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• **Limmer, Andrew J.**
Bury St Edmonds Suffolk IP29 4PA (GB)
• **Stevens, John W.**
Sudbury Suffolk CO10 1PZ (GB)

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(71) Applicant: **Delphi Technologies, Inc.**
Troy, MI 48007 (US)

(74) Representative: **Cummings, Sean Patrick et al**
David Keltie Associates
Fleet Place House
2 Fleet Place
London EC4M 7ET (GB)

(72) Inventors:
• **Lambert, Malcolm**
Bromley Kent BR2 9LN (GB)

(54) **Injection nozzle**

(57) An injection nozzle for an internal combustion engine includes a valve member, (30) having at least first (44), second (46) and third (48) distinct regions, and being engageable with a seating surface (32), which defines a seat cone angle (ϑ_s), so as to control fuel delivery through a nozzle outlet (36). The second region provides a seat region (46) of part-conical form, which defines a first cone angle (ϑ_1). The third region (48), of part-conical form, is arranged immediately downstream of the seat region (46) and defines a second cone angle

(ϑ_2), the seat and third regions (46) defining, at their intersection, a seating line (40) for engagement with the seating surface (32). A first differential angle between the first cone angle (ϑ_1) and the seat cone angle (ϑ_s) is greater than a second differential angle between the second cone angle (ϑ_2) and the seat cone angle (ϑ_s), said first and second differential angles being selected to ensure the seating line (40) tends to migrate in an upstream direction along the seat region (46) as the valve member (30) is worn, in use.

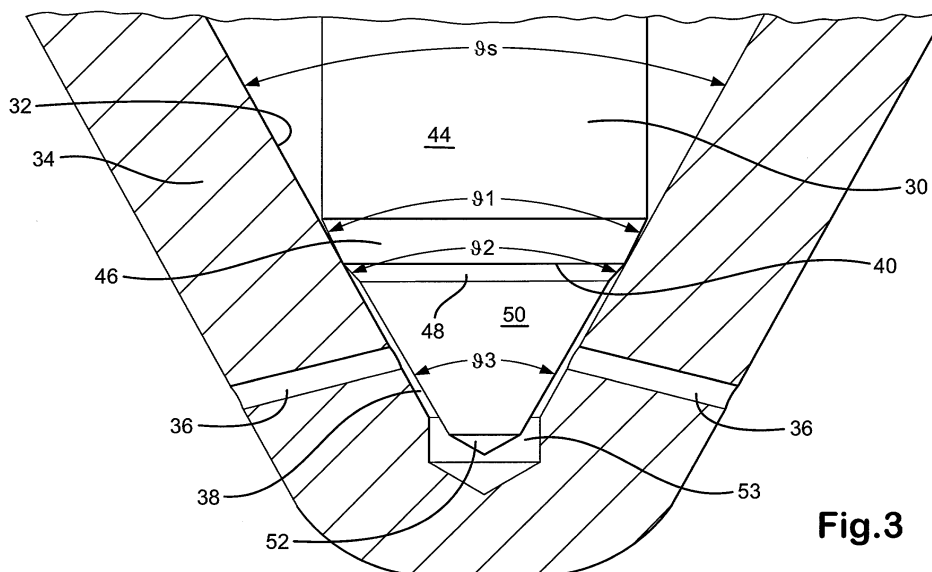


Fig.3

Description

[0001] The invention relates to an injection nozzle for use in a fuel injection system for an internal combustion engine. In particular, but not exclusively, the invention relates to an injection nozzle for use in a compression ignition internal combustion engine, in which a valve needle is engageable with a seating surface to control the injection of fuel to an associated combustion space through a nozzle outlet.

[0002] In one known injection nozzle, for example as shown in Figure 1, a valve needle 10 has a seating surface 12, or seating "line", which engages with a seat defined by an internal surface of a nozzle body bore 14 within which the needle 10 moves. In use, as the valve needle 10 is moved away from the seat, injection nozzle outlets 16 are opened to enable high pressure fuel to be injected to the associated engine cylinder. When the valve needle 10 is moved to re-engage with the seat, the outlets 16 are closed and injection is terminated.

[0003] Immediately downstream of its seating line 12 the valve needle 10 includes a downstream region 18 of frusto-conical form defining a first cone angle, ϑA , which typically is around 60 degrees. The nozzle body bore 14 is also of conical form, and defines a second cone angle, ϑB . The difference between the first and second cone angles is typically about 1 degree.

[0004] Immediately upstream of its seating line 12, the valve needle 10 includes an upstream region 20 of frusto-conical form. The upstream region 20 defines a third cone angle, ϑC , that typically is around 45 degrees. The difference between the third cone angle, ϑC , and the second cone angle, ϑB (i.e. that of the nozzle body bore) is typically about 15 degrees.

[0005] A valve tip region 19, arranged immediately downstream of the region 18, defines a cone angle, ϑD . The differential angle between the cone angle, ϑD , of the valve tip region 19 and the cone angle, ϑB , of the nozzle body bore 14 is typically just a few minutes. The valve tip region 19 terminates in a chamfered tip 22.

[0006] It is a recognised problem in injection nozzle design that the effective diameter of the seating line varies with wear during nozzle service life. The effective seat diameter influences fuel delivery pressure, or nozzle opening pressure (i.e. that pressure at which the valve needle is caused to lift from the bore seat), and this affects the quantity of fuel that is delivered during injection (i.e. when the valve needle is lifted).

[0007] It has been found that a nozzle of the type shown in Figure 1 goes part way to addressing this problem, and has the effect of reducing variations in the effective seat diameter with nozzle wear. It has been found that the variation of the effective seat diameter is reduced for significant periods of operation, and it is an advantage of this that delivery quantity variations are also reduced. Our copending European patent application EP 1 180 596 A1 describes an injection nozzle generally of the aforementioned type.

[0008] By way of further background to the present invention, US 5 890 660 describes an injection nozzle in which a circumferential groove is provided downstream of the valve needle seating line to prevent drift of the effective seat diameter in a downstream direction. This also has the benefit that variations in nozzle opening pressure throughout nozzle service life are reduced.

[0009] It is one object of the present invention to provide a further improved injection nozzle in which the detrimental effects of nozzle wear, and in particular wear of the seating line of the needle, are further reduced.

[0010] In accordance with a first aspect of the present invention, there is provided an injection nozzle for an internal combustion engine, comprising a valve member including at least first, second and third distinct regions and being engageable with a seating surface, which defines a seat cone angle, so as to control fuel delivery through a nozzle outlet. The second region provides a seat region, of part-conical form, defining a first cone angle, and the third region, which is of part-conical form and is arranged immediately downstream of the seat region, defines a second cone angle. The seat and third regions define, at their intersection, a seating line for engagement with the seating surface. A first differential angle between the first cone angle and the seat cone angle is smaller than a second differential angle between the second cone angle and the seat cone angle, the first and second differential angles being selected to ensure the seating line tends to migrate in an upstream direction along the seat region as the valve member is worn, in use. The valve member further includes an end region of at least part-conical form (i.e. part-conical, or a full cone), which is arranged immediately downstream of the third region and which defines an additional cone angle, wherein a further differential angle between the additional cone angle and the seat cone angle is smaller than the first differential angle.

[0011] It is a feature of this aspect of the invention that whilst the tendency for the seating line to wear causes fuel delivery variations, the effective diameter of the seating line varies in an upstream direction, increasing in value, so that the fuel delivery tends to decrease over the nozzle service life. This is a particular benefit as wear in other parts of the fuel injection system can lead to fuel delivery increases, so that the combination of effects tends to limit the net fuel delivery variations to an acceptable level, or substantially avoids net variations altogether.

