

The effect of the throttles diameter installed on the auxiliary channel on the flow rate of the fluid flowing through them and the heating of the fluid in the magnetic field

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Abstract: This article discusses the effect of the diameters of the throttles installed in the auxiliary paths on the flow rate of the fluid flowing through them and the heating of the fluid in the area of the magnetic coupling. The simulation was carried out in the STAR-CCM+ package.

Introduction

Leak-free pumps are used for pumping liquids and do not leak [1–5]. Usually they pump caustic liquids that have a negative impact on human life and health, as well as on the environment.

Leak-free pumps do not require frequent maintenance [6–12], such as cantilever pumps with oil seals or mechanical seals. They are more reliable.

The basic principle of a leak-free pump is to transmit torque from the engine to the pump rotor through a fixed diaphragm.

According to a method of transferring energy from an engine to a liquid, a leak-free pump can be:

1. With electromagnetic coupling,
2. With a leak-free motor.

The leak-free pump with an electromagnetic coupling is divided into a leak-free pump with a synchronizing coupling and a leak-free pump with an asynchronous coupling.

Pumps with hermetic motors are divided into pumps with “wet” rotors and “wet” rotors and stators.

The following advantages and disadvantages of a leak-free pump can be distinguished from conventional pumps.

Benefits:

1. No leak at all
2. No routine maintenance is required during the entire service life.
3. The operating time before the first repair is usually at least 50,000 hours.
4. Reduce noise and vibration (especially in sealed pumps with sealed motors),
5. High fire and explosion safety.

Disadvantages:

1. The cost of the pump is higher
2. Low efficiency
3. Maintenance and repair of the operating company is extremely complex.
4. The difficulty of operating the pump on contaminated and hot liquids.



5. Heavy weight and size

6. Power limitation.

There are some difficulties in developing a leak-free pump.

In most cases, most leak-free pumps are equipped with plain bearings that operate on the pumped liquid. If the pumped liquid has abrasive inclusions, this can cause problems.

When a leak-free pump with a magnetic coupling is used on a hot fluid, the magnets heat up, and as a result, they lose their magnetism until the magnetic coupling fails completely.

In addition, since the operation of a leak-free pump at high pressure in the system is very difficult, an increase in the thickness of the sealing separator leads to an increase in losses in the sealing separator.

In addition, hermetic pumps require maximum radial and axial unloading due to the low bearing capacity of sliding bearings, and due to the design characteristics of such pumps, the proximity of the bearings used to diagnose their condition is very limited.

The aim of the project is to develop a sealed pump with a magnetic coupling for the chemical industry.

This article attempts to simulate the fluid flow in the wet part of a leak-free pump with a magnetic coupling using computational fluid dynamics methods in order to study the effect of the diameters of the throttles installed in auxiliary paths on the flow rate of the fluid flowing through them and the heating of the fluid in the magnetic coupling region.

The object of study in this work is the area of auxiliary paths of a sealed pump, limited by a sealing cup.

Figure 1 shows a 3D model of the flow part of the pump of the selected area.

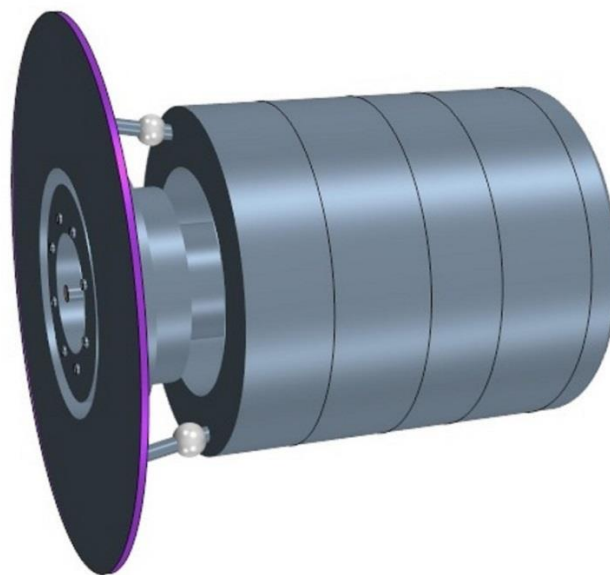


Figure 1. Design geometric model

Methods

The method of numerical simulation is based on the solution of discrete analogues of the basic equations of hydrodynamics [4–8]. For an incompressible fluid ($\rho = \text{const}$) it is:

Mass conservation equation (continuity equation)

$$\frac{\partial \overline{u_j}}{\partial x_j} = 0,$$

where $\overline{u_j}$ is the projection of the averaged fluid velocity on the j-th axis (j=1,2,3);

Equation of conservation of momentum (averaging by Reynolds):

$$\rho \left[\frac{\partial U_i}{\partial t} + U_i \frac{\partial U_i}{\partial x_j} \right] = - \frac{\partial P}{\partial x_i} + \frac{\partial}{\partial x_i} \left[T_{ij}^{(v)} - \rho u_i u_j \right], \quad \text{where}$$

U, P — averaged speed and pressure;

$T_{ij}^{(v)} = 2\mu \overline{S_{ij}}$ — viscous stress tensor for incompressible fluid;

$\overline{S_{ij}} = \frac{1}{2} \left[\frac{\partial u_i}{\partial x_j} + \frac{\partial u_j}{\partial x_i} \right]$ — instant strain rate tensor;

$\rho \langle u_i u_j \rangle$ — Reynolds stresses.

The Reynolds system of equations is open due to the presence of unknown Reynolds stresses. The system can be closed using the k- ω SST turbulence model. This model combines the advantages of both k- ω and k-models. In the parietal region, the k- ω model is used, and in the core of the flow, k- ϵ .

For the thermal calculation, the following hydrodynamic equation, the equation of fluid energy for temperature, was used:

$$\frac{\partial}{\partial t} \int_V \rho E dV + \oint_A \rho H \mathbf{v} \cdot d\mathbf{a} = - \oint_A \mathbf{q}'' \cdot d\mathbf{a} + \oint_A \mathbf{T} \cdot \mathbf{v} d\mathbf{a} + \int_V \mathbf{f}_b \cdot \mathbf{v} dV + \int_V S_u dV$$

where E is full energy

H — total enthalpy

\mathbf{q}'' — heat flux vector

\mathbf{T} — viscous stress tensor

\mathbf{v} — speed vector

\mathbf{f}_b — body force vector representing the combined rotational forces of the body, gravity and fan mode

S_u — contributes to terms of energy sources, such as radiation sources, interfacial energy sources, or energy sources due to chemical reactions.

The total energy is related to the total enthalpy H :

$$E = H - p / \rho,$$

where:

$$H = h + |\mathbf{v}|^2 / 2$$

h is a static enthalpy.

The computational grid constructed for the area of the pump seal with the pump magnetic coupling consisting of about 1 mln. polyhedral cells with a base size of 3 mm, shown in the figures 2,3.

To determine the effect of the diameters of the throttles installed in the auxiliary paths of the hermetic pump on the flow rate of the fluid flowing through them and the temperature of the fluid in the area of the magnetic coupling, several 3D models of the flow part with different diameters of the throttles were simulated. To simplify the hydrodynamic modeling, the throttle diameter in the shaft was changed, since it most affects the temperature of the pumped fluid in the region of the magnetic coupling.

