



(12)

EUROPEAN PATENT APPLICATION

(43) Date of publication:
27.03.2002 Bulletin 2002/13

(51) Int Cl.7: **F04D 5/00, F04D 29/02**

(21) Application number: **01402295.8**

(22) Date of filing: **05.09.2001**

(84) Designated Contracting States:
**AT BE CH CY DE DK ES FI FR GB GR IE IT LI LU
MC NL PT SE TR**
Designated Extension States:
AL LT LV MK RO SI

(30) Priority: **20.09.2000 JP 2000285182**
02.07.2001 JP 2001200637

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(54) **Regenerative pump**

(57) The light, cheap, and high-performance regenerative pump, for pumping a methanol-water fuel of a fuel cell, is adapted to the fuel. At least one of an impeller 1 of the regenerative pump and an inner wall 2 of the

pump is made of polyphenylene sulfide or polyphenylene sulfide containing a filler, and a thrust clearancer formed between the pump chamber inner wall 2 and an impeller peripheral face is set so as to be assured even in a state where the impeller 1 swells.

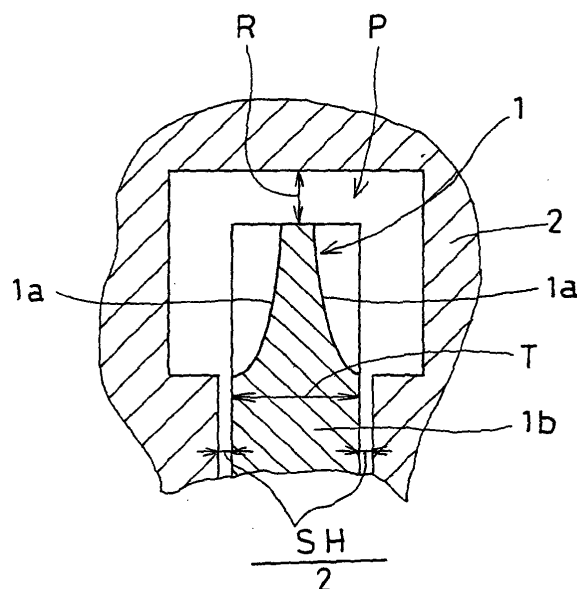


Fig. 1

Description

BACKGROUND OF THE INVENTION

Field of Invention

[0001] The invention relates to a regenerative pump for use in a fuel supply system of a vehicle or the like. More particularly, the invention belongs to the technical field of a regenerative pump used to pump a mixed solution of water and methanol.

Related Art

[0002] Generally, a regenerative pump of this kind having an impeller and a pump chamber having the impeller rotatably mounted therein is used for a fuel supply system of a vehicle or the like. A regenerative pump for pumping fuel in a fuel tank to supply the fuel to an engine side is known. Such a regenerative pump, that achieves a reduction in weight by making the impeller of a thermoplastic resin material, has been proposed. Because the impeller is made to have a vane shape by forming a plurality of recesses on its outer periphery, a resin material of high strength has to be selected so that such a process can be made with great accuracy.

[0003] On the other hand, as one of factors for improving the flow rate (increasing pump efficiency) by reducing a leakage loss of the regenerative pump, a gap (thrust clearance) between the inner wall of the pump chamber and both side faces in the rotary shaft direction of the impeller is set to be as small as possible while steadily maintaining the thrust clearance. In the case of making the impeller of a resin, when the impeller is used for long time, there is a case such that the impeller swells due to an influence of the fuel with which the impeller is in contact. If this happens, the thrust clearance decreases and it is expected that the discharge pressure decreases and the pump locks. Consequently, as the resin material selected, the resin material must be non-hygroscopic, have high corrosion resistance, high wear-and-tear resistance, and the like to the fuel used so that the thrust clearance is maintained in a proper state for long time.

