Sumitomo Drive Technologies

AERATOR INPUT REQUIREMENTS

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Aerator Input Requirements

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Project Input Requirements and Importance in Aerator Applications

Aerators are a fundamentally essential process in the efficient treatment of wastewater. The basic function of an aerator is to increase oxygen transfer so that beneficial bacteria can break down the pollutants in the water. The increasing world populations and demands for responsible ecological actions to safeguard our increasing water supply requirements can only emphasize the growing importance of aerators. Aerators account for the largest fraction of wastewater plant energy costs. There are many types of aerator drives and this discussion is limited to vertical, impeller-driven oxidation ditches – as shown in *Figure 1* below. This discussion would be valuable for water treatment personnel, Aerator suppliers, and power transmission suppliers wanting to supply new or replacement equipment and the importance in having accurate demand requirements to provide long-term, trouble free operation of the mechanical components of aerator drive equipment.

Get the Right Application Information and Project Requirements for the Job

Figure 2.
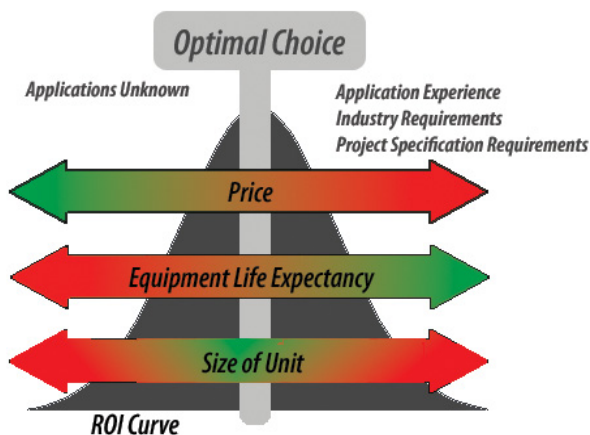
The selection of power transmission components, specifically gear reducers for use in aerator drive applications, are a mix of industry requirements, project- specific requirements, and application experience, all of which combine to generate equipment selections. These forces act together with the intention of creating equipment selections, which will operate efficiently and continuously with minimal maintenance requirements. However, one of these requirements may pull or push the equipment selection out of the optimum selection range. *Figure 2* is a graphical representation of this typical selection process.

When the selection is out of the optimum position, the result is usually premature failure and/or increased maintenance or higher initial cost and long term ROI. Therefore it is critical to the end user and suppliers to provide accurate and realistic load data requirements in addition to environmental and facility requirements.

Specifications and Industry Requirements

Consultants, who often base their documents on a combination of user requirements, experience, and industry requirements, usually generate specifications. These specifications define the minimum requirements for a project. Generally only a small portion of the entire specification refers to the power transmission equipment.

Aerator Original Equipment Manufacturers (OEMs) use these specifications to design their impeller equipment to process the wastewater-to-oxygen transfer levels prescribed for the locality, based on empirical data for water type, weather, etc. The aerator OEM will typically calculate load conditions on the impeller, using observed and test data-derived load formula. Since the impellers are more efficient at lower speeds than standard base speeds of an electric motor, a speed reducer or gearbox is required to decrease the impeller shaft speed. The gearbox manufacturer submits these shaft load conditions, along with the applicable equipment specifications, for consideration.
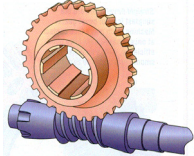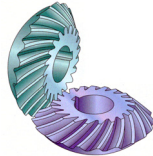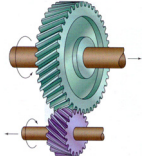
Unfortunately, there is no one agreed-upon standard for submission of mechanical and shaft load requirements. It is vital that the aerator OEM and gearbox manufacturer are able to communicate any special or non-standard industry requirements to one another.

While not often specified, it is considered an industry standard that gearbox assemblies will be outdoors and unprotected from the environment and elements. The gearbox manufacturer would have to be aware of this when making an appropriate equipment offering.