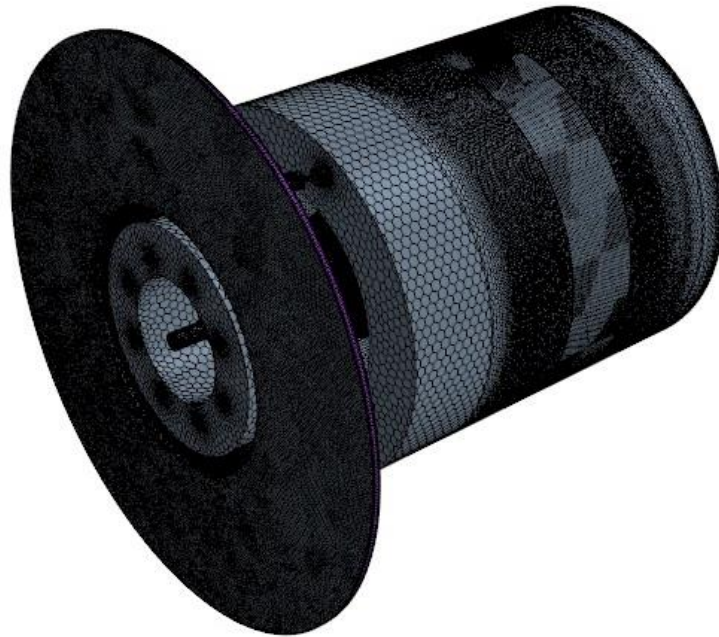


Figure 2. Design grid model

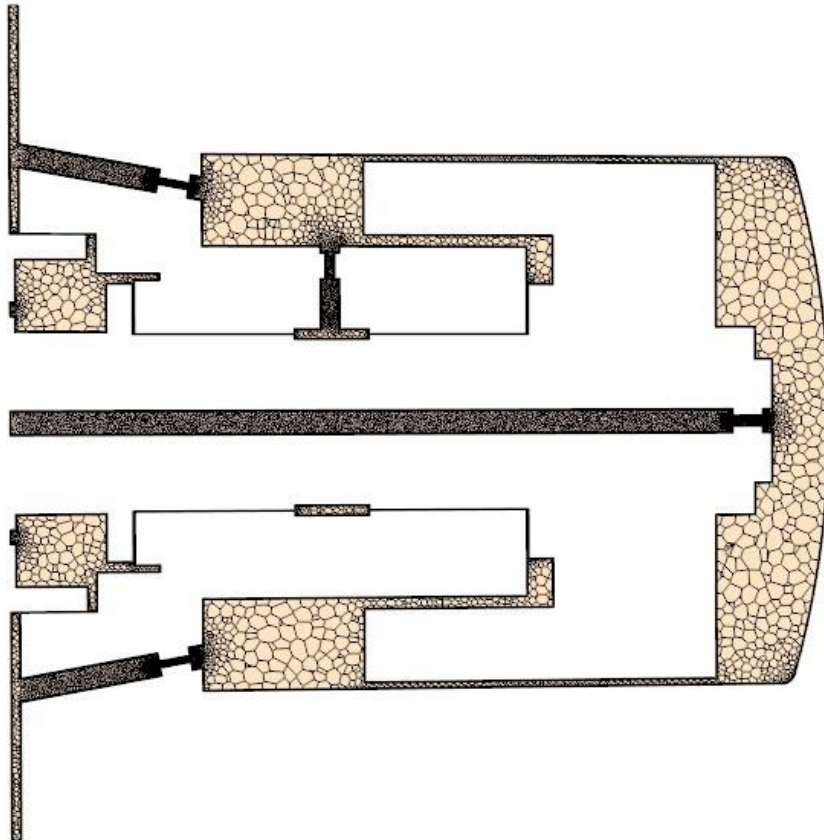


Figure 3. Estimated meridional section

In order to minimize errors associated with numerical calculation, all models were calculated with the same parameters of the computational grid and with the same boundary conditions.

Heat is generated inside the magnetic coupling due to eddy currents generated on the protective shell in the areas of the ends of the magnets. Heating is set on the surface of the sealed cup in the area of the magnets as 5% of the total transmitted power through a magnetic coupling from the motor shaft to the pump shaft (100 W). Since the working fluid lubricates the plain bearings, heating also occurs in them.

Heating is set on the rotating part of the bearing (sleeve).

The evaluation criteria (quality) for the selection of throttles in the auxiliary paths of the hermetic pump are: the temperature of the fluid in the area of the magnetic coupling, the flow rate flowing through the auxiliary paths, as well as the volumetric efficiency of the pump.

Results

In the process of simulating the flow of liquids in the magnetic coupling region of an leak-free pump, patterns of the distribution of liquid temperatures were obtained.