[0004] In such a case, when the fuel is gasoline, there is a technique of selecting a phenol resin containing reinforcement as the thermoplastic resin material, for example as disclosed in JP-A-9-112489. According to the technique, a regenerative pump is built by attaching an impeller made of the phenol resin containing the reinforcement in a pump chamber made of a metal material such as aluminum alloy, thereby realizing lighter weight while maintaining the thrust clearance.

[0005] In recent years, it has been proposed that a fuel cell be used for a low emission vehicle and there is a case such that a mixture solution of methanol and water (hereinbelow, described as methanol-water fuel) be employed as the fuel of the fuel cell. A technique of using

a regenerative pump of this type employed in the gasoline fuel vehicle, as means for supplying the methanol-water fuel to the fuel cell side, has been proposed. The phenol resin material containing the reinforcement employed here is not always suitable for the methanol-water fuel. Consequently, a resin material that is non-hygroscopic, has high corrosion resistance and high wear-and-tear resistance, and the like to the methanol-water fuel has to be newly selected. This is a problem to be solved by the invention.

[0006] Further, in the case where the pump chamber inner wall is made of aluminum alloy, as in the conventional regenerative pump for a gasoline fuel, the aluminum alloy is corroded by the methanol. A method of surface treating the pump chamber inner to improve the corrosion resistance and the wear-and-tear resistance by electrolessly plating the surface of the metal material with nickel or a method of using a metal material having resistance to corrosion by methanol, such as a stainless steel can be considered. In this case, however, the pump chamber becomes heavy and a reduction in weight is not possible which is a problem.

[0007] To solve the problem, a method of selecting a resin material having high resistance to corrosion by methanol, as the material of the pump chamber inner wall, can be also considered. In this case, however, when the same resin material is used for both members, such as the impeller and the pump chamber inner wall, having a configuration such that one of the members rotates in a state where they face each other in proximity to each other, there is a fear that a seizure phenomenon may occur. It is therefore necessary to use a resin material that does not cause such a phenomenon, and this is also a problem to be solved by the invention.

SUMMARY OF THE INVENTION

[0008] The invention has been achieved in consideration of the circumstances to solve the problems and provides a regenerative pump including: an impeller; and a pump chamber having rotatably the impeller mounted therein, wherein at least one of the impeller of the regenerative pump and an inner wall of the pump is formed by using polyphenylene sulfide so as to pump water, methanol, or a mixture solution of water and methanol.

[0009] With the configuration, even when the methanol-water fuel is pumped, a thrust clearance is stable, so that lighter weight and lower cost can be achieved.

[0010] In the regenerative pump, the thrust clearance formed between the pump chamber inner wall and an impeller peripheral face is set so as to be assured even in a state where the impeller swells. Thus, the high-performance regenerative pump can be maintained for a long time.

[0011] Further, in the regenerative pump, polyphenylene sulfide contains a filler. Consequently, the strength of the vane portion of the impeller and the reli-

ability of the pump can be improved, and a reduction in pump efficiency, due to a wear in the impeller and the pump chamber inner wall, can be suppressed.

BRIEF DESCRIPTION OF THE DRAWINGS

[0012]

FIG. 1 is a cross section showing the main portion, for explaining a clearance between an impeller and an inner wall;

FIG. 2A is a graph showing the relationship between a thrust clearance and a discharge flow rate of a regenerative pump and the relationship between the thrust clearance and pump efficiency when a methanol-water solution is pumped, and FIG. 2B is a graph showing the relationship between the thrust clearance and the discharge flow rate of the regenerative pump and the relationship between the thrust clearance and the pump efficiency when methanol is pumped; and

FIG. 3 is a table showing a swelling amount and a swelling ratio when those of PF are set as "1", as a result of impregnation tests of impellers made of resin materials.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENT

[0013] An embodiment of the invention will now be described. In FIG. 1, reference numeral 1 denotes an impeller of a regenerative pump assembled in a fuel supply system for a methanol-water fuel. A drive shaft (not shown) extending from a driving unit is externally fit to a disc-shaped center portion of the impeller 1, and the impeller 1 rotates integrally with the drive shaft in association with the driving of the driving unit. The impeller 1 of the embodiment is integrally molded of polyphenylene sulfide (PPS) selected from thermoplastic resin materials on the basis of the consideration, which will be described hereinafter. A plurality of recesses 1a are formed in the periphery of the impeller 1 in both faces in the axial direction, thereby creating a closed vane.

