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(54) **EQUIPMENT FOR WASHING THE FLOATING PLASTIC WASTE USING ULTRASOUND**

(57) The invention relates to an ultrasonic washing equipment for washing the floating plastic waste whose density is lower than the density of the washing liquid. The equipment of the present invention comprises a plastic waste washing tank (1) consisting of individual metal segments of rectangular cross-section (1.1, 1.2, 1.3) having ultrasonic modules arranged inside; a spiral conveyor (6) with a container (7) for feeding plastic waste into the washing tank (1), directed at an angle of 60° from the top down to the bottom of the washing tank (1); a screw conveyor (8) for unloading the washed plastic waste from the washing tank (1), arranged at the top of the washing tank (1); deflecting plates (11) to passively slow down the upward movement of the plastic waste in the washing tank (1) and to direct the flow of the rising plastic waste closest to the cavitation zone generated by the ultrasonic modules; an output (12) for the removal of dirt accumulated at the bottom of the washing tank (1) during the washing of plastic waste; an inlet (13) for refilling the liquid in the washing tank (1).

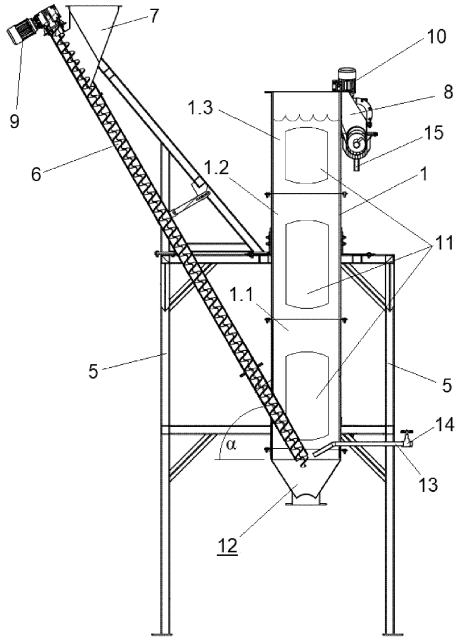

Fig. 2

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Description

TECHNICAL FIELD

[0001] The invention relates to the field of washing the plastic waste, specifically to an equipment for washing the floating plastic waste using ultrasonic cavitation.

PRIOR ART

[0002] Ultrasonic washing technology is widespread in the world, also in the field of washing plastic waste. Chinese patent application No. CN108160606 describes an equipment for ultrasonic cleaning of polyester fragments. The equipment comprises a rack on four supports consisting of a frame formed from transverse beams. The equipment further comprises a cylinder for washing of polyester waste, the cylinder being filled with washing liquid and placed on a rack, the lower part of the cylinder is surrounded by an ultrasonic generator. At the bottom of the washing cylinder there is a tunnel-shaped guide to direct the washed polyester waste to a screw discharge conveyor mounted at the bottom of the washing cylinder, directed at an angle of 60° from the bottom of the washing cylinder to the top, the discharge end of which is well above the top of the washing cylinder and which removes the washed polyester waste from the washing equipment.

[0003] The polyester waste to be washed is fed into the ultrasonic cylinder from above. Under the influence of gravity, the waste slides down the liquid-filled washing cylinder, where the cavitation caused by the ultrasonic generator washes the polyester waste. The washed polyester waste is removed through the bottom of the unit by a screw conveyor outside the washing equipment.

[0004] The equipment is perfectly suited for washing polyester waste heavier than the washing liquid. The main disadvantage of this equipment device occurs when it is necessary to wash floating plastics whose density is lower than the density of the washing liquid. The problem is that ultrasound induced cavitation only occurs in high-density environments such as water or other liquids, while materials with a lower density than the liquid remain floating on the surface of the water. For this reason, materials such as polyethylene waste must somehow be kept fully submerged in the liquid for an appropriate period of time in order to properly subject them to the cavitation-induced vibrations and thereby separate the impurities from their surface. In addition, cavitation does not work in intense liquid flow, so the feeding of the material to be washed into the liquid must be at a low flow without causing liquid flow turbulence.

