Sept. 3, 1957 WOLF-DIETER BENSINGER ET AL 2,804,863

CAM FOR INTERNAL COMBUSTION ENGINES

Filed Sept. 22, 1953

Fig.1

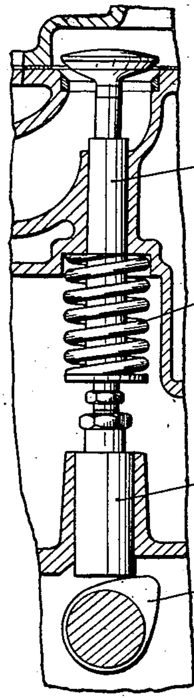


Fig.2

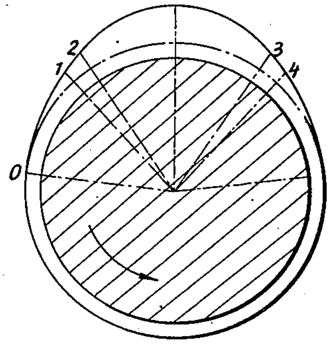


Fig.3

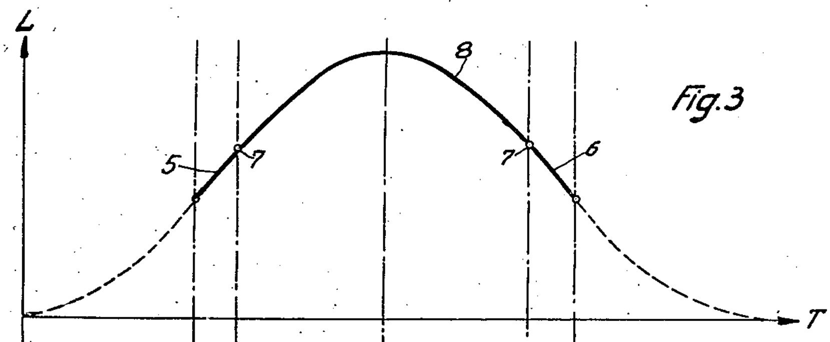
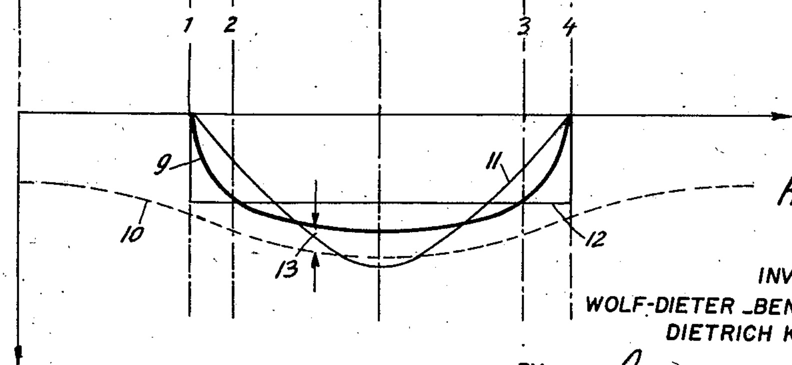


Fig. 4



INVENTORS.
WOLF-DIETER BENSINGER &
DIETRICH KURZ.

BY Dicke and Craig.
ATTORNEYS.

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CAM FOR INTERNAL COMBUSTION ENGINES

Wolf-Dieter Bensinger and Dietrich Kurz, Stuttgart-Unterturkheim, Germany, assignors to Daimler-Benz Aktiengesellschaft, Stuttgart-Unterturkheim, Germany

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4 Claims. (Cl. 123—90)

The present invention relates to a cam for an internal combustion engine, such as used for actuating a spring-pressed poppet valve or for actuating spring-controlled valve pistons, e. g. the pistons of fuel injection pumps or feed pumps.

The actuation of a spring-pressed reciprocatory element, such as a poppet valve, comprises two phases: the acceleration and the deceleration of the member. During the deceleration phase the spring must positively maintain engagement of the reciprocatory member with the cam. For that purpose, the variable force produced by the spring, which force depends on the position of the member, must at any such position surpass by a certain safety amount the deceleration force, i. e. the force required to decelerate the member in accordance with the lift curve prescribed by the shape of the cam, said safety amount depending on the friction, the allowances for the departure of dimensions and other factors from the prescribed values, on oscillations of the elements etc.

It is an object of the present invention to provide a cam permitting the spring to be rendered as light as possible.