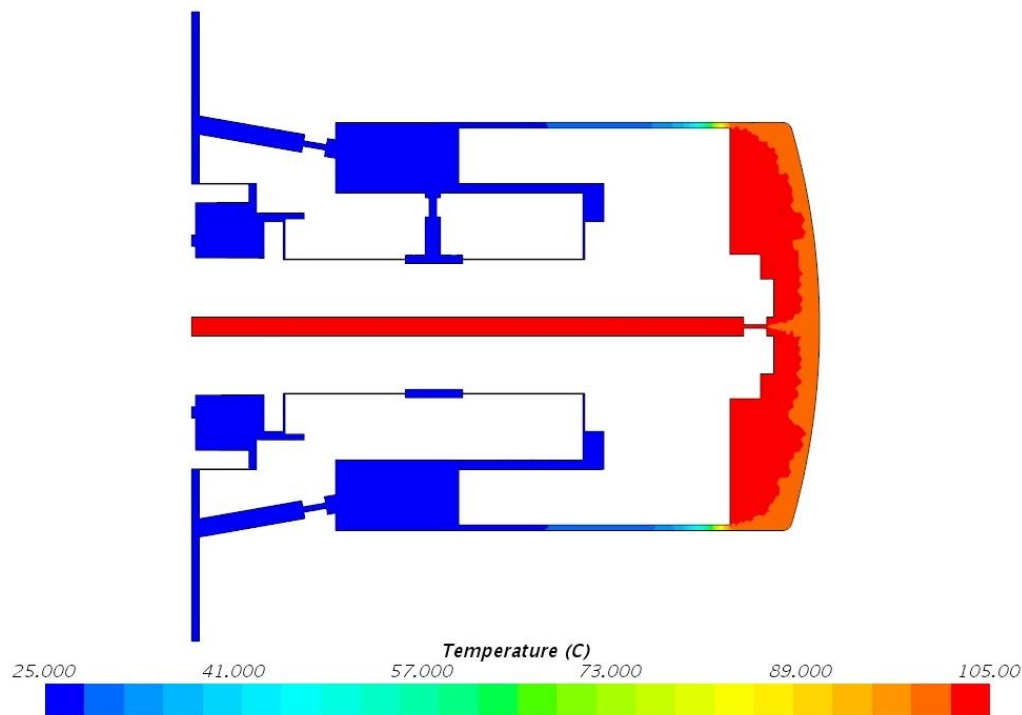


Figure 4. Fluid temperature distribution field (throttle diameter 1mm)

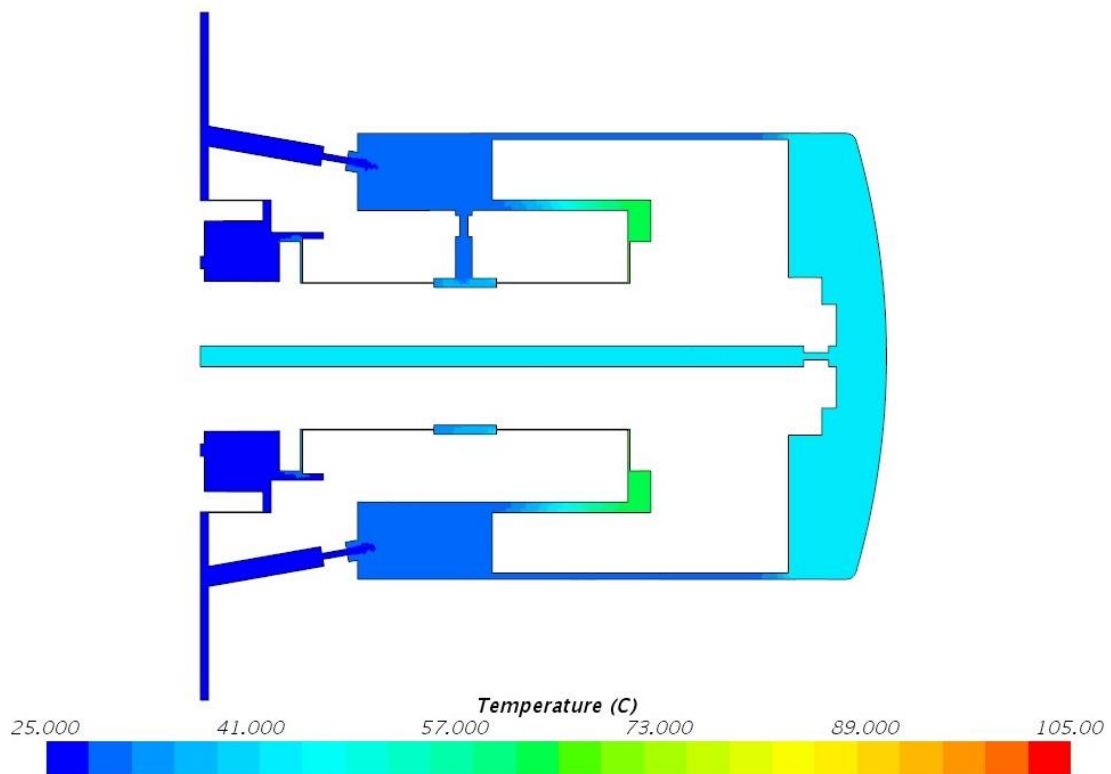


Figure 5. Fluid temperature distribution field (1.8mm throttle diameter)

