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(54) Internal combustion engine with pistons which rotate and move axially

(57) This invention describes the configuration, construction, working principle and possible applications for PROHPI internal combustion engines. This new type of engines works by means of one or more both rotating and reciprocating cylindrical pistons within cylinders with the following characteristics:

- Piston top and cylinder head have matching wavy (e.g. sine wave alike) surfaces;
- By rotation and reciprocation, matching wave forms form alternating compressing and expanding chambers;
- During maximum compression, compressed air or air - fuel mixture is pressed through channel like connections between compressing chambers and combustion and expansion chambers;
- Fuel can be injected and / or ignited just before or within such channels;
- PROHPI engines can be configured for two stroke or for four stroke operation;
- PROHPI engines can be configured for Otto, Diesel or direct injection spark ignition operation;

The PROHPI engine can be applied for stationary and non-stationary power units, e.g. to drive generators, compressors or pumps, pile or driving sheet drivers and aviation, automotive, train, nautical or other mobile primary drive lines and/or range extenders.

Figure 1

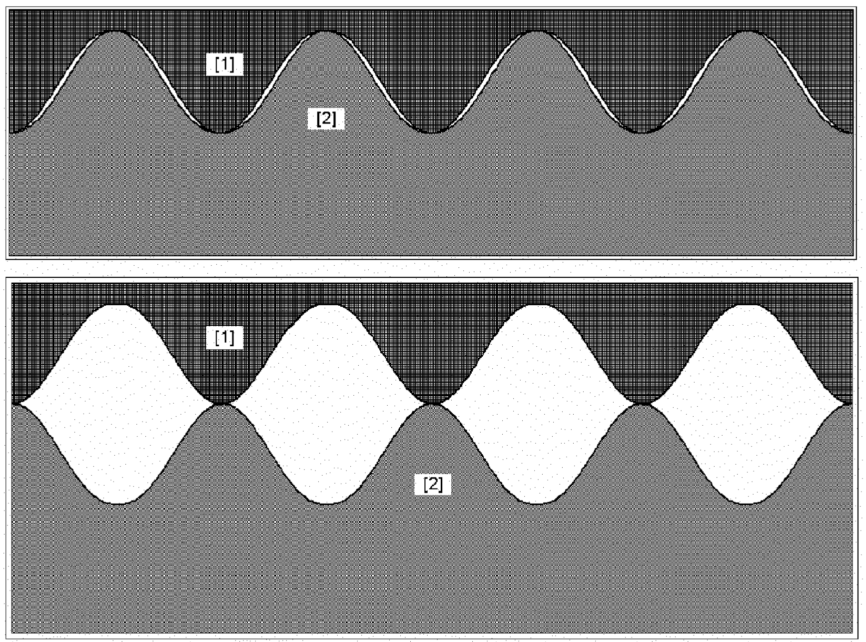

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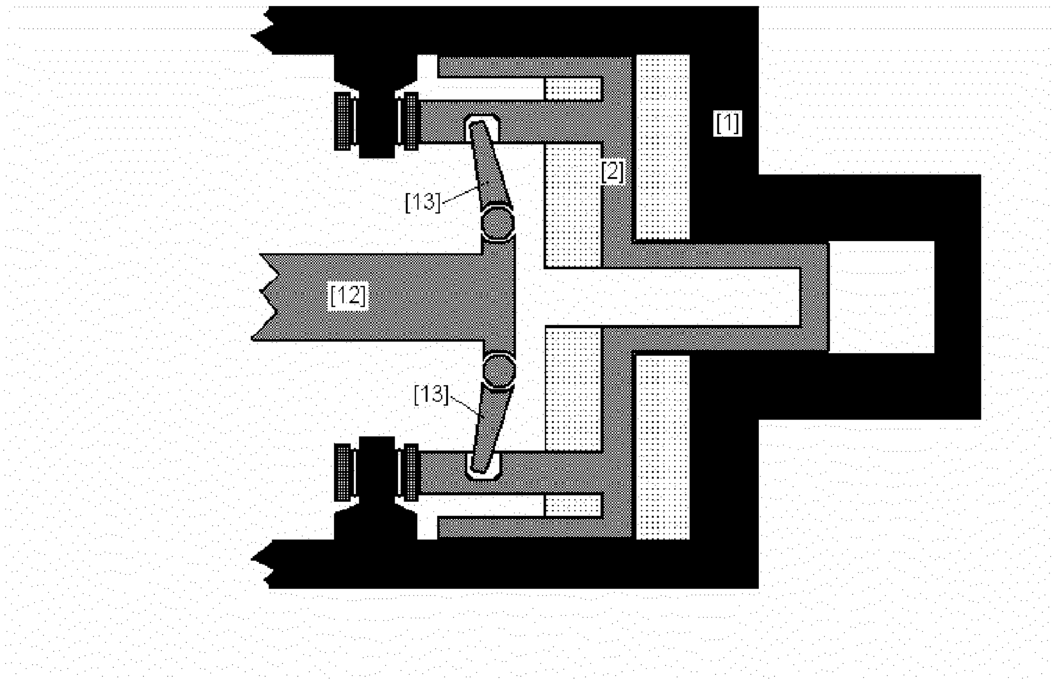
Figure 5



Description

Introduction

[0001] Internal combustion engines all work with compression of air or an air - fuel mixture, possible fuel injection, combustion and subsequent expansion. This cycle takes place either in a continuous mode (like gas turbines) or in a discontinuous mode. By far the most of the discontinuous combustion engines use one or more reciprocating pistons in cylinders for the compression and expansion and a crank shaft for transfer of their linear movement to a rotating movement. A small percentage, mainly formed by Wankel combustion engines, has flat, more or less triangular, rotating 'pistons' which, by their shape and the shape of the chamber, provide for compression, combustion and subsequent expansion in certain areas around their circumference, pushing the triangle forwards to rotate. A large number of other variants, both with reciprocating pistons and with rotating pistons, have been proposed but did not make it further than some prototypes or small series. Assumed advantages could not live up to the inherent advantages of the current mainstream configuration, nor to the high degree of maturity and perfection of the reciprocating piston engine.

