

A cylinder liner for an internal combustion engine of the diesel type

The present invention relates to a cylinder liner for an internal combustion engine of the diesel type, 5 having a running surface in the form of a substantially cylindrical inner surface, and having at least one inwardly open oil track with external supply of lubricating oil and with at least one recess, which is only open towards the inside of the cylinder.

10 In connection with cylinder liners, it is a known problem that sometimes in unfortunate circumstances seizures may occur between the piston rings and the running surface of the cylinder liner. Such seizures seem to occur at random in that they may occur both 15 during the running-in of a new liner and during ordinary operation. Initiation of this type of seizures is assumed to take place at the top of the cylinder liner where the piston rings and the running surface are exposed to the heaviest load.

20 During the compression stroke of the piston a pressure build-up takes place above the piston, the scavenge air fed from the turbocharger being compressed from an initial pressure of, for example, between 3 and 4 bar to a considerably higher pressure at the top 25 position of the piston, such as a pressure of 100-150 bar. During the first part of the compression stroke, the pressure build-up is slow, and by far the majority of the pressure increase does not occur until the piston is reaching its top position. Around the top 30 position of the piston, the fuel valves open and the fuel is injected into the cylinder and ignited, whereupon the cylinder pressure during combustion increases to the maximum combustion pressure, which may, for example, be between 160 and 200 bar, and at the same



time the temperature in the upper part of the cylinder increases to more than 500°C. During combustion, the massive pressure rise in the combustion chamber above the piston crown causes combustion gas to spread into the annular spaces between the piston ring grooves and the piston rings, where the pressure affects the back of the rings and presses them out against the running surface of the liner. The high temperature during combustion also causes lower viscosity of the lubricating oil film on the running surface, so that the oil film is broken more easily. The risk of the oil film being broken is further increased by the relatively slow movement of the piston around its top position. The sliding speed of the piston rings vis-à-vis the running surface, required for maintaining the oil film on the running surface, is thus very low. During the expansion stroke the piston is pushed downwards, and by far the majority of the pressure decrease takes place in the first half of the expansion stroke, whereupon the pressure decreases relatively slowly, and just before the piston passes the scavenge air ports the pressure may typically have decreased to about the pressure of the scavenge air. The pressure load in the area around the top of the cylinder is thus very heavy compared with the pressure load on the rest of the cylinder. The area around the top of the liner is thus in all respects the part of the running surface exposed to the heaviest load.

Various attempts have previously been made to prevent seizures, which have occurred in a lower area of the liner, from spreading to other and larger areas. DK 170430 describes a cylinder liner with two annular recesses in the form of grooves, which are only open towards the inside of the cylinder and which are positioned immediately above and immediately below the

scavenge air ports, respectively. The recesses collect part of the lubricating oil which is pushed downwards by the piston rings during the expansion stroke, and prevent seizures, which have initiated and spread in the area below the scavenge air ports by the skirt of the piston touching the cylinder liner, from spreading to the area above the recesses.

JP-A 62-32207 shows a cylinder liner with inlets for the supply of lubricating oil in the upper part of the liner, and with a circumferential, zigzagging oil reservoir in the form of a recess positioned in the lower third of the liner slightly above the scavenge air ports. The recess is only open towards the inside of the liner and serves to improve the distribution of the lubricating oil, oil being collected and retained in the recess during the downward movement of the piston past the recess, and subsequently released again to the piston rings. Due to the zigzag shape of the recess the oil is distributed along the rings when the piston moves upwards past the oil reservoir after having passed its bottom position below the scavenge air ports. The recess thus retains lubricating oil which would otherwise be lost in the scavenge air ports.

These known examples of recesses in the running surface are located in the lower part of the liner, which means that the piston rings pass the recesses largely without load, because the pressure in the combustion chamber is low at these positions of the piston.

It is known that seizures may occur through a local breakage of the oil film whereby the piston rings can get in direct contact with the running surface and thus initiate a seizure, and that the seizures cause local overheating, which on subsequent inspection may be observed as damage to the materials of the liner and the



piston rings due to heat. The formation of seizures has so far been assumed to be caused by scuffing of the surfaces due to lack of lubrication, which during the ongoing operation has resulted in harmful generation of heat giving to the materials the discoloration characteristic of seizures.

