Section A-Research paper

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Modelling of different Sludge Centrifuge Separators using MPC

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***Abstract* –The work focus on laboratory based prototype modelling of centrifuge for sludge dewatering. Input parameters of different centrifuges effect the response. The MPC responses are analyzed for various industrial centrifuges in terms of performance characteristics. The index factor of centrifuge unit is taken as output parameter. The index factor is related to capacity and performance characteristics of various centrifuges used for sludge analysis.**

Keywords – Centrifuge, Model Predictive Control (MPC), sludge.

I. INTRODUCTION

Sewage treatment plants are utilized for solid separation from diluted product. The wastewater is passed through devices in the following order, i.e, screens, Grid chamber, skimming tank, primary clarifier, aeration tank[or, trickling filter, or, activated sludge process], and secondary clarifier. The two components produced in wastewater treatment are liquids(effluent) and sludge. Sludge is a composition of solids[0.25% to 12%] and liquids[88% to 99.75%] in the wastewater, which we get it mostly from the "primary clarifier" and "secondary clarifier" from the main wastewater treatment plant, and solids in the sludge are a combination of Volatile solids and non-volatile solids. The main objectives of sludge treatment are [1] Volume Reduction, and [2] Strenght Reduction. The strength of the sludge is represented by 2 factors, they are [a] ORGANIC MATTER(y), and [b] microorganisms(x); for organic matter, B.O.D[biochemical oxygen demand] gives strength, whereas, for microorganisms MLSS[mixed liquor suspended solids] gives strength. The volume and strength reduction is carried out in four stages, they are,[1] Sludge thickening(means expelling the water present in the sludge, by making it strong by the concentration); [2] Sludge digestion(anaerobically decomposing the sludge); [3] Sludge conditioning(refers to the washing out of the hazardous toxins like e-waste, etc.); [4] Sludge dewatering and drying(opening the sludge to the sun, to avoid the moisture content and mishandling; in other words, removal of remaining moisture). The density of the sludge is a very important factor during the treatment of the sludge, it is formulated as follows, ρ(sludge)=(mass of sludge)/(volume of sludge). In the volume reduction, a few percentages decreases in the moisture content, resulting in the reduction of sludge volume by 50% or more. After the volume reduction is done by the wastewater plant, then it is passed on through an "anaerobic digester" for strength reduction. The strength reduction of sludge is the B.O.D[biochemical oxygen demand] removal from the solid sludge. The sludge digestion is carried out by two continuous stages, that is; [1] the Acid fermentation stage, and [2] the Methane fermentation stage; in the Acid fermentation stage, the sludge[whose volume is reduced in the previous stage] is added with the acid formers[ANAEROBIC, ACID FORMING BACTERIA'S], which results in the conversion of the sludge into Acids[like, acetic acid, butyric acid, propionic acid, etc.]; in the Methane fermentation stage, the acids which are produced in the Acid fermentation stage, are added with the Methane formers[ANAEROBIC, METHANE FORMING BACTERIA'S], which results in the formation of gases[like CH4, CO2, H2S, etc]. In both Acid fermentation and Methane fermentation stages, we specifically take anaerobic bacteria because if we take aerobic bacteria then a large biomass is produced which is difficult to handle and as well as disposal of this biomass, that's why we use anaerobic bacteria for sludge digestion. The process of this sludge digestion is done in the sludge digesters, these sludge digesters are water and air-tight it has a diameter of 3M to 60M, and a height of 6M to 12M, it is provided with "FLOATING STEEL DOME", whose purpose is to collect the gases which are being produced in the Methane fermentation stage, the sludge is termed as "DIGESTED SLUDGE" after it got processed through the sludge digester, the digestion period[D.P] of the fresh sludge which is provided into the digester depends upon the type of microorganism involved in the digestion, for example:- if we use Mesophillic organisms, whose active temperature ranges from 20°C to 40°C, then the digestion period[D.P] ranges from 30 to 60 days, whereas, if we use Thermophillic organisms, whose active temperature ranges from 45°C to 60°C, then the digestion period[D.P] ranges from 15 to 25 days, which indicates that the active temperature of the microorganism is inversely proportional to the digestion period of the sludge. In sludge conditioning, we

