a pressure which is at least as high as a maximum filling pressure of the working fluid within the working volume.

9. External heat engine according to claim 8, wherein the pressure of the counter-balance fluid is adjustable in accordance with a maximum pressure exerted on the axially movable end-plate (15) of the bellows (10, 11).

10. External heat engine of any one of claims 7 to 9, wherein each one of the respective first or second cylinders (2, 3) is provided with a control-valve (24, 34) for controlling the pressure of the counter-balance fluid.

11. External heat engine of any one of claims 7 to 10, wherein the first and second cylinders (2, 3) are attached to an engine housing (6), within which the coupling member (7) is accommodated, and which is equipped with a relief-valve (64) for the counter-balance fluid.

12. External heat engine of any one of the preceding claims, wherein the conduit (4) is provided with a supply-valve (44) for the working fluid.

13. External heat engine of any one of the preceding claims, wherein the counter-balance fluid matches the working fluid.

14. External heat engine of any one of the preceding claims, wherein the working fluid is a gaseous fluid.

15. External heat engine of any one of the preceding claims, wherein the construction of the engine is that of a Stirling engine of the Alpha-type.

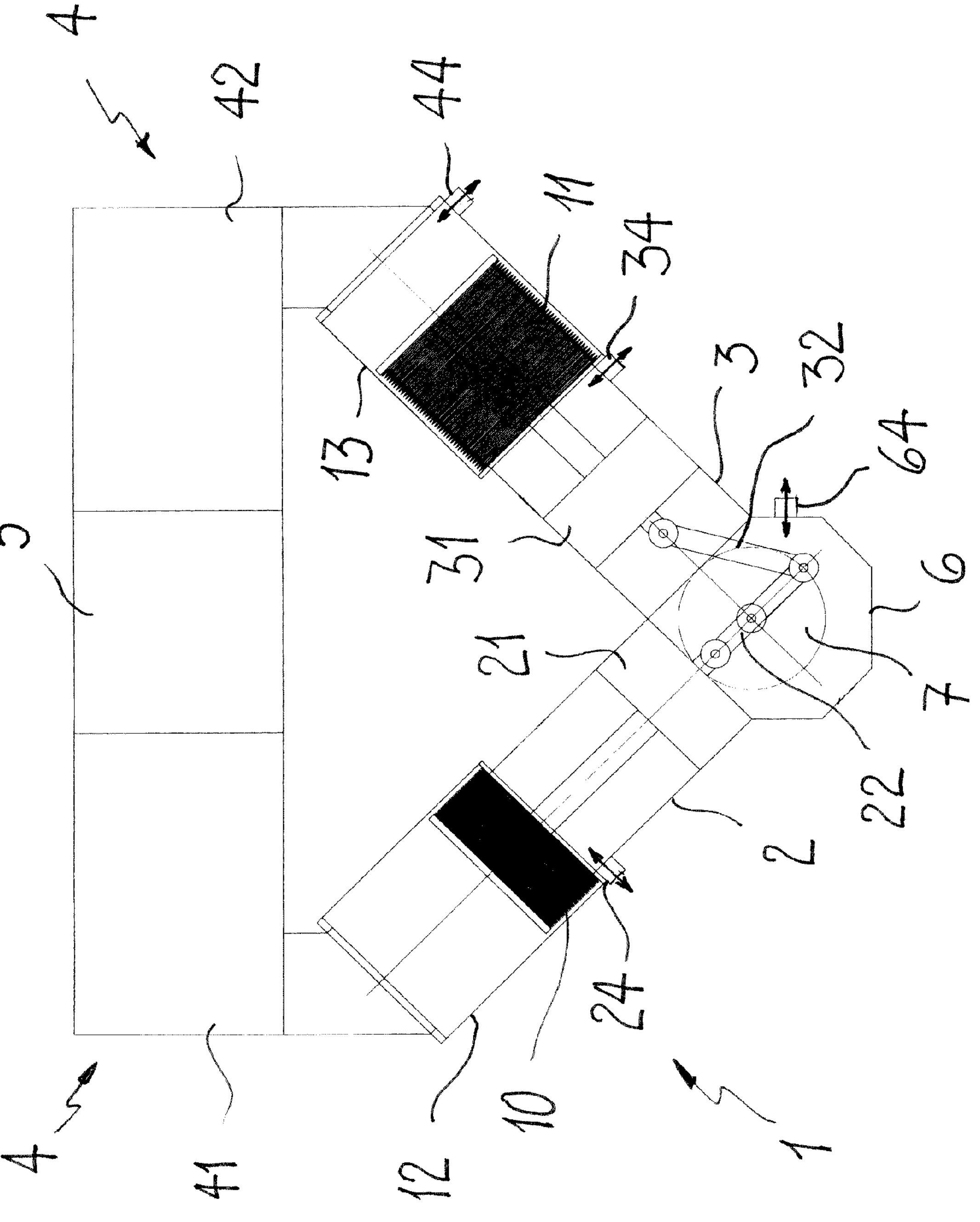

Fig. 1

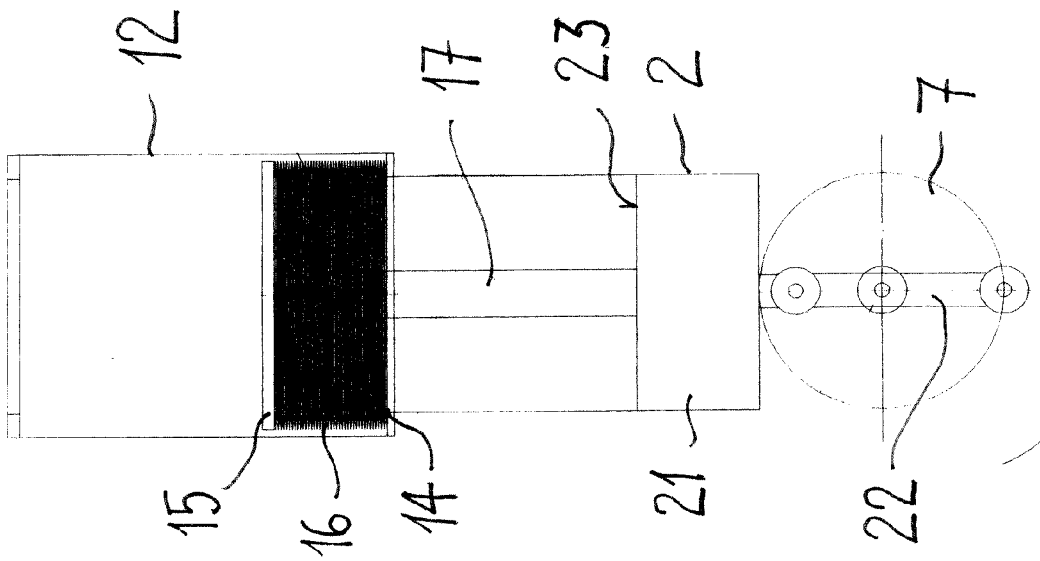

Fig. 3

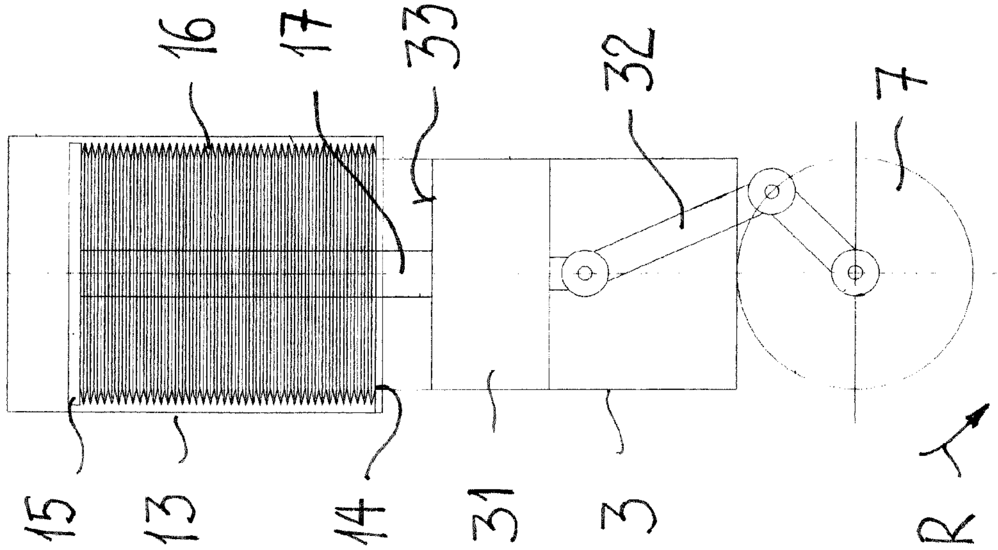

Fig. 2