[0002] Despite this, herewith another new configuration for discontinuous internal combustion engines is proposed, the Pronker ROtating and Hopping PIston (PROHPI) Engine.

Description

[0003] A PROHPI Engine makes, in its basic form, use of one cylindrical piston which both reciprocates and rotates. Essential element is a sine wave alike piston top which moves against a sine wave alike formed cylinder head. Maximum compression is generated when the wave crests of the piston fit within the wave-hollows in the cylinder head (figure 1A where [1] depicts the cylinder head top and [2] depicts the piston top). Maximum expansion occurs when wave crests of the piston move over the wave crests of the cylinder head (figure 1B). The waveforms of the piston and of the cylinder head have a constant amplitude and a constant shape over their full radius in such a way that they can maintain an uninterrupted radial line contact between piston and head at every angle of rotation of the piston for every full wave. Deviations from a pure sinusoidal wave form result in non-infinite accelerations of the piston following the cylinder head and in a non-infinite compression ratio. One or more channels in the wave crests of the cylinder head allow the compressed air or air / fuel mixture to flow from the compression chamber into the combustion and expansion chamber. Figure 2A to 2H shows a representation of the different stadiums of a piston - cylinder head configuration during a four stroke engine cycle.

[0004] For a four stroke configuration, e.g. four full waveforms over 360º form four 'chambers': Two chambers for air or air - fuel mixture intake and compression [3] and two for subsequent combustion, expansion and exhaust ejection [4]. With four full waveforms, the piston makes four reciprocating movements per revolution, generating both four work cycles and four breathing cycles together. For each work cycle, combustion takes place in two centrally opposing chambers, providing a symmetric, balanced load on the piston.

[0005] For a two stroke configuration, e.g. two full waveforms over 360º form two 'chambers' which breath and combust both in parallel as in other two stroke piston engines.

[0006] In order to prevent infinite steepness of the sine wave towards the centre of the piston and of the cylinder head, the centre part of the piston is taken out [5], fitting around a cylindrical centre pylon on the cylinder head [6] or is cylindrically extended [7], fitting in a cylindrical hollow within the cylinder head [8] (see figures 3A and 3B).

[0007] For breathing, that is for exhaust gases to escape during the exhaust part of the cycle and for air or air - fuel intake for the intake cycle, valve-less ports can be used. Those ports can be placed within the outer cylinder wall or within a possible centre cylinder head pylon, or in a combination thereof. For a four stroke configuration, ports can also be placed within the sine wave alike top surface of the cylinder head, or in a combination of the three options.

[0008] In a four stroke configuration, the intake ports enable filling of the intake chamber during the intake cycle when the piston moves away from the cylinder head (Figure 2A to 2D). The next wave in the piston top compresses the air or air - fuel mixture when the piston moves again towards the cylinder head (Figure 2E to 2G). During maximum compression (Figure 2H), the compressed air or air - fuel mixture is pressed through the already mentioned channel or channels (Figure 2, [9]) to the combustion and expansion chambers, in parallel of being ignited or fuel being injected and ignited (gasoline or gas fuelled engines) or self ignited (e.g. diesel fuelled engines). The heated and expanded gas mixture pushes the piston away again from the cylinder head while rollers guide the piston to follow its hopping and rotating motion path and transfer the pushing force on the piston into a rotating movement (Figure 4). After combustion and full expansion, the exhaust port comes free and subsequent closure of the combustion chamber by the next wave of the piston pushes the exhaust gasses out of the chamber.

[0009] In a two stroke configuration, exhaust and intake ports open closely around the position where the piston is in its lower dead centre. Exhaust gasses start to escape just before the lower dead centre (Figure 2D). Subsequently, air or an air - fuel mixture is forced into the chambers between the piston and the cylinder head, e.g. by the downward movement of the piston, meanwhile displacing the last bit of the exhaust gasses which escape in parallel. During maximum compression, the compressed air or the air - fuel mixture is also pressed through the channel like connections between adjacent chambers formed by the wave forms of the piston and cylinder head.

[0010] To let the piston follow the shape of the cylinder head, either the piston has a circular cam [10] that runs over a number of stationary reaction rollers (not necessarily round or centric) [11], or the piston has build in wheels or rollers that follow a stationary reaction cam, or a combination of those two options. Figure 4 shows a possible mechanical solution for the piston to follow the cylinder head.

[0011] To transfer the rotating and hopping piston motion towards a non hopping rotation of the main shaft (Figure 5, [12]), different constructions can be used with sliding contacts between the piston and spreaders on the shaft or with hinging arms [13] on the shaft with sliding contacts with the piston, with multiple hinged arms that connect the piston and the shaft or with sliding (planetary) gears. Figure 5 shows a possible mechanical solution for the transfer of the rotational motion from the piston to the main shaft.

[0012] Configurations:

- The PROHPI concept can be used for four stroke cycles and for two stroke cycles.
- The PROHPI configuration can be used for "Otto", "Diesel" or direct fuelling petrol or gasoline or gas (direct injection) cycles, relying on spark plugs, auto-ignition, or glow plug ignition or combinations thereof.
- The four stroke cycle PROHPI concept can be implemented with four 'waves', six waves or more waves per revolution (always an even number larger or equal than four). This leads to four, six or more ignitions per revolution of the main shaft.
- For a two stroke PROHPI concept, also two or three waves or another even or odd number of waves per revolution can be applied.
- A PROHPI Engine can be configured with a single piston with rotating and reciprocating shaft, e.g. for direct driving dedicated (integrated) compressors, pumps or generators.
- Another configuration is foreseen where a single piston rotates and reciprocates relative to the cylinder / cylinder head without a shaft, e.g. for pile driving or ramming, for sheet piling or for jack hammer equipment.
- Yet another configuration is foreseen where a single piston rotates and reciprocates relative to the cylinder / cylinder head with a non rotating shaft driving directly or by a lever construction one or more reciprocating compressors or pumps.
- The basic engine configuration is foreseen as a single rotating and hopping piston, driving a non-reciprocating shaft and a rotating, contra-reciprocating balance weight. Axial imbalance can be compensated to the full 100% with one, co-rotating or anti-rotating mass following a mirrored cam.
- Another way to compensate for axial vibrations is to apply dual opposing pistons with two opposing cylinder heads, following identical but opposite (mirrored) reciprocating motions, driving the same shaft.
- The connection between a rotating and hopping piston and a rotating, non-hopping shaft can be made with spreaders on the shaft with sliding contacts on the piston or with hinging arms on the shaft with sliding or flexible contacts with the piston, with multiple hinged arms that connect the piston and the shaft or with a sliding (planetary) gear system.
- Rotational vibrations can be reduced by increasing the number of waves / ignitions per revolution of the piston - shaft combination by increasing the number of 'waves' in the piston top and cylinder head.
- Breathing ports can be placed within the sine wave alike top surface of the cylinder head (four stroke only), within the surface of the outer cylinder wall or within a possible centre piston or cylinder head pylon, or in different combinations of those options.
- Breathing volume can be enhanced by applying (an) external exhaust, electrically or mechanically driven compressor(s), e.g. a turbo or roots compressor(s) as applied with state of the art reciprocating piston engines.
- Further improvements can be realised by applying complementary asymmetric wave forms of the piston top and cylinder head and an asymmetric cam for guidance of the piston and for load transfer.

[0013] The PROHPI Engine has the following characteristics:

- The engine has one big piston and cylinder in stead of four, six or more smaller cylinders, while still creating four, six or more work cycles per revolution with a four stroke engine cycle.
- In a four stroke configuration, piston and shaft make one revolution for four (or six or more) ignitions and work cycles where a standard configuration piston engine makes two shaft revolutions for e.g. four (the number of cylinders) ignitions and work cycles. Therefore, output shaft RPM is half (or one third or less) that of a current art piston engine for the same number of work cycles.
- In a four stroke configuration and with e.g. four work cycles per piston and shaft revolution, the piston makes four up and down movements per revolution. Therefore, with half the RPM, single stroke displacement can be half of that of an equivalent four cylinder engine with the same breathing characteristics.
- With half the number of piston and shaft revolutions and with half the volume displacement, shaft torque is double that of a current art four cylinder piston engine running at the same number of work cycles per second and with the same maximum power.
- In a two stroke configuration, a single piston PROHPI engine makes two (or three or more) ignitions and work cycles during one piston and shaft revolution

where a standard configuration two stroke piston engine makes one ignition for one shaft revolution per cylinder.

- The cam and reaction bearings configuration create an effective mode for load transfer between the up and down going motion of the piston and the rotation of the piston (and shaft).
- The number of reaction bearings can be identical to the number of wave forms over one revolution of the piston. E.g., for a basic four wave configuration, piston load will be spread over four reaction bearings, for a six wave configuration, load can be spread over six reaction bearings.
- Despite the short stroke and associated large piston area, creating high piston loads, the cam and reaction bearing loads are limited because the breathing cycle takes place in parallel with the working cycle. Work is transferred directly from the driven piston area to the breathing piston area and takes place without any mechanical losses.
- Furthermore, four times a small stroke in stead of four times two long strokes per working cycle results in significant lower accelerations of the piston and associated reaction loads.
- The piston motion during highest compression has a short dwell time compared to a piston rod and crank shaft configuration, leading to less compression leakage. Load transfer angle just before and just after maximum compression is more favourable, again leading to lower loads on the reaction bearings.
- Meanwhile, a better motion - time profile for the piston with better breathing characteristics is obtained in the lower dead centre (LDC) since LDC dwell time is long relative to a piston rod and crank shaft configuration, leading to reduced breathing energy losses.
- Mean vector contact speed between piston and cylinder wall is higher relative to a regular piston engine because of the rotation of the piston, maximum contact speed is lower, due to the small vertical stroke. Mean and maximum contact speed is significantly lower in comparison with a Wankel engine.
- The piston is loaded axially and rotationally, the piston is not pressed sideways to the cylinder wall (as with the standard crankshaft configuration), resulting in reduction of the piston - cylinder friction and wear.
- The connection arms or the sliding (planetary) gear system between the piston and shaft are loaded very lightly: Only the torque transmission from piston to shaft is transferred, no compression and acceleration loads of the piston are born by the connecting arms or gears.
- A PROHPI Engine can be build with (a) valve-less ported cylinder head (or heads) in stead of valves, camshaft(s) and associated mechanisms of a current art four stroke piston engine.
- The absence of valves leads to a reduction of breathing resistance and a further reduction of breathing associated energy losses.
- Relative to two stroke engine concepts, better port timing can be created: Specifically, port timing can be made asymmetric with respect to lower dead point of the piston and port timing can be made fully independent for the input and the output ports.
- Relative to a Wankel engine configuration, a simplified sealing concept between piston and cylinder wall can be applied using piston rings.
- As with a Wankel engine configuration, the sealing between the compression and combustion/expansion chamber and the breathing chamber is made up of a 'dry', i.e. non-lubricated, sealing line. However, the lower contact speed will be significantly lower and sealing contact doesn't need to be continuous in time. A small number of stationary spring seals in the cylinder head, in intermittent contact with the piston, can be applied.
- During maximum compression, air is forced from the compression chamber into the combustion and expansion chamber. Using this, direct injection configurations with very intensive, high velocity mixing during injection can be realised, enabling lean combustion for all injected fuel.
- Because of high velocity mixing and lean combustion for all fuel (and not only the outside of an injection cloud), low particulate matter, low CO and hydrocarbon and reduced NOx formation can be realised.
- Because of high velocity mixing and associated short burn times, and because of the mechanical configuration, dwell time in the top dead centre can be limited, limiting mechanical loads on the reaction bearings and limiting heat losses to piston and cylinder head and limiting pressure leakages along piston - cylinder seals.
- The accelerated flow from the compression space to the combustion space cost energy. A significant part of this energy can be regained while this accelerated, (fuel mass increased) and expanded gas flow is subsequently decelerated in the combustion space, giving additional moment to the rotation of the piston.
- Part of the combustion load on the piston is already directly tangential, driving the rotation of the piston directly, without any mechanical losses.
- In four stroke spark ignition (SI) configurations, the separation between the compression chambers and the combustion chambers, together with a continuous flow within the combustion chamber without dead ends, lead to a reduced chance of air - fuel mixture to pre-ignite or detonate (knock) for the same compression ratio. This property can be used to increase the compression ratio for SI engines, to allow lower octane fuels or to a combination of those options.
- In a four stroke - four wave engine configuration, there are two smaller combustion chambers in stead of one larger for each ignition.