More particularly, it is an object of the invention to reduce the maximum force exerted by the spring maintaining engagement between cam and actuated member to a minimum as is desirable in order to reduce the weight, cost and size of the spring and in order to obtain favorable conditions with respect to natural oscillations of the spring.

According to the present invention, the cam has a profile shaped to produce a movement of the actuated member which, when represented in a rectangular coordinate system as a function of the angular position of said cam, is indicated by a curve which, within the deceleration phase, is composed of oblique sine curves and of a polynomial curve of a high degree. As a result, a cam is obtained with which the actuated member, such as the poppet valve, can be kept in continuous engagement at a high rotary speed of the cam with a comparatively light spring. Moreover, the cam may be readily so designed as to comply with the specific requirements of any particular case.

The present invention will be described hereinafter in detail with reference to a specific embodiment thereof, it being understood, however, that such detailed description serves the purpose of illustration rather than that of limitation of the invention. In the drawings,

Fig. 1 illustrates a section through a cam shaft and a spring-pressed poppet valve of an internal combustion engine actuated thereby, the invention being applicable to the cam of such cam shaft,

Fig. 2 shows a detail of Fig. 1 on an enlarged scale illustrating the cam shaft,

Fig. 3 is a graph showing the lift of the valve represented in a rectangular coordinate system as a function of the angular position of the cam shown in Fig. 2, and

Fig. 4 is a graph showing the deceleration of the valve represented in a rectangular coordinate system as a function of the angular position of the cam.

The poppet valve P which may be the inlet valve or the outlet valve of an internal combustion engine, is subjected to the force of a spring S which rests on a shoulder of the cylinder block and acts on a spring plate fixed to the valve stem thereby tending to keep the valve closed. Contrary to the force exerted by the spring S, the valve P may be positively opened by action of a cam C forming part of a rotating cam shaft journalled in the cylinder block, such cam C acting upon a plunger I interposed between the cam C and the poppet valve P. The spring S must be so dimensioned as to maintain uninterrupted engagement between the stem of valve P, plunger I and cam C.

The object of the present invention is to so design the cam C that at a certain rotary speed of the cam shaft such engagement will be maintained with a minimum of spring power.

0, 1, 2, 3 and 4 are critical points on the periphery of the lobe of the cam which will act on the plunger I successively. During the first phase of the cam actuation, while the portion of the periphery between the points 0 and 1 acts on the plunger, the actuated member I, P will be accelerated up to its highest speed which is reached when the point 1 of the cam periphery contacts the plunger. In the following phase which will be called the deceleration phase hereinafter, the speed of the actuated two-part member I, P is lowered to a full stop and is then reversed until the downward speed of the closing movement of the valve attains a maximum. This happens when point 4 of the cam contacts plunger I.

The valve lift L produced by the cam is represented in Fig. 3 in a rectangular coordinate system as a function of the angular position T of the cam. Since the cam revolves at a constant speed, the abscissae representing the angular position of the cam will also represent the time. In Fig. 3 the deceleration period extends from instant 1 to instant 4. According to the present invention, the lift curve in Fig. 3 within the deceleration phase between 1 and 4 is composed of oblique sine curves **5** and **6** joined at the points **7** to a polynomial curve **8**.

Preferably, the polynomial curve is of the fourth degree representing the function

$$y=a+bx+cx^2+dx^3+ex^4$$

a, b, c, d, e being constants. An oblique sine curve represents the function $y=h\cdot x+f\cdot \sin gx$. Its first derivative is $y=f\cdot \sin gx$, in this equation h, f and g being constants. The constants a to h are so chosen that the joined ends of the curves **5**, **6** and **8** at **7** have identical inclination and curvature. Preferably, each of the oblique sine curves **5** and **6** has a length of one quarter of a period.

The deceleration force which must be exerted upon the reciprocatory member I, P in order to impart the movement thereto illustrated by the diagram in Fig. 3 is represented by the curve **9** in Fig. 4. As is well understood in the art, the deceleration curve **9** represents the second derivative of the lift curve **5**, **8**, **6**. Hence, a force as represented by curve **9** would be sufficient if exerted upon the reciprocatory member I, P to maintain the same in permanent engagement with the cam when the same revolves at the permissible maximum speed. In fact, however, the spring S exerts a higher force which varies as the spring is compressed and relaxed. Such force would be capable to impart a higher deceleration to the reciprocatory member I, P, such higher deceleration being indicated by curve **10** in Fig. 4. Since the force is proportional to the product of the mass and the acceleration or deceleration, curve **10** represents the actual force produced by spring S divided by the mass of the member I, P. Expressed in other words, curve **10** represents the maximum acceleration which spring S could impart to the poppet valve member I, P in the direction towards the cam theoretically in view of the mass of such member.