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EUROPEAN SEARCH REPORT

Application Number
EP 15 40 5002

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X Y	US 5 317 874 A (PENSWICK LAURENCE B [US] ET AL) 7 June 1994 (1994-06-07) * figures 1-6 * -----	1-7, 13-15 8-12	INV. F02G1/043
Y	EP 0 167 407 A2 (MITSUBISHI ELECTRIC CORP [JP]) 8 January 1986 (1986-01-08) * figures 1-5 * -----	8-12	
A	JP S56 111248 U (-) 28 August 1981 (1981-08-28) * figure 2 * -----	1-7	
A	JP H06 185410 A (MITSUBISHI ELECTRIC CORP) 5 July 1994 (1994-07-05) * figures 1-6 * -----	1-7	
A	DE 30 36 530 A1 (WITZENMANN METALLSCHLAUCHFAB [DE]) 19 May 1982 (1982-05-19) * figure 1 * -----	1-7	
			TECHNICAL FIELDS SEARCHED (IPC)
			F02G

The present search report has been drawn up for all claims

2

Place of search	Date of completion of the search	Examiner
The Hague	14 July 2015	Flamme, Emmanuel

CATEGORY OF CITED DOCUMENTS

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14-07-2015

Patent document cited in search report		Publication date	Patent family member(s)			Publication date
US 5317874	A	07-06-1994	DE	4122824	A1	26-02-1998
			GB	2279449	A	04-01-1995
			JP	2933390	B2	09-08-1999
			JP	H1114175	A	22-01-1999
			US	5317874	A	07-06-1994
EP 0167407	A2	08-01-1986	DE	3574757	D1	18-01-1990
			EP	0167407	A2	08-01-1986
			JP	S6119953	A	28-01-1986
			US	4620418	A	04-11-1986
JP S56111248	U	28-08-1981	NONE			
JP H06185410	A	05-07-1994	NONE			
DE 3036530	A1	19-05-1982	NONE			

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