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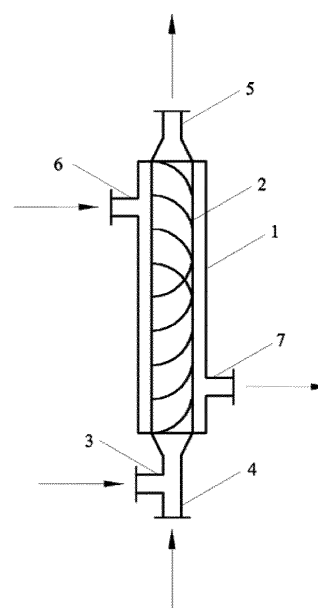
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(54) **PIPE-TYPE MIXER**

(57) Disclosed is a pipe-type mixer, comprising an inner sleeve pipe (2) taking a mixing action and an outer sleeve pipe (1) taking a heat-exchange action, wherein the inner sleeve pipe (2) is located inside the outer sleeve pipe (1), and the cross section of the inner sleeve pipe (2) is a hexagon and is formed of a combination of one section of inner pipe twisting clockwise along the pipe centre and one section of inner pipe twisting anticlockwise. The pipe-type mixer is for a complex fluid with high solid content, high viscosity or containing fibers, while realizing enhanced mass transfer and heat transfer, and has anti-fouling, anti-blockage and alternative mechanical stirring functions.



**FIG. 1**

**Description****BACKGROUND****Technical Field**

**[0001]** The present invention belongs to fluid mixing equipment, and particularly relates to a pipe-type mixer having a heat-exchange function.

**Related Art**

**[0002]** Mixing is a unit operation using a mechanical or hydrodynamic method to disperse two or more materials to each other to achieve a certain degree of uniformity. With the gradual deepening of scientific researches, more and more attentions have been paid to the mixing effect in chemical engineering, petroleum, power and light industry etc. In many fields, mechanical stirring, gas circulation stirring and hydraulic stirring are used to achieve a mixing purpose. Moreover, many projects or project mating processes require heating or temperature control in feedstock, discharging and reaction. Temperature affects the system energy consumption and is a key factor of ensuring normal and efficient reaction processes. Therefore, combining a heat-exchange technology with a mixing technology to research and develop an efficient and energy-saving mixer is of great significance for reducing the production costs and saving the energy.

**[0003]** At present, mixing equipment commonly used in the industry comprises a stirring and mixing kettle, a static mixer and a circulation mixer. Commonly used heat-exchange equipment comprises a pipe-type heat exchanger, a plate heat exchanger and a finned heat exchanger. However, these equipment may not simultaneously enhance mixing and heat exchange, which limits the selection of process solutions and conditions and has become a major bottleneck in enhanced transfer of a fluid process. On the other hand, many process raw materials, such as a fermentation raw material (straws and poultry manure systems etc.), have high solid content, high apparent viscosity and complex rheological property. These factors may all cause blockage and fouling of the equipment, so that the transfer efficiency of the process is substantially reduced, and the continuous and stable operation of a system is affected. With the advancement of the mixing technology and the heat-exchange technology, mixers are inserted into many heat exchangers, such as a horizontal liquid-solid fluidized bed heat exchanger with a Kenics static mixer inserted in a pipe. This configuration may effectively improve the particle distribution. However, the heat exchangers of this type of structures are only suitable for systems with low solid content of 2 wt% to 4 wt%. This is because the presence of a part-in-pipe makes systems with high solid content have extremely high flow resistance during heat exchange and thus the power consumption in this process is increased. In recent years, pipe-type mixers have developed rapidly, such as a multi-pole vortex pipe-type mixer, an S-K type mixer and a pipe bundle pipe-type static mixer, which are mainly suitable for filtering flocculates in water. This type of pipe-type mixer is only suitable for simple fluids with low solid content and low viscosity, such as sewage. Chinese patent CN201510185307.8 invents a pipe-type mixer with a spiral passage. A spiral groove is formed in the outer wall of an inner pipe, and the spiral groove is connected with the inner wall of an outer pipe to form the spiral passage. The mixer of this structure may provide a large mixing length in a short axial distance and provide a better mixing effect within the same mixing time. However, due to the spiral passage, this configuration is only suitable for the systems with low solid content. For the systems with high solid content, especially straws containing fibers, this passage is easily blocked, and thus the mixing effect may be reduced. In addition, the patent is only for enhanced mixing, but not for enhanced heat exchange at the same time.