[0014] The impeller 1 is rotatably attached in a pump chamber P. An inner wall 2 of the pump chamber P is also made of polyphenylene sulfide (PPS) similar to that of the impeller 1 for the reasons discussed below. There is a relatively wide gap between the inner wall 2 and the recesses 1a formed in the periphery of the impeller 1. The gap and a gap R between the inner wall 2 and the peripheral face of the impeller 1 form a space in which the fuel is pressure fed in a swirl flow. On the other hand, the inner wall 2 and both faces in the axial direction of an impeller inside diameter portion 1b are formed so as to face each other in the proximity to each other with a narrow gap SH (thrust clearance of which numerical val-

ue is expressed as a sum of the gaps between the inner wall 2 and the faces in the axial direction of the impeller 1). By setting the narrow thrust clearance SH to a value as will be described below, a regenerative pump having high pump efficiency for a long time can be constructed.

[0015] Now, at the time of selecting a material for the impeller 1 of the regenerative pump and that of the inner wall 2, the relationship between the thrust clearance SH (mm, millimeters) of the regenerative pump and the discharge flow rate Q (L/h, liter/hour) and the relationship between the thrust clearance SH (mm) and pump efficiency (P (%)) when the regenerative pump is assembled in a fuel supply system and the fuel supply system is operated to perform the pumping operation will be considered.

[0016] A graph of FIG. 2A shows the result of pumping the methanol-water fuel by a regenerative pump assembled in the fuel supply system. In the graph, measurement values of the discharge flow rate Q and the pump efficiency (P (%)) with respect to arbitrary thrust clearances SH are plotted. The mixture ratio (weight ratio) between methanol and water in the methanol-water fuel is set to about 1:1. The discharge pressure of the regenerative pump is set to 100 kPa (kilo Pascal).

[0017] In view of the above conditions, the following is found. Because the solution to be pumped has relatively high viscosity like the mixture solution of methanol and water and, moreover, discharge pressure is relatively low, in the case of pumping the solution having a low leakage loss, by setting the thrust clearance SH to 0.04 mm or less, a high discharge flow rate Q can be achieved and the pump efficiency can be maintained at nearly 15%. When the thrust clearance SH exceeds 0.07 mm, the discharge flow rate Q decreases sharply, and the pump efficiency decreases to 10% or lower. Consequently it can be determined that, in such a fuel system, by setting the thrust clearance SH to 0.07 mm or less, that is, by setting the maximum limit value of the thrust clearance SH to 0.07 mm and preventing the thrust clearance SH from exceeding the value, the function of the regenerative pump can be sufficiently displayed.

[0018] In contrast, a graph of FIG. 2B shows the result of pumping only methanol as the fuel by a regenerative pump assembled in the fuel supply system. In this graph as well, measurement values of the discharge flow rate Q and the pump efficiency (P (%)) with respect to arbitrary thrust clearances SH are plotted. The discharge pressure of the regenerative pump in this case is set to 400 kPa (kilo Pascal).

[0019] In view of the results, the following is found. Because the solution to be pumped has relatively low viscosity, like methanol, and the discharge pressure is relatively high, in the case of pumping the solution having a high leakage loss, by setting the thrust clearance SH to 0.02 mm or less, high discharge flow rate Q can be achieved and a high pump efficiency can be maintained at about 25% or higher. However, when the thrust

clearance SH is set to 0.04 mm or larger, the function of the regenerative pump deteriorates. It is understood that the higher the ratio of methanol in the mixture becomes and the lower the viscosity of the solution becomes, the thrust clearance SH has to be reduced.