[0012] It may be advantageous to select the first differential angle so as to be less than 5 degrees, and preferably less than 3 degrees.

[0013] An additional region of the valve member upstream of the seat region may be of substantially cylindrical form, or may also be of part-conical form.

[0014] It has been recognised that in some circumstances wear of the injection nozzle tending to decrease fuel delivery quantity can be disadvantageous, particularly if small deliveries are required (such as pilot injec-

tions of fuel). In accordance with a second aspect of the invention, the injection nozzle for the internal combustion engine is therefore provided with a valve member which is engageable with a seating surface, defining a seat cone angle, so as to control fuel delivery through a nozzle outlet, the valve member including an upper region of cylindrical form, a seat region arranged immediately downstream of the upper region and defining a first cone angle, wherein the upper region and the seat region define, at their intersection, a seating line for engagement with the seating surface. The valve member further includes a second region, arranged immediately downstream of the seat region, defining a second cone angle, and an end conical region, arranged immediately downstream of the second region. A first differential angle between the first cone angle and the seat cone angle is smaller than a second differential angle between the second cone angle and the seat cone angle, the first differential angle being selected to ensure the seating line migrates in a downstream direction along the seat region as the valve member becomes worn, in use, and the second differential angle being selected to prevent said migration of the seating line beyond a pre-determined amount.

[0015] In a preferred embodiment, the seat region and the second region define a first intersection therebetween, the seat and second regions being shaped such that a radial clearance between the first intersection and the seating surface is sufficiently small for the seat region to provide a load bearing surface for the needle during closure, thereby to limit migration of the seating line, which results from wear, in the downstream direction.

[0016] In a further preferred embodiment, the second region and the end region define a second intersection therebetween, said second and end regions being shaped such that a radial clearance between the second intersection and the seating surface is sufficiently large to confine wear of the valve member to the seat and second regions.

[0017] Preferably, the end region defines a lower cone angle, and wherein a third differential angle between the lower cone angle and the seat cone angle is approximately the same as the first differential angle.

[0018] It is preferable if the second differential angle is up to 20 degrees greater than the first differential angle, and more preferably if the second differential angle is between 5 and 15 degrees greater than the first differential angle.

[0019] The invention also provides, in a third aspect, an injection nozzle for an internal combustion engine includes a valve member having a major needle axis and being engageable with a seating surface, defining a seat cone angle, so as to control fuel delivery through a nozzle outlet, the valve member including a downstream seat region of part-conical form, which defines a first cone angle, and, at its uppermost edge, a seating line for engagement with the seating surface, a first circumferential groove, arranged immediately downstream of

the downstream seat region, an upper region arranged so that a lower edge thereof defines, at its intersection with the downstream seat region, the seating line, and a lower region arranged immediately downstream of the first circumferential groove. A lower edge of the first circumferential groove and the lower region together define a line of intersection which itself defines, together with the seating surface, a radial clearance that is sufficiently small so that the downstream seat region defines a load bearing surface for the valve needle, and wherein the first circumferential groove serves to prevent the seating line migrating beyond a pre-determined amount, with wear of the needle.

[0020] This combination of features is particularly beneficial as wear of the seating line, which occurs in a downstream direction, is not only confined to the seat region, but is also limited due to the provision of the groove.

[0021] The lower region may be an end region, arranged immediately downstream of the first circumferential groove, which defines a lower cone angle, and wherein the lower cone angle is less than the first cone angle.

[0022] In one preferred embodiment, the upper region of the nozzle forms an upstream seat region of part-conical form, said upstream seat region defining an upper cone angle, wherein a first differential angle between the first cone angle and the seat cone angle is substantially the same as a second differential angle between the upper cone angle and the seat cone angle, thereby to ensure wear of the seating line, in use, maintains the seating line at approximately the same axial position along the valve member.

[0023] As the injection nozzle components wear, in use, contact pressure between the valve member and its seating is distributed, in generally equal amounts, over both the upstream and downstream seat regions, with the primary contact point on the valve needle which engages with the seat remaining at approximately the same axial position. As a result, the effective seating diameter changes very little with wear, so that variations in fuel delivery quantity due to wear are limited.

[0024] The upper region that is immediately upstream of the upstream seat region may alternatively be of cylindrical form.

[0025] In another embodiment, the injection nozzle may include a second circumferential groove located downstream of the first circumferential groove and positioned axially along the valve member so that, when the seating line is engaged with the seating surface the second groove approximately aligns with the outlet.

[0026] The first and second grooves may be spaced apart by an intermediate region of part-conical form which defines a further cone angle selected so that the intermediate region provides an additional load bearing surface for the valve member. The provision of the intermediate region further limits the extent of wear of the needle seat region (i.e. the combined upper and lower

portions).

[0027] The invention will now be described, by way of example only, with reference to the accompanying drawings in which:

Figure 1 is a section drawing of a known injection nozzle generally of the type shown in EP 1 180 596 A1,

Figure 2 is a schematic drawing of a first embodiment of the present invention providing improved wear characteristics, and

Figures 3 to 6 are schematic drawings of alternative embodiments of the nozzle to that shown in Figure 2.

[0028] As described previously, a generally known type of injection nozzle is shown in Figure 1, in which a valve member in the form of a needle 10 is engageable with a seating to control fuel injection through a plurality of outlet openings 16 (two of which are shown) into an associated engine cylinder or other combustion space.

[0029] Figure 2 shows an injection nozzle of a first embodiment of the invention, which provides improved seat wear characteristics over the nozzle shown in Figure 1. Again, the nozzle includes a valve needle 30 that is slideable within a bore provided in a nozzle body 34 and engageable with a seating surface 32 defined by the bore. The valve needle 30 is typically movable by means of an injection control valve arrangement (not shown), typically of the type actuated by means of a piezoelectric actuator, as would be familiar to a person skilled in the art.

[0030] Alternatively the valve needle 30 may be movable by electromagnetic means, or simply by means of hydraulic forces causing the valve needle 30 to lift from its seating 32.

[0031] The nozzle body 34 is provided with a set of at least first and second outlets 36 which provide a flow path for fuel into the combustion chamber from an injection nozzle delivery chamber 38. The delivery chamber 38 is together defined by the seating surface 32 and an outer surface of the valve needle 30 in a region downstream of a valve needle seating surface, or seating line, 40 of annular form. The seating line 40 is engageable with the seating surface 32 to control fuel flow into the delivery chamber 38 from an upstream supply chamber 42. In use, the upstream supply chamber 42 is supplied with high pressure fuel for injection. When it is required to inject fuel into the engine cylinder the valve needle 30 is actuated or otherwise caused to lift so as to move the seating line 40 away from its seating surface 32.

[0032] The valve needle 30 includes at least three distinct regions, and in this example four distinct regions. A first region 44, at the uppermost end in the view shown in Figure 2, is of substantially cylindrical form. A second region 46, of frusto-conical or part conical form is ar-

ranged immediately downstream of the first region 44 and defines, or includes, at its uppermost edge, the seating line 40. A third region 48 of substantially frusto-conical form is arranged immediately downstream of the second region 46 and a fourth, or end region, 50 of substantially conical form is arranged immediately downstream of the third region 48. The fourth region 50 includes, and terminates in, a chamfered tip 52 which extends into a sac volume or chamber 53 defined at the blind end of the nozzle body bore 32. The valve needle 30 is shaped such that when the valve needle 30 is seated, the fourth region 50 is positioned in the vicinity of, and so substantially occludes, the outlets 36. The second, third and fourth regions 46, 48, 50 of the valve needle 30 define first, second and third cone angles ϑ_1 , ϑ_2 , ϑ_3 respectively and each is of uniform cone angle along its respective lengths.