- Irregular firing of or combustion in the two combustion chambers will lead to a tilting moment on the piston, leading to increased friction, wear and resistance. With two pole spark plugs placed in series, asymmetric misfiring of a SI configuration can be limited. Pressure measurement and (digital) injection control by means of an Engine Management Unit can avoid or further minimize asymmetric piston loading.
- The surface over volume ratio is higher than of a regular piston engine. Because there are separate chambers for compression and for combustion, and because of the short dwell time in the upper dead centre, the adverse heat loss effect hereof is partly compensated.
- The combustion chambers form deviates from an optimal spherical shape. Also, the sealing line is longer compared to a standard piston - cylinder configuration.
- For a four cylinder equivalent configuration, only two fuel injectors or carburettors and only two spark plugs or glow plugs (if any) are needed. For a six cylinder equivalent configuration, only three spark plugs and/or three fuel injectors are needed.
- In general, part count is significantly lower compared to an equivalent reciprocating piston engine because of the lower number of pistons and cylinders while maintaining an even load - time profile, because of the absence of a crankshaft and because of the absence of valves and camshafts and associated mechanisms.
- The reciprocating movement of the piston (or pistons) can be used to drive the engines fuel and/or fuel injection pump, oil pump and/or cooling water pump.
- Power density of a PROHPI Engine with respect to weight can be very high because of compact design (e.g. single cylinder - piston with half the displacement compared to a four cylinder of equal power), simple load path, absence of valve trains and the limited number of parts in general.
- Power density with respect to volume can be high because of the same reasons.

[0014] The PROHPI Engine can be used for the following applications:

[0015] Possible applications for the PROHPI engine are generators and other stationary and non-stationary power units, e.g. to drive fans, compressors or pumps, for light hand tooling like chain saws, mowers etc., for reciprocating tooling like pile or driving sheet drivers and jack hammers, as power source for fan, rotor or propeller aircraft or hover craft and for all general automotive, train, nautical or other mobile primary drive lines and models thereof or range extenders or apu's (auxiliary power units) there for.

Claims

1. An internal combustion engine concept, working principle, configuration, construction and application is claimed with the following characteristics:

    - It makes use of one or more cylindrically shaped pistons that make a combined rotating and reciprocating movement;
    - Where such (a) piston(s) has (have) (a) tangential waveform top surface with two or more identical waves per revolution of the piston around its cylindrical axis;
    - Where said waveform has a constant amplitude and constant shape over the full radius when the horizontal axis is expressed in radians or degrees (possibly with a rotational skew);
    - Where the cylinder head has a complementary, e.g. mirrored or mirrored but slightly modified tangentially waved surface facing the piston top;
    - Where the centre of the piston has a co-axial cylindrical hole or a co-axial cylindrical extension which closely fits around a cylindrical pylon on the cylinder head respectively within a cylindrical hole within the cylinder head;
    - Where the tangential waveforms of the piston top and of the facing surface of the cylinder head are formed such that they can maintain at least one radial contact line from the co-axial cylindrical hole or from the co-axial cylindrical pylon to the outer circumference of the piston, for each wave, during the full revolution of the piston around its cylindrical axis;
    - Where the reciprocating or hopping motion during each revolution around its cylindrical axis is such that the piston follows the wave form of the cylinder head while maintaining (semi) contact for each full wave, with a number of 'hops' identical to the number of waves around one 360º axial revolution;
    - Where the rotating piston top in (semi) contact with the complementary, e.g. mirrored or more or less mirrored cylinder head surface form alternating compressing and expanding chambers.

2. An internal combustion engine as in claim 1 is claimed where the waveform as mentioned in claim 1 has the following characteristics:

    - The wave form approximates a sinusoidal curve. Deviations from a true sinus wave are such that the wave tops are slightly narrower and steeper and the wave hollows are slightly broader in comparison to a true sinus wave;
    - The waved surfaces of the piston and the cylinder head match each other in such a way that the volume between piston top and cylinder

head varies from a maximum to a minimum, where the minimum value is between one fifth and one thirtieth of the maximum value, during rotation over each wave.

3. An internal combustion engine as in claim 1 or claim 1 and 2 is claimed which is **characterised in that**:

- Each piston - cylinder head combination has four, six or more (always even) piston top waves, forming two, three or more inhalation and compression chambers and two, three or more combustion, expansion and exhaust ejection chambers, enabling a four stroke engine operation;
- Intake channels, exhaust channels and possible by-pass channels provide for intake of air or air - fuel mixtures, for ejection of exhaust gasses and for possible recirculation flows towards the inhalation and compression chambers respectively from the combustion, expansion and exhaust ejection chambers formed between the piston top and the cylinder head;
- Intake channels, exhaust channels and possible by-pass channels have ports in either the cylinder wall, the wall of the cylinder head or piston central pylon or in the cylinder head top or in any combination of the options thereof, where intake timing, exhaust timing and possible recirculation timing is controlled by the location of the ports in the cylinder head and the position of the piston during its hopping and rotating movement. Intake, exhaust and possible recirculation ports are repeated rotational symmetric for each second wave of the cylinder head top.

