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(54) **Fuel injector atomizer for automotive mixture preparation systems**

(57) The present patent application refers to a double layer fuel injector atomizer for automotive mixture preparation systems, in which the fuel injector can generate a spray pattern, which may be shaped in a desired form

to create an appropriate spray momentum without the use of any auxiliary mechanical adaptor on the downstream side of the atomizer.

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Description

[0001] The present patent application refers to a double layer fuel injector atomizer layout for mixture preparation systems, which provides a spray pattern shaped in a desired form and with an appropriate momentum without the use of any mechanical adaptor on the downstream side of the atomizer.

State of the Art

[0002] The fuel injector is a key element in the combustion control process of any Spark Ignited (SI) Internal Combustion (IC) engine. The combustion quality (Pressure and post-combustion products) is, amongst others, strongly related to the mixture preparation homogeneity in the combustion chamber prior to combustion. Therefore the fuel/gas mixture produced in the intake port (upstream side of the valve seats) at each engine cycle is decisive for the combustion result.

[0003] The primary cycle in a SI-engine is the air-cycle, which introduces at each intake stroke a certain amount of fresh gas (hereafter referred to as the gas-core) in the combustion chamber. The liquid fuel is injected into the gas core to mix with the gas before being introduced into the cylinder.

[0004] For all layouts related to the invention the metering of the fuel into the gas core is performed by a duty-cycle controlled fuel injector. The fuel injector can basically be divided in three functional parts:

- the actuator part, which works in a duty-cycle if electro-mechanical or in simple on/off if purely mechanical.
- the sealing part, which normally is integrated at the top face of the atomizer plate.
- the metering/atomizing part, which is the disk-shaped atomizer plate in which the fuel nozzle holes are located, and which perform the fuel metering and atomization.

[0005] The fuel is usually delivered by a pressurized fuel rail (hereafter referred to as rail) (100) to the top of the fuel injector (200) then it passes through the sealing seat area (300) and finally it is metered and injected into the gas core through the atomizer plate (400). Figure 1 shows an example of a flat seat injector layout.

[0006] Recent experimental work with low vaporizing fuels such as ethanol either pure or blended with gasoline (flex-fuel) has shown that the physical mixing and vaporization processes depend on the dynamic ratio between the momentum (momentum = mass x velocity) of the spray and that of the gas core.

[0007] In the gas core the mass is uniformly distributed over the volume. This is not true for the fuel spray. The spray is composed of droplets of various diameters produced by the breakup capability of the atomizer device and of vapor, which diffuses from the free droplet surfac-

es. Initially, the most important mass fraction is contained in the droplets. The droplet velocity vectors are also determined by the atomizer design.

[0008] The atomizer plate is normally designed with one or multiple nozzle holes, which guide each produced spray in a given direction according to the ratio between the length (L_H) and diameter (D_H) of each nozzle hole. The spray momentum distribution varies across the spray volume mainly controlled by three factors: the initial droplet distribution, the droplet free path vaporization, and any coalescence of droplets in the spray volume. Generally the initial droplet distribution is related to the available rail-pressure and the nozzle hole effective flow area. The effective flow area of a nozzle hole or holes cannot be freely chosen. It is determined by the steady average flow requirement imposed by the engine type and displacement.

[0009] The number of nozzle holes will determine the initial breakup of droplets (size and velocity). To provide a homogeneous momentum distribution within the spray it is important that the initial droplets and their velocity vectors are contained within precise limits determined by both the dynamic gas core momentum and by a precise control of the droplet coalescence phenomenon.

[0010] Today the general practice in fuel atomizer design is to apply a multiple nozzle holes approach where the overall spray-shape is reached by several individual sprays emerging from one or more groups of holes. Usually, one group of holes, forming a single spray is applied to engines with one intake valve per cylinder and two separate groups of holes (twin-spray atomizers) to engines with two intake valves per cylinder.

[0011] As previously stated, an increase in the number of nozzle holes will, by unchanged rail-pressure and effective flow area, produce an initial liquid breakup of droplets with smaller average diameters. The average result in the near-field area of the injector tip (on the downstream side of the atomizer) is an increase of the active spray surface and thereby an increased vaporization capability, which contributes to a decrease of the overall spray momentum.