**[0004]** On the other hand, Chinese patent CN201510305639.5 invents a sleeve pipe-type heat exchanger suitable for sewage with high solid content. This sleeve pipe-type heat exchanger is suitable for the sewage with high solid content, and dirt impurities in the sewage are not easily fouled on four walls of a sewage passage or do not easily block the sewage passage, thereby guaranteeing the heat-exchange efficiency and the continuous and stable operation of the heat exchanger. Furthermore, thanks to extremely high pipe side and shell side convection heat transfer efficiency, the heat exchanger has relatively high enhanced heat-exchange performance. However, the cross section of a twisted pipe in the heat exchanger is a triangle. For complex fluids with high solid content and high viscosity or containing fibers, this configuration has a dead angle and does not achieve an enhanced mixing effect. Moreover, although a twisted pipe heat exchanger, a twisted pipe of which has an elliptical cross section, has certain advantages in the enhanced heat-exchange performance, the twisted pipe heat exchanger is limited to single-phase fluids without solid particles, such as sulfuric acid cooling, ammonia preheating and lubricating oil cooling.

**[0005]** Based on the above, for the complex fluids with high solid content and high viscosity or containing fibers, it is of important significance to develop novel fluid mixing equipment with enhanced mass transfer and heat transfer functions, which may reduce the system mixing and heat-exchange energy consumption and improve the reaction efficiency.

## SUMMARY

**[0006]** In view of the above shortcomings of the prior art, the present invention is directed to provide a pipe-type mixer which aims at a complex fluid with high solid content and high viscosity or containing fibers and also realizes enhanced mass transfer and heat transfer, and has anti-fouling, anti-blockage and alternative mechanical stirring functions. The present invention has important application background in fields of petrochemical engineering, food processing and biofermentation etc.

**[0007]** The present invention is implemented by the following technical solution:

a pipe-type mixer, comprising an inner sleeve pipe taking a mixing action and an outer sleeve pipe taking a heat-exchange action. The inner sleeve pipe is located inside the outer sleeve pipe, and the cross section of the inner sleeve pipe is a hexagon, and the cross section of the inner sleeve pipe is a hexagon and is formed of a combination of an inner pipe twisting clockwise along the pipe centre and an inner pipe twisting anticlockwise.

**[0008]** The pipe-type mixer is suitable for a material system with high solid content and high viscosity, and has the advantages of simple structure, anti-blockage and anti-fouling performance and integration of heat exchange and mixing.

**[0009]** Preferably, the cross section of the inner sleeve pipe is an equilateral hexagon. The centre axis of the inner sleeve pipe is straight or curved. Preferably, a straight centre axis is used.

**[0010]** The inner sleeve pipe is formed of a combination of an inner pipe uniformly twisting clockwise along the pipe centre and an inner pipe uniformly twisting anticlockwise. Preferably, a torque of the inner sleeve pipe, namely a pipe length corresponding to a pipe wall spirally deforming 360 degrees around the pipe centre axis, is 300 to 800 mm, preferably 500 to 800 mm. Experiment finds that an extremely high torque causes a too small space of a medium passage, and then the mixer may not work normally and is easy to foul, but an extremely low torque may reduce the mixing and heat-exchange effect. In addition, the torques of the two sections of inner pipes twisting clockwise and anticlockwise may be the same or different, which has no obvious impact on the mixing and heat-exchange effect.

**[0011]** Preferably, the inscribed circle diameter of the hexagonal cross section of the inner sleeve pipe is 20 to 150 mm, preferably 80 to 150 mm. Experiment finds that both a too large inscribed circle diameter and a too small inscribed circle diameter may affect the heat-exchange efficiency and the mixing effect and easily cause wall surface fouling or blockage of the inner sleeve pipe.

**[0012]** There is no limitation to the shape of the cross section of the outer sleeve pipe, which may be a circle, a square, a hexagon and the like. In order to facilitate the production and achieve relatively high heat-exchange efficiency, the cross section of the outer sleeve pipe is preferably a circle. A distance between the inscribed circle diameter of the inner sleeve pipe and the inscribed circle diameter of the outer sleeve pipe is 5 to 15 mm, preferably 10 to 15 mm. Experiment finds that both a too large distance and a too small distance may reduce the heat-exchange effect. Particularly, the too large distance also may cause higher energy consumption and cost.