The object of the invention is to design a cylinder liner in a manner so that during operation the initiation of seizures between the piston rings and an area of the running surface where the contact pressure between the piston rings and the running surface is particularly high is counteracted.

In view of this object, the cylinder liner according to the invention is characterized in that the recesses include at least a first and a second group, each having at least two recesses which have a discontinuous extent in the circumferential direction of the liner, that the recesses in the groups are located in the top 15 per cent of the length of the running surface, and that the recesses in the different groups are arranged with mutual separation in the longitudinal direction of the liner and with such a mutual arrangement in the circumferential direction of the liner that any line on the running surface parallel to the axis of the cylinder liner is intersected by at least one of the recesses.

The top of the running surface is located at the longitudinal position in the liner where the top piston ring has its top dead centre, and the running surface extends downwards to the bottom dead centre of the lowest piston ring. The length of the running surface is thus greater than the stroke by about the height of the ring pack.

The location of the recesses close to the top of the running surface in the area with the heaviest load



does, in fact, remove a support area for the rings and introduces discontinuous ring support, which should lead to heavier load on the rings and an increased risk of seizures, but in spite of this the wear of the rings and the liner is reduced, because the recesses intervene in the initial formation of seizures.

The general perception so far of the fundamental mechanism of seizure formation is presumably incorrect as it presupposes a steadily progressive process which, over a period of time, leads to seizures. Seizures are initiated by sudden, very local overheating caused by heavy friction between the piston ring and the running surface resulting in a brief, regular weld between the piston ring and the running surface. The welding takes place during the expansion stroke by the high combustion pressure pushing the piston ring out through the oil film on the running surface. Since the combustion pressure also exerts an extremely massive downward impact on both the piston and the piston ring, the piston ring is immediately torn loose again with a simultaneous tearing out of material of the running surface, which becomes rough. The tearing out brings about further heat generation, thus allowing another weld. Upon the subsequent passing of piston rings, the local seizure may be either smoothed out or spread into a larger area of the running surface.

The positioning of even a very narrow recess in the running surface crosswise of the direction of movement of the piston rings intervenes in the actual initial formation of seizures in the area around the recess. An increased temperature level is a prerequisite for the welding to take place. If the piston ring breaks the oil film, heat will generate because of increased friction between the ring and the running surface. At the moment when the ring passes a recess in the running surface,



the heating is briefly replaced by cooling, and since the materials of both the piston ring and the liner have suitably low average temperatures, heat is continuously conducted away from the heated point on the piston ring.

- 5 The brief interruption of heat generation is thus sufficient for preventing the initial formation of seizures.

Apart from counteracting the initiation of seizures, the recesses according to the invention have a
10 further advantage known per se of serving as passive oil reservoirs and preventing occurred seizures from spreading.

It is not a straightforward thing to position recesses in the running surface at the place where the
15 piston rings are pushed out the most against the running surface, and where also temperature and lubricating oil conditions as described above are critical. Since the recesses remove some support area for the ring there is a risk that it may become distorted in its groove in the
20 piston when passing the recess, because the ring, being relatively thin and elastic, is exposed to a heavy load. If the ring becomes distorted, it may become damaged by hitting the edge of the recess.

Such distortion of the piston rings and the
25 resulting wear thereof can be avoided according to the invention by forming the recesses with a discontinuous extent in the circumferential direction of the liner, and by arranging them with mutual separation in the longitudinal direction of the liner. When a piston ring
30 passes some of these recesses, it is supported by the remaining running surface between the recesses.

Arranging the discontinuous recesses so that any line on the running surface parallel to the axis of the cylinder liner is intersected by at least one of the
35 recesses ensures that any point at the circumference of



the piston rings will pass one or more cooling recesses at each piston stroke.

The recesses in the groups may be formed as grooves extending in the circumferential direction of the liner, 5 which renders possible an advantageously simple manufacture of the liner. The grooves may, for example, be cut or ground into the running surface.

The recesses in a group are preferably located at the same longitudinal position in the liner, which 10 further simplifies the manufacture, because fewer positionings are required during machining.