[0012] A simplified argumentation based on steady state boundary conditions, which unfortunately is wrong at the high-turbulent unsteady flow conditions in the intake port area, often leads to the conclusion that the simple multiplication of nozzle holes will automatically improve the spray homogeneity and vaporization capability both in the injector far field and in the cylinder.

[0013] Many high-speed visualizations and 3-D numerical simulation experiments made in the intake port or in the cylinder have shown that this is hardly ever the obtained result. Due to uncontrolled coalescence and high-turbulence in the injector far field the spray is randomly recomposed in a highly nonhomogeneous state.

[0014] Furthermore, the multiplication in the number of nozzle holes in the atomizer generates other inconveniences. Below a certain diameter value a further decrease in the hole diameter increases exponentially the

manufacturing tolerance requirements and thereby the cost of the entire manufacturing process.

[0015] Only a precise control of both the initial droplet breakup and coalescence phenomena by an appropriate double-layer layout, as proposed by the invention, generates a controlled enhanced vaporization and homogeneity of the mixture transferred to the combustion chamber during the intake stroke.

Brief Description of the Invention

[0016] The object of the present invention is a fuel injector atomizer plate provided with at least two concentric circular layers of nozzle holes that generate droplets with a desired size and average spray direction to allow an improved spray momentum control in the injector far field and thereby improve the mixture distribution in the combustion chamber. The present invention refers only to the atomizer layout, which may be used in a wide range of injectors, with no limitation to a specific injector actuator or metering device design.

Description of Figures

[0017] The present application will be better understood in the light of the attached figures, given as mere examples, but not limitative, in which:

- Figure 1 shows a fuel rail and details of an electro-mechanical injector with its respective main parts;
- Figure 2 shows the layout of a flat seat atomizer plate with details of both the sealing and the nozzle hole areas;
- Figure 3a shows in detail the area of interest for the suggested atomizer design, wherein the A-A axis represents the symmetry axis of the injector;
- Figure 3b shows the location of the two concentric layers of nozzle holes, which characterizes the invention;
- Figure 4a shows an atomizer plate with an asymmetrical layout of the nozzle hole positions in the concentric layers;
- Figure 4b shows an atomizer plate with a symmetrical layout of the nozzle hole positions in the concentric layers;
- Figure 5 shows another possible variation in which the nozzle hole axes are inclined with respect to the injector axis.

Description of a preferable configuration

[0018] The invention may be better understood by figure 2, which shows a flat atomizer plate (1) together with the lower part of the cylindrical pintle (2) including the integrated upper part of the flat seat structure (3). The core of the present invention concerns only the center area of the atomizer (4), which is located inside the perimeter limited by the inner sealing ring (3). This part of

the atomizer (4) is entirely located on the downstream side of the sealing area (3).

[0019] Figure 3 shows further details of the atomizer area of interest. The axis A-A represents the injector symmetry axis. Although a flat area is used in the present example to represent the central area of the atomizer (4), other shapes (dome or conical), which could be of interest may be used.

[0020] According to the present invention, two concentric layers of nozzle holes (5, 6) are located in the center area of the atomizer (4), with an inner layer (5) characterized by a radius R1 and an outer layer (6) characterized by a radius R2 from the symmetry axis A-A.

[0021] Typical but not limitative values for R1 are between 0.2 and 0.5 mm and for R2 between 0.6 and 1 mm.

[0022] The total number of nozzle holes is distributed only in the inner and outer layers in such a way that the number of nozzle holes in the outer layer (6) is always equal or superior to the number of nozzle holes in the inner layer (5).

[0023] The axes of the nozzle holes located in the outer layer (6) and thereby the axis of each spray emerging from a hole are always parallel to the injector axis A-A. By this design, the sprays produced by the nozzle holes in the outer layer (6) form a trunk-conical shape with a cone angle β , typically between 10° and 20°, a symmetry axis located on the injector axis A-A and embrace the inner-layer sprays.

[0024] The axes of the nozzle holes located in the inner-layer (5) form a positive angle α with the injector axis A-A. The value of α is determined in such a way that the sprays generated by the inner layer (5) produce a grazing collision with the sprays from the outer layer (6) at a desired distance from the injector tip, as Figure 3b shows. By this means the coalescence phenomenon is well controlled. Typically, but not limited to, the values of α remain between 30° and 100°.

