Chapter III

PELLET FLOCCULATION

3.1 History and literature reviews of pellet flocculation

The history of agglomeration technique of mineral to oil had historical importance because it led to the discovery of flotation. The process was first studied by A.E. Cattermole (Gaudin, 1939; Yusa et. al., 1975) in one of his procedures, acidified ore pulp was mixed with enough quantity of fatty acid to fill the pores between adjacent grains of valuable mineral. The objective was to form a relatively hard, compact association of mineral particles and oil, which could be gathered as a heavy sediment in classifiers.

Eighteen years later, the same idea was applied by W.E. Trent in connect with coal (Gaudin ; Yusa et. al.,). The trent process depended upon the production of relatively larger spherical agglomerates of oil with coal and separation of these spherical agglomerates from unagglomerated waste by screening or classification. It resulted in very good recovery of coal, in comparative tests, it had a better grade concentration than flotation.

In the Christensen process, the agglomeration technique was extended to very finely ground oxidized minerals, the separation of the spherical agglomerates from unagglomerated particles being effected by froth flotation (Yusa et al.,).

Stock (1952) reported that when dried barium sulphate was suspended in dry benzene in stoppered Nessler tube and was horizontally mechanical shaked in automatic shaker. After 24 hours the solid completely aggregated, produced discrete sphere 0.5-1 mm. in diameter. It was tentatively suggested that the phenomenon was caused by the fact that barium sulphate had a hydrophilic surface and consequencely tend to aggregate so as to presented to the hydrophobic benzene the minimum surface per unit volume. Expected that spherical agglomeration would not occur in a solvent which is miscible with water.

Smith and Puddington (1960) did not agree with stock's suggestion. Conducting a few careful experiments, they showed that spherical agglomeration did not took place when the system contained no water. Thus, the mechanical agglomeration of barium sulphate suspended in organic media into spherical agglomeration took place when the system contained a small quantity of water as a second liquid, which was necessary for used as interparticle bridging agent.

Above history were about organo-pellet flocculation, which pellet flocs were produced in an organic dispersion. In the case of aqua-pellet flocculation, in which pellet flocs were produced in water dispersion had introduced in following review.

Yusa and Gaudin (1964) presented formation of pellet-like flocs of kaolinite by polymer chains, direct pelletizing from aqueous suspension. The tecnique had been developed by insertion of a flocculant consisted of long molecules in pulp of kaolinite and mechanical work given to pulp. It was found that large and compact kaolinite flocs, pellet-like in appearance, could be produced from a suspension under special conditions, on the basis of the experiment of a pelletizing machine was constructed. The machine consisted of a horizontally mounted drum, the drum was rotated at a peripheral speed of 2.3 meters per minute. Prior to the rotation partially hydrolyzed polyacrylamide was add to kaolinite suspension. It was found that pellet-like flocs could be readily wet screened.

The wet pelletizing engineering, offered a basic of the new scientific branch (Yusa et al., 1975). Compact floc was produced by a third coagulation, known as pellet flocculation, as distinguished from normal coagulation and flocculation. The pellet-flocculating device, horizontal-cylindrical drum, or aquapelletizer had been already in commercial used in Japan. In this device, polymer was used as the interparticle bridging agent. Inside the pelletizing device, voluminous flocs formed by flocculation roll over or collide against the wall as the drum was revolved. The water was exuded from flocs by external force distributed unevenly on surface of the flocs. The results were pellet flocs and separated water, the water from pellets flew through slits in the wall of the consolidating section and pellet flocs were finely discharged from the end of the cylindrical drum as low water content cakes. The following sludges were tested by pelletizer such as, clay sludge exhausted from gravel pit, bentonite sludge exhausted from a construction field where shield tunneling was under way, activated sludge containing oily sludge that exhausted from an automobile manufacturing plant, sludge dredged out of seabeds or riverbeds.

Granulo-dehydrator was one of pellet sludge dewatering machine had been use in Japan (Japan Water Works Association, 1978), which was a gravity system dehydrator of revolving drum style. When the raw sludge was fed with high molecule coagulant and stirred slowly, the sludge particles gathered together and conglomerated. Gently rolling motion was given to these particles in the water, they became pellet-like flocs and the water between the particles removed as result and agglomerated into lumps. In case of this phenomenon took place, further moisture separated because of the pressure by the thick sludge. Therefore, when sludge concentration was too low or less than 2 % seem that the conglomeration could not be achieved, separation of solids from liquid became difficult. The moisture elements that removed from paticles were discharge through the slit provided on the drum and cake carried to the opening of the end of the drum. Although the granulo-dewatering method was inferior in dehydrability to vacuum filter, pressure filter, centrifugal separator but the mechanism was simple and rarely got defective. The rate of solids substance treatment in granulo-dehydrator was 60-130 kg./$m.^2$h. and the 65-85 % water content of the cake was discharged from the machine. This machine often operated in combination with sludge drying process.