[0033] It is not readily apparent from the scale of the drawing in Figure 2, but the cone angle, ϑ_1 , subtended by the second region 46 of the valve needle 30 is different from the cone angle, ϑ_2 , subtended by the third region 48. The seating surface 32 defines a seat cone angle, ϑ_s , (also referred to as the nozzle body cone angle), which is different again from the first and second cone angles, ϑ_1 , ϑ_2 . The difference in cone angle between ϑ_1 and ϑ_s is typically between 0.1 and 3 degrees and the second region 46 of the valve needle has a length, d, (along its outer surface) of between about 0.05 to 0.4 millimetres.

[0034] The third region 48 of the valve needle 30 is shaped such that the differential angle between its cone angle, ϑ_2 , and the seat cone angle, ϑ_s , is typically between 1 and 20 degrees greater than the further upstream differential angle, defined by the cone angle, ϑ_1 , of the second region 46 and the seat cone angle ϑ_s .

[0035] The fourth region 50 is shaped to define a differential angle with the seat cone angle ϑ_s of, typically, between 0 degrees (i.e. the cone angles are the same) and 2 degrees. The cone angle, ϑ_3 , of the fourth region 50 is typically less than the second cone angle, ϑ_2 .

[0036] The third and fourth regions 48, 50 of the valve needle 30 are shaped so as to define, at their line of intersection (identified at 55), a radial clearance or gap between the seating surface 32, of between approximately 5 and 15 μm .

[0037] In operation, the effective diameter of the seating line 40 will tend to decrease as the second region 46 of the valve needle 30 becomes worn. The relatively large radial clearance between the line of intersection 55 and the seating surface 32 is particularly beneficial as it ensures wear of the valve needle 30 is substantially restricted to the second and third regions 46, 48. The finite length, d, of the second region 46, as defined by the location of the third region 48, serves to limit the extent of wear of the seating line 40, and thus limits the extent to which the effective seating diameter is reduced. The limit of reduction in effective seating diameter is defined by the diameter of a line of intersection

54 between the seat region 46 and the third region 48 of the needle 30.

[0038] By comparing the known valve needle in Figure 1 with the embodiment in Figure 2, it will be appreciated that, effectively, an additional valve needle region, in the form of the second region 46, is provided to define the seating line 40. This additional region may be considered to provide a downstream seat region 46 for the needle, as opposed to just a seating line 40. In use, the valve needle 'beds in' over this seat region 46 as the needle wears and the seating line 40 is caused to migrate to lower values (i.e. axially down the needle), with the effective diameter being limited by the effective diameter of the intersection 54 between the second and third regions 46, 48. The cone angles and lengths of the second and third regions 46, 48 are shaped so that a very small radial clearance, typically between 0.5 and 10 μm , is defined between the valve needle surface at the intersection 54 and the seating surface 32, so that the seat region 46 provides an effective load bearing surface for the needle during closure.

[0039] Generally, as a consequence of wear of the valve needle and migration of the effective seating diameter to lower values, the quantity of fuel injected during an injection event will be increased (if all other control parameters remain the same). In the Figure 2 embodiment, however, the extent of the reduction in the effective seating diameter is limited, so that any such increase in fuel delivery quantity is also limited. By selecting the length, d , of the seat region 46 carefully and by appropriate positioning of the third region 48, a tolerable limit on fuel delivery increase can be achieved, despite seat wear. Additionally, the length, d , of the seat region 46 is selected to be between about 0.05 to 0.4 millimetres, and by incorporating this seat region 46 of relatively long length, loading of the needle is distributed over a large surface area, with the effect that contact pressure, and hence wear, is reduced.

[0040] It will be appreciated that the aforementioned benefits are obtained regardless of the shape of the first region 44 of the valve needle 30, upstream of the seating line 40, which may alternatively be of conical form, rather than cylindrical.

[0041] It has been found that the following combination of features provides a particularly advantageous nozzle performance: (i) providing a downstream seat region 46, to define the seating line 40, having a relatively long length and a relatively small differential angle (with the seat cone angle) to reduce the effects of wear (ii) providing a further (third) region 48, downstream of the seat region 46 and upstream of the fourth, end region 50 of the needle, which has a larger differential angle (with the seat cone angle) compared to that defined by the seat region 46 and which defines, at its intersection with the seat region 46, a very small radial clearance with the seating surface 32, such that the seat region 46 provides a load bearing surface for the needle, and (iii) providing a relatively large radial clearance between an

end region 50 of the valve needle and the seating surface 32 so as to restrict valve needle 30 wear to the seat region 46 and the region 48 immediately downstream of this.

[0042] An alternative embodiment of the invention is shown in Figure 3. For some applications, any increase in fuel delivery quantity over the service life of the nozzle can be disadvantageous, even if the increase is limited (as for the embodiment described previously). Moreover, in some fuel injection systems, and particularly common rail fuel injection systems, other parts of the system also suffer from effects of wear which tend to have a similar effect of increasing fuel delivery quantity. In systems for which fuel delivery increase occurs due to wear in other parts of the system, it is therefore advantageous if seat wear within the nozzle has the effect of decreasing fuel delivery quantity as a means of compensation.

[0043] In Figure 3, similar parts to those shown in Figure 2 are denoted with like reference numerals. In this example, the seat region 46 of the valve needle, is arranged immediately upstream of the seating line 40, adjacent to the first region 44. The seat region 46 defines a cone angle ϑ_1 and, together with the seat cone angle ϑ_s , defines a relatively small differential angle of just a few degrees, typically between 0.5 and 5 degrees. The third region 48 of the needle 30 downstream of the seating line 40 defines a cone angle ϑ_2 which, together with the seat cone angle ϑ_s , defines a differential angle that is greater than that defined by ϑ_1 and ϑ_s . Typically, for example, the third region 48 in Figure 3 is shaped to define a differential angle with the seat cone angle of between about 1 and 20 degrees.

[0044] The end region 50 of the valve needle 30 has a uniform cone angle along its entire length (with the exception of the slight chamfering of its tip) and aligns in the vicinity of the nozzle outlet when the valve needle is seated. Put another way, the valve needle 30 is received in the nozzle bore so that the end region 50 locates within that region of the bore in which the outlets 36 are provided.

[0045] The provision of a seat region 46, immediately upstream of the seating line 40, to define a relatively small differential angle may be referred to as an "inverted" or "negative" seat region; that is a seat region which wears in a direction upstream of the seating line 40. This is in contrast with the embodiment of Figure 2, where a "non-inverted" or "positive" seat region is included downstream of the seating line 40.

[0046] For the embodiment of Figure 3, as the seating line 40 is caused to wear the effective seating diameter will tend to increase to higher values as the seating line 40 migrates along the upstream seat region 46. This has the effect of decreasing fuel delivery quantities and, thus, may compensate for the effects of wear in other parts of the fuel injection system which give rise to an increase in fuel delivery quantity. The valve needle 30 is therefore shaped to provide a means for compensating for the effects of wear in the fuel injection system,

this being provided by the seat region 46 upstream of the seating line 40 having a relatively small differential angle (with the seat cone angle) compared to the differential angle defined by the third region 48 (with the seat cone angle) downstream of the seating line 40.