SUMMARY OF THE INVENTION

[0005] The object of this invention is an equipment for washing the fine floating plastic waste with a density lower than water, such as PE film chips, using ultrasound-induced cavitation and vibrations. The equipment comprises:

- a vertical metal segmental plastic waste washing tank with a rectangular cross-section, having ultrasonic plastic waste washing modules installed inside,
- a frame supporting the plastic waste washing tank,
- a spiral conveyor for feeding plastic waste into the washing tank from the bottom of the tank,
- a container for plastic waste installed at the top end of the plastic waste spiral feeding conveyor,
- a screw conveyor for the discharging the washed plastic waste that has risen to the surface of the washing tank,
- engines of the first and second conveyors,
- deflectors installed inside each segment of the plastic waste washing tank between the ultrasonic modules, designed to slow down the rise of plastic waste through the washing liquid to the top of the washing tank and direct the flow of the plastic waste rising up the washing tank closest to the zone of cavitation/vibration generated by ultrasound,
- an outlet for the removal from the washing tank of dirt separated and settled to the bottom of the washing tank during the washing of the plastic waste,
- an inlet for replenish the plastic waste washing tank with washing liquid.

[0006] The speed of the conveyor drives for feeding plastic waste to and from the washing tank and, at the same time, the efficiency of the plastic waste washing equioment are controlled by the conveyors' motors. The length, diameter and horizontal angle of the spiral plastic waste feeding conveyor are selected so that the upper part of the spiral feeding conveyor is above the vertical plastic waste washing tank filled with water or any other kind of the washing liquid. In the optimal case, the angle of inclination of the spiral plastic waste feeding conveyor with respect to the horizontal is about 60°. This prevents the washing liquid from entering the upstream plastic waste processing steps, such as shredding. The spiral plastic waste feeding conveyor and the plastic waste washing tank are intercommunicating vessels, so the water level in the spiral plastic waste feeding conveyor is the same as that in the plastic waste washing tank.

[0007] The invention relates to floating plastics whose waste density is lower than that of water. Therefore, the plastic waste, fed by the spiral feeding conveyor into the plastic waste washing tank from below, automatically rises to the surface of the washing liquid. Processes with a washing effect are used to wash the rising plastic waste, in this case the ultrasonic cavitation/vibration washing, realized by ultrasonic modules installed inside the washing tank and attached to the two opposite inner surfaces of each segment of the washing tank, is used. The ultrasonic modules are electrically connected to the ultrasonic generators installed outside the washing equipment in a

separate cabinet.

[0008] In order for the floating plastic waste to be qualitatively processed by ultrasound, it must be in the intense ultrasound field for a sufficient amount of time, i.e. from one to several minutes. As the researches have shown, one of the main technical problem that hinders the effective ultrasonic treatment of the floating plastic waste is the rapid rise to the water surface of plastic waste particles placed in water in the ultrasonic field. In order for the plastic waste to remain in the washing tank for the optimal processing time, the plastic waste can be shredded to particles smaller than 20 mm, thus slowing down to acceptable value the spontaneous movement of the plastic waste up the liquid. However, such plastic shredding turned out to be technologically too expensive. Therefore, it was decided to install additional structural elements that passively slow down the rise of the plastic waste up the washing tank and direct the plastic waste towards the ultrasonic modules, i.e. closest to the cavitation zone generated by ultrasound. In this way, sufficient plastic waste processing time and, at the same time, more efficient ultrasonic treatment of the plastic waste is ensured.

[0009] The cavitation bubbles formed during the ultrasonic treatment of the plastic waste reduce the adhesion of pollutants, including fats, to the plastic waste. In this way, the dirt is separated and removed from the surface of the washed plastic waste.

[0010] The washed and surfaced plastic waste is discharged from the washing tank by a screw conveyor installed at the top of the plastic waste washing tank and being in liquid communication with the plastic waste washing tank. The dirt separated from the surface of the plastic waste and accumulated at the bottom of the plastic waste washing tank is removed from the plastic waste washing tank through the outlet installed at the bottom of the plastic waste washing tank, using a system of two sequentially opened shutters.

