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The Integrated Vortex-Grid Clarification Process and its Application

Tong Zhengong
School of Civil Engineering of East China Jiaotong University, Nanchang, 330013, China

Abstract: Based on Micro-vortex coagulation and Hazen theory, the process of integrated vortex grid clarification bears four characteristics. Firstly, there are a lot of micro-whirling reactors whose surfaces hole rate is designed by the raw water quality in the first and second flocculation zone. Then, an inclined-tube in the precipitate zone is installed. Thirdly, a sludge concentration zone in the tank is also equipped. Lastly, by applying the low return or non-return technologies and changing some inner structure which will reduce the total energy cost. We have not only achieved a more efficient use of the cubage of the reactors, but also reduced the total energy consumption. The paper argues that in comparison to other clarification technology, the Micro-vortex clarification process deserves wide application for its various advantages, such as a higher coagulation efficiency, a shorter reactivity time, a better quality of finished water, a stronger adaptive capability, a more convenient construction and the like.

Key words: Micro-vortex flocculation, clarification ,water quality, integration

INTRODUCTION

To safeguard the security of drinking water and improve the quality of drinking water comprehensively, the supply of high quality tap water for the general residents has embodied our government's desire to carry out the scientific outlook on development. Presently, our country urban water supply industry is confronted with pressure in the improvement of the polluted water sources and the enhancement of water quality standards. In combination with the current economic situation, improving and strengthening the tradition water purification processing craft is one of the economical and effective technological means for water plants to enhance water yield and improve effluent quality. In the 1970s and 1980s, a lot of waterworks in China built clarification tanks that was integrated water purification structures including mix, flocculation and precipitation. Nowadays, many clarification tanks are posing some problems such as aging, low water production, high energy consumption and poor water quality and so on, which falls far behind the users' demand for water and water quality.

In coagulation dynamics, foreign water treatment experts (Carlson, *et al*., 2000)make research mainly into the quantitative relationship of the flocculation speed, structure density, hydraulic conditions with the floc rupture to explore the best mixing intensity and the best flocculation time. Suspended sludge, sludge recycle and discharge and automatic control of clarification tanks are the priority in the research of transforming clarification tanks. The research shows that a high concentration of return sludge can form two solid-liquid systems with a better flocculation, a high density, and a good separation performance (Volk *et al*., 2002).The patented product Actiflo& reg high speed sedimentation tank by OTV-Kruger, a subsidiary company of French Veolia and the patented products high density clarification tank (DENSADEG) by French Degremont Corporation, have been widely used in Europe (Shi and Kong, 2007), which have many advantages such as a higher sedimentation efficiency, a better effluent water quality, a lower operation cost, a smaller size, a bigger capacity against the impact resistance and so on. Nevertheless, they also expose some shortcomings. Besides a quite dispersive arrangement and a higher investment cost due to the relatively high prices of equipments and materials for patented products, the guide wall built additionally between flocculation and sedimentation cannot totally avoid uneven distribution of water which affects the quality of water. The Domestic transformation technique for clarification tanks mainly includes the following three parts (Zhou *et al*., 2008): Firstly, add grid in the original reaction chamber to enhance the effect of reaction; Secondly, install the inclined tubes in the sedimentation areas to improve the precipitation efficiency. Thirdly , add the sludge collectors and other equipments in the bottom of the tank to alter sludge device. In combination with the advantages of mechanical agitation clarification tank and Degremont high density sedimentation tank, Shanghai Municipal Engineering Design General Institute invented the centrally placed high density sedimentation tank process (SMEDI-I, SMEDI-II high density clarification tank). Currently, reflux pumps, the mixers and other mechanical devices need to be added for the domestic products because of the high construction costs; and problems like anticorrosion of the equipments should also be considered in high-corrosion water treatment.