**[0013]** Further, the inscribed circle diameters of the inner sleeve pipe and the outer sleeve pipe may be adjusted within the scope of the present invention according to an actual requirement. In order to realize better anti-fouling and anti-blockage functions and achieve a better mixing effect and higher heat-exchange performance, preferably, for a material with total solid content TS of 4% to 10%, an inner sleeve pipe with the inscribed circle diameter  $D_1$  of 20 to 80 mm and an outer sleeve pipe with the inscribed circle diameter  $D_2$  of 30 to 95 mm are preferably used, and for a material with total solid content TS of 10% to 15%, an inner sleeve pipe with the inscribed circle diameter  $D_1$  of 80 to 150 mm and an outer sleeve pipe with the inscribed circle diameter  $D_2$  of 95 to 165 mm are preferably used.

**[0014]** Further, a combination of one section of inner pipe twisting clockwise along the pipe centre and one section of inner pipe twisting anticlockwise is used as a constituting unit. The sleeve pipe of the present invention may comprise one or more such constituting units. According to the inner sleeve pipe of the present invention, a length ratio of the inner pipe ( $L_1$ ) uniformly twisting clockwise along the pipe centre to the inner pipe ( $L_2$ ) uniformly twisting anticlockwise may be preferably  $L_1:L_2=(0.5-2):1$ . The length ratio within this range has no obvious impact on the mixing effect, and the length ratio less than or greater than this range may cause an obvious reduction of the mixing effect.

**[0015]** In one technical solution, the pipe-type mixer of the present invention comprises a material mixing passage and a heat-exchange medium passage. The material mixing passage is composed of the inner sleeve pipe. Two ends of the material mixing passage are respectively provided with a material inlet and a material outlet. The heat-exchange medium passage is composed of an annular space between the outer sleeve pipe and the inner sleeve pipe. Two ends of the heat-exchange medium passage formed by the space between the outer sleeve pipe and the inner sleeve pipe may be closed. A heat-exchange medium inlet pipe and a heat-exchange medium outlet pipe are arranged on the heat-exchange medium passage or a heat-exchange medium main passage. In order to achieve the better heat-exchange effect, preferably, the material inlet corresponds to the heat-exchange medium outlet pipe, and the material outlet corresponds to the heat-exchange medium inlet pipe.

**[0016]** Beneficial effects of the present invention:

1. The present invention is suitable for a material system with high solid content TS of 4 wt% to 15 wt% and containing

solids or fibers, has no dead angles, is difficult to foul and block.

2. Compared with a triangular twisted pipe mixer, the mixer is relatively small in dead zone proportion and may significantly enhance the mixing effect.

3. Thanks to extremely high pipe side and shell side convection heat transfer efficiency, the mixer is relatively high in enhanced heat-exchange performance and relatively low in process pump power consumption.

4. The mixing passage is formed by splicing a coaxial circular pipe and a twisted pipe which are nested to each other, and may be conveniently manufactured by a conventional machining technology, and the cost is low.

5. Materials may be fully mixed and subjected to heat exchange in the mixing passage, so as to improve the later system reaction efficiency and reduce the energy consumption.

## BRIEF DESCRIPTION OF THE DRAWINGS

### [0017]

Fig. 1 is an overall diagram of a mixer having a heat-exchange function;

Fig. 2 is an inner passage hexagonal twisted pipe; and

Fig. 3 is a sketch of the cross section of a mixer.

[0018] In the drawings, 1: outer sleeve pipe; 2: inner sleeve pipe; 3: A inlet pipe; 4: B inlet pipe; 5: outlet pipe; 6: heat-exchange medium inlet pipe; 7: heat-exchange medium outlet pipe; 8: cross section of hexagonal inscribed circle  $O_1$ ; 9: hexagonal cross section; and 10: cross section of outer sleeve circular pipe  $O_2$ .

## DETAILED DESCRIPTION

[0019] The present invention is further described below in combination with accompanying drawings and embodiments. However, the following descriptions are not comprehended as limiting the scope of the present invention.

[0020] A pipe-type mixer which aims at complex fluids with high solid content and high viscosity or containing fibers and also realizes enhanced mass transfer and heat transfer comprises an inner sleeve pipe and an outer sleeve pipe. The inner sleeve pipe is located inside the outer sleeve pipe, and the cross section of the inner sleeve pipe is a hexagon and is formed of a combination of an inner pipe twisting clockwise along the pipe centre and an inner pipe twisting anticlockwise. The pipe-type mixer is suitable for a material system with high solid content and high viscosity, and has the advantages of simple structure, anti-blockage and anti-fouling performance and integration of heat exchange and mixing.

[0021] As shown in Fig. 2, the inner sleeve pipe of the present invention may be a hexagonal twisted pipe which has a hexagonal cross section formed of a combination of an inner pipe uniformly twisting clockwise along the pipe centre and an inner pipe uniformly twisting anticlockwise. The cross section of the hexagonal twisted pipe is a regular hexagon, and the centre axis thereof is straight or curved. Preferably, the straight centre axis as shown in Fig. 2 is used.