Equipment Specifications

Efficiency has a high impact on long-term operating energy costs. The gearbox is typically a helical or spiral-bevel/helical combination-type reducer. Worm gearing is not typically allowed due to its relatively low efficiency. Worm gearing has a lower efficiency due to high frictional losses from the 'sliding' action caused by the teeth in the worm shaft sliding against its mating worm gear tooth. Spiral Bevel gearsets are more efficient than a worm set because there is less 'sliding' action. Helical gearsets tend to be the most efficient, with the lowest 'sliding' action on tooth-to-tooth contact. Table 1 below shows the average efficiency per gearset type, where multiple gearsets, or stages, might be required to meet the required ratio. *Table 2* further shows the estimated total efficiency for a cost/kW-h, assuming a demand power requirement of 50kW.

Table 1. Efficiencies

	Worm Gearing	**Spiral Bevel & Helical**	**Helical**
Average Efficiency / set	85~70%	5 / 1.25%	1.25%
Ex. Typical 63:1 ratio	78%	92.5%	96.25%

Table 2. Long-Term Energy Cost

50kW Power Demand Operating continuously 5 years @ $.12/kW-h	**Worm Gearing**	**Spiral Bevel/Helical**	**Helical**
	$336,900	$284,100	$273,000

As you can see from *Table 2*, just changing to a helical-type gearbox results in a 19% savings in energy operating costs vs. worm-style gearing and 4% vs. spiral bevel/helical gearing. This savings is dramatically increased if there are multiple aerators in the water treatment process, as demonstrated in the *Chart 1.*

Other typical gearbox equipment specifications include:
- Vertical shafts (output shaft down)
- Drywell Low Speed Shaft Construction
- Motor Lantern
- HS Coupling
- Various Gearbox condition monitoring devices

Chart 1.

5 Year Savings Example for Multiple Units
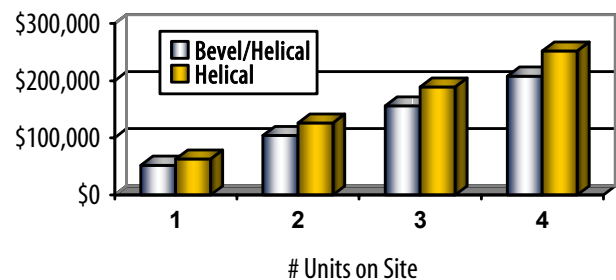
Project Input Requirements

Each water treatment operation varies due to the aeration process utilized and the type and condition of the water, along with the average environmental variables like rainfall, humidity, and temperature, which effect flow and evaporation rates.

> The Aerator OEM will typically specify:
> - Number of Drives
> - Input motor power/RPM & frame size
> - Required output RPM or desired reduction ratio
> - Low speed shaft load condition

The Low Speed Shaft Load conditions are defined by the Axial (F_a) and Radial (F_r) load conditions by the distance to the gearbox lower bearing support (L). See *Figure 3*. [*Note:* sometimes the distance (L) may be defined to the gearbox mounting feet or low speed shaft shoulder, but always to a specific and identifiable point of reference.]

The Axial force is defined as the thrust load from the operating force of the impeller and/or the weight of the impeller. The Radial force is defined as the overhung load applied to the shaft and gearbox and is due to the maximum calculated combined force of the imbalance of the impeller and dynamic fluid forces acting on the impeller.
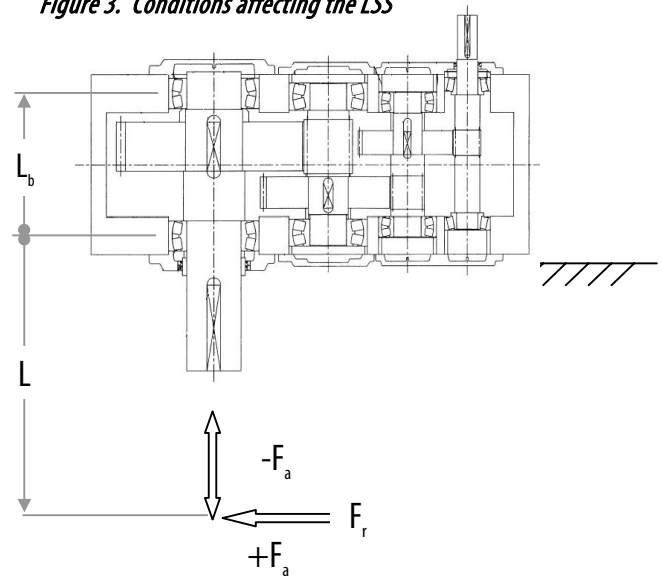
These forces can sometimes be provided in a combined format known as the *Bending Moment*. This value is typically provided in force multiplied by distance, or lb_f-in [or kNm], and is always referred about the reducer low speed shaft. It would then be the