In order to improve the performance of clarification tank, develop its applicable scope, enhance the efficiency of flocculation process, the ability of anti impact and the effect of movement, save investment and decline water operation cost, it is necessary to develop one kind of more optimal economical efficient clarification technologies, and take into account structural styles, constructing conditions and operation management conditions.

THE INTEGRATED VORTEX CLARIFICATION PROCESS

The integrated vortex clarification process is proposed on the basis of micro-vortex coagulation and Hazen theory which mainly involves technologies including micro-vortex coagulation, inclined plate/tube sedimentation separation and sludge thickening, with an overall consideration of structural styles, constructing conditions and operation management conditions. The structure of clarification tank is shown in Fig. 1. Flowing out of piping mixer, the raw water with coagulant goes through the inlet branch (12) into the bottom of the tank. Through the re-equipped nozzle (9) and the shorter throat (8) it arrives at the water distribution trumpet-shaped object and runs into the first vortex reaction chamber (5). After the transition zone it pours down into the second vortex reaction chamber (6).Then it outflows from the bottom of the second chamber to the buffer area (7). and the floc with good sedimentation effect is concentrated in sludge thickening zone (10) while the clear water is further conducted the solid-liquid separation through the inclined-tube (4) installed in the precipitation zone. From the clear water zone (3) for well-proportioned water distribution, the separation water flows into the ring shaped collection launder (2) placed on the outer wall of the tank. A little of concentrated sludge in the sludge thickening zone refluxs to the first reaction chamber through the throat whose backflow quantity can be controlled by the operating lever (1)set on the top of the tank, while most of the sludge discharges outside by the symmetrical ring discharge sludge tube (11) in the bottom of the tank. The main characteristics of integrated vortex clarification process are as follows:

First, vortex-grid flocculation reactors, which are developed from the integrated application of vortex theory and the small grid flocculation technology, are installed in the flocculation units referring to the inside room of the first and the second vortex reaction chamber (Fig. 2). The flocculation reactor is made of a net hollow sphere shaped by arc-shaped solid ropes with a certain roughness. Latticed holes of similar sizes are set on the spherical surface, with an opening ratio 50% to 70%, and both the inside and outside of the spherical surface have a little roughness. The rising velocity of flow of the first vortex reaction chamber is 50~90m/h, and the opening ratio of vortex grid reactor is 55%~70%, with the counterparts of the second vortex reaction chamber being 30~70m/h and 50%~65%. Since the vortex reaction time of every reaction chamber, the height of vortex zone and the sequence of combination matching of vortex grid flocculation reactor are designed in regard to raw water quality, in the process of micro-vortex coagulation, the velocity and direction of water flow of the vortex grid flocculation reactors will

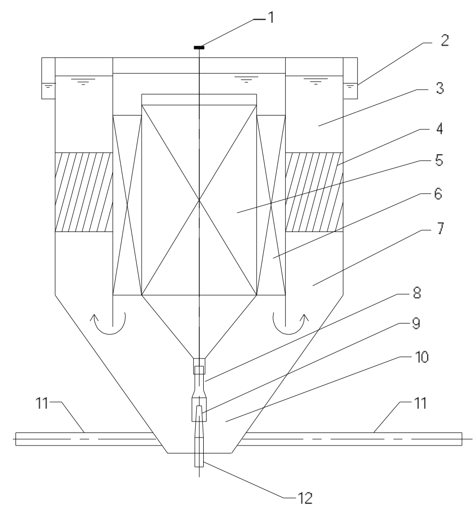

Fig. 1: The schematic diagram of the highly effective integrated vortex clarification reactor