[0020] A thermoplastic resin material that is suitable for the material of the impeller and the inner wall of the regenerative pump for pumping the methanol-water fuel will now be addressed. Examples of resin materials that are non-hygroscopic, and have high corrosion resistance, and high wear-and-tear resistance with respect to methanol are, generally, polyacetal (POM), phenol resin (PF), polyethylene terephthalate (PETP), polyphenylene sulfide (PPS), polyether ether ketone (PEEK), polyimide (PI), and polyamide (PA). The percentage of water absorption of each of the resin materials is as follows.

polyacetal (POM)	0.220
phenol resin (PF)	0.060
polyethylene terephthalate (PETP)	0.08 to 0.09
polyphenylene sulfide (PPS)	0.015
polyether ether ketone (PEEK)	0.2
polyimide (PI)	0.3 to 0.6
polyamide (PA)	0.4 to 1.3

[0021] From the above, it can be determined that the material having a high percentage of water absorption has a low water resistance. It can be therefore said that PPS, PF, and POM having low water absorption are resin materials suitable for the methanol-water fuel.

[0022] An impregnation test of the resin materials of PPS, PF, and POM, which are regarded as materials suitable for the methanol-water fuel, by using methanol, water, and a mixture solution of methanol and water was conducted to measure the swelling ratio of each of the resin materials in each of the solutions.

Specifically, impellers having a thickness of 5 mm made of the resin materials of PPS, PF, and POM, respectively, were formed. Regenerative pumps in which the impellers were mounted were assembled in fuel supply systems. The fuel supply systems were allowed to pump one of water, methanol, and the methanol-water mixture solution (methanol : water = approximately 1 : 1 (weight ratio)) for 1500 hours. After that, the thickness of each of the impellers was measured, and the swelling amount M (mm) of each of the impellers in each of the cases was measured. In the test, the liquid temperature was set to 70 degrees, and the discharge pressure was set to 300 kPa.

[0023] The swelling ratio B (%) can be obtained by dividing the measured swelling amount M by the thickness of the impeller and multiplying the resultant by 100 ($B = M/5 (100)$). On the basis of the measured amounts obtained in the impregnation test and the swelling ratio B calculated as described above, the swelling amount M and the swelling ratio B of each of the resin materials

when that of PF is set as 1 was calculated. FIG. 3 is a table of the results of the calculation.

[0024] In the table of FIG. 3, the swelling amount M of POM in the impregnation test using the methanol-water solution is a negative value. This means that POM shrinks in the methanol-water solution and the thrust clearance SH, i.e., the gap between the impeller and the inner wall increases. As stated above, such a state results in a deterioration of the discharge flow rate and the pump efficiency, so that it is recognized that POM is an undesirable material for the regenerative pump pumping a methanol-water fuel.

[0025] A desirable resin material for the material of the regenerative pump will now be considered from a viewpoint of a dimensional change in thrust clearance SH caused by swelling of the impeller.

The upper limit value of the thrust clearance SH in the case of pumping the methanol-water solution (methanol : water = about 1 : 1 (weight ratio)) is, as understood from FIG. 2A, 0.07 mm. When the impeller having a thickness of 5 mm is mounted in the regenerative pump, the thrust clearance SH between the impeller and the inner wall is set to 0.07 mm, and the methanol-water solution is pumped, if the thickness tolerance of the impeller is estimated as about 0.03 mm, the swelling amount M allowed for the impeller, which does not deteriorate the function of the regenerative pump, that is, the allowable swelling amount corresponds to an amount obtained by subtracting the thickness tolerance of the impeller from the upper limit value of the thrust clearance SH ($0.07 - 0.03$), that is, 0.04 mm.