[0011] As mentioned, the screw conveyor for discharging the washed plastic waste from the washing tank is installed at the top of the plastic waste washing tank. The upper end of the screw discharge conveyor is raised above the level of the liquid in the plastic waste washing tank and raised so that the discharge conveyor forms an angle of about 10° with the horizontal. An additional shower washing of plastic waste can be applied to the upper part of the discharge conveyor for additional washing/rinsing of the plastic waste. The dirty water is removed through a nipple at the bottom end of the screw discharge conveyor connected to a water removal hose.

DESCRIPTION OF DRAWINGS

[0012] The invention will further be described in more detail with reference to the accompanying drawings, wherein:

Fig. 1 is a general view of the equipment of the present invention for the ultrasonic washing of the plastic waste;

Fig. 2 is a cross-sectional side view of the plastic waste ultrasonic washing equipment of the present invention;

Fig. 3 1 is a cross-sectional view of the plastic waste ultrasonic washing tank of the present invention through the line A-A of fig. 1.

DETAILED DESCRIPTION OF THE INVENTION

[0013] As shown in the figures, the ultrasonic equipment for washing of the floating plastic waste with a density lower than water, such as, for example, polyethilene (PE) film chips, comprises:

- a vertical metal segmental plastic waste washing tank 1 of rectangular cross-section, assembled from separate segments 1.1, 1.2 and 1.3 vertically connected to each other by screw connections, with integrated plastic waste ultrasonic washing modules 2, 3 and 4,
- a frame 5 for supporting the plastic waste washing tank 1,
- the spiral conveyor 6, directed from above diagonally down to the bottom of the plastic waste washing tank 1, for feeding the plastic waste into the washing tank 1 from the bottom of the tank 1,
- plastic waste loading container 7, installed at the upper end of the plastic waste spiral feed conveyor 6 and being in liquid communication with the plastic waste spiral feeding conveyor 6,
- the screw conveyor 8 for the discharging the washed plastic waste that has risen to the surface of the washing tank 1,
- engines 9 and 10 of the first and second plastic waste feeding and discharging conveyors 6 and 8,
- deflecting elements 11 installed inside each segment 1.1, 1.2, 1.3 of the plastic waste washing tank 1 between the ultrasonic modules 2, 3, 4, designed to slow down the rise of plastic waste through the washing liquid to the top of the washing tank 1 and direct the flow of the plastic waste rising up the washing tank 1 closest to the zone of cavitation/vibration generated by ultrasound modules 2, 3, 4,
- an outlet 12 for the removal from the washing tank 1 of dirt separated and settled to the bottom of the washing tank 1 during the washing of the plastic waste,
- an inlet 13 for replenishing the plastic waste washing tank 1 with washing liquid.

[0014] As shown in the attached figures, the tank 1 for ultrasonic cleaning of plastic waste is assembled from separate segments 1.1, 1.2 and 1.3, vertically connected to each other by screw connections with spacers, mounted on a supporting frame 5. Assembling the washing tank 1 from separate segments 1.1, 1.2, 1.3 allows, in the

event of a breakdown or technical service, after draining the plastic waste washing liquid from the washing tank 1, to carry out the necessary maintenance or repair work. The number of segments 1.1, 1.2, 1.3 may vary depending on the desired efficiency of the plastic waste washing equipment.

[0015] The speed of gears of the spiral 6 and screw 8 conveyors and, at the same time, the efficiency of the plastic waste washing equipment is controlled by motors 9 and 10 of both conveyors. A spiral conveyor 6, having a spiral 6a placed inside a cylindrical body 6b, is used to feed the plastic waste into the washing tank 1. The spiral 6a of the feeding conveyor 6 is made of a thick twisted wire of rectangular cross-section. Since the spiral screw is a hollow structural element, the use of the feeding conveyor 6 of such a structure with the spiral 6a inside the cylindrical body 6b prevents the clogging of the feeding conveyor 6 with the plastic waste.

