PERFORMANCE OF FLOATING HORIZONTAL AERATORS IN AERATED LAGOONS AND OXIDATION DITCHES

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LARRY W. MOORE
CIVIL ENGINEERING DEPARTMENT
UNIVERSITY OF MEMPHIS

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Larry W. Moore
Civil Engineering Department
University of Memphis

I. INTRODUCTION

When selecting aeration equipment to use for a specific application, issues to address include reliability, serviceability, capital cost, system appurtenances, and cost of operation and maintenance. Another important consideration is oxygen transfer rate (OTR). Horizontal floating aerators have relatively high transfer rates and have been used successfully in aerated lagoons and oxidation ditches. Using equipment with high OTR values reduces the horsepower input that is required and subsequently lowers capital cost and O&M costs. Mixing of wastewater in lagoons and oxidation ditches is also important to maintain solids in suspension.

While oxygen transfer (instead of mixing) may be the controlling factor in design of facultative aerated lagoons, mixing often is the controlling design constraint in an oxidation ditch reactor. Obviously, it is important to adequately mix the wastewater with the biomass to ensure effective pollutant removal. Mixing is promoted by ensuring that wastewater velocities in the reactor are sufficient to create turbulence which keeps the biomass and solids in the mixed liquor suspended. Generally, average sustained velocities of about 1 fps are considered sufficient for this task. TNRCC also has a requirement of 100 HP/Mgal as a secondary requirement to ensure adequate mixing.

Data on dissolved oxygen levels and channel velocities in the Lindale, Texas, Oxidation Ditch will be presented in this paper. In addition, channel velocities were determined in the Mertzon, Texas, Oxidation Ditch before and after the aeration basin was converted from a fixed rotor design to a floating horizontal aerator design.

In February, 2000, the City of Hattiesburg, Mississippi, installed floating horizontal aerators in its two aerated lagoons. The floating horizontal aerators replaced aspirating aerators to improve treatment process performance. Dissolved oxygen levels and plant performance (BOD and TSS removal efficiencies) before and after brush aerator installation will be presented.

II. BACKGROUND ON FLOATING HORIZONTAL AERATORS

Until the last few years, aeration of oxidation ditches was typically achieved by fixed horizontal or vertical aerators manufactured by several different companies. The fixed aerators were typically brush type or disk type units. While these fixed units have generally performed well, there have been shortcomings. First, the blades on some units have separated from the shaft upon extended use, substantially reducing aeration capacity and mixing in the oxidation ditch. Maintenance of the units occasionally proved troublesome to treatment plant operators. Some units have failed to maintain adequate channel velocities, resulting in significant biomass accumulation on the ditch bottoms. Another concern is that fixed units do not operate at optimum depth because oxidation ditch surface water levels fluctuate a few inches during the day as a result of diurnal variations in influent wastewater flow rates.

Because of the above problems with original fixed rotor designs, floating horizontal aerators have become popular when existing units need to be replaced. Floating horizontal aerators have a very high oxygen transfer rate. These units are typically installed using a cabling system, which does not require removal of the existing fixed rotors. This allows for continued operation of the treatment system during the retrofit. Moreover, in-channel modifications are not usually required, which facilitates rapid installation and lower capital cost of the retrofit project. The floating horizontal aerators are set at their optimum operating depth to provide maximum oxygen transfer regardless of the water level in the ditch.

Floating horizontal aerators manufactured by S&N AIROFLO of Greenwood, Mississippi, have high pumping rates of about 2100 gpm per horsepower. Thus, in addition to high oxygen transfer rates, these units can provide good mixing in oxidation ditches. The typical unit installed in oxidation ditches is the 15 hp aerator. It has 108 rotor blades with 52 at $13^3/_4$ inches long and 56 at $15^3/_4$ inches long. The main core is 8-inch diameter structural tubing, and the drive shaft and tail shaft are 304 stainless steel. The rotor blades are hot-dipped galvanized (thickness of 7 to 8 mils). Rotor blades on the 15-hp unit are set at a depth of 9.5 inches. A USEF electric motor running at 1800 rpm operating through an AGMA class III gear reducer turns the rotor. Actual rotor speed is 83 rpm. The unit has a double-grooved, banded belt (Kevlar) that connects the motor and gear reducer. Both ends of the rotor have water-lubricated UHMW (ultra high molecular weight) plastic bearings with excellent wear characteristics.