When an allowable swelling ratio (%) per 1 mm of the impeller is calculated by dividing the allowable swelling amount of 0.04 mm by the thickness of the impeller, since the thickness of the impeller is 5 mm, the following is calculated.

$$0.04 (5/100 = 0.8 (\%))$$

When the swelling ratio B of the resin material is equal to or lower than the allowable swelling ratio based on the allowable swelling amount, even if the resin material swells, the thrust clearance SH does not become 0 (zero), and it shows that the material is suitable as a resin material for the regenerative pump. As obvious from the table of FIG. 3, the swelling ratio B of PPS, when that of PF is set as 1 is 0.11. Specifically, the swelling ratio B of PF is 4.45% and that of PPS is 0.49%. Consequently, the resin material that satisfies the stated condition is only PPS. Thus, PPS can be selected as the material of the regenerative pump.

[0026] It is also understood from the table of FIG. 3 that the swelling ratio B in the case of pumping water is almost the same when each of PPS and PF is used as the material for the impeller, so that either resin material may be used. When the swelling ratio B in the case of pumping methanol is examined, it is understood that the

swelling ratio B of PF is higher than that of PPS. It is estimated that, in the case of using PF as the material of the impeller, swelling greatly increases when methanol is added to the solution. Consequently, PF cannot be used as the material for the regenerative pump for pumping methanol. As a result, as the material for the regenerative pump for pumping methanol, water, or the mixture solution of methanol and water, only PPS is selected as the suitable resin material.

[0027] As described above, in the regenerative pump for pumping the methanol, water, or the mixture of methanol and water, PPS is employed as the material of the impeller. In this case, the upper limit value of the thrust clearance SH and the swelling ratio B are set on the basis of the mixture ratio of methanol and water. From the upper limit value, swelling ratio B, and thickness T of the impeller, the thrust clearance SH, in the state where the impeller is swollen, that is, the minimum thrust clearance SH can be estimated. By calculating the upper limit value of the thrust clearance SH and the thickness T of the impeller so that the minimum thrust clearance SH does not become zero (a slight gap is left), the regenerative pump which does lock or of which the performance does not deteriorate, even when the impeller becomes swollen, can be constructed.

[0028] Because it is necessary to select a material having low swelling ratio B in the methanol-water solution as the material of the inner wall, PPS is selected. In this case, the inner wall and the impeller that rotates while facing the inner wall in the proximity are made of the same material, so that there is the possibility that the seizure phenomenon occurs. However, polyphenylene sulfide has low swelling ratio B and, moreover, at the time of assembling the impeller in the pump chamber, the thrust clearance SH is preset on the basis of the swelling ratio B. Consequently, even if the impeller is used for long time and becomes swollen, it is set so that the impeller and the inner wall do not come into contact with each other. Further, polyphenylene sulfide does not easily cause the seizure phenomenon and has excellent fluidity so that molding is easy. It has been confirmed that even if the impeller is thin or has a complicated shape, it can be molded by using polyphenylene sulfide with high accuracy. On that basis, the possibility of seizure can be avoided.

[0029] In the embodiment of the invention constructed as described above, in the case of using the regenerative pump for the fuel supply system for the fuel cell using the methanol-water fuel, the impeller 1 of the regenerative pump and the pump chamber inner wall 2 are made of polyphenylene sulfide having non-hygroscopicity and a high corrosion resistance with respect to the methanol-water solution and having a low swelling ratio B in the methanol-water solution. As a result, the impeller 1 and the inner wall 2 do not corrode and are not largely swollen by the methanol-water fuel, and the thrust clearance SH is stable, so that the function of the regenerative pump can be maintained for a long time.

[0030] By setting the thrust clearance SH on the basis of the swelling ratio B calculated on the basis of the impregnation test of the fuel system, even if the impeller 1 or the inner wall 2 does swell through long-term use, the thrust clearance SH does not become zero. As a result, the regenerative pump can be maintained for long time in the state where the discharge flow rate is high and the pump efficiency is high. Further, the thrust clearance SH does not become zero, so that the impeller 1 and the inner wall 2 do not come into contact with each other. Consequently, although the impeller 1 and the inner wall 2 are made of the same material, i.e., polyphenylene sulfide, there is no possibility that the seizure phenomenon occurs.