[0047] Figure 3 shows the first region 44 of the valve needle 30 upstream of the seat region 46, as being of cylindrical form, but it will be appreciated that the aforementioned advantages are also achieved if the first region 44 is of conical form, either defining the same differential angle with the seat cone angle, in which case it forms a continuous region with the upstream seat region 46, or defining a greater differential angle to that defined by the upstream seat region 46 (with the seat cone angle). The latter configuration provides the benefit that migration of the seating line 40 is limited, as determined by the finite length of the seat region 46.

[0048] In a particularly preferred embodiment it has been found that shaping the upstream seat region 46 and the seating surface 32 to together define a differential angle of less than 3 degrees provides a hydraulically self-centralising force to the end region 50 the needle 30. If at least two outlets 36 are provided, this has the advantage of achieving good "hole-to-hole" flow balance. For small values of needle lift, and if fuel sprays are relatively wide, improved hole-to-hole flow balance is particularly important and the selection of the upstream differential angle within this range provides a particular benefit in such circumstances.

[0049] A possible disadvantage of the nozzle shown in Figure 3 compared to that in Figure 2 may occur in some applications for which very small fuel delivery quantities are required, for example where it is required to deliver a low volume, pilot injection of fuel prior to a main injection of fuel. If the effective seat diameter tends to increase with wear, thus tending to decrease fuel delivery quantities, it is possible that the pilot injection of fuel may disappear altogether.

[0050] Figure 4 shows a further embodiment of the invention which ensures the effective seating diameter tends to decrease with wear (i.e. as in the Figure 2 embodiment).

[0051] In this embodiment the first region 44 of the valve needle 30 is of cylindrical form, and the seat region 46 is shaped to define a cone angle, ϑ_1 . The differential angle defined by the cone angle ϑ_1 of the seat region 46 and the seat cone angle ϑ_s is typically between about 0 degrees 10 minutes and 3 degrees (i.e. relatively small). Thus, as the seating line 40 wears it tends to migrate downstream along the seat region 46 and, thus, the effective diameter tends to decrease. Any variation in fuel delivery quantity due to this wear is therefore in the form of an increased fuel delivery quantity.

[0052] In Figure 4, it can be seen that the valve needle 30 also includes a circumferential groove 58 immediately downstream of the seat region 46. The provision of the groove 58 serves to limit the extent to which the seat region 46 can wear, in use, so that there is a limit on the

variation (increase) in fuel delivery quantity, and nozzle opening pressure, with such seat wear. In this respect the groove 58 provides a similar function to the third region 48 in the Figure 2 embodiment. Immediately downstream of the groove 58, the lower end region 50 of the valve member 30 defines a cone angle, ϑ_3 , which is greater than the first cone angle, ϑ_1 , of the seat region 46.

[0053] The embodiment shown in Figure 4 is similar to the injection nozzle described in US 5 890 660. However, in US 5 890 660 the effective seating diameter tends to migrate to higher values (i.e. as defined by the upstream region of the valve needle) due to the inverted differential angle upstream of the seating line 40. In contrast, Figure 4 provides an injection nozzle for which the effective seating diameter tends to migrate to lower values, due to the differential angle defined by the seat region 46 (with the surface 32), so that any problems associated with reduced fuel delivery quantities which may arise in the nozzle in US 5 890 660 are overcome.

[0054] A line of intersection 55 is defined between the circumferential groove 58 and the lower end region 50. The radial clearance between the line of intersection 55 and the seating surface 32 is very small, typically between 0.5 and 10 μm (and preferably between 0.5 and 5 μm), to ensure that the seat region 46 provides an effective load bearing surface for the needle 30 as it seats, in use.

[0055] An alternative embodiment to that shown in Figure 4 is shown in Figure 5, in which the needle is provided with both an upstream seat region 46a (i.e. that region immediately upstream of the seating line 40) and a downstream seat region 46b (i.e. that region immediately downstream of the seating line 40). The cone angles of the upstream and downstream seat regions 46a, 46b are both selected to define relatively small differential angles with the seat cone angle, ϑ_s . Typically, for example, the upstream and downstream seat regions 46a, 46b are shaped so that each defines a differential angle with the nozzle body cone angle, ϑ_s , of between about 0 degrees 10 minutes and 5 degrees. Preferably, the differential angles defined by the seat regions 46a, 46b are substantially the same, but alternatively they may be slightly different, providing always that they are relatively small.

[0056] The embodiment in Figure 5 also includes a circumferential groove 58, which serves to limit the extent of wear of the downstream seat region 46 of the valve needle 30.

[0057] When the injection nozzle is used initially, the effective seating diameter is defined by the surface or line of intersection 40 between the upstream seat region 46a and the downstream seat region 46b. As the injection nozzle components wear, in use, contact pressure between the valve needle 30 and the surface 32 tends to distribute approximately equally over both seat regions 46a, 46b, although the primary line of contact remains at approximately the same axial position (i.e. that

of the original seating line 40). As a result, the effective seating diameter changes very little with wear, and hence the fuel delivery quantity and nozzle opening pressure also varies only a little.

[0058] A further alternative embodiment to that shown in Figures 4 and 5 is shown in Figure 6, in which the valve needle is provided with a first circumferential groove 58 located immediately downstream of the downstream seat region 46b (as in Figure 5), with a second circumferential groove 60 being provided further downstream so as to approximately align with the outlets 36 when the valve needle 30 is seated. The first and second circumferential grooves 58, 60 are separated by an intermediate region 62 of the valve needle 30. The intermediate region 62 defines a differential cone angle with the seat cone angle ϑ_s which, typically, is between about 10 minutes and 3 degrees. This region 62 provides a load bearing surface upon needle closure, which serves to reduce the loading on, and hence wear of, the upper and lower seat regions 46a, 46b.

[0059] One benefit of providing the second groove 60, approximately at the same axial position along the major axis of the valve needle 30 as the outlets 36, is that it permits fuel pressure to homogenise within that region of the delivery chamber adjacent to the inlet ends (i.e. inner ends) of the outlets 36. This has the effect of equalising fuel delivery quantity through each of the outlets 36, and helps to ensure equal spray formations are achieved through each outlet also.

[0060] If the nozzle is provided with a second set of outlets, occupying a different axial position along the valve member to the first set of outlets 36, an additional circumferential groove may be provided to align with this second set, as described above for the first set. For each set of outlets provided, a further circumferential groove may be provided in the same manner.

[0061] All of the injection nozzles described hereinbefore are of VCO (valve covered orifice) type, in which the valve needle 30 covers or occludes the inlet end of the or each nozzle outlet 36 when it is seated (i.e. when no injection takes place). The present invention is equally applicable, however, to sac-type injection nozzles in which the or each nozzle outlet is not covered by the valve needle when it is seated, but the inlet end of each outlet is in constant communication with the sac chamber at the blind end of the nozzle body bore. In sac-type nozzles it is unseating and seating of the valve needle that again controls whether or not injection occurs through the outlets, as in VCO-type nozzles.

[0062] It will be appreciated that the differential angles (i.e. the difference in cone angle between two different surfaces), the cone angles and other dimensions stated in the previous description are given by way of illustrative example only, and that values falling outside of the specified ranges and having different values to those quoted may also be implemented to provide substantially the same technical function of the invention, as set out in the accompanying claims.