With respect to maintenance, the S&N AIROFLO aerator should be observed weekly to confirm optimum performance. Synthetic oil in the gear reducer should be changed once every six months in an oxidation ditch and once every 12 months in an aerated lagoon. The Kevlar belt, which has a self-tensioning device that keeps the belt at the proper tension, will usually need replacing after 12 to 24 months of operation.

III. PERFORMANCE AT THE LINDALE, TEXAS, OXIDATION DITCH

The Lindale, Texas, Wastewater Treatment Plant (WWTP) is an oxidation ditch designed to treat 1.2 mgd of medium strength municipal wastewater. The oxidation ditch is approximately 10 feet deep, and it has eight 15-horsepower S&N AIROFLO aerators. This ditch, which was designed with S&N AIROFLO aerators as original equipment, went into operation in 1999. The facility is currently operating at about 30% of design capacity, and only four of the floating horizontal aerators are in use at the present time.

The oxidation ditch is 40 feet wide at the top and 28 feet wide at the bottom. It has straight concrete walls on the inside and angled (45°) concrete walls on the outside. The total horizontal flow distance around the ditch at its centerline is approximately 440 feet. The aerators are separated by a distance of approximately 105 feet in the straight channel portion of the ditch. Measurements of DO and velocity were taken at three points (five feet from inside wall (Point C), channel centerline (Point B), and five feet from outside wall (Point A)) in the channel cross-section. Measurements were made at several depths (1.0, 3.0, 5.0, 7.0, and 9.0 feet at points B and C and at 1.0, 2.0, 3.0 and 4.0 feet at point A) and at four locations longitudinally in the ditch. Probe depth and orientation were checked before and after readings to assure accuracy. Replicate readings were taken at each location; if values varied by more than 10% of the arithmetic average of the two readings, readings were continued until consecutive values satisfied this level of reproducibility. Results of velocity testing with 4 aerators operating and 8 aerators operating are shown in Tables 1 and 2, respectively. Dissolved oxygen measurements with 4 aerators operating were between 4.5 and 5.0 mg/l at the 4 locations in front of the aerators and at the various depths. Dissolved oxygen measurements with 8 aerators operating were between 4.2 and 5.0 mg/l at the 4 locations in front of the aerators and at the various depths.

Table 1. Velocities in Lindale Oxidation Ditch with Four Aerators Operating

		Velocity in ft/sec at given distance in front of aerator			
Location	Depth, ft	20 ft	40 ft	60 ft	80 ft
A	1	1.15	1.75	1.9	1.61
	2	0.77	1.1	1.73	1.61
	3	0.72	1.15	1.33	1.49
	4	0.6	1.2	1.35	1.6
B	1	2.33	2.1	1.86	1.8
	3	1.12	1.08	1.1	1.18
	5	1.1	0.9	0.81	0.81
	7	1.05	0.75	0.6	0.55
	9	0.93	0.55	0.32	0.05
C	1	0.3	0.85	1.32	1.21
	3	0.25	0.3	0.43	0.54
	5	0.41	0.28	0.38	0.38
	7	0.43	0.35	0.1	0.34
	9	0.3	0.25	0.12	0.17

Table 2. Velocities in Lindale Oxidation Ditch with Eight Aerators Operating

Location	Depth, ft	Velocity in ft/sec at given distance in front of aerator			
		20 ft	40 ft	60 ft	80 ft
B	1	2.5	2.13	1.75	1.75
	3	1.36	1.74	1.54	1.26
	5	1.6	1.39	1.22	1.17
	7	1.25	0.03	0.87	1.03
	9	0.94	0.65	0.73	0.61
C	1	1.9	1.05	1.43	1.84
	3	1.2	0.8	0.92	1.57
	5	?	0.9	0.78	1.16
	7	0.8	0.45	0.76	0.92
	9	0.8	0.45	1.05	0.73