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wash away the e-waste, unwanted waste, or toxic waste, that is, we remove all the hazardous waste from the "digested sludge", this process is done before the sludge dewatering and drying stage, for the prevention of messing up the wastewater treatment process; we also call this stage as "ELUTRICATION".So, sludge dewatering is to be done in different ways, either by "mechanical driers" or by using "sun-drying beds"; in "mechanical driers", we use objects like huge fans, etc. for drying the "digested sludge", whereas, in "sun-drying beds" the main phenomenon used as major factors are "evaporation{it is the process of vaporization of the water molecules when a liquid is exposed to the sun}" and "self-filtration" through a combination of "sand bed" and "gravel bed", which acts as a "sand filter" for the remaining water in the digested sludge, the influent digested sludge layer should not exceed more than 20cm when it is entered into the drying bed, when this sludge[digested] is exposed to sun then the moisture in the digested sludge is evaporated due to the exposure to the sun, and few percentages of moisture are filtered through the sand filter[gravel bed + sand bed] which is present below the layer of the fresh digested sludge. The sludge cake which we have after the sludge dewatering and drying process is used either by manure, disposed of by incineration/burning it, burying them, or filling the low-lying areas.Centrifuge product is effected by dimension, appearance, density, viscosity, speed of rotor and gravity force[1]. Centrifugation enhances the rate of sedimentation of particles that are suspended[2]. The application of sludge disposal using centrifugation is categorized into three types namely – thickening, dewatering and combination of both. For each application different centrifuges are employed and each centrifuge yields relative dryness ranges because sludge obtained from similar plants may differ according to the localities and environment. When a sample is taken in a test tube then after centrifugation the solid particles settle down and known as pellet, the upper layer is called supernatant. The centrifuges used are bottle centrifuge, Disk type centrifuge and tubular bowl centrifuge.

II. MODELLING

The index factor is taken as response of centrifugal models that relates to effective capacity or throughput [4]. The effective capacity is product of terminal settling velocity and index factor as stated in equation (1), allows performance comparison between geometrical and hydrodynamic centrifuges [5].

$\sum B$ of equation (2) corresponds to bottle centrifuge where w is angular velocity, V- is volume of the sludge occupied in the bottle,r1 and r2 are radii of bottle from low and high level of sludge in the bottle. $\sum T$ of equation (3) corresponds to tubular bowl centrifuge and L is the length of the tubular bowl. $\sum D$ of equation (4) corresponds to disk type centrifuge where an angle is included in the equation, representing the angle made between central axis and wall of disk centrifuge, n relates to the internal space.

$$Q_0 = 2u_t * \sum \quad (1)$$

$$\sum B = \left\{ {w^2 * V^-}/{2g \ln 2\left(\frac{r_1}{r_1+r_2}\right)} \right\} \quad (2)$$

$$\sum T = \left\{ {(w^2 * 2\pi L)}/{g} \right\} * \left(3/4\left(r_2^2\right) + 1/4(r_1^2)\right) \quad (3)$$

$$\sum D = \left\{ {(w^2 * 2\pi n)}/{3g} \right\} * \left(cot\theta * \left(r_2^3 - r_1^3\right)\right) \quad (4)$$

III. MODELLING USING MPC

Simulation is carried out by using MPC toolbox present in Simulink. Reference input, measured output, manipulated variable(mv), measured disturbance(md) are considered as external variables that influence the plant yield.

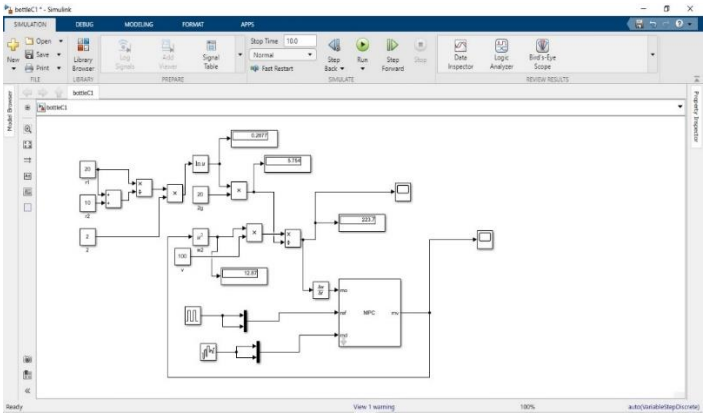

Fig.1. Model of bottle centrifuge.

The model of plant is designed as per the equations of different centrifuge index factors. The output is given to mo which is measured output parameter.

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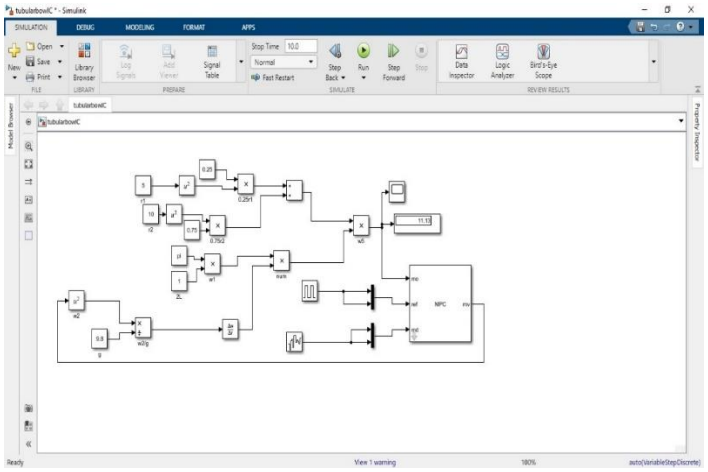

Fig.2. Model of tubular bowl centrifuge.