Claims

1. An injection nozzle for an internal combustion engine, the nozzle comprising:

a valve member (30) including at least first (44), second (46) and third (48) distinct regions and being engageable with a seating surface (32), which defines a seat cone angle (ϑ_s), so as to control fuel delivery through a nozzle outlet (36),

wherein the second region provides a seat region (46) of part-conical form, defining a first cone angle (ϑ_1), and the third region (48), which is of part-conical form and arranged immediately downstream of the seat region (46), defines a second cone angle (ϑ_2), the seat region (46) and the third region (48) defining, at their intersection, a seating line (40) for engagement with the seating surface (32), wherein a first differential angle between the first cone angle (ϑ_1) and the seat cone angle (ϑ_s) is smaller than a second differential angle between the second cone angle (ϑ_2) and the seat cone angle (ϑ_s), said first and second differential angles being selected to ensure the seating line (40) tends to migrate in an upstream direction along the seat region (46) as the valve member (30) is worn, in use, the valve member (30) further including an end region (50) of at least part-conical form, which is arranged immediately downstream of the third region (48) and which defines an additional cone angle (ϑ_3), wherein a further differential angle between the additional cone angle (ϑ_3) and the seat cone angle (ϑ_s) is smaller than the first differential angle.

2. The injection nozzle as claimed in Claim 1, wherein when the valve needle (30) is seated, the end region (50) is located in the vicinity of the nozzle outlet (36).

3. The injection nozzle as claimed in Claim 1 or Claim 2, wherein the first differential angle is selected to be less than 3 degrees.

4. The injection nozzle as claimed in any one of Claims 1 to 3, wherein an additional region (44) of the valve member (30) upstream of the seat region (46) is of substantially cylindrical form.

5. An injection nozzle for an internal combustion engine, the nozzle comprising:

a valve member (30) having a major needle axis and being engageable with a seating surface (32), defining a seat cone angle (ϑ_s), so as to control fuel delivery through a nozzle outlet (36), the valve member including a downstream seat region (46; 46b) of part-conical form,

which defines a first cone angle (ϑ_1), and, at its uppermost edge, a seating line (40) for engagement with the seating surface (32);

a first circumferential groove (58) arranged immediately downstream of the downstream seat region (46; 46b);

an upper region (44; 46b) arranged so that a lower edge thereof defines, at its intersection with the downstream seat region (46; 46b), the seating line (40), and

a lower region (50) arranged immediately downstream of the first circumferential groove (58), a lower edge of the first circumferential groove (58) and the lower region (50) together defining a line of intersection (55) which defines, together with the seating surface (32), a radial clearance that is sufficiently small so that the downstream seat region (46) defines a load bearing surface for the valve needle (30), wherein the first circumferential groove (58) serves to prevent the seating line (40) migrating beyond a pre-determined amount with wear of the needle.

6. The injection nozzle as claimed in Claim 5, wherein the radial clearance is between 0.5 and 5 μm .

7. The injection nozzle as claimed in Claim 5 or Claim 6, wherein the lower region (50) defines a lower cone angle (ϑ_3) that is less than the first cone angle (ϑ_1).

8. The injection nozzle as claimed in any one of Claims 5 to 7, wherein the lower region (50) forms an end region of the valve member (30).

9. The injection nozzle as claimed in any one of Claims 5 to 8, wherein the upper region (44; 46b) forms an upstream seat region (46a) of part-conical form, said upstream seat region (46a) defining an upper cone angle which defines, together with the seat cone angle (ϑ_s), a first differential angle that is substantially the same as a second differential angle between the first cone angle (ϑ_1) and the seat cone angle (ϑ_s), thereby to ensure wear of the seating line (40), in use, maintains the seating line (40) at approximately the same axial position along the valve member (30).

10. The injection nozzle as claimed in any one of Claims 5 to 9, further comprising a second circumferential groove (60) located downstream of the first circumferential groove (58) and positioned axially along the valve member (30) so that when the seating line (40) is engaged with the seating surface (32) the

second groove (60) approximately aligns with the outlet (36).

11. The injection nozzle as claimed in Claim 10, wherein the first and second grooves (58, 60) are spaced apart by an intermediate region (62) of part-conical form which defines a further cone angle selected so that the intermediate region (62) provides an additional load bearing surface for the valve needle (30).

12. An injection nozzle for an internal combustion engine, the nozzle comprising:

a valve member (30) which is engageable with a seating surface (32), defining a seat cone angle (ϑ_s), so as to control fuel delivery through a nozzle outlet (36),

the valve member (30) including a cylindrical upper region (44), a seat region (46), arranged immediately downstream of the upper region (44), defining a first cone angle (ϑ_1), wherein the upper region (44) and the seat region (46) define, at their intersection, a seating line (40) for engagement with the seating surface (32), a second region (48), arranged immediately downstream of the seat region (46), defining a second cone angle (ϑ_2), and an end conical region (50), arranged immediately downstream of the second region (48),

wherein a first differential angle between the first cone angle (ϑ_1) and the seat cone angle (ϑ_s) is smaller than a second differential angle between the second cone angle (ϑ_2) and the seat cone angle (ϑ_s), said first differential angle being selected to ensure the seating line (40) migrates in a downstream direction along the seat region (46) as the valve member (30) becomes worn, in use, and the second differential angle being selected to prevent said migration of the seating line (40) beyond a pre-determined amount.

13. The injection nozzle as claimed in Claim 12, wherein the seat region (46) and the second region (48) define a first intersection (54) therebetween, said regions (46, 48) being shaped such that a radial clearance between the first intersection (54) and the seating surface (32) is sufficiently small for the seat region (46) to provide a load bearing surface for the needle (30), thereby to limit migration of the seating line (40) in the downstream direction due to wear.

14. The injection nozzle as claimed in Claim 12 or Claim 13, wherein the second region (48) and the end region (50) define a second intersection (55) therebetween, said regions (48, 50) being shaped such that a radial clearance between the second intersection

and the seating surface (32) is sufficiently large to confine wear of the valve needle to the seat and second regions (46, 48).

15. The injection nozzle as claimed in any one of Claims 12 to 14, wherein the end region (50) defines a lower cone angle (ϑ_3), and wherein a third differential angle between the lower cone angle (ϑ_3) and the seat cone angle (ϑ_s) is approximately the same as the first differential angle. 5
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16. The injection nozzle as claimed in any one of Claims 12 to 15, wherein the second differential angle is up to 20 degrees greater than the first differential angle. 15
17. The injection nozzle as claimed in Claim 16, wherein the second differential angle is between 5 and 15 degrees greater than the first differential angle. 20
18. The injection nozzle as claimed in any one of Claims 1 to 17, being one of (i) VCO-type or (ii) sac-type. 25