[0025] Figure 4 shows two illustrative examples of possible layouts for the nozzle hole locations. Figure 4a shows an atomizer having an inner layer (5) with two opposite nozzle holes and an outer layer (6) with 3 nozzle holes with an angular separation of 72° between the two nearest nozzle holes and 144° between these and the third nozzle hole. Figure 4b shows an atomizer having an inner layer (5) with three nozzle holes and an outer layer (6) with three nozzle holes with an angular separation of 120° in both layers.

[0026] Figure 5 shows another possible variation of the Double Layer (DL) atomizer layout. In this arrangement the entire configuration of both the parallel sprays generated by the outer layer nozzle holes (6) and the divergent sprays (5) generated by the inner layer nozzle holes is tilted at an offset angle γ , typically between 1° and 10°, with respect to the injector axis.

[0027] Engine tests, which compare the invented DL-atomizer layout with conventional multi-hole either parallel or divergent spray layouts, have shown that the improvement in the spray momentum homogeneity on a

typical flex-fuel engine at low loads in warm engine conditions provides an average decrease of 6 % in HC exhaust gas emission.

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Claims

1. Fuel injector atomizer for injection systems, constituted of an atomizer plate (1), located on the downstream side of the injector pintle (2) with an upper part of a sealing seat structure (3), having a central atomizer area (4), located within the perimeter limited by the inner sealing ring (3), **characterized by** having two concentric layers of nozzle holes (5, 6) in the central area of the atomizer (4), wherein the inner layer (5) has a radius R1 and the outer layer (6) has a radius R2 with respect to the symmetry axis of the injector, said nozzle hole axes located in the inner layer (5) forming a positive angle α with respect to the injector axis, and the nozzle hole axes located in the outer layer (6) are parallel to the injector axis.
2. Atomizer of claim 1, **characterized by** the atomizer (1) having flat, dome conical or spherical shape.
3. Atomizer of claim 1, **characterized by** said outer layer (6) having a number of nozzle holes equal to or higher than the total number of nozzle holes in the inner layer (5).
4. Atomizer of claim 1, **characterized by** α being between 3° and 10° with respect to the injector axis.
5. Atomizer of claim 1, **characterized by** the fact that the entire nozzle hole configuration of both inner and outer layers can be tilted at an offset angle β with respect to the injector symmetry axis.