[0031] With such a configuration, because both the impeller 1 and the inner wall 2 are made of a resin material, lighter weight, as compared with the conventional regenerative pump in which the inner wall is made of a metal material, is realized. Further, polyphenylene sulfide is cheaper than a metal material, so a lower cost is also achieved.

[0032] The invention is not limited to the foregoing embodiment. Either the impeller or pump inner wall may be made of polyphenylene sulfide. When the invention is carried out, polyphenylene sulfide can contain a filler. Examples of the filler are glass fiber, carbon fiber, and fluorocarbon resin. By containing such a filler, the dimensional stability at the time of molding is improved, and mechanical strength is also increased. In the case of using the material containing the filler for the impeller, the strength of the vane portion is increased. In the case of using the material containing the filler for the pump inner wall, the reliability of the pump can be improved. In the case of using the carbon fiber or fluorocarbon resin, sliding resistance can be reduced, so that deterioration in pump efficiency due to wear and tear of the impeller and the pump inner wall can be suppressed. The amount of the filler is adjusted according to a required performance. It is preferably about 30 to 50 percent by weight.

Claims

1. A regenerative pump, comprising:

an impeller (1); and

a pump chamber (P) having therein the impeller (1) rotatably mounted,

characterized in that at least one of the impeller (1) of the regenerative pump and an inner wall (2) of the pump chamber (P) is formed by using polyphenylene sulfide to pump one of water, methanol, and a mixture solution of water and methanol.

2. The regenerative pump according to claim 1, **char-**

acterized in that a thrust clearance (SH) formed between the pump chamber inner wall (2) and an impeller peripheral face is set so as to be assured even in a state where the impeller (1) swells.

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3. The regenerative pump according to claim 1 or 2, **characterized in that** polyphenylene sulfide contains a filler.

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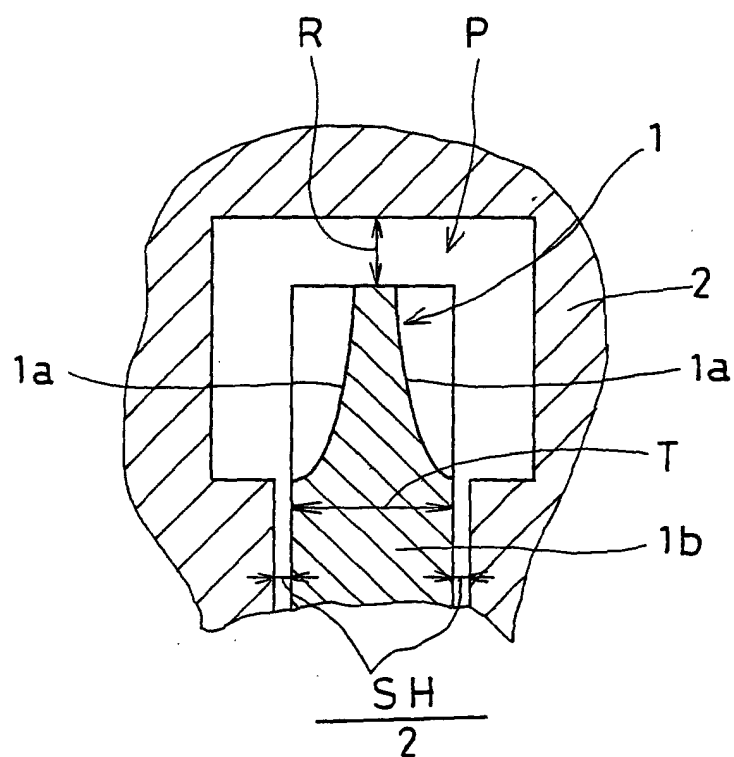


