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Common strategy to prevent the Danube's pollution technological risks with oil and oil products – CLEANDANUBE

Operation: no.2(2i)-2.2-5, code MIS-ETC 653

<u>STUDY 2</u>

STUDY ON THE DESIGNATION OF TECHNOLOGICAL AND CONSTRUCTION PARAMETERS TO BEE ATTAINED. BASIS PREPARATION OF PRELIMINARY DRAFT

Working team:

Lead partner: National Research & Development Institute for Gas Turbines COMOTI Bucharest, Romania

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CONTENT

STUDY ON THE DESIGNATION OF TECHNOLOGICAL AND CONSTRUCTION PARAMETERS TO BEE ATTAINED. BASIS PREPARATION OF PRELIMINARY

1 Research and new methods of ecological waste

Waste oil discharged into the Danube (accidentally or otherwise) can eliminate / reduce the processing in a special facility, separate them into single-phase components, components that can be easily re-integrated into natural cycles.

Following this operation, it separates two fluid phases, one consisting of oil, another of water, and solid phase (semi), composed of mud and other materials from oil drilled solids from the water.

Water with solid phase (sludge, decanted and cleaned) are discharged into the Danube, and oil can be stored and eventually re-used in different processes.

The solid phase contains very small quantities of oil soluble salts, but a series of chemical elements with nutritional data, the order of macroelements (P, K, N, Ca, Mg, S) and even trace elements (Fe, Mn, Cu, Zn, Co, etc.). This is complemented by favorable chemical characteristics of plant growth, and neutral reaction and cation exchange capacity.

2 Centrifugal separation of oil waste

The presence of oil waste is a major problem in terms of environmental factors as well as economic, these wastes are hazardous fauna and flora in the development and further investment is needed greening affected areas.

Waste oil composition is diverse, depending on the types of waste and stock of origin and the nature of oil spilled.

Waste oil has a composition consisting basically of three types of phases of compounds:

¬ The first part consists of a phase oil and contains various species of heavy hydrocarbon compounds and resins or asphalt category.

¬ The second phase consists of water in various minerals that are dissolved.

¬ The third phase consists of mineral compounds are in solid phase.

Separation of the three phases is a difficult technical problem and high costs.

The project proposes the separation of waste oil by centrifugation.

The following is the general scheme of the greening process of petroleum products.