[0016] The length, diameter and inclination angle of the plastic waste spiral feeding conveyor 6 are selected so that the upper end of the plastic waste feeding conveyor 6 is above the vertical plastic waste washing tank 1 filled with water or any other kind of washing liquid. In the optimal case, the angle α of the inclination of the spiral feeding conveyor 6 with respect to the horizontal is about 60°. This prevents the washing liquid in the washing tank 1 from entering the upstream plastic waste processing steps, such as shredding. The spiral plastic waste feeding conveyor 6 and the plastic waste washing tank 1 are intercommunicating vessels, so the water level in the spiral plastic waste feeding conveyor 6 is the same as that in the plastic waste washing tank 1.

[0017] The density of the floating plastic waste, major part of which consists of PE films, is about 920 kg/m^3, i.e. is smaller than that of water, so the plastic waste fed by the spiral feeding conveyor 6 to the bottom of the plastic waste washing tank 1 automatically rises to the surface of the washing liquid. To wash the rising plastic waste, the ultrasonic cavitation generated by ultrasound modules 2, 3 and 4 is used. The ultrasonic modules 2, 3, 4 are tightly installed in stainless steel housings attached to inner surfaces of the two opposite walls of segments 1.1, 1.2 and 1.3 of the plastic waste washing tank 1, and are electrically connected to ultrasonic generators installed outside the washing equipment in a separate cabinet. The design of the plastic waste washing tank 1 was chosen so that it was possible to attach the ultrasonic modules available on the market to the walls of the washing tank segments 1.1, 1.2, 1.3 and create a power of about 10W/l, which corresponds to the power used by most manufacturers of ultrasonic cleaning equipment.

[0018] In order for plastic waste to be qualitatively processed by ultrasound, it must be in the intense ultrasound field for a sufficient amount time, i.e. from one to several minutes. The equipment, as it has been mentioned, relates to the washing of floating plastic waste whose density is lower than that of water or other washing liquid. The main technical problem that hinders the effective ultrasonic treatment of the floating plastic waste is the rapid rise to the surface of plastic waste placed in water in the ultrasonic field. During the development of the plastic waste ultrasonic washing equipment of the present invention, several methods were evaluated to slow down to acceptable values the spontaneous movement of the plastic waste up the washing liquid. One of them was to crush the plastic waste to particles smaller than 20 mm, thereby slowing down the spontaneous movement of the plastic waste up through the liquid. However, such shredding turned out to be technologically too expensive. Another method for controlling the upward movement of plastic waste, which was evaluated during the development of the device prototype, was the placement of a horizontally rotating propeller in the lower segment of the plastic waste washing tank between the lower ultrasonic modules. A digital model of the equipment thus modified showed that mixing of the plastic waste washing liquid can reduce the upward movement of the plastic waste particles to the surface by about 10 times. However, it was discovered that the efficiency of cavitation and, at the same time, the washing quality in intensive liquid flow significantly decreases, and the material feeding into the liquid must be at a low flow rate, without causing liquid flow turbulences.

[0019] Therefore, it was decided to install additional deflecting elements 11, which passively slow down the rise of plastic waste up the washing tank 1 and additionally direct the plastic waste towards the ultrasonic modules 2, 3, 4, i.e. closest to the cavitation zone generated by ultrasound. The deflecting elements 11 consist of deflecting plates 11 installed in pairs inside the washing tank 1 in each segment 1.1, 1.2, 1.3 between the ultrasonic modules 2, 3, 4. The deflecting plates 11 are inclined so as to form an angle β between 15-20° with respect to the vertical, and their upper ends are directed in opposite directions from each other towards the respective ultrasound modules 2, 3, 4. Such construction of the deflecting plates 11 creates a passive barrier to the upward movement of the flow of plastic waste within the washing liquid and additionally directs the flow of plastic waste closer to the ultrasonic modules 2, 3, 4. In this way, sufficient plastic waste processing time and more efficient ultrasonic processing of plastic waste are ensured. The cavitation vacuum bubbles formed in the plastic waste washing liquid during the ultrasonic treatment of the plastic waste reduce the adhesion of pollutants, including fats, to the plastic waste. Thus, the dirt is separated and removed from the surface of the washed plastic waste.