Fig. 1

Fig. 2 (A)

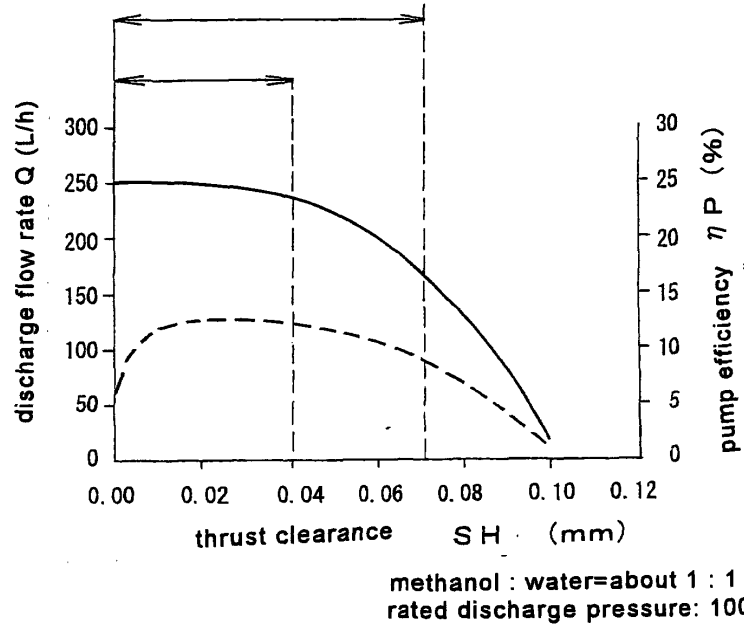
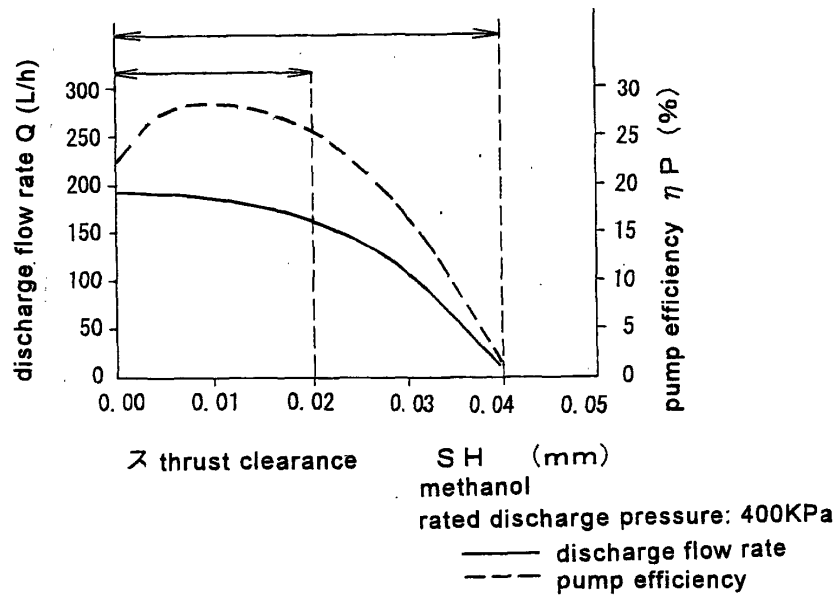


Fig. 2 (B)



resin material	swelling amount M ₁ when that of PF is 1			swelling ratio B ₁ when that of PF is 1		
	water	methanol	methanol-water *	water	methanol	methanol-water *
(PPS) polyphenylene sulfide	1	0.11	0.130	1	0.11	0.13
(PF) phenol resin	1	1	1	1	1	1
(POM) polyacetal	5.8	-	-0.213	5.8	-	-0.21

* methanol : water=about 1 : 1 (weight ratio)
 rated discharge pressure: 300KPa
 impregnation time: 1500h
 liquid temperature: 70°C

Fig. 3