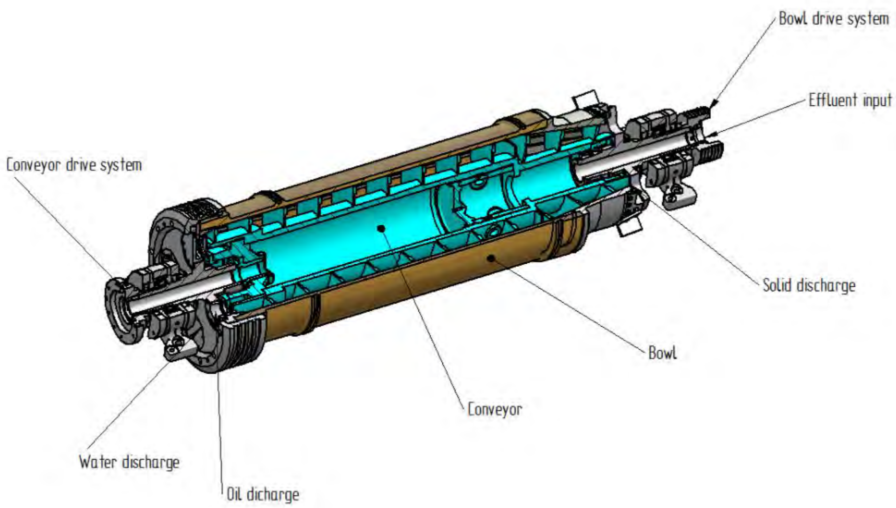

Fig. 1 General configuration of a centrifugal separator

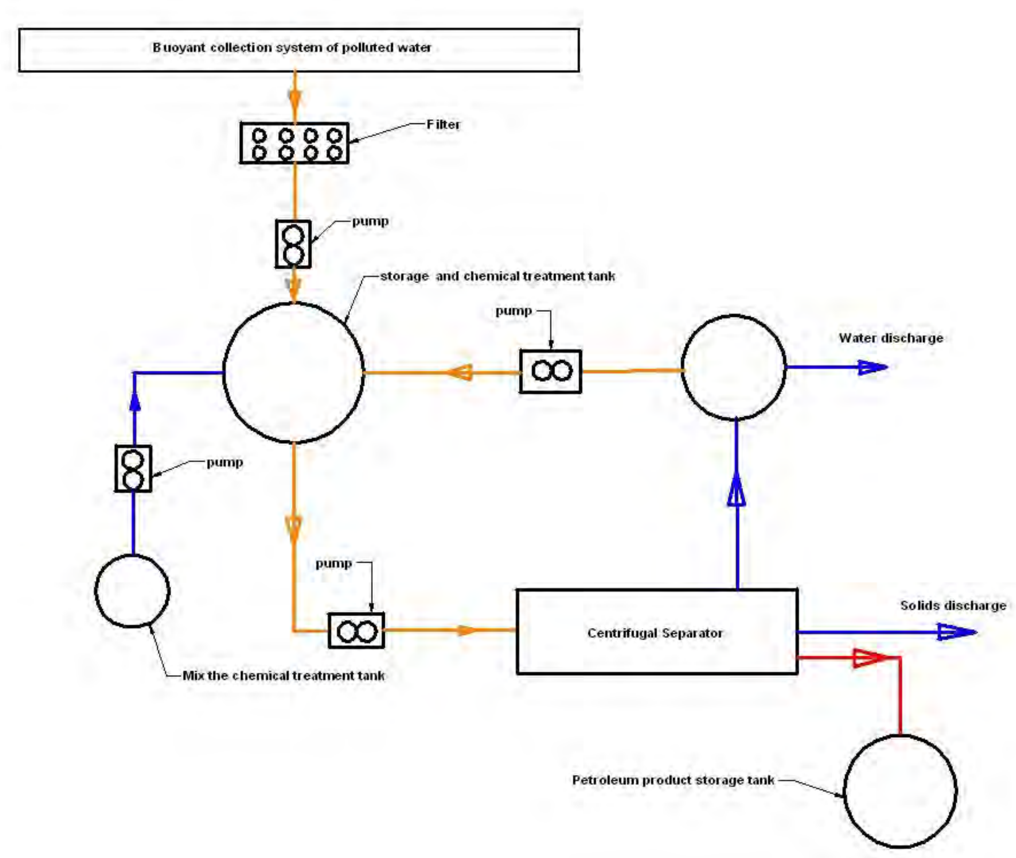

Fig. 2 The general proposal scheme for centrifugal separation plant

Contaminated water is collected, filtered and then pumped into a tank that is chemically treated and diluted with recycled water. The mixture is processed in centrifugal separation plant and resulting components are disposed differently: it is mostly recycled water, petroleum products collected and stored, cleaned solids are discharged into the Danube.

Centrifugal separation is the division of the constituents of a heterogeneous mixture, different based on their specific weight, using centrifugal force created during rotation. Decanter centrifuge separated by specific gravity liquids, spilling the top, centre, easy fluid, and one hard on the periphery. Can be employed in the same manner and to the separation of a liquid which has solid particles in suspension. Speed centrifuges can reach up to 60,000 revolutions per minute (ultracentrifuge). Separation is facilitated by dividing the conical liquid layer by means of conical plates.

Components with different densities separator works in principle only by sedimentation, a process that produces the separation of liquids and solids in suspension due to the difference in density. If the density difference is large, then gravity can provide enough force for separation to occur within a reasonable time - as is the case with large tanks or separators with blades or angled plates. If the density difference is small, then it would take too much gravitational separation, and separation force must be increased by adding the centrifugal forces several times higher than that of gravity.

Centrifugal force can be created either by the flow of the mixture as a hydro cyclone or mechanically driven rotation, as in sedimentation centrifuges.

The main beneficial features of the separator in this range of sedimentation equipment is its ability to remove solids separation zone separated from the continuous system.

Centrifugal separator can be used for most types of liquid / solid, given its ability to handle a variety of different mixtures and concentrations.

The separator can be used for three phase separation in which liquid is composed of water and oil. It can be operated so as to give a high degree of separation.

3 Theoretical aspects of the phenomenon of centrifugal separation

In the second co-acting centrifugal force fields: gravitational forces and centrifugal forces.