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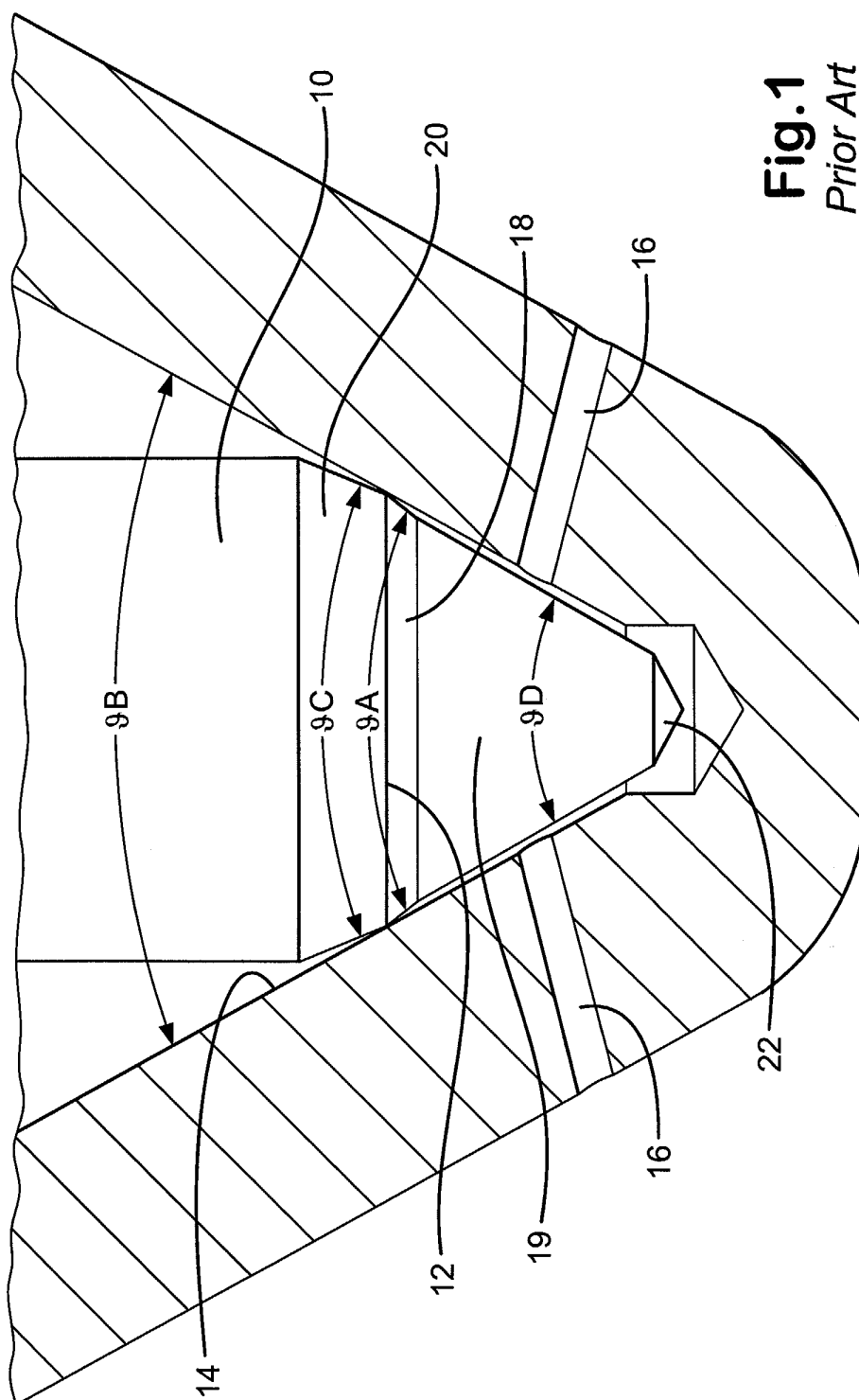
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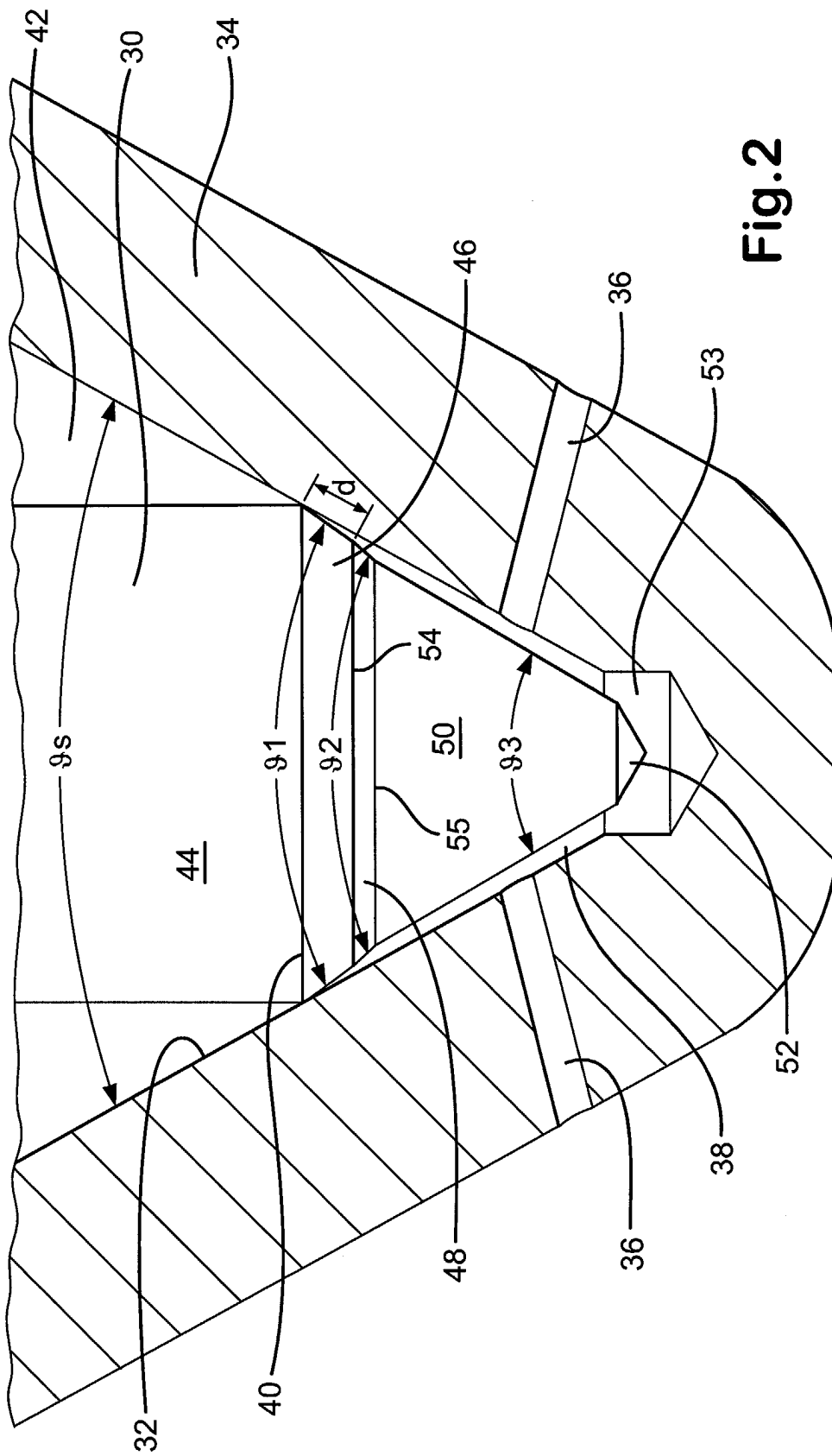