Further, preferably the recesses in each group have a total extent in the circumferential direction of the liner of maximum 80 per cent, and preferably maximum 60 15 per cent, of the circumference of the running surface. If the recesses in a group have a total extent in the circumferential direction of the liner of more than 80 per cent of the circumference of the running surface, the piston rings need to have an inexpediently high 20 rigidity in order to avoid excessive distortion in the piston ring grooves. If the recesses in a group have a total extent in the circumferential direction of the liner of maximum 60 per cent of the circumference of the running surface, this will provide satisfactory support 25 of the piston rings, while at the same time just two groups of recesses are able to cover the entire circumference of the running surface.

A particularly advantageous balancing of the need to avoid seizures against the need to minimize distortion of the piston rings when passing the recesses can 30 be obtained by each group comprising at least five, and preferably at least eight recesses. With five, and preferably eight, recesses in each group, the distance between the support areas for the piston rings in the 35 circumferential direction is not large.

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Furthermore, the recesses in each group may be distributed evenly along the circumference of the running surface, thus simplifying the manufacture of the liner and minimizing the length of the piston ring sections to pass the recesses.

In a preferred embodiment the running surface is intended for the use of piston rings of a piston, which piston rings have a predetermined minimum height, and the recesses in the groups have a height which is smaller than said minimum height of the piston rings, preferably maximum 75 per cent of this minimum height, suitably a height in the interval from 1 to 3 mm. If the height of the recesses is bigger than the minimum height of the piston rings, they will shortcircuit the seal against the running surface of at least one of the piston rings when it passes the recesses. As the recesses are located in the area with maximum pressure during both compression and combustion, the shortcircuit will have a negative impact on the efficiency of the engine. If the height of the recesses is maximum 75 per cent of the minimum height of the piston rings, this will effectively ensure against leakage and improve support of the piston rings. A recess height between 1 and 3 mm will effectively interrupt the formation of seizures while maintaining good support of the piston rings typically with ring heights of more than 10 mm.

Recesses belonging to different groups may have a mutual spacing in the longitudinal direction of the liner of at least 35 mm. In this way, interference is avoided between stress concentrations in the areas around the ends of the recesses in the different groups.

The invention further relates to a cylinder liner for an internal combustion engine of the diesel type, having a substantially cylindrical inner surface, which may constitute the running surface for the piston rings



on a piston, which piston rings have a predetermined minimum height, and having at least one inwardly open oil track with external supply of lubricating oil and at least one groove which is only open towards the
5 inside of the cylinder, which cylinder liner is characterized in that the at least one groove extends around the entire inner surface of the liner and has a height of less than 30 per cent of the minimum height of the piston rings, that the grooves have a bigger depth in
10 the radial direction of the liner than half their height in the longitudinal direction of the liner, and are positioned in the top 15 per cent of the length of the running surface.

Distortion of the piston rings in the piston ring
15 grooves with the resulting wear of the piston rings is prevented in this embodiment by the at least one groove having a height of less than 30 per cent of the minimum height of the piston rings. A piston ring is thus always supported by the running surface over an area corresponding to at least 70 per cent of the height of the piston
20 ring and can, accordingly, pass the groove without becoming inexpediently distorted in the ring groove. As mentioned above, the grooves counteract the initiation of seizures.

25 A suitable life of the liner can be obtained by the grooves having a bigger depth in the radial direction of the liner than half their height in the longitudinal direction of the liner. If, for example, the minimum height of the piston rings is 6 mm, and the running
30 surface during normal smooth operation is worn by approximately 0.02 mm per 1000 hours of operation, then in this case the grooves will have a depth of 0.6 mm and will not be worn down until after approximately 3.4 years of constant operation. Usually, marine engines are
35 designed for approximately two years of constant



operation between every service inspection, and in that perspective the determined depth of the grooves is considered a suitable lower limit.

Each groove may extend along the circumference of the running surface at a constant longitudinal position in the liner. Thus, as described above, the groove is prevented from shortcircuiting the piston rings.

Furthermore, at least three grooves can be made. As the grooves according to this embodiment are relatively narrow, it may be an advantage to arrange three or more grooves close to each other in order to improve the prevention of seizures.

In the top 10 per cent of the length of the running surface, the distance between the grooves may be less than eight times the groove height. At this relatively close positioning in the uppermost area of the running surface, the formation of seizures may largely be prevented in the area of the running surface with the heaviest load.