3.1 Centrifugal force

Centrifugal acceleration developed inside the cylinder radius r and angular rotational speed "ω" is:

$$a = r\omega^2$$

Intensity rotio of the two fields (centrifugal and gravitational), is called the effectiveness factor Z (or G- value)

$$G = \frac{r\omega^2}{g} = \frac{r}{g}\left(\frac{2\pi n}{60}\right)^2$$

$$\frac{G=n^2\, r}{900}$$

Where:

r max.= bowl inner radius [m]

ω = angular speed [rad/sec2]

g = gravitational acceleration = 9.81 [m/sec2]

n = bowl speed [rpm]

360 ° = 6.287 radian

Frequently for centrifuges used, the effectiveness factor z has values:

- The low efficiency centrifuges 30
- Centrifuging the crystals 100-150
- The sugar centrifugation 450-650
- The supercentrifuge> 3000
- The ultracentrifuge 10^5-10^8

Slippage force is (**S) (fig.3)**

$$S = \sin\alpha\; G$$

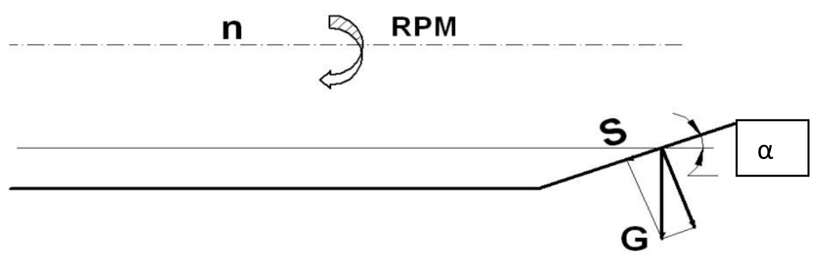

Fig. 3

3.2 Equivalent surface (sigma value) (fig.4)

$$\Sigma = \frac{1}{160} n^2 L_{cyl} r^2$$

Where;

Σ = sigma value[m^2]

n = Bowl speed [rpm]

L_{cyl} = barrel length[m]

r_e = maximum radius of cylinder (half diameter) [m]

Sigma value is the equivalent surface in sq. m of a static flotation tank to produce the same solid/liquid separation results.

3.3 Dewatering surface

Dewatering surface [sq.m] is the surface of the cylinder section (the cylindrical portion) $A_{c,n} = \pi D L_{cyl}$ or $A_{c,n} = \frac{\Sigma}{G}$

Where;

$A_{c,n}$ =Decanter surface settling[sq.m]

Σ = sigma value [sq.m]

G = centrifugal force

D = internal diameter in meters $\sigma = 2r_e$

L_{cyl}= length of the longitudinal section in meters.

3.4 The dewatering volume (fig.5)

Centrifugal separator dewatering volume is obtained assuming the total volume of liquid in the cylinder of the bowl .
This volume is a function of diameter flats.

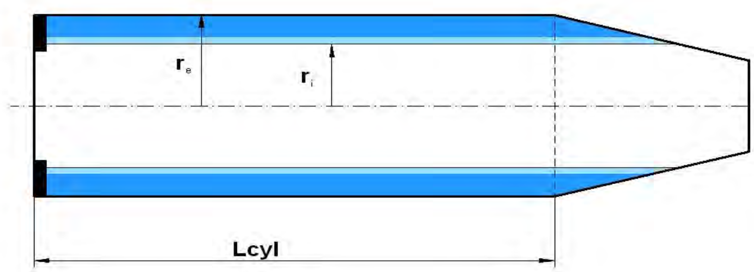

Fig. 4

To calculate the dewatering volume cylindrical part take into a consideration the cylindrical length L_{cyl} [only, the bowl inner radius $r_{e(in\ m)}$and the $r_{i(in\ m)}$ where r_i approx = 60% $r_{e.}$
Dewatering volume is: **$Dv=(r^2_e-r_i^2)\pi x\ L_{cyl}$ (cu.m)**

3.5 Retention time

$R_t = \frac{3600\ V_{td}}{Q\ input}$,

Where,

R_t = retention time

V_{td} = bowl total dewatering volume

Q input =Slurry feed rate [l/h]

The retention time is the time liquid remains in the bowl before being discarged. Retention time depends on characteristics of the feed slurry like this:

- specific weight of solid;
- viscosity of liquid phase
- amount of substance treatment

Longer retention time will result in more efficient solid/liquid separation.