[0022] Torque is one of important parameters of the hexagonal twisted pipe, namely a pipe length corresponding to a pipe wall spirally deforming 360 degrees around the pipe centre axis. The torque of the hexagonal twisted pipe is 300 to 800 mm. The inscribed circle diameter of the hexagonal cross section of the hexagonal twisted pipe is 20 to 150 mm, as shown in Fig. 3. A length ratio of the inner pipe ( $L_1$ ) uniformly twisting clockwise along the pipe centre to the inner pipe ( $L_2$ ) uniformly twisting anticlockwise in the inner sleeve pipe of the present invention is  $L_1:L_2=(0.5-2):1$ . Materials directly exchange heat with a heat-exchange medium through the pipe wall of the hexagonal twisted pipe.

[0023] The outer sleeve pipe in the example may be a common circular sleeve pipe. The cross section of the outer sleeve pipe is a circle, and the pipe diameter is greater than that of the inner sleeve pipe. A distance between the wall of the outer sleeve pipe and the inner sleeve pipe is 5 to 15 mm. In the example, the cross sectional structures of the inner and outer sleeve pipes are as shown in Fig. 3.

[0024] Fig. 1 illustrates a relatively complete pipe-type mixer, consisting of an outer sleeve pipe 1, an inner sleeve pipe 2, a material A inlet 3, a material B inlet 4, a material outlet 5, a heat-exchange medium inlet 6 and a heat-exchange medium outlet 7. The outer sleeve pipe is a heat-exchange medium passage, and the inner sleeve pipe is a material mixing passage. The inner sleeve pipe is located inside the outer sleeve pipe. The cross section of the inner sleeve pipe is a hexagon and is formed of a combination of one section of inner pipe uniformly twisting clockwise along the pipe

centre and one section of inner pipe uniformly twisting anticlockwise, as shown in Figs. 2 to 3. Two ends of the inner sleeve pipe are respectively connected with the material pipe inlet A and the material pipe inlet B and one material outlet 5. The heat-exchange medium flows into an annular space between the sleeve pipe with the circular cross section and the twisted pipe with the hexagonal cross section from the heat-exchange medium inlet 6 and flows out from the heat-exchange medium outlet 7. The outer sleeve pipe is provided with a heat preservation material.

#### Performance test

**[0025]** The structure as shown in Fig. 1 was adopted below: the outer sleeve pipe was a circular sleeve pipe; a material A was a straw; a material B was a CMC (Carboxy Methylated Cellulose) solution (with a mass fraction of 1%); and a heat-exchange medium was water. The temperature of the material inlet was 10°C, and the temperature of the heat-exchange medium inlet was 55°C. The mixing effect was characterized by a tracer agent method. A KCl solution at a concentration of 0.7 mol/L was injected at the inlet, and a voltage thereof was measured with a conductivity meter (DDSJ-

308A) at the outlet. A dimensionless variance ( $\sigma_{\theta}^2$ ) and a Berkeley number (Pe) of residence time distribution were

calculated by the voltage. If  $\sigma_{\theta}^2$  is closer to 1, the mixing effect is better; and if Pe is closer to 0, the axial back-mixing is grater, and the flow state is close to complete mixing flow. In Table 1, for the embodiments and the comparison examples, the materail inlet speeds are the same, and the heat-exchange medium inlet speeds are also the same;  $D_1$  is the diameter of a hexagonal inscribed circle, and  $D_2$  is the diameter of an outer pipe;  $n_1$  and  $n_2$  are resectively torques of the two sections of twisted pipes; and  $L_1$  and  $L_2$  are respectively lengths of the two sections of twisted pipes (as shown in Fig. 2).

**[0026]** Operation conditions and mixing and heat-exchange characterization results of Embodiments 1 to 7 and Comparison Examples 1 to 8 are as shown in Table 1.