In a second embodiment, each groove may extend upwards and downwards between the ends of a cylindrical section of the running surface, the height of which section is smaller than the minimum height of the piston rings. In this way, the grooves are prevented from shortcircuiting the piston rings, while at the same time the support area of the rings is increased for the same area of grooves.

In respect of both of the embodiments of the invention described above, the recesses or the grooves may suitably have a depth of at least 2 mm in the newly-manufactured liner to ensure a long life of the liner without remachining of the recesses or the grooves in the inner surface.

The oil track may be located below the recesses or the grooves to prevent the supply of oil from being



affected by the high pressures occurring at the top of the liner.

The invention will now be described in further detail below by means of examples of embodiments with 5 reference to the drawing, in which

Fig. 1 shows a partial side view, partial longitudinal sectional view of a cylinder liner, in which a segment of a piston at the top dead centre is outlined,

Fig. 2 shows a developed segmental view of the 10 uppermost section of the cylinder liner with recesses in the inner surface,

Fig. 3 shows a developed segmental view corresponding to that in Fig. 2 of a second embodiment of the uppermost section of the cylinder liner with recesses 15 in the inner surface,

Fig. 4 shows a developed segmental view on a larger scale of a third embodiment of the uppermost section of the cylinder liner with recesses in the inner surface,

Fig. 5 shows a developed segmental view corresponding to that in Fig. 2 of a fourth embodiment of the 20 uppermost section of the cylinder liner with recesses in the inner surface, and

Fig. 6 shows an enlarged cross-sectional view of a recess in the running surface of a cylinder liner with 25 associated piston ring and piston.

Fig. 1 shows a cylinder liner 1 for a large two-stroke crosshead engine. Depending on the size of the engine, the cylinder liner may be manufactured in different sizes with bores typically in the interval 30 from 250 mm to 1000 mm, and corresponding lengths typically in the interval from 100 cm to 420 cm. The liner 1 is usually made from cast iron, and it may be integral or divided into several sections, which are assembled in extension of each other. In case of a 35 divided liner, it is also possible to make the upper



section from steel coated with a suitable running layer. Crosshead engines of the above type may have high effective compression ratios, such as 1:16 - 1:20, which cause heavy loads on the piston rings.

5 The liner 1 may be mounted in a known manner in an engine, not shown, by positioning an annular, downward surface 2 on the top plate in the frame box or cylinder block of the engine, whereupon a piston 3 is mounted in the cylinder liner, and a cylinder cover 4 is positioned
10 at the top of the liner on its annular, upward surface 5 and tightened to the top plate by means of cover studs, not shown.

 The liner 1 has a substantially cylindrical inner surface, which constitutes a running surface 6 for the
15 piston rings 7 on the piston 3. An annular row of scavenge air ports 8 is positioned in the lower section of the cylinder liner. The piston 3 is movable in the longitudinal direction of the liner between a top dead centre, at which the upward surface 9 of the piston is
20 positioned in a bore in the cylinder cover 4, and a bottom dead centre, at which the upward surface of the piston is just below the lower end of the scavenge air ports 8. The running surface 6 extends from an upper edge 10 located just above the top dead centre of the
25 uppermost piston ring, to a lower edge 11 located just below the bottom dead centre of the lowest piston ring. An undulate lubricating oil track 12 may be positioned in the inner surface of the liner below the upper third of the running surface, into which lubricating oil is
30 admitted through inlet holes 13 for lubrication of the running surface 6 at the inner surface of the liner.

 Within the area marked by a, which constitutes the top 15 per cent of the length of the running surface, a number of recesses are positioned in the running



surface 6, which are only open towards the inside of the cylinder liner.

Fig. 6 shows an enlarged longitudinal sectional view of a segment of the running surface 6 and the piston 3. The piston 3 has a piston ring groove 16, in which a piston ring 7 is positioned in a known manner. The piston ring groove 16 is higher than the piston ring 7, and, during combustion, combustion gas spreads from above through the gap 17 into the annular space 18, present between the bottom of the ring groove 16 and the cylindrical inner surface of the piston ring. Due to the high pressure of the combustion gas, the elastic piston ring 7 is pushed in the direction indicated by the arrow out against the running surface 6, which is covered by a lubricating oil film 19, whereby the piston ring 7 seals the piston 3 vis-à-vis the running surface 6. The running surface 6 is provided with a recess 14, which in the present example is formed as a sharp-edged groove, but which may also have rounded edges 20 at the transition to the running surface 6. When the piston moves up and down, lubricating oil is scraped down into the recess 14.