[0020] The screw conveyor 8, that is designed to discharge the plastic waste that has risen to the surface of the washing tank 1, is installed at the top of the plastic waste washing tank 1 and is in liquid communication with the plastic waste washing tank 1. The upper discharge end of the screw conveyor 8 is raised slightly above the level of the washing liquid in the plastic waste washing tank 1 and lifted up so that the screw conveyor 8 forms

an angle of about 10° with the horizontal. Such a design ensures that the washing liquid in the screw discharge conveyor 8 does not go outside but remains inside the washing tank 1.

[0021] According to the results of laboratory measurements, the humidity of the plastic waste fed into the washing tank 1 is in the range of 1-2%, while the humidity of the washed and discharged plastic waste reaches 57-76%. Since a part of the washing liquid in the plastic waste washing tank 1 is removed together with the discharged plastic waste, the washing liquid is constantly manually added to the tank 1 through the washing liquid inlet 13 with the help of the valve 14.

[0022] An additional shower washing of the plastic waste can be applied to the upper part of the discharge conveyor 8 for additional washing/rinsing of the plastic waste. The dirty water is removed through a nipple 15, arranged at the bottom end of the screw discharge conveyor 8, connected to a water removal hose.

[0023] The dirt separated during ultrasonic cavitation from the surface of the plastic waste and accumulated at the bottom of the washing tank 1 is periodically removed from the plastic waste washing tank 1 through the outlet 12, arranged at the bottom of the plastic waste washing tank 1, using a two-valve system.

Claims

1. An equipment for ultrasonic washing of floating plastic waste, comprising a plastic waste washing tank arranged on a supporting frame, conveyors for feeding plastic waste into the washing tank and discharging the plastic waste from the washing tank, ultrasound generating devices, **characterised in** comprising

   - a vertical plastic waste washing tank (1) assembled from separate metal segments (1.1, 1.2, 1.3) of rectangular cross section vertically connected to each other by screw connections and having ultrasonic plastic waste washing modules (2, 3, 4) attached to internal surfaces of the opposite walls of each segment (1.1, 1.2, 1.3),
   - a spiral conveyor (6) with a container (7) for feeding the floating plastic waste into the washing tank (1), directed at an angle of about 60° from the top diagonally down to the bottom of the plastic waste washing tank (1),
   - a screw conveyor (8) for discharging the washed plastic waste from the washing tank (1), installed at the top of the plastic waste washing tank (1) and being in liquid communication with the plastic waste washing tank (1),
   - deflecting elements (11) installed inside each segment (1.1, 1.2, 1.3) of the plastic waste washing tank (1) between the ultrasonic modules (2, 3, 4), designed to passively slow down the rise of the floating plastic waste through the washing liquid to the top of the washing tank (1) and direct the flow of the plastic waste rising up the washing tank (1) closest to the zone of cavitation/vibration generated by the ultrasound modules (2, 3, 4),
   - an outlet (12) for the removal from the washing tank (1) of dirt separated and settled to the bottom of the washing tank (1) during the washing of the plastic waste,
   - an inlet (13) for refilling the plastic waste washing tank (1) with washing liquid.

2. The equipment according to claim 1, **characterised in that** the upper end of the discharge screw conveyor (8) is raised slightly above the level of the washing liquid in the plastic waste washing tank (1) so that the screw conveyor (8) forms an angle of about 10° with the horizontal.

3. The equipment according to claim 1, **characterised in that** the deflecting elements (11) are deflecting plates (11) installed in pairs inside in the each segment (1.1, 1.2, 1.3) of the washing tank (1) between the ultrasonic modules (2, 3, 4) and inclined vertically at an angle β with their upper ends directed towards the respective ultrasound modules (2, 3, 4).