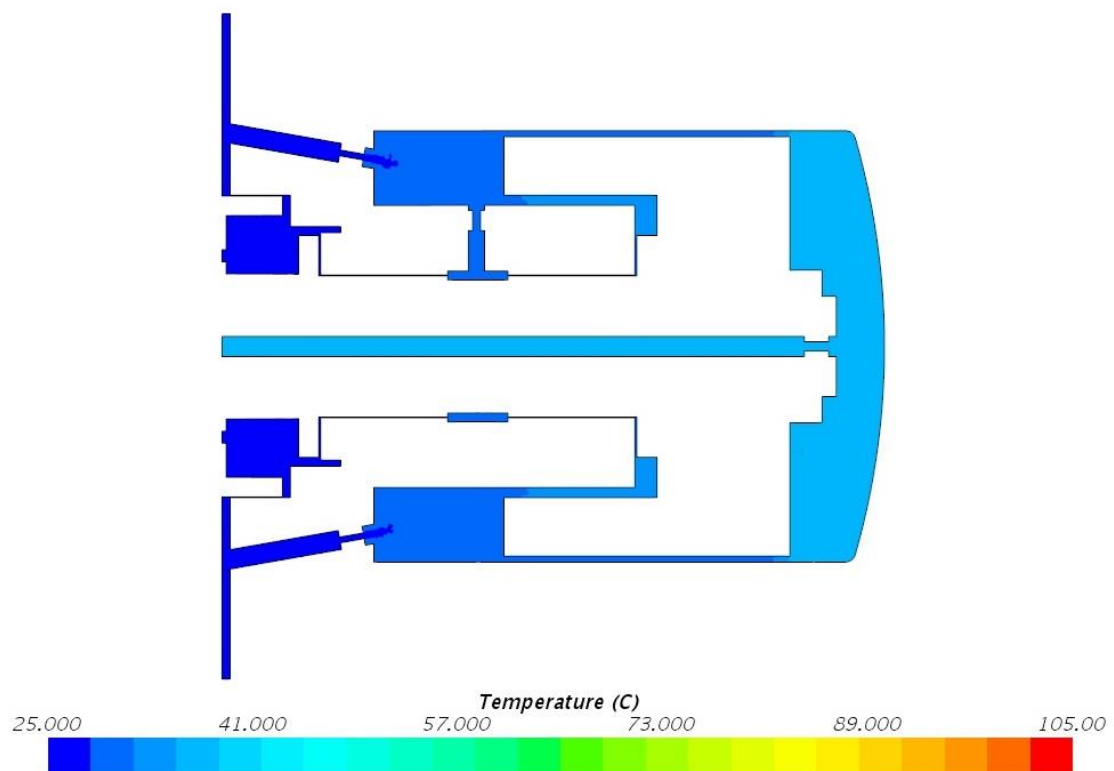


Figure 6. Fluid temperature distribution field (2.3 mm throttle diameter)