Based on the foregoing data, it appears that horizontal velocities in the ditch are somewhat less than desired with 4 aerators operating. Nevertheless, velocities on the outside of the ditch are excellent, and velocities in the center of the ditch are generally good. In the center of the ditch (Point B), velocities near the bottom averaged 0.46 ft/sec. At the inside location (Point C), velocities averaged less than 0.5 ft/sec at all depths below 3 feet deep. However, the bottom of the oxidation ditch was probed with the calibrated depth measurement rod, and no measurable accumulation of solids was observed at the various sampling points. It is interesting to note that velocities in the center of the channel declined slightly with increasing distance from the aerator. At the inside location of the ditch, velocities were similar or slightly higher with increasing distance from the rotor. Velocities at the outside location were typically above 1 fps, and this was likely attributed to the 1:1 slope on the outside wall. Moreover, as the water exits the curved portion of the ditch much of the energy is directed toward the outside wall.

With 8 aerators operating, the velocities generally exceeded the desired value of 1 ft/sec at nearly all locations within the ditch. The average velocities at Point B and Point C were 1.28 ft/sec and 1.03 ft/sec, respectively. Consequently, mixing in the ditch with the design aeration capacity appears to be quite adequate. Because velocities at the outside location were generally well above 1 fps with only four aerators operating, no measurements were made at that location with eight units operating.

IV. PERFORMANCE AT THE MERTZON, TEXAS, OXIDATION DITCH

The Mertzon, Texas, WWTP is an oxidation ditch designed for 0.10 mgd and a BOD concentration of 200 mg/l. Total oxygen requirements are approximately 370 lb/day. A 10-hp fixed rotor was replaced with a 7.5-hp floating horizontal aerator. The 7.5-hp unit is estimated to deliver 410 lb/day of oxygen to the wastewater at 30°C, which would be capable of meeting the treatment requirements for this facility. This 7.5-hp floating horizontal aerator should provide pumping rates of 18,000 gpm. Based on a 52 square foot profile of the tank cross-section, a minimum average velocity in the tank of about 0.8 fps is expected.

On November 20, 1997, representatives of S&N AIROFLO used a Marsh McBirney Flo-Mate 2000 current meter and probe to measure horizontal velocities in the ditch. The meter was set for a data integration period of 30 seconds. The probe was attached to a calibrated rod for accurate vertical positioning of the probe and proper alignment with channel velocities. Velocity measurements were made with the original 10-hp fixed rotor in operation and the new 7.5-hp floating horizontal aerator.

A small flat-bottom boat was moored in the channel at the desired location to provide a working platform. Velocity measurements were made at a distance of 23 feet in front of the aerator. Operating depth in the channel was 5 feet. The top width of the channel was 18 feet; the bottom width was 8 feet; and the channel sidewalls had a slope of 1:1. Average cross-sectional area was 65 square feet. A vertical velocity profile was obtained at the channel centerline and four feet on either side of this location. Measurements were made at 1-foot intervals starting at 0.5 feet depth.

The velocity data collected during this analysis are tabulated in Tables 3 and 4. Also presented are average horizontal velocities, overall channel average velocity, and measured flow rate. With the original unit the average channel velocities were about 1 fps in either channel of the oxidation ditch. However, the east channel just downstream from the aerator had a significant variation in values. Bottom velocities were about 0.5 fps, which are low. In fact, solids accumulation of 3 to 6 inches was noted during probing and velocity measurements with the original rotor.

In the east channel average horizontal velocities were approximately 15% higher with the 7.5-hp floating horizontal aerator versus the 10-hp fixed aerator. In the west channel average velocities were about 36% higher with the floating horizontal rotor. The minimum bottom velocity observed (0.80 fps) is over four times the lowest value observed with the original equipment operating. Average bottom velocities exceeded the desired value of 1 fps with the S&N AIROFLO unit. Consequently, only the very heaviest and largest of solids (e.g., medium-sized sand) would be expected to settle at any point in the channel. In addition, surface velocity profiles were more uniform, though the average surface velocity just downstream from each aerator was similar.