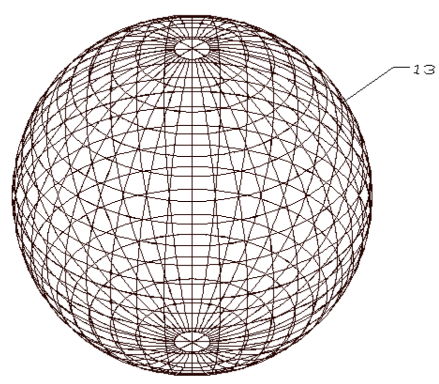

Fig. 2: The structure diagram of vortex-grid flocculation reactor

change when water goes through holes. Furthermore, the frictional resistance of the surface of net solid rope causes micro-vortex flow, and a large number of micro- vortex flows can promote proliferation and collision of the particles effectively in water. On the one hand, the colloid formed by the hydrolization of coagulant diffuses quickly under the influence of micro- vortex flow, and collides adequately with the colloid in water, making the colloid in water escape steadily fast. On the other hand, the bigger velocity difference among flow layers caused by vortex grids leads to relative movement of the carrying particles in the flow layer; meanwhile the centrifugal inertial force aroused by the turning effort of vortex flow brings about radial movement of particles along the vortex, thus offering more collision opportunities for the unstable colloid in water under the influence of micro-vortex flow and contributing to a higher condensation efficiency. At the same time, the vortex-grid flocculation reactor can make smaller movements in water under the influence of water flow, so the netted holes of the reactor surface is not easy to stop up. When a large number of vortex reactors are placed in the reaction zone, because of relatively small flow velocity in the reactor, the massive larger flocs (alum) accumulate in the vortex grid reactor and then suspend in the water, which adsorb and flocculate unstable colloid in the water, and the absorbed floc particles then adsorb the flocs in the water again. Under the influence of vortex flow, excessive large flocs are broken into smaller flocs with remaining flocculating capacity and low density flocs will be broken and re-flocculated into higher density flocs in favor of the separation of precipitation. Three-dimensional contact flocculation can remove colloid in water effectively, and the flocs in the lumen of the vortex-grid flocculation reactor can maintain for a long time. then floc sludge outside the reactor can be removed completely, so the sludge discharge operation is simplified, and the movement is more stable.

Second, inclined-tube (-plate) settlers are installed in clarification/separation chambers, which has strengthened sedimentation of small particles, ensured precipitation effect and perfected clarification efficiency of the clarification tanks, with high surface hydraulic load (design according to 7~15m3/m2•h).

Third, sludge thickening units are added, which can complete sludge thickening effectively, and the density of discharge sludge is high (solid content can reach 1%~3%). It can also decrease the pressure of sludge treatment facilities, and reduce sludge disposal costs.

Fourth, apart from the reduction of the length of the throat and the flow velocity of nozzle, the low return or non-return technologies are adopted in the system (returning control is 0~ 50%), which, on the one hand, increases the utilization rate of the volume of the first reaction chamber, on the other hand, reduces head loss and energy consumption.

PROJECT APPLICATIONS

Reconstruction extension project of South City Water Supply Plant of Jimo water supply company in Shandong Province: The treatment scale of former hydraulic circulating clarifier in the waterworks is 10000m3/d (actual water yield is 7000 m3/d). After the reform of the vortex clarification technology, the water production increases to 15000 m3/d, and the turbidity of Clarified effluent remains below 3NTU.

Main technical improvements

- The partition wall between flocculation chamber and sedimentation zone is extended to increase the volume between them and thus enhance its utilization ratio;
- Install vortex reactors into the first and second flocculation chambers to enhance flocculation effects through the eddy and contacting flocculation;
- Non-toxic PVC inclined tube is added in the precipitation zone;
- Reduce energy by reducing the reflux ratio of the circulator clarifier, shortening the length of throat and reducing the exit velocity of nozzle;
- The ring perforation discharge sludge tubes are added in the bottom of the tank and assist high pressured recoil washing water tube in cleaning accumulation sludge at the bottom of the tank.