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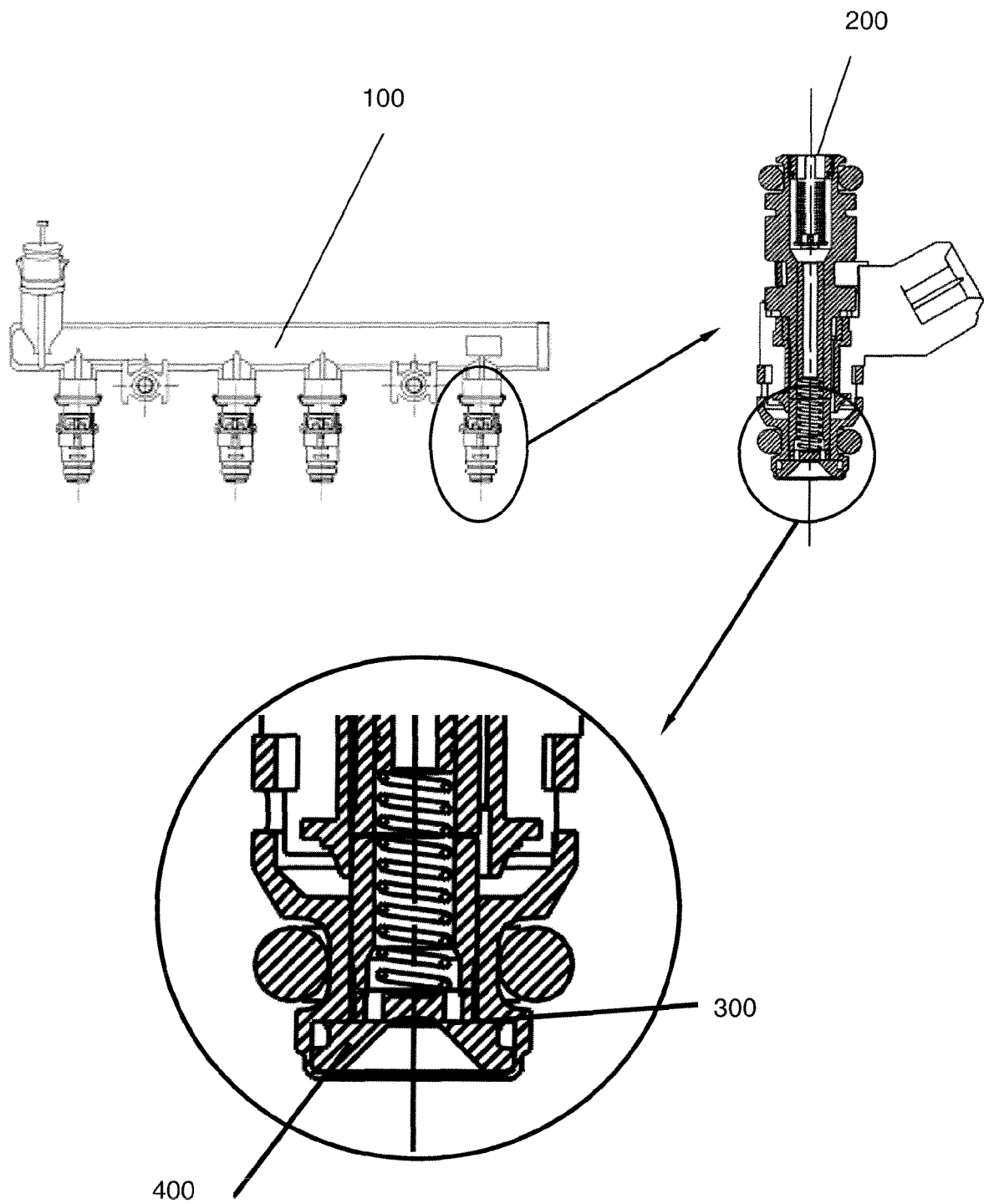