Fig. 2

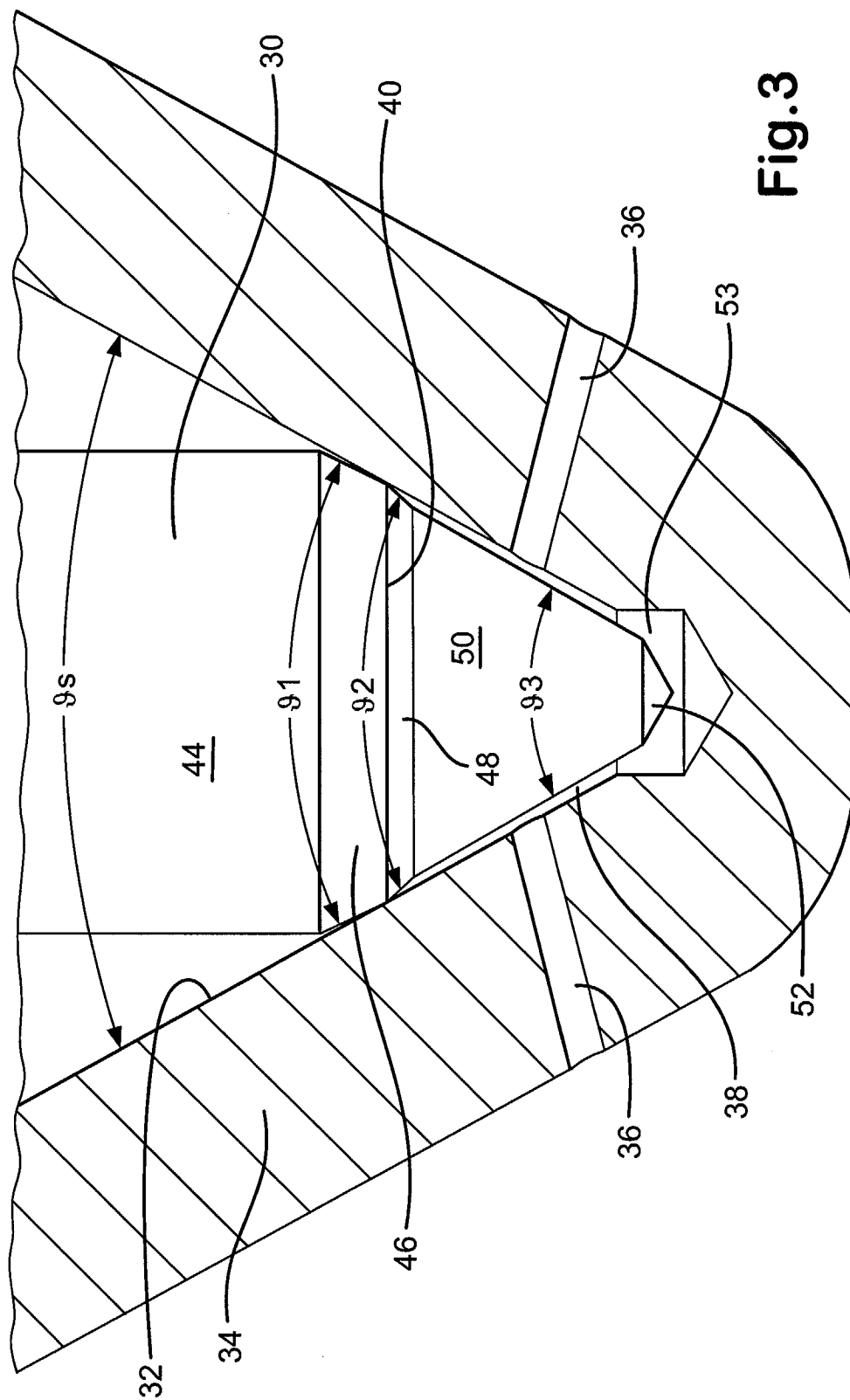


Fig. 3

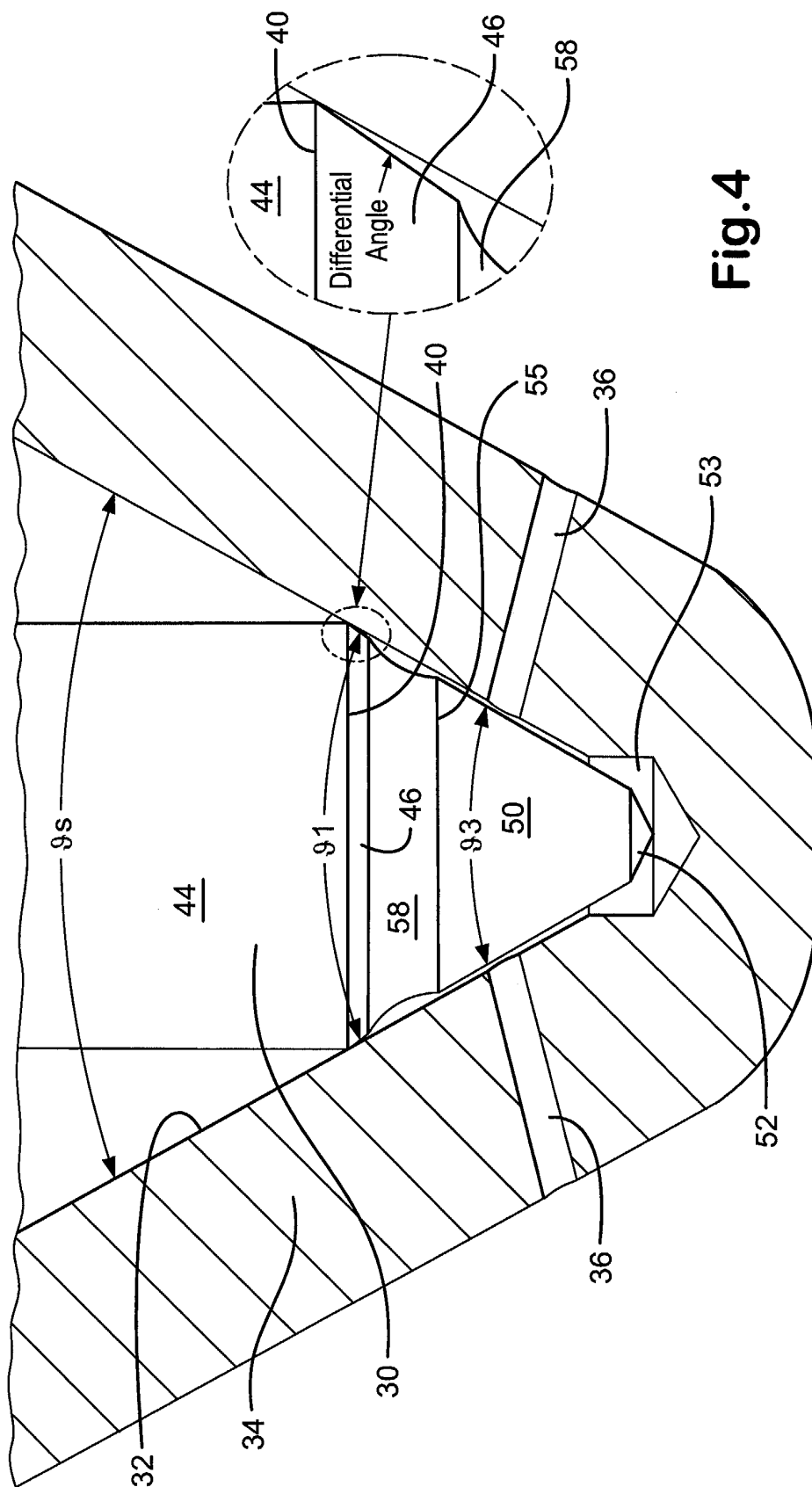