Effects of implementation and operation: After the reformation, the water yield is more than twice as much as that of the former tank, while the ton water investment increases less than 30 Yuan. So far, it has run stably two years, and the effluent quality has been enhanced markedly, with the pre-filter water turbidity less than or equal to 3NTU and the filtered water turbidity less than or equal to 1NTU. Besides, turn-off tank has never happened during the operation (Zhang *et al*., 2006)

Technological design of clarification tank in Luojing Project for the relocation of Shanghai Pudong Iron & Steel Co Ltd: After biological treatment of the sewage of some workshops in Baosteel, the first class of pollutants had met the discharge standards, but the average concentration of suspended solids was 200mg/L. In order to save water, the company decided to reuse the sewage, and the concentration of effluent SS was required to be 10mg/L. It has become the guidelines of the company's t the sewage recycling system project to stabilize the turbidity of pre-filter water below 3NTU all the year round with the reasonable technology, the minimal investment, and the greatest benefit, at the same time, the shortest time and the smallest areas.

Main technical measures

- Adopt vortex flow clarification technology. The vortex clarifier (the designed water quantity is 420 m3/h, its diameter 12.0m, and the total height 7.5m) gathers some functions in one unit such as mixing, coagulation, flocculation, liquid / solid separation, automatic sludge elimination and sludge circulation.
- The vortex clarification tank consists of up-flow solid contact and circulation separative unit. Its main components are two reaction chambers (the first vortex flocculation reaction chamber with a diameter about 2.4 meters; the second one, at the outside lane of the first one, with a diameter about 3.6 meters) and one separation chamber (the sedimentation zone outside of reaction zone, with an inclined tube to enhance the retention time and concentration of sludge).
- Design coagulant dosage system. Coagulant (PAC) and lime slurry are added before the lift pump of adjusting tank in order to mix completely with the tank .The dosage of flocculant is adjusted by the main control room which controls dosing pump according to the detected influent flow to ensure the removal of suspended solids.
- Design automatic sludge discharge system. The bottom of the reactor is sludge storage and concentration area. Precipitation sludge is stored temporarily and concentrated in this area. The continuous running of scrapping-slime raker mixs sludge equable to make it convenient for the sludge pump. On the basis of the information gathered by the sludge interface instrument and mud scraper force moment switch, the pump, while discharging sludge regularly, enhances the solid content of sludge simultaneously and saves the water consumption through the control of the cycle and the duration of the discharge.
- In order to prevent deposition of sludge in the reaction zone, set a DN200 manual mud headstock gear in the lower part of the first reaction zone to be handled by workers to discharge regularly.

Effects of implementation and operation: As a whole, in the micro-vortex reaction process, the raw water reacts fully. The clear produced alum, obvious particles and good settle ability all contribute to a high efficiency of the micro-vortex reactor. At present, the vortex clarifier in the project of the recycle water treatment of sewage in Baosteel has been running for almost two years, and the ton water investment is less than 35 Yuan. When the water volume is 420m3/h, after controlling the dosage of alum properly and discharging the sludge timely, the treated water turbidity of the clarification tank can remain below 3NTU stably, and after filtration by the V filter tank, the turbidity of the finished water can be controlled below 1NTU basically. Because the effluent turbidity of clarification tank is lower, the consumption of the backwash water of the filter reduces obviously and the work cycle has been prolonged (Tong and Hu, 2009).

SUMMARIZATION AND PROSPECTS

The integrated high efficiency vortex clarification process can not only enhance the efficiency of water purification process of flocculation reaction, shorten the coagulation time, reduce the head loss and the chemicals consumption, and improve the water quality, but also increase the efficiency of precipitation separation, improve the solid content of the sludge. Besides, it brings many other advantages like occupying a smaller area, running steadily, bearing capability against impact load, saving more in the overall project investment, decreasing operation cost and so on. The wide application of this technology can explore the potential of the existing water supply facilities to the greatest extent and make the minimum investment for the maximum benefit, which proves one of the most economical and effective technologies for current water supply industries to increase the water yield and improve effluent water quality. Most importantly, it provides scientific advice and guidance especially for the reconstruction or expansion of the old plants, which possesses a high practical value and offers better water quality and social benefits.

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