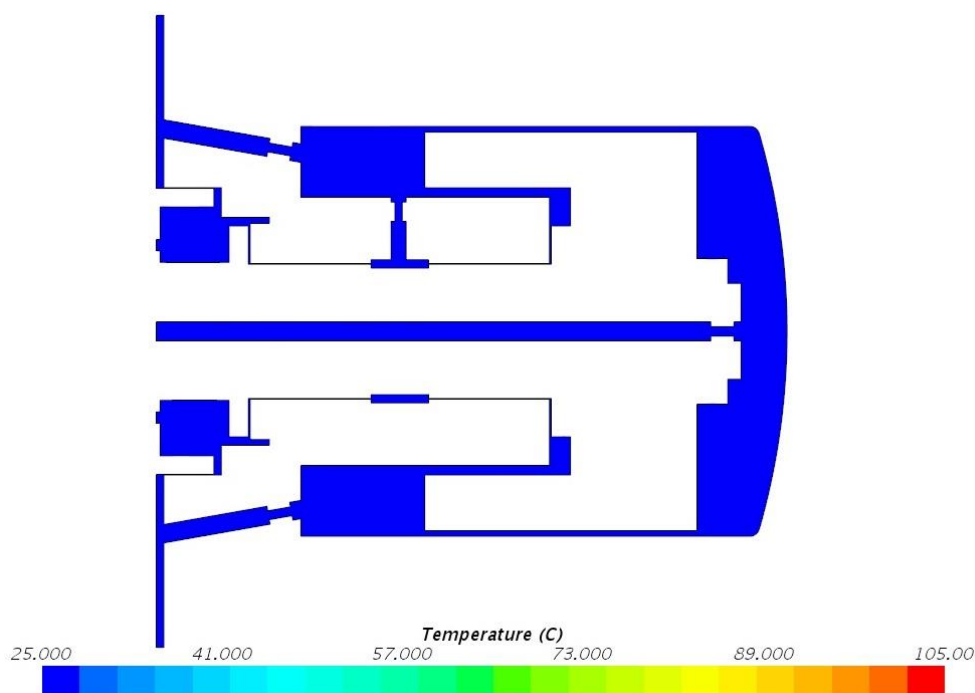


Figure 7. Fluid temperature distribution field (2.5 mm throttle diameter)

Conclusions

In the process of hydrodynamic simulation of the wet part of the pump, the values of the temperature of the pumped fluid in the region of the magnetic coupling and the flow rate flowing through the auxiliary paths were obtained. According to these results, a graph of the temperature versus flow rate is constructed.

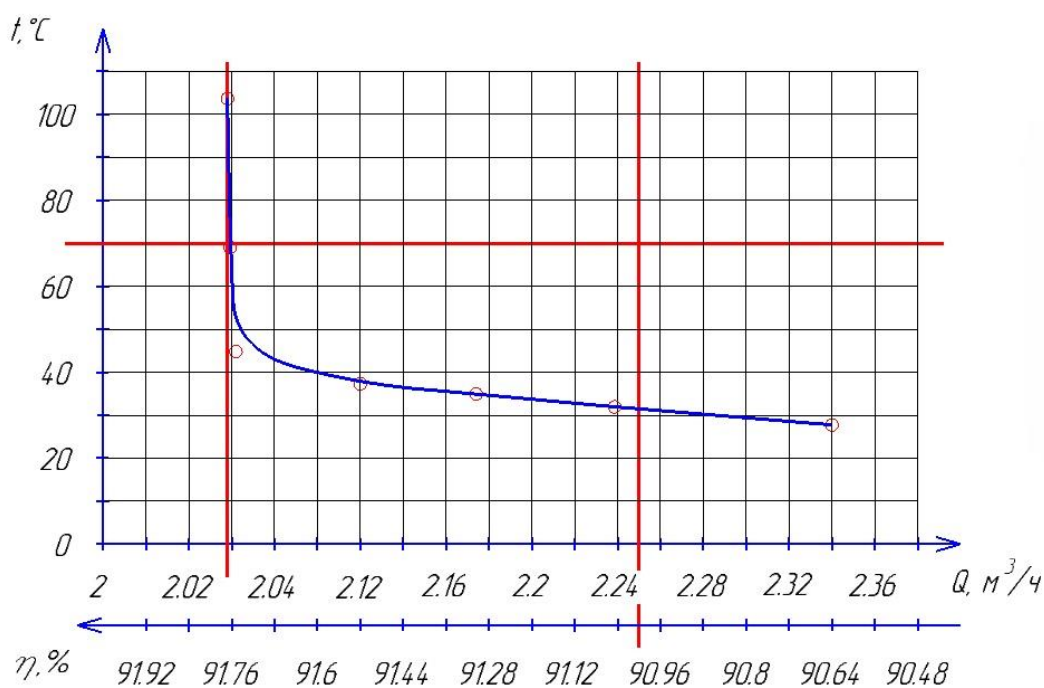


Figure 8. The dependence of temperature on fluid flow in auxiliary paths

Limitations are imposed on temperature (70 °C), volumetric efficiency (91%) and minimum throttle diameter (1 mm). As a result of which, conclusions were drawn that it is advisable to use a throttle with a diameter of 1.8-2.36 mm.

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