4. An internal combustion engine as in claim 1 or claim 1 and 2 is claimed which is **characterised in that**:

- Each piston - cylinder head combination has two, three or more piston top waves, forming two, three or more combined inhalation and compression chambers and combustion, expansion and exhaust ejection chambers, enabling a two stroke engine operation;
- Two stroke breathing is assisted by the piston bottom, a possible balance weight piston, a turbo charger, or an external compressor, or a combination of the four above mentioned means, which push the air or air - fuel mixture into the chambers during maximum expansion and/or during the first part of compression between piston and cylinder head;
- Intake channels, exhaust channels and possible by-pass channels provide for intake of air or air - fuel mixtures, for ejection of exhaust gasses and for a possible flow from 'below' the piston towards the changing space between the piston top and the cylinder head;
- Intake channels, exhaust channels and possible by-pass channels have ports in either the cylinder wall or the wall of the cylinder head or piston central pylon or in any combination of the options thereof, where intake timing, exhaust timing and possible by-pass timing is controlled by the location of the ports in the cylinder head and the position of the piston during its hopping and rotating movement. Intake, exhaust and possible by-pass ports are repeated rotational symmetric for each wave of the cylinder head top.

5. An internal combustion engine as in claim 1 or claim 1 and 2 and claim 3 or 4 is claimed where:

- In line with claim 3, the inhalation and compression chambers and the combustion, expansion and exhaust ejection chambers are one by one connected by one or more transfer channels in the wave tops of the cylinder head, enabling air or air - fuel mixture to move from the compression chamber towards the combustion and expansion chamber during maximum compression or;
- In line with claim 4, the different compression chambers are one by one connected by one or more transfer channels in the wave tops of the cylinder head or in the wave hollow of the piston (or in a combination thereof), enabling air or air - fuel mixture to move from the closing compression chamber towards the forwardly adjacent chamber during maximum compression.

6. An internal combustion engine as in claim 1 or claim 1 and 2 and claim 3 or 4 and claim 5 is claimed where:

- One or more fuel injectors are placed just before or within the so called transfer channels as claimed in claim 5 or;
- One or more fuel injectors are placed just before or within the so called transfer channels as claimed in claim 5 and one or more spark, laser or glow ignition devices are placed in or just after the so called transfer channels as claimed in claim 5 or;
- Only one or more spark, laser or glow ignition devices are placed just before, in or just after the so called transfer channels as claimed in claim 5.

7. An internal combustion engine as in claim 1 or claim 1 and 2 and claim 3 or 4 and claim 5 and 6 is claimed where:

- During the period of maximum compression, an auto - igniting or glow plug assisted igniting

fuel, e.g. diesel oil is injected through injectors as in claim 6, running either in two stroke or in four stroke operation;
- During the period of maximum compression, a spark or laser - ignited fuel, e.g. gasoline, petroleum gas, natural gas or hydrogen is injected through injectors as in claim 6, running either in two stroke or in four stroke operation;
- An air - fuel mixture is inhaled which is ignited with ignition devices as in claim 6, during the period of maximum compression, letting the engine run in either two stroke or in four stroke operation.

8. An internal combustion engines as in claim 1 or claim 1 and 2 and claim 3 or 4 and claim 5 to 7 is claimed with the following possible elements in its embodiment:

- An engine construction where the piston(s) is (are) guided to follow the shape of the cylinder head, keeping in close contact, either by a circular cam on the piston bottom that runs over a number of stationary reaction wheels, axles or bearings, or by wheels connected to the piston bottom that follow a stationary reaction cam, or a combination thereof (this way, the piston or pistons make a hopping motion while rotating around their cylindrical axis);
- An engine construction where a balance weight follows a mirrored, co-rotating or anti-rotating mirrored hopping movement with a mass and an amplitude such that mass reaction forces are balanced;
- An engine construction where two bottom - opposing pistons, each with their own cylinder head, make co-rotating or anti-rotating mirrored movements such that mass reaction forces are balanced;
- An engine construction where the rotating and hopping motion of the piston is transferred towards a non hopping rotation of the engine shaft by using spreaders on the shaft with sliding contacts between spreader tips and the piston, by using tangentially hinging arms on the shaft with sliding contacts between the arm tips and the piston, by using tangentially multiple hinged arms that connect the shaft and the piston or by using a sliding planetary gear system.

9. An internal combustion engine as in claim 1 or claim 1 and 2 and claim 3 or 4 and claim 5 to 7 and possible elements from claim 8 is claimed where intake air is precompressed by an external turbo charger or an external mechanical booster in order to generate more power for the same piston displacement.

10. Applications for the internal combustion engine as in claim 1 or claim 1 and 2 and claim 3 or 4 and claim 5 to 7, possible elements from claim 8 and possibly claim 9 are claimed in the following areas of use (but not limited there to):

- To drive an automotive, train, aeronautic, hovercraft, nautical or other mobile primary drive line or of models thereof;
- To drive one or more stationary or non-stationary generators for electricity production in general or to form a range extender or an Auxiliary Power Unit (APU) for automotive, train, aeronautic, hovercraft, nautical or other mobile applications;
- To drive one or more stationary or non-stationary fans, compressors or pumps;
- To drive any motorized hand tooling, e.g. chain saws, mowers, etc.;
- To drive tooling which makes use of the reciprocating motion of the piston or piston head, like pile drivers, driving sheet drivers or hand or mechanical operated jack hammers.

Pronker ROtating and Hopping PIston Engine:

Figure 1

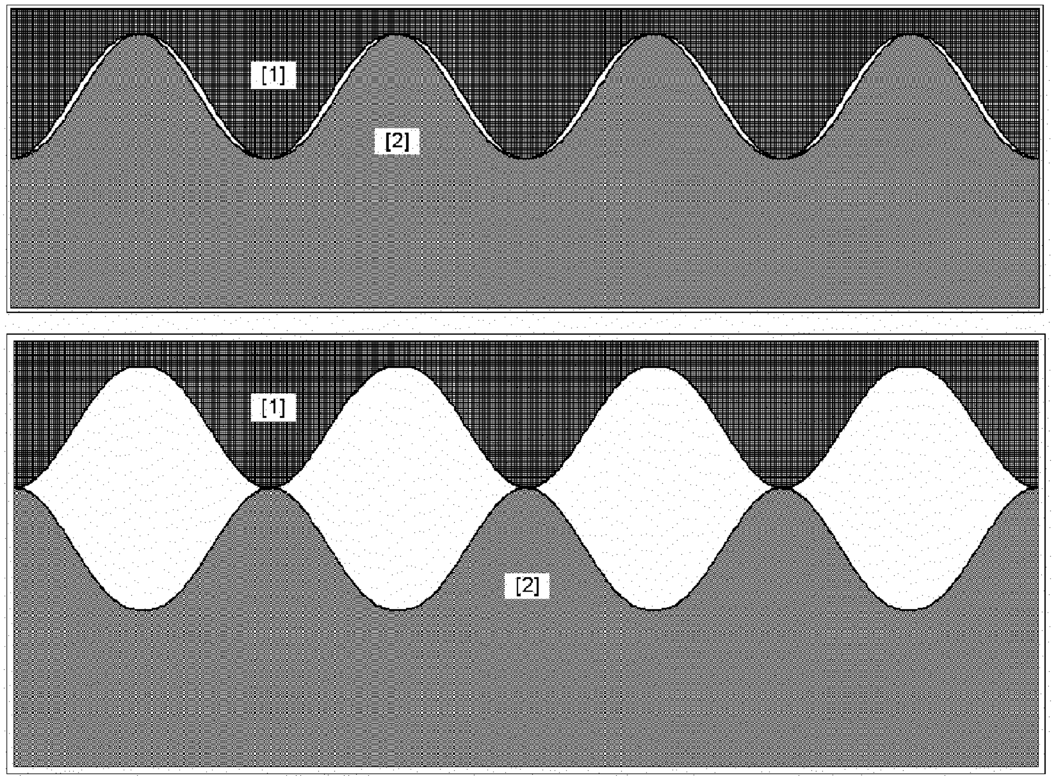


Figure 2 A - D

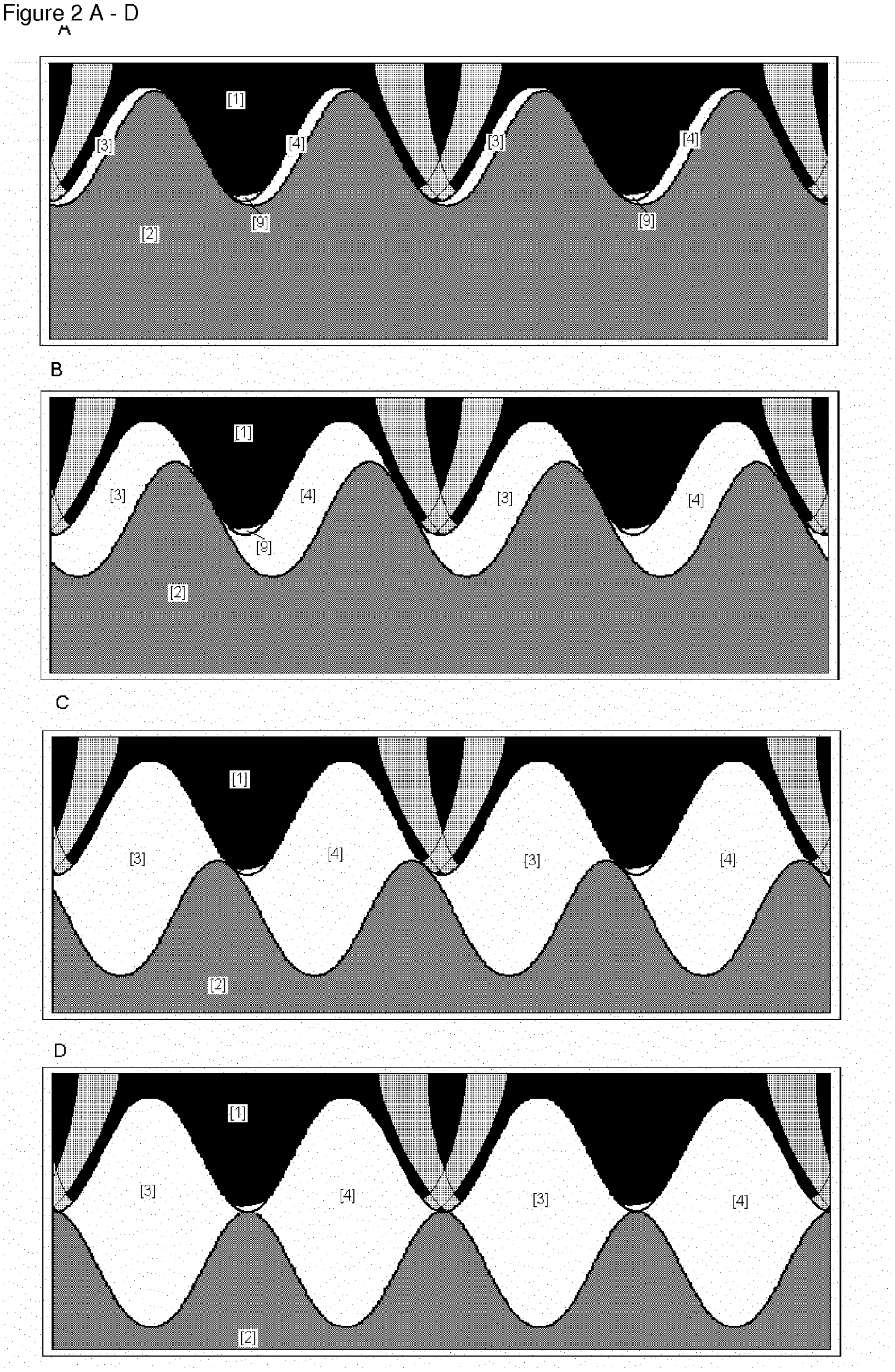


Figure 2 E – H

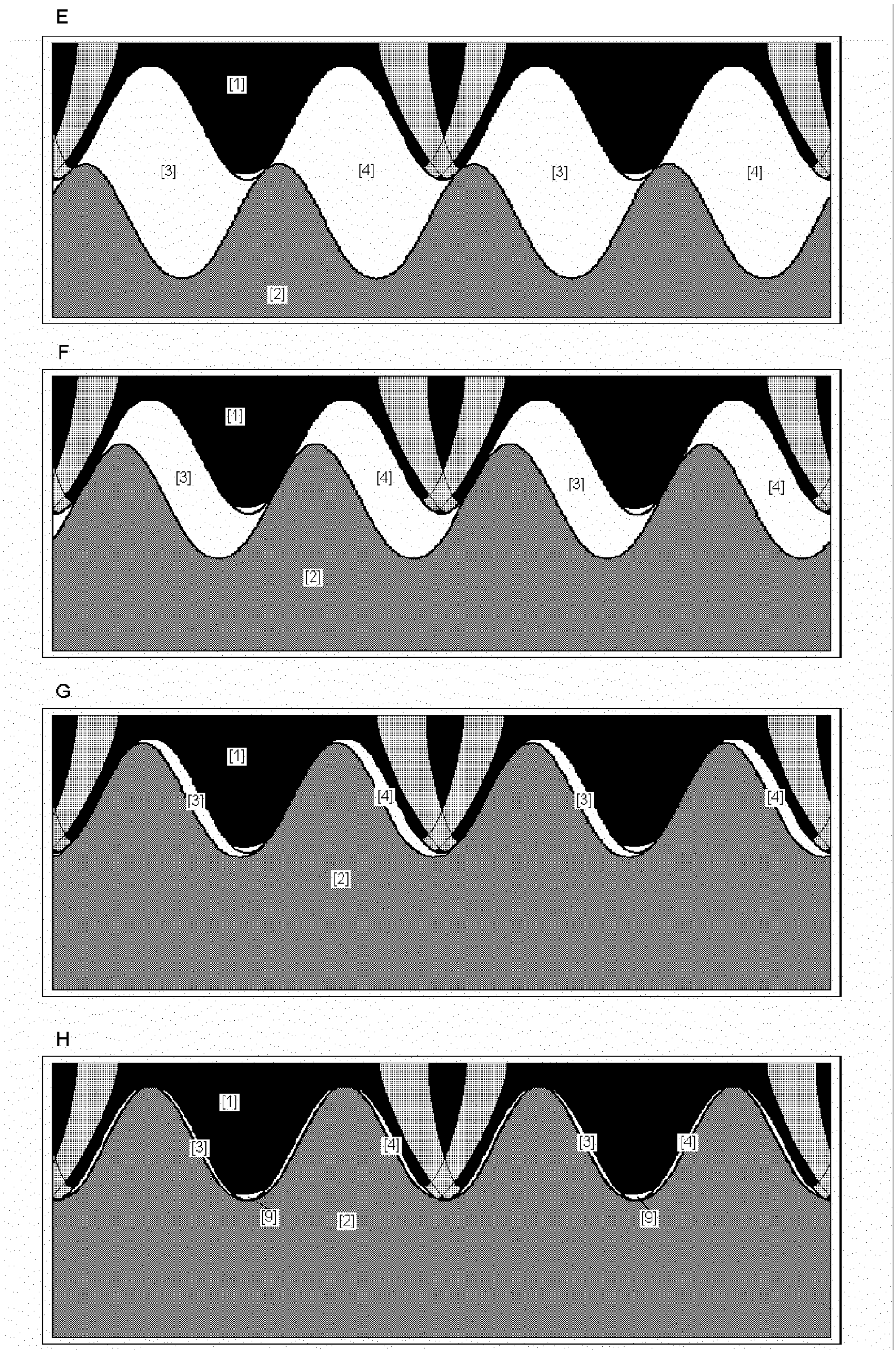


Figure 3 A - B

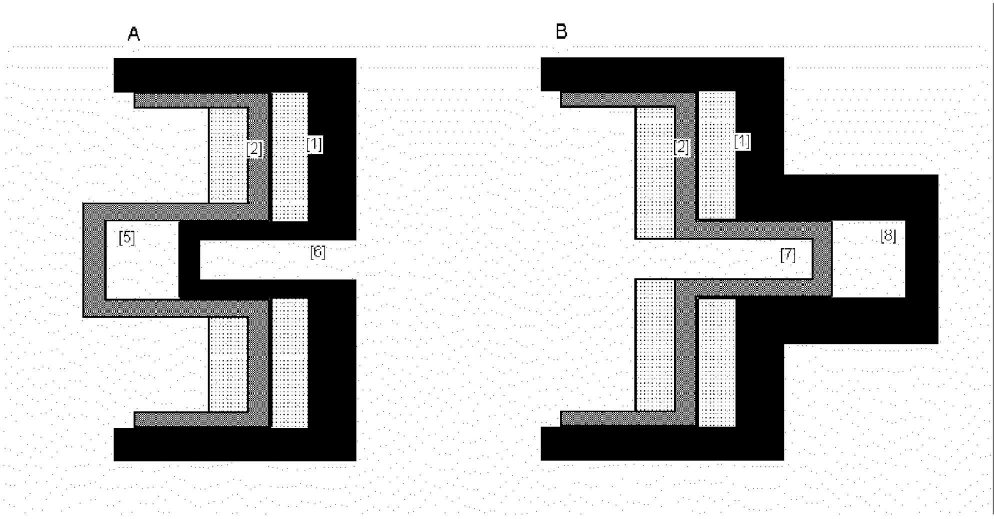


Figure 4

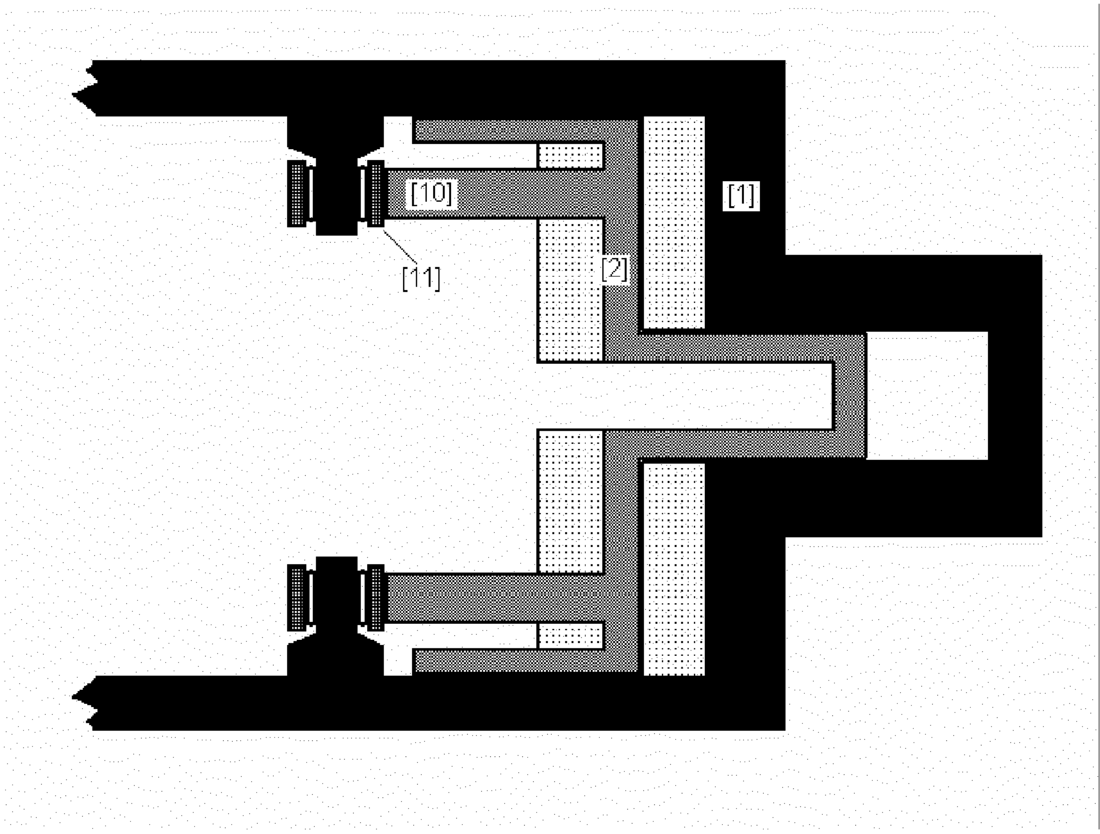
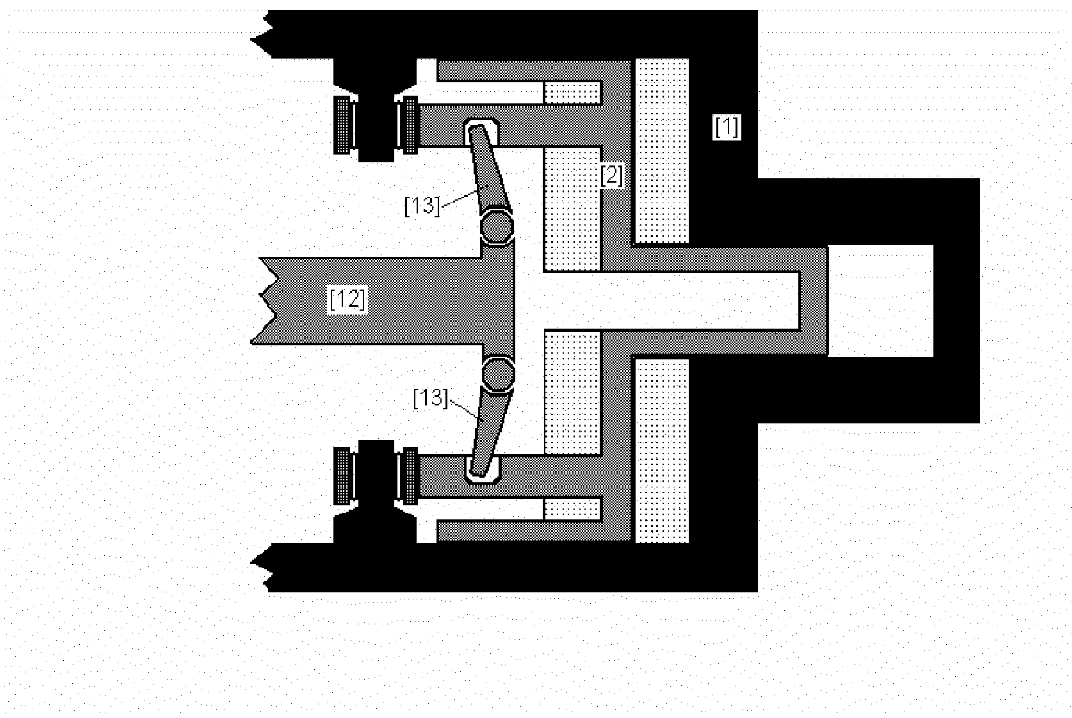


Figure 5



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EUROPEAN SEARCH REPORT

Application Number
EP 13 15 7698

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	EP 0 843 074 A1 (KAJINO YUKIO [JP]) 20 May 1998 (1998-05-20) * the whole document *	1-10	INV. F01C1/08 F01C9/00
X	DE 274 940 C (VON DITMAR, PETER) 7 November 1912 (1912-11-07) * the whole document *	1-10	
X	DE 10 2006 018024 A1 (KIRCHNER LEO [DE]) 25 October 2007 (2007-10-25) * the whole document *	1-7,9,10	
X	FR 2 805 566 A1 (LARAKI ABDESLAM AMINE [MA]) 31 August 2001 (2001-08-31) * the whole document *	1-4,7-10	
X	WO 91/05940 A1 (RICHARDS KEVIN [GB]; MULLER MICHAEL PAUL [GB]) 2 May 1991 (1991-05-02) * the whole document *	1-4,7-10	

TECHNICAL FIELDS SEARCHED (IPC)

F01C
F04C

The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
Munich	11 July 2013	Sbresny, Heiko

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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