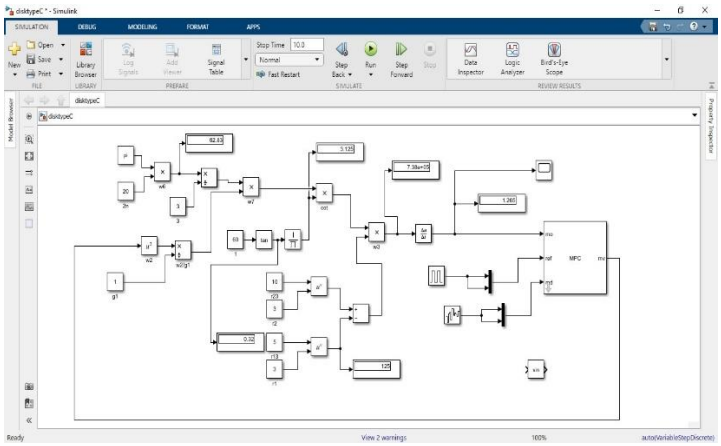

Fig.3. Model of disk type centrifuge.

A disturbance model is taken and analyzed the response for the three centrifuge models. The case is written as: plant=rss(3,2,3);

rss denotes arbitrary continual prototype. The digits represent state, output and input.

Figure-3 shows that pulse input signal is taken from source block. mo is measured output, ref is reference input and md is external known measurable perturbation. The mv port indicates manipulated variable whose output is given to w which is angular velocity.

IV. RESULTS

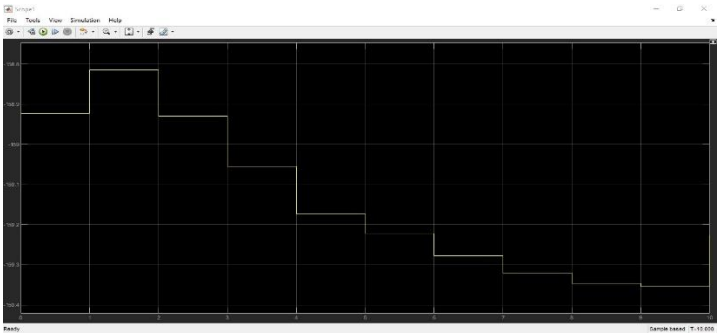

Fig.4. MPC response of plant for bottle centrifuge.

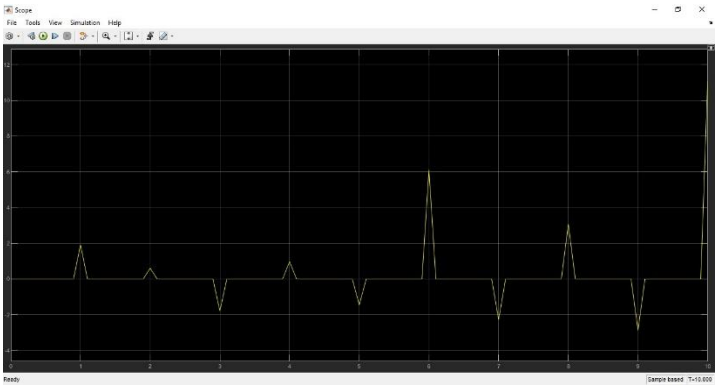

Fig.5. MPC response of plant for tubular bowl centrifuge.

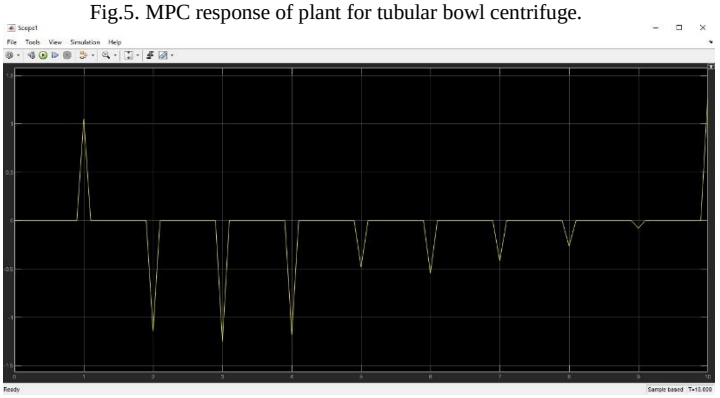

Fig.6. MPC response of plant for disk type centrifuge.

From figures 4,5, 6 it is observed that the graphs are obtained according to the index factors of each centrifuge. So, by applying the MPC controller different outputs are obtained for the parameters that include set of inputs to those particular centrifuges.

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V. CONCLUSION

The responses of different centrifuge separators are observed that will effect the sludge disposal output. Same controller is applied to all three centrifuges but the main difference is with the equations that alter the index factor. This type of modelling can be performed to real-time handling of centrifuges for obtaining desired sludge thickening and dewatering efficiently.

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