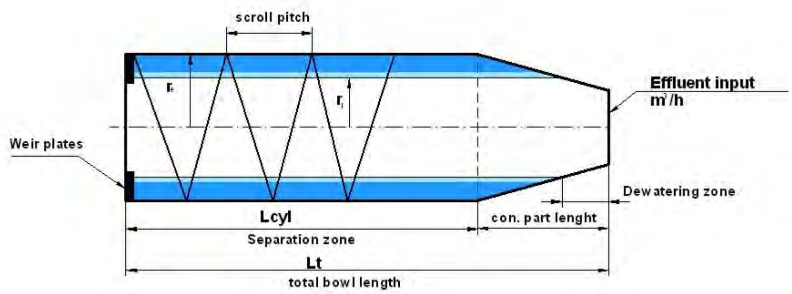

Fig . 5

3.6 Δn's influence on retention (fig. 6)

Depending on water quality by introducing a speed differences between roller and separator conveyor within walking distance increases and hence the quality of the separation process.

Efficiency of separation is achieved by changing Δn, where Δn = differential between the cylinder and conveyor speed.

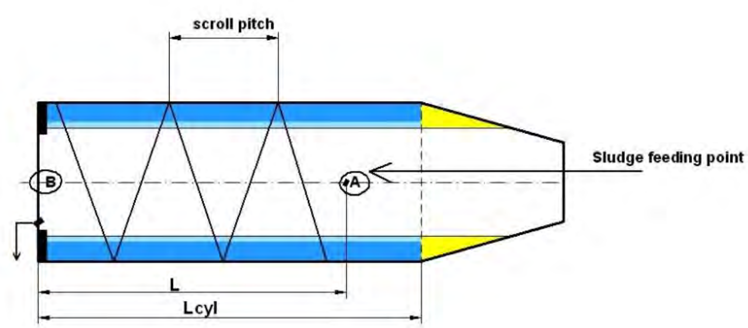

Fig. 6

3.7 The power required to drive the centrifuge

- For training centrifuges power consumption involved the following:
- N_a power required to bring the masses in motion, from sleep mode to speed;
- N_b required to bring the liquid to the centrifuge at the speed of system;
- N_c power to overcome friction in the spinning shaft bearings;
- N_d power to overcome friction between the centrifugal and ambient air;
- N_e power for other resistance to overcome, eg scrapers which remove sediment friction (in centrifuges with continuous operation), the friction in the flow of fluid through the centrifuge, etc.

The starting power is: $N_p= N_a+N_b+N_c+N_d+N_e$

Nominal power:

For discontinuous centrifuges is: $N_{r,c}=N_c+N_d$

For continuous centrifuges is: $N_{r,c}=N_b+N_c+N_d+N_e$

Nominal power system is therefore lower than the starting power. The starting power is even greater as the starting time (up to the speed of the system) is smaller.

Calculation of power N_a. The work (dL) for the basic motion of a stationary mass (dm) is:

$$dL=\frac{v^2}{2}(dm)=\frac{\omega^2 R^2}{2}(dm)=\frac{\omega^2}{2}(dI)$$

where dI = R (dm) is the moment of inertia, equal to the product of mass and square of the distance.

The work should be calculated for all moving masses of the centrifuge. For simplicity will consider only the cylindrical rotor, for which the moment of inertia is:

$$I_a=Mp\,R_2^{\,2}=2\pi hs\rho R_2^{\,2}$$

Mp is the mass of the cylindrical wall of the rotor.

The work to bring the rotor speed mode (with that simplification) is:

$$L_a=\frac{\omega^2}{2}I_a=\pi hs\rho\omega^2 R_2^{\,2}$$

If the starting time is τ, the necessary power to archive nominal speed is:

$$N_a = \frac{L_a}{\tau} = \frac{\pi h s \rho \omega^2 {R_2}^2}{\tau}$$

Calculation of power N_b. It is considered that the speed is high enough that the liquid layer to form a cylindrical inner radius R_1 and outer radius R_2.