This acceleration has a maximum value when the spring is compressed or, in other words, when the tip of the cam lobe acts on plunger I.

It is another characteristic of the present invention that the two curves 9 and 10 are nearly equidistant over most of the deceleration phase. The distance of the curves 9 and 10 denotes a surplus of force which will guarantee the permanent engagement between cam and plunger.

The equidistant relationship of the two curves offers the advantage that with a given acceleration from 0 to 1 and with a given total lift and rotary speed of the cam, a minimum of spring force is sufficient to maintain permanent engagement. An analysis of different possibilities of reducing the lifting speed reached at point 1 in Fig. 2 down to zero reached at the center line of the diagram shows that the areas confined between the elected deceleration curve and the abscissa is invariably the same in all cases. In Fig. 4 the curves 11 and 12 have been drawn as representing theoretical decelerations confining the same areas as curve 9 and approaching extreme conditions. It will appear that in either case curve 10 representative of the size of the spring would have to be moved down in order to secure the same surplus 13 of spring power. Therefore, a deceleration curve, such as 11, or a deceleration curve, such as 12, or any deceleration curve therebetween except curve 9 would require a more powerful spring.

While we have described our invention with reference to a preferred embodiment thereof, we wish it to be clearly understood that the same is in no way limited to the details of such embodiment, but is capable of numerous modifications within the scope of the appended claims.

What we claim is:

1. A mechanism of an internal combustion engine including a curved cam, a reciprocatory member and a spring normally urging said member into engagement with said cam, said cam having a profile shaped to produce a reciprocatory movement of said member and said spring surpassing by a certain safety amount the force required to decelerate said member in accordance with the shape of said cam thereby positively maintaining in engagement said member with said cam; said reciprocatory movement, when represented in a rectangular coordinate system as a function of the angular position of said cam, is indicated by a curve which, within the deceleration phase, is composed of oblique sine curves joined to a polynomial curve of high degree, the joined ends of said curves having identical inclination and curvature.

2. A mechanism of an internal combustion engine including a curved cam, a poppet valve and a spring normally urging said valve into engagement with said cam, said cam having a profile shaped to produce a lift of said

valve and said spring surpassing by a certain safety amount the force required to decelerate said valve in accordance with the shape of said cam thereby positively maintaining in engagement said valve with said cam; said reciprocatory movement, when represented in a rectangular coordinate system as a function of the angular position of said cam, is indicated by a lift curve which, within the deceleration phase, is composed of oblique sine curves joined to a polynomial curve of high degree, the joined ends of said curves having identical inclination and curvature.

3. A mechanism of an internal combustion engine including a curved cam, a poppet valve and a spring normally urging said valve into engagement with said cam, said cam having a profile shaped to produce a lift of said valve and said spring surpassing by a certain safety amount the force required to decelerate said valve in accordance with the shape of said cam thereby positively maintaining in engagement said valve with said cam; said reciprocatory movement, when represented in a rectangular coordinate system as a function of the angular position of said cam, is indicated by a lift curve which, within the deceleration phase, is composed of oblique sine curves joined to a polynomial curve of the fourth degree constituting the crest of said lift curve, the joined ends of said curves having identical inclination and curvature and each of said oblique sine curves has a length of one quarter of a period.

4. A mechanism of an internal combustion engine including a curved cam, a poppet valve and a spring normally urging said valve into engagement with said cam, said cam having a profile shaped to produce a lift of said valve and said spring surpassing by a certain safety amount the force required to decelerate said valve in accordance with the shape of said cam thereby positively maintaining in engagement said valve with said cam; said reciprocatory movement, when represented in a rectangular coordinate system as a function of the angular position of said cam, is indicated by a lift curve which, within the deceleration phase, is composed of oblique sine curves joined to a polynomial curve of the fourth degree constituting the crest of said lift curve, the joined ends of said curves having identical inclination and curvature and each of said oblique sine curves has a length of one quarter of a period and within the deceleration phase the second derivative of said lift curve extends substantially parallel to a curve representing the force of the spring divided by the mass of said poppet valve.

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