The height of the recess 14 is considerably smaller than that of the piston ring 7, and accordingly the piston ring is well supported by the running surface 6 when passing the recess 14. In a second embodiment, not shown, the height of the recess 14 is bigger than that of the piston ring 7 to allow a certain leakage of gas across one or more of the piston rings 7.

If a point 22 on the outer surface of the piston ring 7 has been overheated, this point is cooled when passing the recess 14. If, contrary to expectations, welding takes place between the point 22 on the piston ring 7 and the running surface 6, such welding may be prevented from spreading by the point passing the recess



14, and any major unevenness may be smoothed out by means of one of the edges 20 of the recess.

Fig. 2 shows a developed segmental view of the uppermost section of the cylinder liner, in which in the 5 embodiment shown the area a (see Fig. 1) has two groups of recesses 14 in the running surface 6. Each group constitutes a row of recesses arranged with intervals 21, in the form of grooves 14 positioned along a line perpendicular to the longitudinal axis of the liner. The 10 intervals 21 constitute a supporting surface, which carries the piston rings 7 when they pass upwards or downwards across the row of grooves, so that the rings 7 do not become distorted in the ring groove. The rows of grooves 14 are mutually spaced in the longitudinal 15 direction of the liner, and the grooves in the uppermost row slightly overlap the grooves in the bottom row in the circumferential direction, so that any line on the running surface parallel to the longitudinal direction of the liner intersects one or more grooves 14. The 20 grooves are distributed evenly in the circumferential direction and are of the same length. For a cylinder liner 1 of a diameter of, e.g., 700 cm, each group may suitably comprise 11 grooves, each of a length of 125 mm, and a height of 2 mm - 3 mm, and a depth of 2 mm - 25 3 mm. If only two groups are applied, the uppermost row of grooves may be located approximately from 100 to 200 mm from the uppermost edge 10 of the running surface, and the bottom row of grooves may be located about 50 mm below the uppermost row. More groups improve the 30 seizure-preventing effect, but manufacturing costs of the liner are increased accordingly.

Fig. 3 shows another embodiment of the cylinder liner, according to which three groups of recesses in the form of grooves 14, 15 are positioned in the running 35 surface 6, mutually separated in the longitudinal



direction of the liner. The top and bottom groups both consist of a row of spaced grooves 14 arranged along a line perpendicular to the longitudinal axis of the liner. The group in the middle consists of a row of 5 grooves inclined alternately upwards and downwards. The grooves overlap slightly in the circumferential direction, so that any line on the running surface parallel to the longitudinal direction of the liner intersects one or more grooves 14, 15.

10 Fig. 4 shows another embodiment of the cylinder liner 1, in which the recesses comprise three groups, each having a row of circular recesses in the form of bores 23. The bores 23 are distributed evenly and are mutually displaced in the circumferential direction, and 15 they have a suitable diameter for overlapping slightly in the circumferential direction.

According to the invention, the expression a group of recesses should be interpreted in a broad sense. With reference to the embodiment in Fig. 4, each group may 20 thus be interpreted as the three bores arranged obliquely below each other, as the groups are then mutually displaced in the circumferential direction. A group of recesses may comprise recesses arranged at differing longitudinal positions in the liner.

25 Fig. 5 shows another embodiment of the invention, in which the recesses include five narrow circular grooves 24, which extend continuously around the entire circumference of the running surface and are located in proximity to each other. The height of the grooves is 30 maximum 30 per cent of the minimum height of the piston rings, largely corresponding to the outline in Fig. 6. These narrow grooves allow the piston ring to pass the groove without such distortion that make the edge of the ring hit against the edge of the groove.



Within the scope of the invention, it is possible to form the recesses in many different shapes, e.g., with undulating course, rectilinear or angular course, and it is also possible to combine the different 5 embodiments. For example, the discontinuous recesses may be located closer to each other in the circumferential direction if they have a small height.

The location of the recesses or the grooves in the uppermost area of the running surface exposed to the 10 heaviest load has a disruptive effect on the mechanism which causes seizures. When seizures do not occur in the uppermost area, the piston rings are practically unable to cause seizures, because the ring load is smaller further down on the running surface.