The mass of a thin cylinder, the thickness (dR), radius R and height h, in the liquid centrifuged is:

$$dm_b = 2\pi R h \rho_1 (dR)$$

and moment of inertia:

$$dI_b = 2\pi h \rho_1 R^3$$

For the entire layer of liquid, moment of inertia is:

$$I_b = \int_{R_1}^{R_2} 2\pi h \rho_l R^3 (dR) = \frac{1}{2}\pi h \rho_l \left(R_2^4 - R_1^4\right)$$

and the work needed to bring the liquid layer to speed the system is ;

$$L_b = \frac{\omega^2}{2} I_b = \frac{1}{4}\pi h \rho_l \omega^2 \left(R_2^4 - R_1^4\right)$$

If reach the speed centrifuge system during τ, the power is:

$$N_b = \frac{I_b}{2} = \frac{1}{4}\pi h \rho_l \frac{\omega^2 \left(R_2^4 - R_1^4\right)}{\tau}$$

Calculation of power N_c. Is used formula:

$$N_c = f\frac{M_c \omega^2 r}{\tau}$$

Where:

f is the coefficient of friction of the shaft spinning in the bearing, with the value 0,07 – 0,1;

M_c – mass of all moving parts of the centrifuge;

r- shaft radius in bearing zone.

Calculation of power N_d. The recommended formula:

$$N_d = 0,736 \cdot 10^{-6} \zeta D_2^2 v^3 \gamma_a$$

Where:

N_d-is the consumption of power by friction with the air rotor, în Kw;

ζ – resistance coefficient, equal on average 2,2;

D_2 – Rotor outer diameter, in m;

v – peripheral speed of the rotor, in m/s;

γ_a – specific weight of air, in kgf/m^3.

4 The development of the preliminary project theme (second part)

4.1 Introduction

In the first part of the study were analyzed a part of the theoretical aspects for the parameters that take part in the process of the slams centrifugal separation.

These parameters and others, that will be defined in this part of the study, will be used to realize the preliminary project theme for an water infested with petroleum products purifying installation. Taking in account those said before, in this stage we will define the parameters that must be tracked for the realization of such an installation.

The centrifugal separation installation must meet the next general requirements:

- to be efficient and adaptive to the goal;
- to be the most simple in construction;
- to be not so expensive in exploatation, both in what regards the energy consumption and the raw materials and materials needed.

For the designation of the technological and constructive parameters needed to develop the preliminary project theme, first it must be defined the final technological scheme and then the adopted constructive solution.

4.2 Defining the technological scheme

The technological scheme proposed in stage 1 of the current study (fig.2) is one that refers to the separation of the three-phase mixtures - of the type solid–liquid-liquid, in which the concentrations of the three components of various density are relatively close.

In this concrete approached case, by which is wanted to clean the petroleum polluted Danube waters, the share of each phase in the mixture varies in an obviously way. So if the concentrations of the two liquid phases (water and petroleum products) are in obviously way close, the concentration of the solid phase being in suspension is low.

By this way the most appropriate technological scheme for the proposed application is the one from fig. 7.

To estimate in a correct way the dimensioning of the storage capacity for the solid components it must be done some analysis over the solid phase concentration of Danube's water both in the normal and in flooding period.

This component can be subsequently treated for decontamination unless it meets the imposed environmental conditions.