Table 3. Velocities in Mertzon, TX, Oxidation Ditch with 10-hp Fixed Rotor

Location	Depth, feet	Velocity (fps) 23 ft in front of rotor and given distance from inside wall 5 ft	9 ft	13 ft	Average
East	0.5 ft	1.03	3.21	1.98	2.07
Channel	1.5	1.00	1.80	1.21	1.34
	2.5	0.50	0.97	1.14	0.87
	3.5	0.28	0.92	1.13	0.78
	4.5	0.19	0.51	0.87	0.52
	Average	0.60	1.48	1.27	1.12
				Flow (cfs) =	72.5
West	0.5	0.71	1.20	1.36	1.09
Channel	1.5	0.72	1.18	1.32	1.07
	2.5	0.93	1.19	1.24	1.12
	3.5	0.97	1.11	1.33	1.14
	4.5	0.75	0.92	0.26	0.64
	Average	0.82	1.12	1.10	1.01
				Flow (cfs) =	65.8

Table 4. Velocities in Mertzon, TX, Oxidation Ditch with 7.5-hp Floating Horizontal Rotor

Location	Depth, feet	Velocity (fps) 23 ft in front of rotor and given distance from inside wall 5 ft	9 ft	13 ft	Average
East	0.5 ft	1.39	1.71	1.37	1.49
Channel	1.5	1.15	1.27	1.36	1.26
	2.5	1.21	1.30	1.26	1.26
	3.5	1.21	1.36	1.20	1.26
	4.5	1.02	1.27	1.24	1.18
	Average	1.20	1.38	1.29	1.29
				Flow (cfs) =	83.7
West	0.5	2.25	2.70	1.36	2.10
Channel	1.5	1.79	1.75	1.09	1.54
	2.5	1.00	1.53	1.04	1.19
	3.5	0.95	1.60	0.99	1.18
	4.5	0.80	0.90	0.91	0.87
	Average	1.36	1.70	1.08	1.38
				Flow (cfs) =	89.5

V. FLOATING HORIZONTAL AERATOR PERFORMANCE IN HATTIESBURG, MISSISSIPPI, AERATED LAGOON SYSTEM

The North Wastewater Treatment Plant (WWTP) in Hattiesburg, Mississippi, is a two-cell aerated lagoon followed by a polishing lagoon. Pertinent information about the existing treatment facility is:

Q_{design} = 2.0 mgd

1) One 5.5 acre aerated lagoon
   a) 80 HP of horizontal brush aeration
   b) Approximately 16.1 million gallons
   c) Approximately 8 days of wastewater detention

2) One 4.3 acre aerated lagoon
   a) 80 HP of horizontal brush aeration
   b) Approximately 12.4 million gallons
   c) Approximately 6.2 days of wastewater detention

3) One 4.6 acre settling basin
   a) 40 HP of horizontal brush aeration
   b) Approximately 13.7 million gallons
   c) Approximately 6.8 days of wastewater detention

TOTAL HORSE POWER:	200 HP
APPX. TOTAL VOLUME:	42.2 million gallons
APPX. TOTAL DETENTION TIME:	21 days

Prior to installation of S&N floating horizontal brush aerators, the two aerated lagoons had aspirating aerators. The new units have approximately the same total horsepower as the old aspirating units. A comparison of aerator performance in terms of dissolved oxygen (DO) levels in the two aerated cells is:

Cell 1 – Aspirating Aerators

Operating period	Sept. 24, 1999 – Feb. 8, 2000
Minimum DO	0.1 mg/l
Average DO	0.25 mg/l
Maximum DO	0.8 mg/l

Cell 1 – Floating Horizontal Brush Aerators

Operating period	Feb 10, 2000 – April 27, 2000
Minimum DO	0.1 mg/l
Average DO	1.9 mg/l
Maximum DO	3.5 mg/l

Cell 2 – Aspirating Aerators

Operating period	Sept. 24, 1999 – Feb. 8, 2000
Minimum DO	0.7 mg/l
Average DO	2.0 mg/l
Maximum DO	4.4 mg/l

Cell 2 – Floating Horizontal Brush Aerators

Operating period	Feb 10, 2000 – April 27, 2000
Minimum DO	0.6 mg/l
Average DO	4.9 mg/l
Maximum DO	7.1 mg/l

BOD and TSS removal at this aerated lagoon facility has been excellent since the new FHB aerators were installed. Effluent quality from March, 2000, through December, 2000, is as follows:

Average influent BOD	233 mg/l
Average effluent BOD	21 mg/l
Average BOD removal	91%
Average influent TSS	163 mg/l
Average effluent TSS	20 mg/l
Average TSS removal	88%