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P A T E N T C L A I M S

1. A cylinder liner (1) for an internal combustion engine of the diesel type, having a running surface in the form of a substantially cylindrical inner surface (6), and having at least one inwardly open oil track (12) with external supply (13) of lubricating oil and at least one recess (14, 15, 23), which is only open towards the inside of the cylinder, c h a r a c t e r - i z e d in that the recesses (14, 15, 23) include at least a first and a second group, each having at least two recesses (14, 15, 23) which have a discontinuous extent in the circumferential direction of the liner, that the recesses (14, 15, 23) in the groups are located in the top 15 per cent of the length of the running surface (6), and that the recesses (14, 15, 23) in the different groups are arranged with mutual separation in the longitudinal direction of the liner (1) and with such a mutual arrangement in the circumferential direction of the liner (1) that any line on the running surface (6) parallel to the axis of the cylinder liner is intersected by at least one of the recesses (14, 15, 23).

2. A cylinder liner (1) according to claim 1, c h a r a c t e r i z e d in that the recesses in the groups are formed as grooves (14) extending in the circumferential direction of the liner.

3. A cylinder liner (1) according to claim 1 or 2, c h a r a c t e r i z e d in that the recesses (14, 15, 23) in a group are located at the same longitudinal position in the liner (1).

4. A cylinder liner (1) according to any one of claims 1-3, c h a r a c t e r i z e d in that the recesses (14, 15, 23) in each group have a total extent in the circumferential direction of the liner (1) of





maximum 80 per cent, and preferably maximum 60 per cent, of the circumference of the running surface (6).

5. A cylinder liner (1) according to any one of claims 1-4, characterized in that each group comprises at least five, and preferably at least eight recesses (14, 15, 23).

6. A cylinder liner (1) according to any one of claims 1-5, characterized in that the recesses (14, 15, 23) in each group are distributed evenly along the circumference of the running surface (6).

7. A cylinder liner (1) according to any one of claims 1-6, characterized in that the running surface (6) is intended for the use of the piston rings (7) of a piston (3), which piston rings (7) have a predetermined minimum height, and that the recesses (14, 15, 23) in the groups have a height which is smaller than said minimum height of the piston rings (7), preferably maximum 75 per cent of this minimum height, suitably a height in the interval from 1 to 3 mm.

8. A cylinder liner (1) according to any one of claims 1-7, characterized in that the recesses (14, 15, 23) belonging to different groups have a mutual spacing in the longitudinal direction of the liner (1) of at least 35 mm.

9. A cylinder liner (1) for an internal combustion engine of the diesel type, having a substantially cylindrical inner surface, which may constitute the running surface (6) for the piston rings (7) of a piston (3), which piston rings (7) have a predetermined minimum height, and having at least one inwardly open oil track (12) with external supply (13) of lubricating oil and at least one groove (24) which is only open towards the inside of the cylinder, characterized in





that the at least one groove (24) extends around the entire inner surface (6) of the liner (1) and has a height of less than 30 per cent of the minimum height of the piston rings (7), that the grooves (24) have a bigger depth in the radial direction of the liner (1) than half their height in the longitudinal direction of the liner (1), and are positioned in the top 15 per cent of the length of the running surface (6).

10. A cylinder liner (1) according to claim 9, characterized in that each groove (24) extends along the circumference of the running surface (6) at a constant longitudinal position in the liner (1).

11. A cylinder liner (1) according to claim 9 or 10, characterized in that the grooves (24) comprise at least three grooves (24).

12. A cylinder liner (1) according to any one of claims 9-11, characterized in that in the top 10 per cent of the length of the running surface (6), the distance between the grooves (24) is less than eight times the groove height.

13. A cylinder liner (1) according to any one of claims 9, 11 or 12, characterized in that each groove (24) extends upwards and downwards between the ends of a cylindrical section of the running surface (6), the height of which section is smaller than the minimum height of the piston rings (7).

14. A cylinder liner (1) according to any one of claims 1-13, characterized in that the recesses (14, 15, 23, 24) or the grooves have a depth of at least 2 mm in the newly-manufactured liner (1).

15. A cylinder liner (1) according to any one of claims 1-14, characterized in that the oil track (12) is located below the recesses (14, 15, 23, 24) or the grooves.