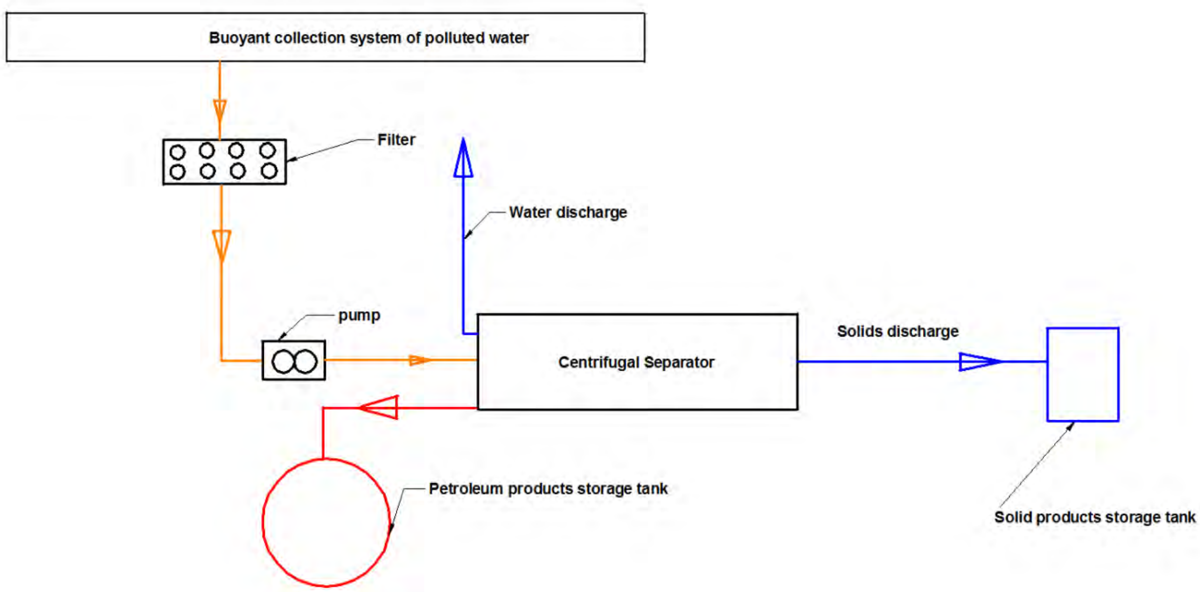

Fig. 7 The general scheme for the petroleum wastes separation system

4.3 Establishing the constructive solution

Following the analysis over the constructive solutions adaptable to the goal of this project, we consider that the solution of a centrifugal separator in a horizontal position is the most convenient, both constructive and functional. in fig.8 is represented the general scheme of a centrifugal separator.

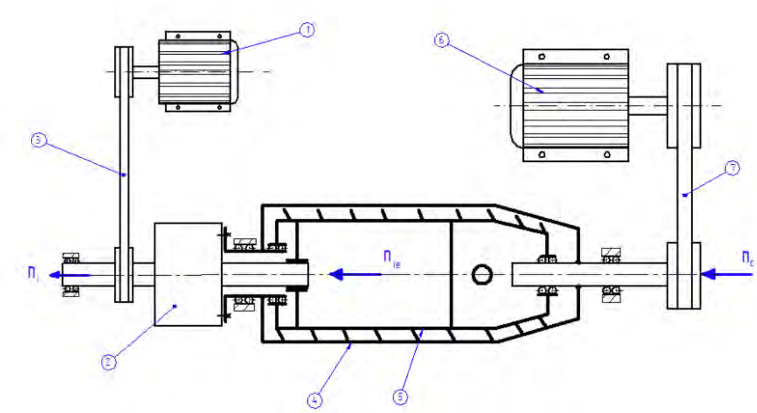

FIG.8 GENERAL SCHEME OF A CENTRIFUGAL SEPARATOR

Note
1. Differential gear drive motor.
2. Differential gear.
3. Belt drive differential gear input shaft.
4. Bowl.
5. Conveyior anssy.
6. Drive motor centrifuge bowl.
7. Belt drive centrifuge bowl.

n_c -rotational bowl speed (rpm)

n_i -rotationall speed of diferential gear input shaft (rpm)

n_{ie} -rotational conveyior speed (rpm)

The centrifugal separator uses a simple principle, that of Archimede's screw .

In a more simple words, the separator is made of a cylindrical tube, that spins at great velocity; inside the tube is a screw that rotate at a different speed from the tube. The difference between the two speeds ensure the movement necessary for transport, and removal of the solids, that accumulate on the walls of the cylinder.

A mixture of liquids and solids in suspension is feed along the centre line , at a fixed position in the cylinder, and is accelerated toward exterior to unite with the rest of the mixture sent on the cylinder walls by the centrifugal force. This force causes then the solids sedimentation on the wall of the cylinder bowl. The cleaned liquid flow along cylinder, to get out through one of the head end, and over a threshold that sets the level of liquid's surface in the cylinder.

The other end of the cylinder is leaned toward interior, and centre, so it ensure a declination, toward are transported the solids to be downloaded from the bowl at the end of declination. While the solids are sent upwards the declination, the liquids are flowing backwards to admission, to unite with the liquid that flow to the other end.

The screw is done from an empty axial shaft, through what is passing the feeding tube toward admission zone. The diameter, number and gear pitch of the transporter are chosen to fit the needs of the mixture that is being treated – the same way with the length of the cylinder, speed difference, and the angle of declination.

The most of the centrifugal separators operates on horizontal axis, in which case they are mounted on bearings at both ends. The rotating cylinder is closed in a housing, which is divided to ensure that the downloaded liquid do not combine with solids after separation.