Table 1 Operation conditions and characterization results of the embodiments

|                      | Structure of inner sleeve pipe                               | Size of pipe diameter/mm | TS/<br>% | Torque/mm                     |                                   |  | L <sub>1</sub> :<br>L <sub>2</sub> | Fouling and<br>blockage | Mixing effect       |        | Heat-exchange<br>effect |
|----------------------|--------------------------------------------------------------|--------------------------|----------|-------------------------------|-----------------------------------|--|------------------------------------|-------------------------|---------------------|--------|-------------------------|
|                      |                                                              |                          |          | n <sub>1</sub><br>(clockwise) | n <sub>2</sub><br>(anticlockwise) |  |                                    |                         | $\sigma_{\theta}^2$ | Pe     |                         |
| Embodiment 1         | Hexagonal twisted pipe                                       | D1=80, D2=95             | 10       | 500                           | 500                               |  | 1                                  | None                    | 0.7956              | 0.7293 | 41                      |
| Embodiment 2         | Hexagonal twisted pipe                                       | D1=80, D2=95             | 10       | 300                           | 300                               |  | 1                                  | None                    | 0.6812              | 1.2805 | 31                      |
| Embodiment 3         | Hexagonal twisted pipe                                       | D1=80, D2=95             | 10       | 800                           | 800                               |  | 1                                  | None                    | 0.7532              | 0.9178 | 34                      |
| Embodiment 4         | Hexagonal twisted pipe                                       | D1=80, D2=95             | 15       | 800                           | 500                               |  | 1                                  | None                    | 0.7365              | 0.9968 | 39                      |
| Embodiment 5         | Hexagonal twisted pipe                                       | D1=80, D2=95             | 15       | 500                           | 500                               |  | 1.5                                | None                    | 0.7631              | 0.8723 | 39                      |
| Embodiment 6         | Hexagonal twisted pipe                                       | D1=20, D2=30             | 4        | 500                           | 500                               |  | 1                                  | None                    | 0.7045              | 1.1518 | 38                      |
| Embodiment 7         | Hexagonal twisted pipe                                       | D1=150, D2=165           | 15       | 500                           | 500                               |  | 1                                  | None                    | 0.7785              | 0.8032 | 36                      |
| Comparison Example 1 | Hexagonal twisted pipe (twisting towards the same direction) | D1=80, D2=95             | 10       |                               | 500                               |  | -                                  | None                    | 0.5712              | 1.9742 | 38                      |
| Comparison Example 2 | Hexagonal straight pipe                                      | D1=80, D2=95             | 10       | 0                             | 0                                 |  | 1                                  | Fouled, blocked         | -                   | -      | -                       |
| Comparison Example 3 | Triangular twisted pipe                                      | D1=80, D2=95             | 10       | 500                           | 500                               |  | 1                                  | None                    | 0.4820              | 2.7276 | 37                      |
| Comparison Example 4 | Elliptical twisted pipe                                      | D1=80, D2=95             | 10       | 500                           | 500                               |  | 1                                  | Blocked                 | -                   | -      | -                       |
| Comparison Example 5 | Hexagonal twisted pipe                                       | D1=15, D2=25             | 4        | 500                           | 500                               |  | 1                                  | Blocked                 | -                   | -      | -                       |
| Comparison Example 6 | Hexagonal twisted pipe                                       | D1=80, D2=84             | 10       | 500                           | 500                               |  | 1                                  | None                    | 0.7577              | 0.8970 | 21                      |
| Comparison Example 7 | Hexagonal twisted pipe                                       | D1=80, D2=100            | 10       | 500                           | 500                               |  | 1                                  | None                    | 0.7332              | 1.0129 | 28                      |
| Comparison Example 8 | Hexagonal twisted pipe                                       | D1=160, D2=175           | 15       | 500                           | 500                               |  | 1                                  | Slightly fouled         | 0.3408              | 4.6075 | 17                      |

**[0027]** It can be seen from the above table that the mixer of Comparison Example 1 has relatively high heat-exchange performance, but the fluid stirring of the hexagonal structure twisting towards the same direction is not as good as that of the mixer of Embodiment 1. Although the triangular twisted pipe mixer of Comparison Example 3 has relatively good heat-exchange effect, the mixing effect is not as good as that of the hexagonal twisted pipe. The hexagonal straight pipe and the elliptical twisted pipe are blocked and thus may not be measured. By the above analysis, the pipe-type mixer with the twisted pipe having the hexagonal cross section has relatively good effect.

**[0028]** By comparison of Embodiments 1 to 3, since the extremely high torque of the hexagonal twisted pipe of the material passage makes the space of the medium passage too small and then causes the mixer to be unable to work normally, the twisted pipe with the torque exceeding 800 mm is easily fouled, and an extremely low torque may reduce the mixing and heat-exchange effect. Therefore, the mixing and heat-exchange effects of the mixers of Embodiments 2 to 3 are not as good as that of the mixer of Embodiment 1. If the torque of the twisted pipe is within 300 to 800 mm, the mixing and heat-exchange effect is relatively good. If the torque exceeds this range, the twisted pipe is easily fouled or blocked, and the mass transfer and heat transfer effect is reduced.