4. The equipment according to claim 2, **characterised in that** the angle β is in the range between 15-20°.

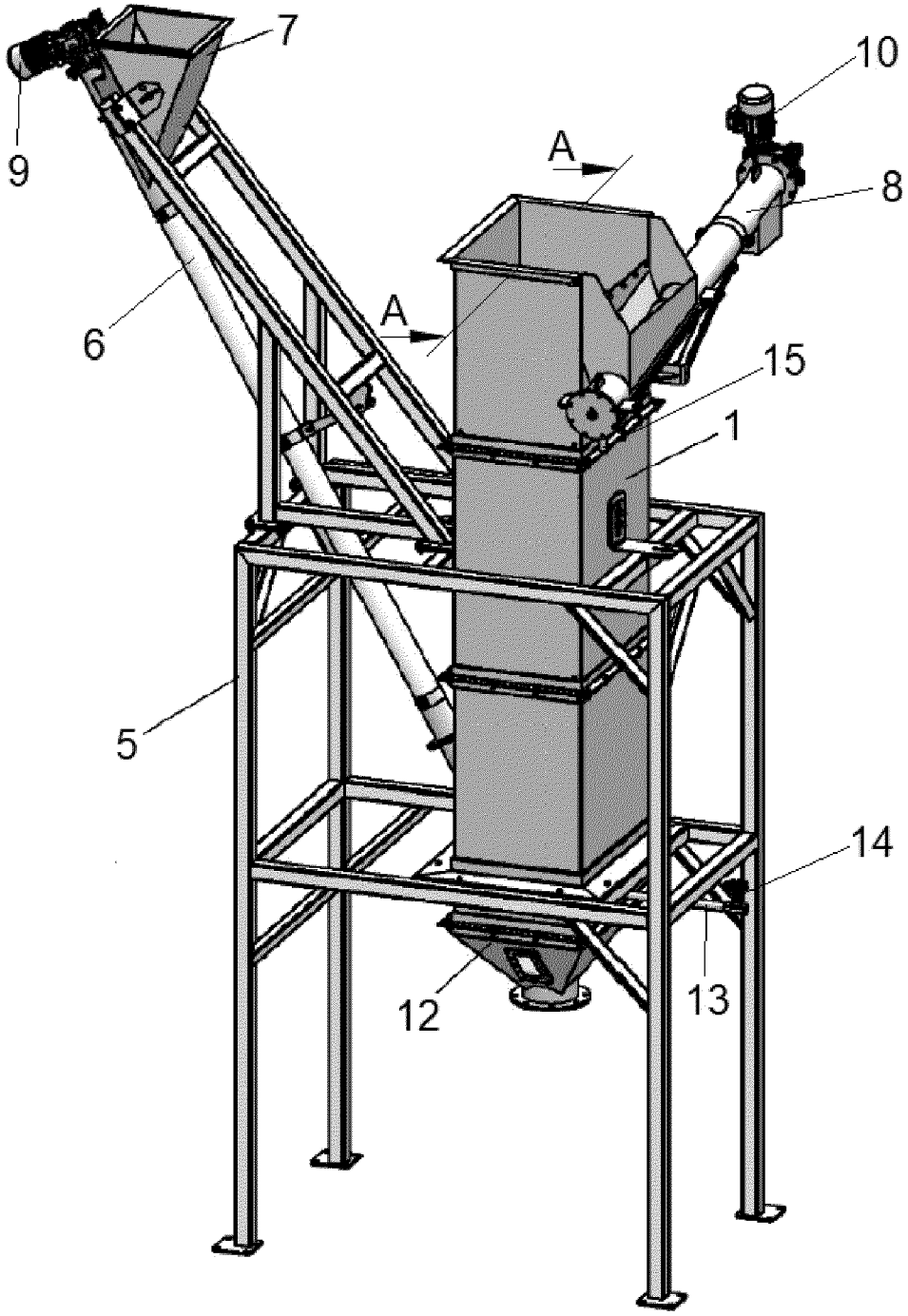

Fig. 1

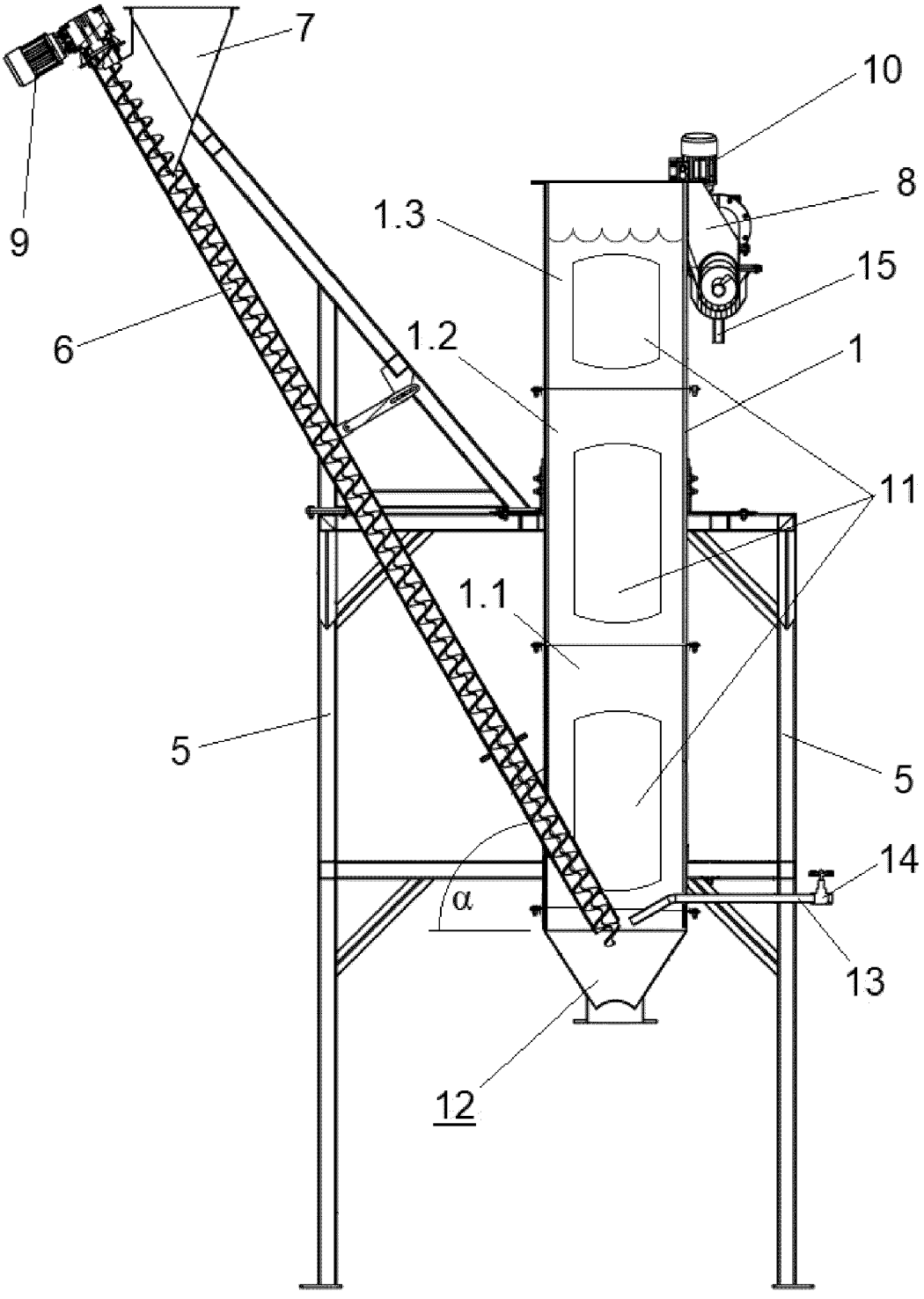

Fig. 2