The decanter is completed by a drive motor, usually electric, and a gearbox, that controls the speed difference of the transporter.

The separator works in principal only by the mean of sedimentation, a process that causes the separation of liquids and solids because of the density difference. If the difference is big, then the gravity can ensure enough force for the separation to produce in a reasonable time – as appropriate to great tanks or with slides or inclinated plate separators. If the density difference is small, then the gravitational separation will take to much, and the separation force must be increased through the imposition of a centrifugal force a few times bigger than gravity.

The centrifugal force can be imposed because of the mixture's flow, like in a hydrocyclon, or by mechanical driven rotation, like in the sedimentation centrifuges.

There are a few types of cylinders for the sedimentation centrifuges:

- The centrifuge with tubular cylinder, used primarily for liquid/liquid separation, for which every used of suspended solids will mean the shutdown of operations for solid removal;
- The centrifuge with perforated basket, used for solids removal;
- The centrifuge with stacking disc, developed at the beginning for liquid/liquid separation(milk from cream), but it was improved to remove solids (but not in a continuous way)

The main good characterises of this separator is its ability to remove solids from the separation zone on a continuous bases. It can operate unsurveilled , weeks at a time, even months.

Compared to:

- Gravitational sedimentation – the gravitational separator can achieve degrees of separation that would be impossible to reach in a slides separator; it to produce drier solids;
- Hydrocyclones – the separator has a greater capacity for liquids, it can manoeuvre higher concentrations of mixtures, and produces solids much more drier;
- The centrifuges with tubular bowl – the separator has bigger capacities, the ability to manoeuvre concentrated mixtures, and continuous operation;
- Centrifuge with perforated basket – the separator operates in a continuous mode, can manoeuvre higher concentrations of solids, and produces drier solids;
- Centrifuge with stacking disc – the separator is indeed continuous in operation, can manoeuvre higher concentrations of solids in feeding process and can produce drier solids.

The centrifugal separator can be used for the most of the separation types liquid/liquid/solid, considering its ability to manoeuvre a range of mixtures and different mixtures.

It can be used for the three phase separation in which the liquid is compose by water and petroleum. It can be operated in such a way so it will give a high degree of separation. Where the mixtures is a waste that requires prioritary treatment for safe storage, the separator can remove water from the wastes up to a high degree of dry. Finally, but not last, the separator can be used in the treatment of the petroleum – oil sludge wastes.

This range of potential users, together with the possibility of its continuous use, with the ability to work with various concentrations, and availability of miscellaneous capacities for processing; explain why the separator has become such an important equipment in processing.

4.4 Basic construction of the centrifugal separator

The centrifugal separator is in principle a quite simple device, although is far from being easy to built. Being realized in principle from a rotating cylinder and a interior transport screw; the separate liquids getting out at one end and the solids at the opposite end. The first quality of the separator is its capacity to remove large amounts of suspended solids from a mixture of liquids, with a resonable low level of retained liquid in removed solids.

This apparent simplicity of the separator is complicated by the diverse range of projects variations. The purpose of this chapter is to describe both the operational base elements of the separator and the special features.

A basic construction of an centrifuge with all main components is shown in fig.9. The “heart” of the separator is the rotary assembly, which contain a cylinder, inside of it is an Archimedic screw, (with small tolerance between it and the cylinder). At one end of the cylinder it is found a gear box that realize a small difference between the speed of cylinder and the screw.

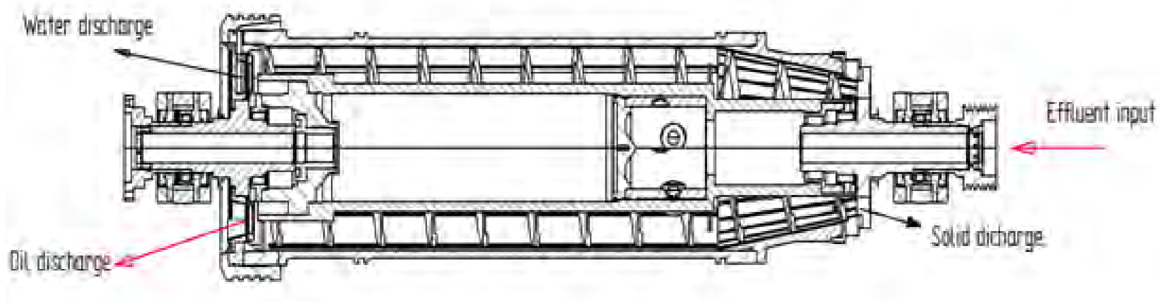

Fig. 9

The rotary ensemble, usually horizontal, is sustained by a bearing at each end. All around the cylinder is a housing that collect the cleaned liquid at one end and dry oil sludge at the other. The support boxes of the bearings and the housing are mounted together with precision on a rigid stand.