**[0029]** For the material system with high solid content, prevention of blockage and fouling and enhanced mixing and heat exchange may be realized by changing the torques, lengths or hexagonal inscribed circle diameters of the two sections of twisted pipes and the diameter of the outer pipe. In Embodiment 4 and Embodiment 5, the torques and the lengths of the two sections of twisted pipes are respectively changed, while in Embodiment 7, the structural sizes of the inner pipe and the outer pipe are changed. It can be seen according to characterization results that the mixing and heat-exchange effect is close to that of Embodiment 1, so that the above various combinations may be flexibly selected according to specific situations in actual operation.

**[0030]** It can be seen from Embodiment 6 and Comparison Example 5 that for materials with high solid content and high viscosity and containing fibers, a too small hexagonal inscribed circle diameter easily causes blockage. It can be seen from Embodiment 1 and Comparison Examples 6 to 7 that under the condition of the same inner pipe, decrease or increase of the annular space between the inner pipe and the outer pipe has little impact on the mixing effect, but a too small annular space may lead to an insufficient temperature difference which is not enough to heat the material in the inner pipe, so the heat-exchange effect is reduced; and on the contrary, if the annular space is too large, the cooled heat-exchange medium may not flow out in time, which will also lead to an insufficient temperature difference, so the heat-exchange effect is also reduced, and meanwhile, higher energy consumption and cost also may be caused. It can be seen from Embodiment 7 and Comparison Example 8 that a too large hexagonal inscribed circle diameter may cause slight fouling, which damages a rotational flow pattern and increases heat-exchange heat resistance, thereby reducing the mixing effect and the heat-exchange performance. Based on the above, for a material with the TS of 4% to 10%, an inner pipe with  $D_1$  of 20 to 80 mm and an outer pipe with  $D_2$  of 30 to 95 mm are preferably used, and for a material with the TS of 10% to 15%, an inner pipe with  $D_1$  of 80 to 150 mm and an outer pipe with  $D_2$  of 95 to 165 mm are preferably used. Under the conditions of the above TS and pipe diameter, strong anti-fouling and anti-blockage functions and relatively high mixing effect and heat-exchange performance may be achieved, while the foregoing effects may be severely affected in case of relatively large deviations.

**[0031]** The specific implementations and implementation effects of the pipe-type mixer of the present invention are described above by only taking the pipe-type mixer with relatively simple design for example in combination with mixing performance characterization methods generally accepted in the professional field. However, the protection scope of the present invention is not limited thereto. Actually, the pipe-type mixer having a heat-exchange function, provided by the present invention, may be transformed into various specific structural forms according to the structural features. For example, a plurality of inner sleeve pipes are arranged in the outer sleeve pipe; the torques and the pipe diameters are changed according to different material systems, and a plurality of inner pipes uniformly twisting clockwise and inner pipes uniformly twisting anticlockwise are arranged and combined. If the combination of one section of inner pipe twisting clockwise along the pipe centre and one section of inner pipe twisting anticlockwise is used as one constituting unit, the inner sleeve pipe of the present invention also may comprise one or more constituting units. The pipe-type mixers formed by the above various transformations and combinations thereof shall all fall within the protection scope of the present invention.

## Claims

1. A pipe-type mixer, comprising an inner sleeve pipe taking a mixing action and an outer sleeve pipe taking a heat-exchange action, wherein the inner sleeve pipe is located inside the outer sleeve pipe; and the cross section of the inner sleeve pipe is a hexagon and is formed of a combination of an inner pipe twisting clockwise along the pipe centre and an inner pipe twisting anticlockwise.
2. The pipe-type mixer according to claim 1, wherein the cross section of the inner sleeve pipe is an equilateral hexagon.