Fig. 4

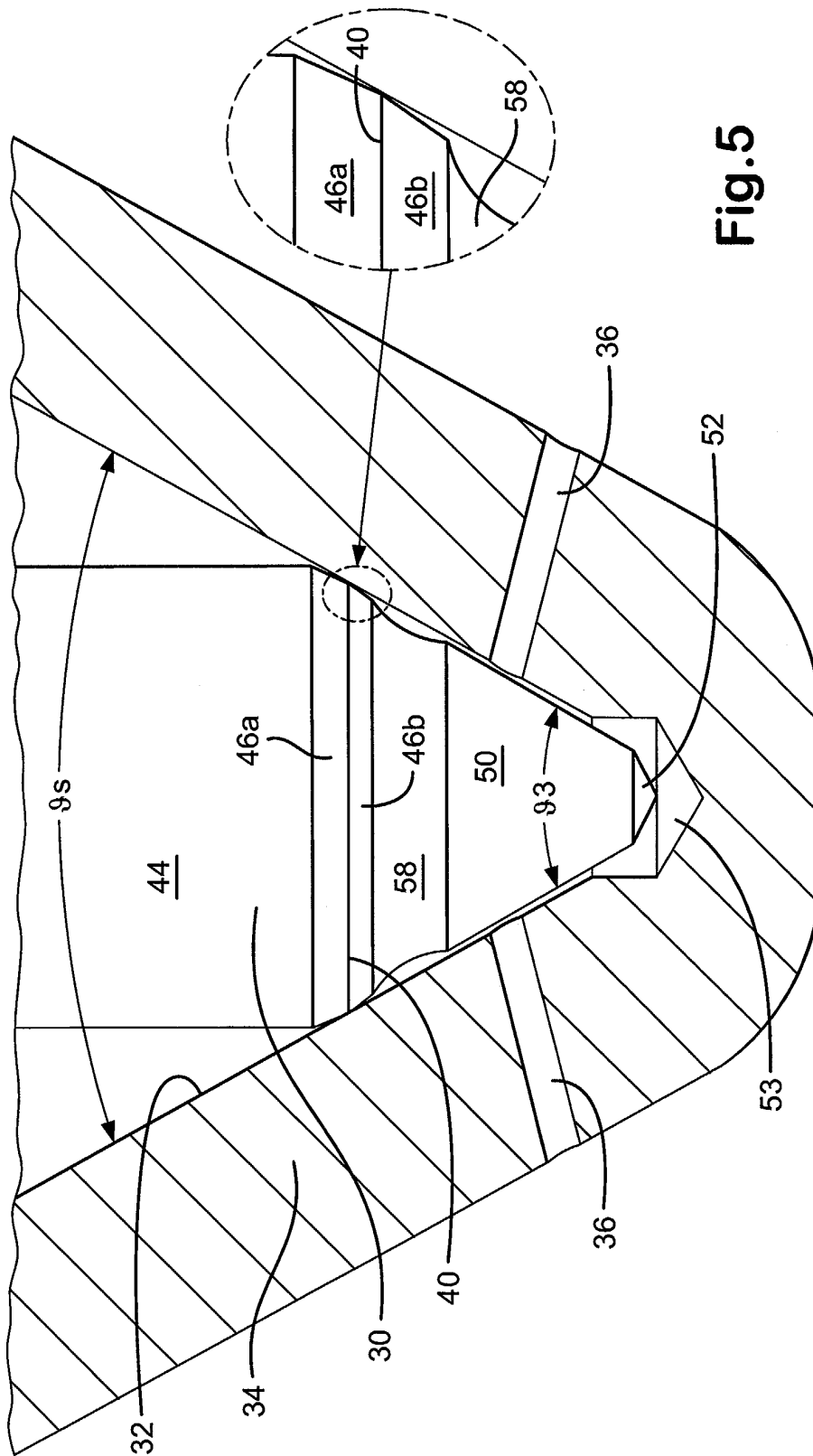


Fig. 5

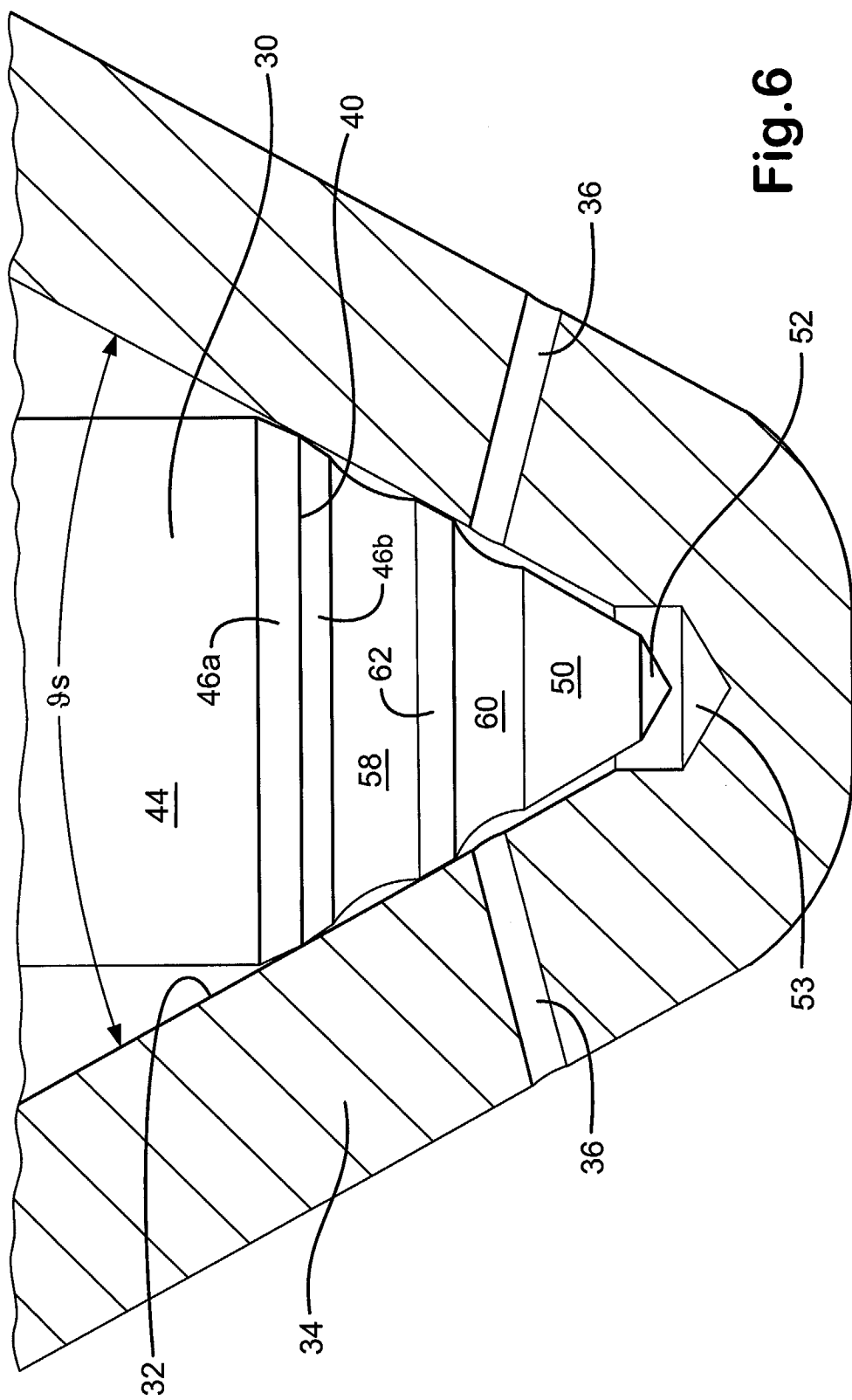


Fig. 6