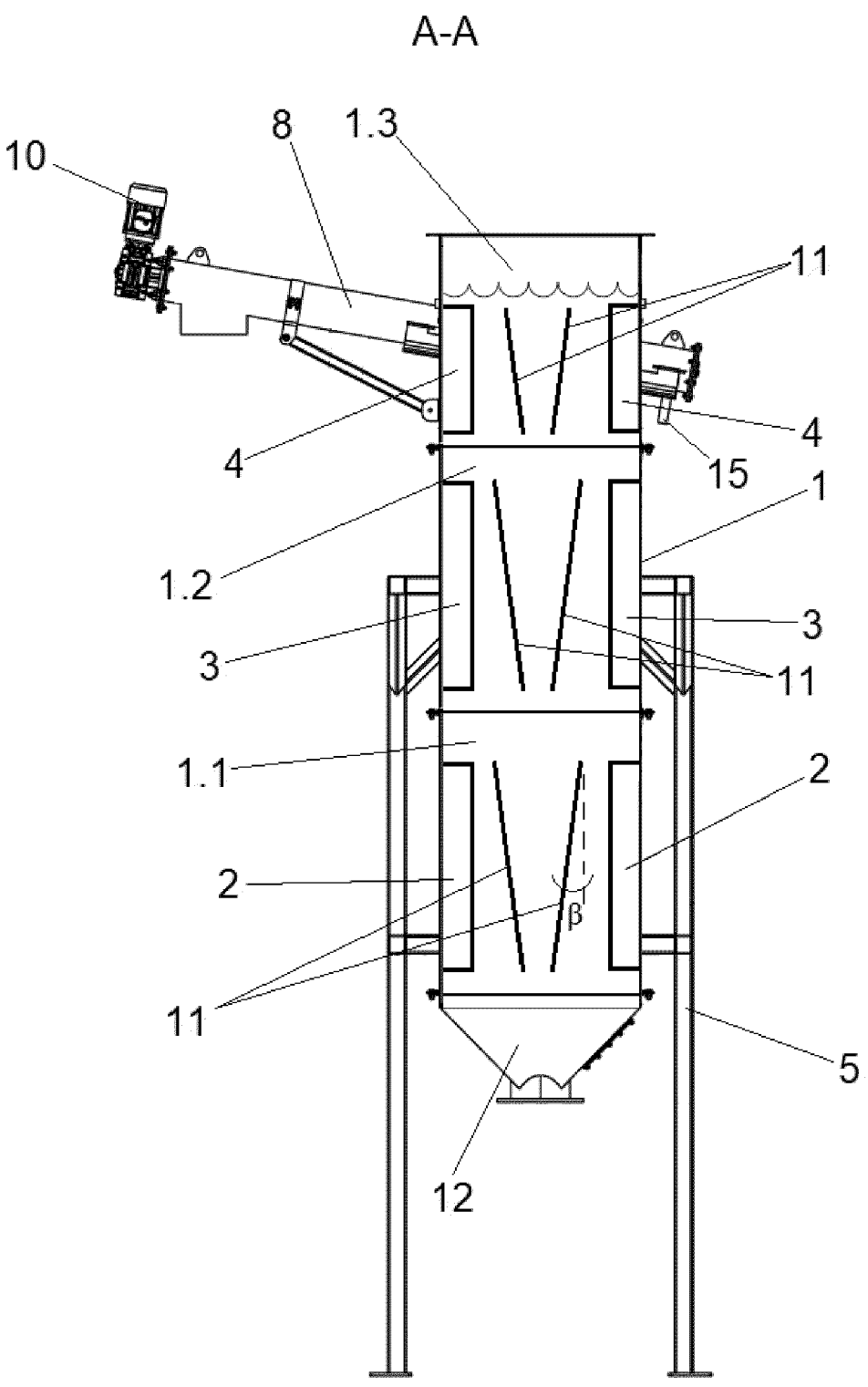

Fig. 3

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- CN 108160606 **[0002]**