3. The pipe-type mixer according to claim 1, wherein the centre axis of the inner sleeve pipe is straight or curved; and the inner sleeve pipe is formed of a combination of the inner pipe uniformly twisting clockwise along the pipe centre and the inner pipe uniformly twisting anticlockwise.
- 5 4. The pipe-type mixer according to claim 1, wherein a torque of the inner sleeve pipe, namely a pipe length corresponding to a pipe wall spirally deforming 360 degrees around the pipe centre axis, is 300 to 800 mm, preferably 500 to 800 mm.
- 10 5. The pipe-type mixer according to claim 1, wherein the inscribed circle diameter of the hexagonal cross section of the inner sleeve pipe is 20 to 150 mm, preferably 80 to 150 mm.
6. The pipe-type mixer according to claim 1, wherein a distance between the inscribed circle diameter of the inner sleeve pipe and the inscribed circle diameter of the outer sleeve pipe is 5 to 15 mm, preferably 10 to 15 mm.
- 15 7. The pipe-type mixer according to claim 1, wherein for the inner sleeve pipe, a length ratio of the inner pipe uniformly twisting clockwise along the pipe centre to the inner pipe uniformly twisting anticlockwise is (0.5-2): 1.
8. The pipe-type mixer according to claim 1, wherein a combination of one section of inner pipe twisting clockwise along the pipe centre and one section of inner pipe twisting anticlockwise is used as one constituting unit; and the inner sleeve pipe of the present invention may comprise one or more constituting units.
- 20 9. The pipe-type mixer according to claim 1, wherein the pipe-type mixer comprises a material mixing passage and a heat-exchange medium passage; the material mixing passage is composed of the inner sleeve pipe; two ends of the material mixing passage are respectively provided with a material inlet and a material outlet; the heat-exchange medium passage is composed of an annular space between the outer sleeve pipe and the inner sleeve pipe; and a heat-exchange medium inlet pipe and a heat-exchange medium outlet pipe are arranged on the heat-exchange medium passage or a heat-exchange medium main passage.
- 25 10. The pipe-type mixer according to claim 9, wherein the material inlet corresponds to the heat-exchange medium outlet pipe, and the material outlet corresponds to the heat-exchange medium inlet pipe.
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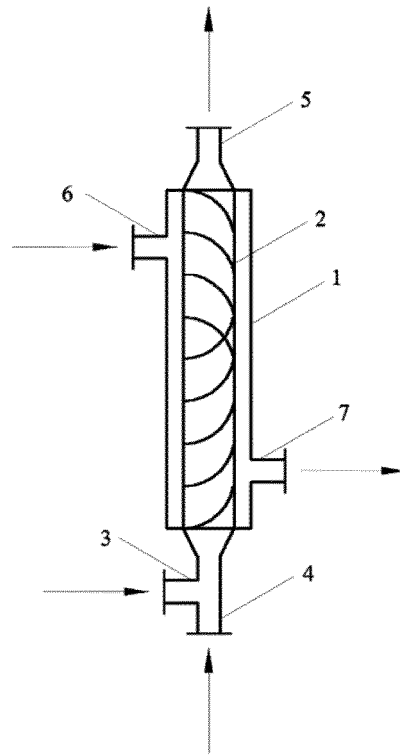


FIG. 1

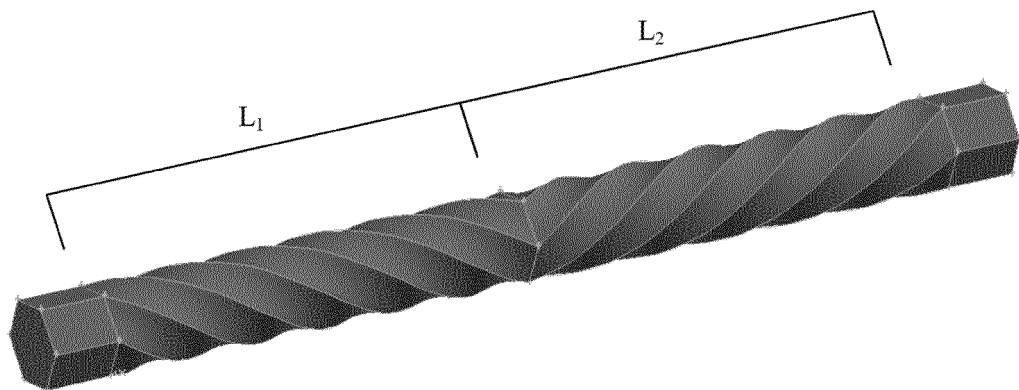


FIG. 2

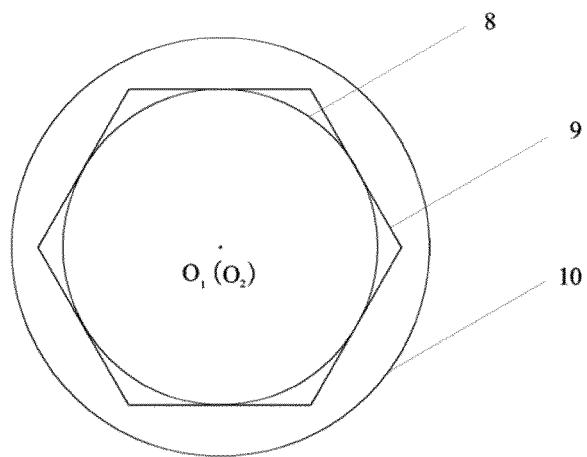


FIG. 3

## INTERNATIONAL SEARCH REPORT

International application No.  
PCT/CN2017/087364

## A. CLASSIFICATION OF SUBJECT MATTER

F28F 1/02 (2006.01) i; F28D 7/10 (2006.01) i  
According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