A new fluidized bed pellet separator was presented by Tambo and Matsui (1987a), the separator was experimental for separation of high turbidity suspensions, ranging from hundreds to thousands mg./l. concentration, with very high upflow rate of 30 cm./min. (5 minutes detention time). The experiment began by addition of coagulant as aluminum salt at neutral pH to charge destabilize of clay particles in flash mixer. After that, anionic polymer flocculant was added to coagulated particles, to gave strong binding force to microflocs, before they were sent to the bottom of the fluidized bed pellet separator, which was consisted of multiple-stage paddles agitator. Thus the separator produced denser pellets around 1 mm. in size and good effluent as results.

Innovative sludge-pelletizing thickener, a new ultra compact sludge treatment system has been developed (Watanabe et. al., 1990), the name was Ball-shaped Effective Sludge Thickening System (BEST). In this system, primary plus secondary sludge was directed to a sludge conditioning tank, where it was dosed with an inorganic coagulant and mixed to neutralize the surface charge of the sludge particles. This conditioned sludge was sent to a cylindrical pelletizing thickener, where an amphoteric polymer was added to conditioned sludge, in order to pelletizing the sludge. This results in pellets having a diameter of 8 to 20 mm. The retention time of sludge in the system was only 10 to 20 minutes, compared to about 12 hours when conventional thickeners were used. Further, the soluble phosphorus could be converted to an insoluble substance by additional of inorganic coagulant and entraped in the pellet sludge. And because of the short retention time of the sludge in the system, there was less opportunity for the sludge to became septic and to released phosphorus into the supernatant which normally was returned to the wastewater flow.

3.2 Mechanism of pellet flocculation for moderate-high and high concentration suspension

Because pellet flocculation tecnique is a new branch of flocculating science and engineering, there are many aspects of mechanism for explain the phenomena of pellet flocculation. Some aspects of the pellet flocculation mechanism for morderately high and high concentration suspension were shown as follow :

3.2.1 Three typical states of pellet flocculation mechanism by Yusa et al.

3.2.1.1 A dispersed state of fine solid particles (in a flocculated system, these particles were connected randomly to form loose, bulky flocs)

3.2.1.2 A state of loose bulky floc, before sedimentation

3.2.1.3 A compact, pellet floc produced by uneven force given on floc surface. The liquid in floc was exuded at points where the external force were weak, the floc became more compact as result. There were two ways to accomplish this phenomenon:

a) The rolling technique, to roll the floc along a plane or curved surface;

b) The collision technique, to imple the flocs to collide with each other, or with a plane or curved surface (Yusa et. al.,1975).

3.2.2 Pellet flocculation mechanism stated by Tambo and Matsui

The pellet flocculation mechanism had been shown that pellet flocs were happen by mode of one by one attachment of the elementary particles onto the solids in the metastable state. The metastable state products were considered as the system which had already an elementary structure of the final aggregate but did not have enough size and/or concentration to make instant aggregate by themselves. Therfore, if high concentration solids which have the same activity to the metastable state compound. When the elementary particles were introduced into the metastable system, very quickly association of the elementary particles with active-solid surface would occured in accordance with the mode of one by one attachment of the elementary particle onto the soilds. This kind of aggregation scarely caused bulky agglomerates. Thus the aggregated result would be very dense pellet, consisted of elementary particles regularly arrange around active materials (Tambo and Matsui, 1987a).

3.2.3 Pellet flocculation mechanism stated by Watanabe and others

Watanabe et al., (1990) stated the pellet flocculation mechanism that there were 3 steps to produced pellet sludge.

3.2.3.1 Sludge conditioning by using metal coagulant such as aluminum or iron salt to charge neutralization of sludge

3.2.3.2 Formation of large, strong flocs with amphoteric polymer flocculant. The flocculation reation was considered to proceed in the following manner :

a) The cationic portion of the amphoteric polymer molecule adhered to the anionic portion of conditioned-sludge surface;

b) The cationic portion of the amphoteric polymer molecule then combined with the free anionic portion of the molecule to form apparent macromolecules. Thus the undissociated anionic portion of the polymer molecule was dissociated and charged due to change in pH when mixed with sludge;

c) The macromolecules bridge the particles of the conditioned sludge to form large flocs.

3.2.3.3 Growth of large flocs into pellets by rolling pellets along the reactor wall. The rolling action required for particle growth was brought about by both a verticle and a horizontal circulating flows along the reactor wall.

These 3 main steps were followed by supernatant separating from the reactor and the thickened sludge as result.