FIGURE 1

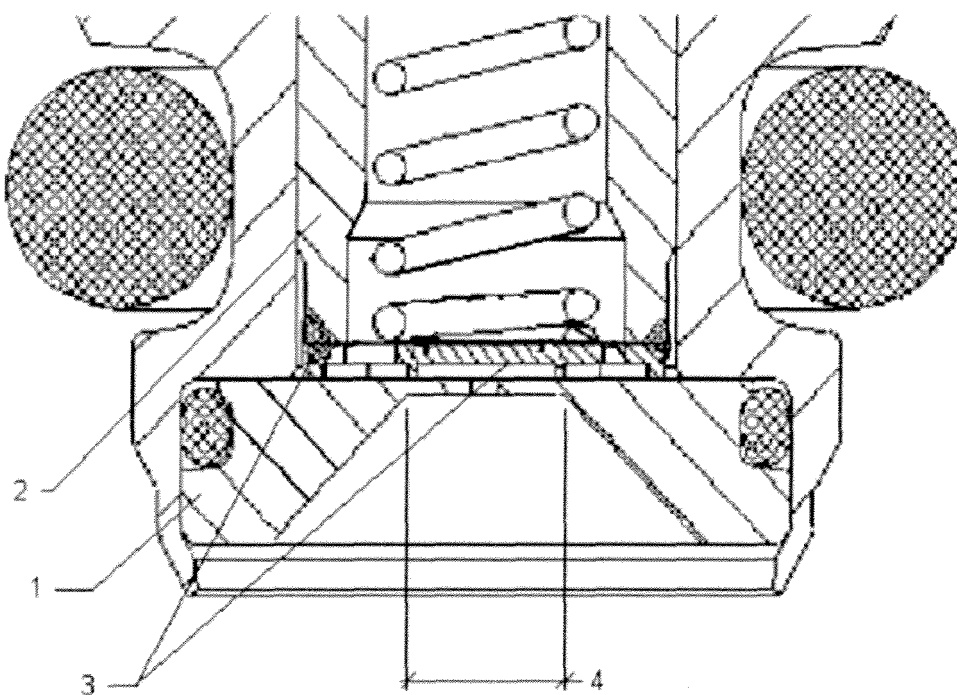


FIGURE 2

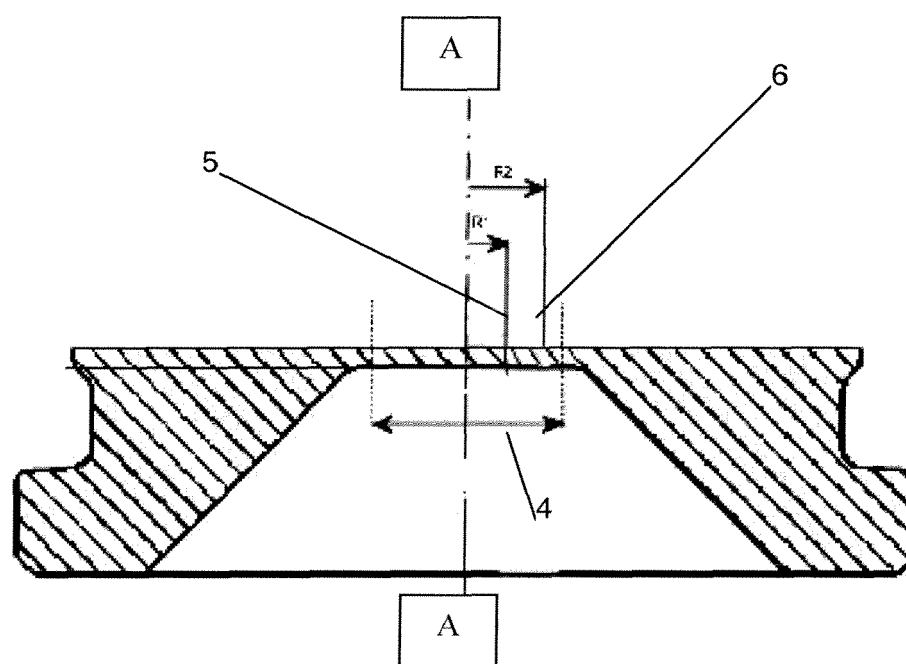
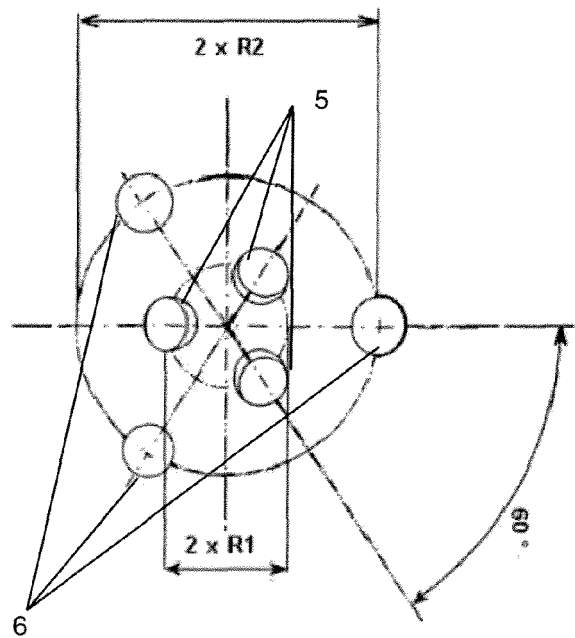
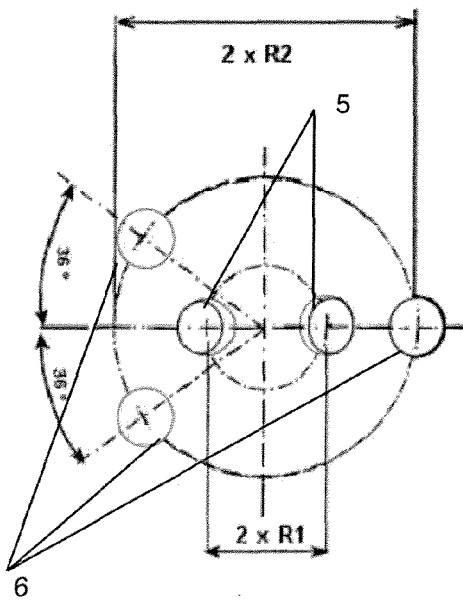
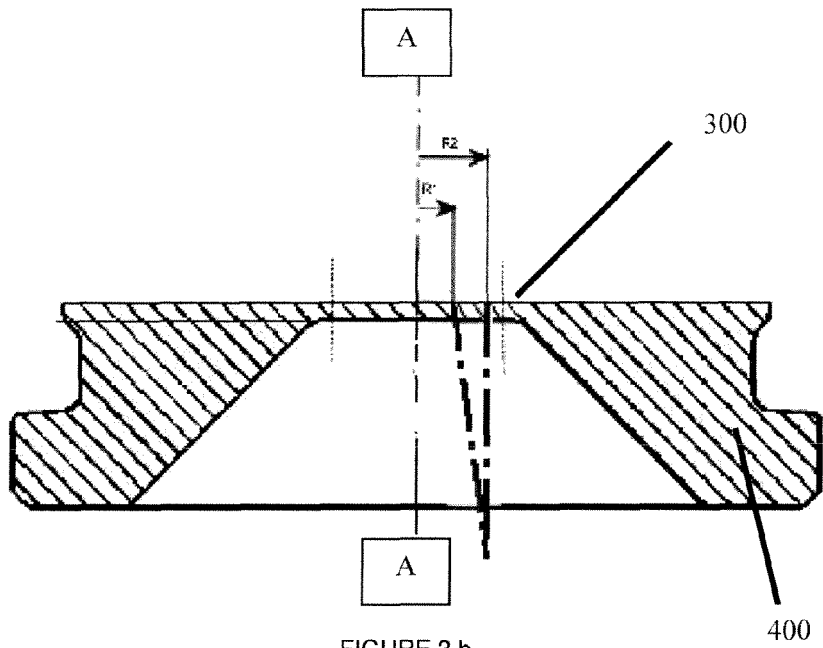