F28F 1; F28F 13; F28D 7

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

CNABS, VEN, CNKI: 混合, 管, 热交换, 换热, 螺旋, 扭曲, 左旋, 右旋, 内, 外, mixing, pipe, duct, tube, heat exchange, spiral, inner, outer, external, distort

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

| Category* | Citation of document, with indication, where appropriate, of the relevant passages                                                         | Relevant to claim No. |
|-----------|--------------------------------------------------------------------------------------------------------------------------------------------|-----------------------|
| A         | CN 205279802 U (EXTEK ENERGY EQUIPMENT (ZHEJIANG) LTD.) 01 June 2016 (01.06.2016), description, paragraphs [0037]-[0059], and figures 1-13 | 1-10                  |
| A         | CN 205860827 U (FOSHAN UNIVERSITY) 04 January 2017 (04.01.2017), entire document                                                           | 1-10                  |
| A         | CN 204268942 U (CHANGZHOU CHANGBAO JINGTE ENERGY PIPE CO., LTD.) 15 April 2015 (15.04.2015), entire document                               | 1-10                  |
| A         | CN 101112252 A (CAMPBELL FRANCE S A S) 30 January 2008 (30.01.2008), entire document                                                       | 1-10                  |
| A         | JP 2016161250 A (HINO MOTORS LTD.) 05 September 2016 (05.09.2016), entire document                                                         | 1-10                  |
| A         | JP 03241290 A (NORITAKE CO., LTD.) 28 October 1991 (28.10.1991), entire document                                                           | 1-10                  |

☐ Further documents are listed in the continuation of Box C. ☒ See patent family annex.

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|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------|
| Date of the actual completion of the international search<br>08 February 2018                                                                                                                                 | Date of mailing of the international search report<br>05 March 2018  |
| Name and mailing address of the ISA<br>State Intellectual Property Office of the P. R. China<br>No. 6, Xitucheng Road, Jimenqiao<br>Haidian District, Beijing 100088, China<br>Facsimile No. (86-10) 62019451 | Authorized officer<br><br>YANG, Yi<br>Telephone No. (86-10) 62084859 |

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# **INTERNATIONAL SEARCH REPORT** **Information on patent family members**

International application No.  
PCT/CN2017/087364

| Patent Documents referred<br>in the Report | Publication Date  | Patent Family      | Publication Date |
|--------------------------------------------|-------------------|--------------------|------------------|
| CN 205279802 U                             | 01 June 2016      | None               |                  |
| CN 205860827 U                             | 04 January 2017   | None               |                  |
| CN 204268942 U                             | 15 April 2015     | None               |                  |
| CN 101112252 A                             | 30 January 2008   | DE 602007004781 D1 | 01 April 2010    |
|                                            |                   | MX 2007008461 A    | 18 December 2008 |
|                                            |                   | US 2008017623 A1   | 24 January 2008  |
|                                            |                   | NZ 556480 A        | 28 February 2009 |
|                                            |                   | FR 2903861 B1      | 15 April 2011    |
|                                            |                   | EP 1886586 A1      | 13 February 2008 |
|                                            |                   | AT 457657 T        | 15 March 2010    |
|                                            |                   | RU 2007127618 A    | 27 January 2009  |
|                                            |                   | JP 2008022850 A    | 07 February 2008 |
|                                            |                   | CA 2593998 A1      | 24 January 2008  |
|                                            |                   | HK 1113063 A1      | 16 July 2010     |
|                                            |                   | FR 2903861 A1      | 25 January 2008  |
|                                            |                   | AU 2007203180 A1   | 07 February 2008 |
|                                            |                   | EP 1886586 B1      | 17 February 2010 |
| JP 2016161250 A                            | 05 September 2016 | None               |                  |
| JP 03241290 A                              | 28 October 1991   | JP 3100051 B2      | 16 October 2000  |
|                                            |                   | JP H03241290 A     | 28 October 1991  |

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**REFERENCES CITED IN THE DESCRIPTION**

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**Patent documents cited in the description**

- CN 201510185307 [0003]
- CN 201510305639 [0004]