Sometimes the stand is mounted on a layer with the drive motor, and, where is necessary, a secondary system, for rotation speed control of the shaft gear box, and is mounted, to vary the speed of transporter and cylinder

The main drive is shifted towards the cylinder and moves it through a set of transmission belts type V. Anyway this system can be laid down axial with the pinion. The stand is usually mounted on vibration insulators.

The feeding is realized, in cylinder, through the holes from the transporter, the entering of the sludge is done through a coaxial and stationary feeding tube from a stand mounted on the main layer.

The feeding sludge is measured and send through the feeding tube in the rotary cylinder. The suspended solids settles on the walls of the cylinder, from where are picked up by the helicoil transporter and removed from separator through the conical end of the cylinder. The resulted liquids flow toward the opposed end and are stored in unloading vessels.

4.5 Parameters that must be defined in the developing of the preliminary design theme

Starting from the technological scheme presented in fig. 7, it must be defined the parameters and requirements for each component of the system

4.6 The floating collecting system for polluted waters

This system must meet the following conditions:

- to be provided with a floating system to maintain it over the level of water;
- to create a barrier that will not allows the crossing of polluted waters downstream;
- to be provided with a admission system for the polluted waters with a rough preliminary filtration of the collected products.

4.7 The filtration and suction system

- The filtration system must be dimensioned in such a way to allow the crossing of designed flow in the quantity and quality needed for the suction pump to function;
- The suction pump must ensure the designed flow for the centrifugal installation. For an medium capacity installation, as it results from the study began for stage 3 of the project (15÷25 m^3/h), it must ensure an adjustable output pressure of 4÷7 bar.

4.8 Defining the functional parameters of the centrifugal separator

- The dimensioning of the building elements of the separator that will match the functional requirements (designed flow for processing polluted water). For these it will be used for calculating the relationships from chapter 2.3.;
- The achievement of some variable speeds n_c (speed of the separator housing) and n_i (speed from the entry in the differential gearbox) so the speed difference Δn between cylinder and transporter can process the separation for every features of the polluted element.

5. Conclusions

The strategy proposed by this project have in this context a new method of intervention, prompt and reliable removal of pollution with oil products, the method devised by specialists involved project partners, based on outstanding professional experience.

It proposes the use of the most effective and used multiphase mixtures separation method based on the difference between the different specific weight of the components. In most cases the system is non-invasive (does not require chemical treatment than in cases of catastrophic spills).

Target groups are centres for tracking and monitoring of the Danube water pollution through the development and awareness of the entire population on the banks of the Danube

Promote a highly effective common strategy based on developing new scientific ideas, leads not only near the Romanian and Bulgarian economies but also to achieve sustainable development in the area of common interest, and we hope to develop new collaborative projects based on experience and closer link between research conducted by universities and further developing new scientific ideas, leads not only near the Romanian and Bulgarian economies but also to achieve sustainable development in the area of Community interest, and we hope to develop new collaborative projects based on experience and closer link between research conducted by universities and further.

Protecting the environment through advanced processing efficiency, to complete environmental components (water and solids) and re-oil industrial circuit (without further special treatment) leading to the sustainability of the intrinsic value of natural resources in the region, which identifies the specific objective no. 3 Programmers.

The project has two main objectives:

- Through a coordinated joint management system, develop a strategy for dealing with technological risks of pollution of the Danube with oil and oil products, thus ensuring an efficient protection, and natural values of the area, which perfectly overlaps Objective no.1, Priority Axis no.2.
- To protect the natural environment primarily in the area, which clearly extends protection to a population of firms that work in this area and whose operating results and keep the environmental quality of existing local infrastructure by creating a rapid response service and especially effective for the prevention and timely elimination of possible disastrous consequences of crises caused by human or technological accidents, which identify practical Objective no.3, Priority Axis no.2.