FIGURE 3 a



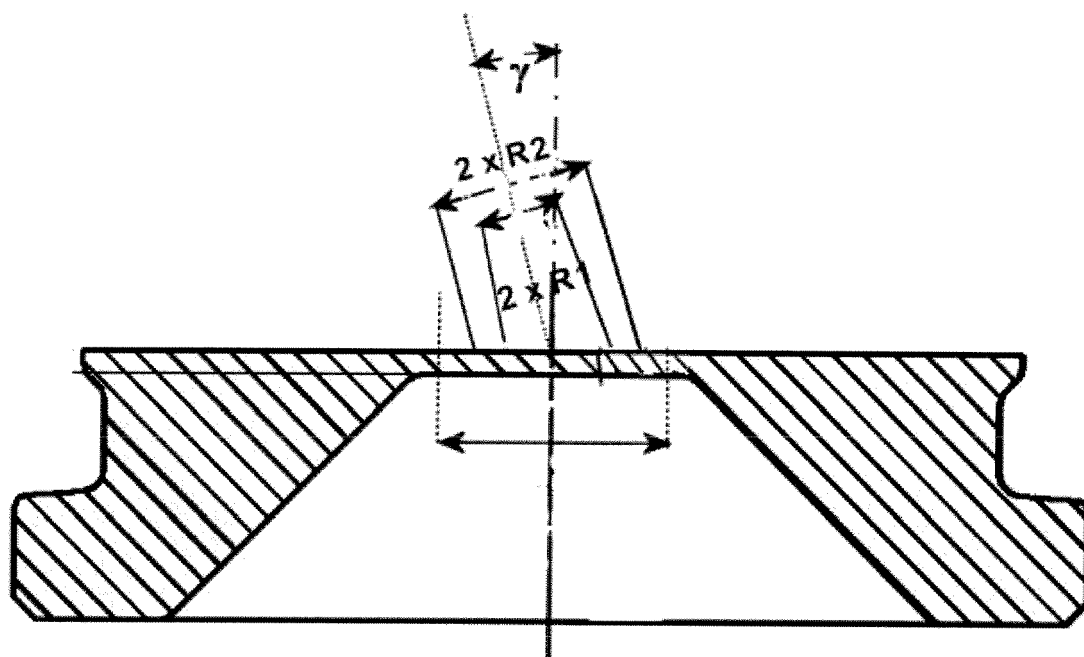


FIGURE 5