Figure 3. Conditions affecting the LSS

gearbox manufacturer's responsibility to correctly convert the Bending Moment back into Force and Distance. For this reason, gearbox manufacturers typically prefer to have the individual forces and distances, so there are fewer chances for human error in conversions.

Unique Operation Conditions

It is imperative that the Aerators OEM knows and provides the maximum load values for these applications. Due to the unique operating conditions of these drives, there are various operating characteristics that can affect the gearbox in several ways. In a typical aerator application, the gearbox supports the entire impeller assembly. The gearbox not only has to support the entire weight of the impeller assembly, but depending on the impeller design itself or direction of rotation, the forces generated will either add to the weight or subtract from it.

As you can see in the impeller example shown in *Figure 4*, when rotating in the direction shown, the blades of the impeller would produce an upward thrust ($-F_a$). If the impeller were rotating in the opposite direction than shown, a downward thrust ($+F_a$) would result.


Figure 4. Forces acting on Impeller
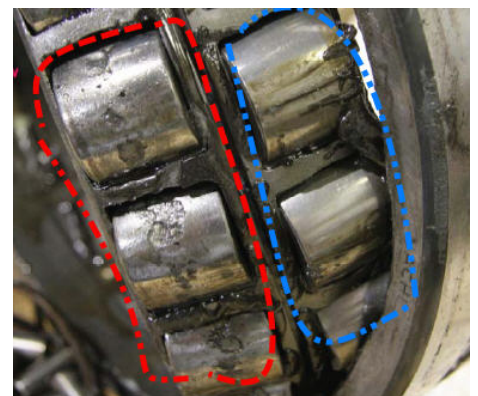
WATER 'PUSHING' ON IMPELLER, 'PUSHES' IMPELLER UPWARDS
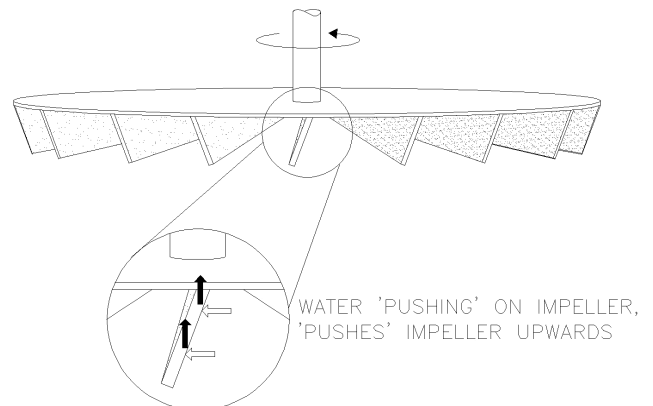
The gearbox also has to support the radial load (F$_r$). This force is a combination of many variables, partially including any imbalance to the impeller and shaft assembly, variable water conditions (including any solids which may be in the tank), and the variable force of the water due to the violent nature of the application where the impeller blades actually impact the water surface.

The radial load on the impeller causes a deflection of the low speed shaft. This deflection, or shaft run-out, creates excessive load conditions on the gearbox bearings and seals. The effect of radial load and the impact on the gearbox output shaft is illustrated in *Figure 5*.
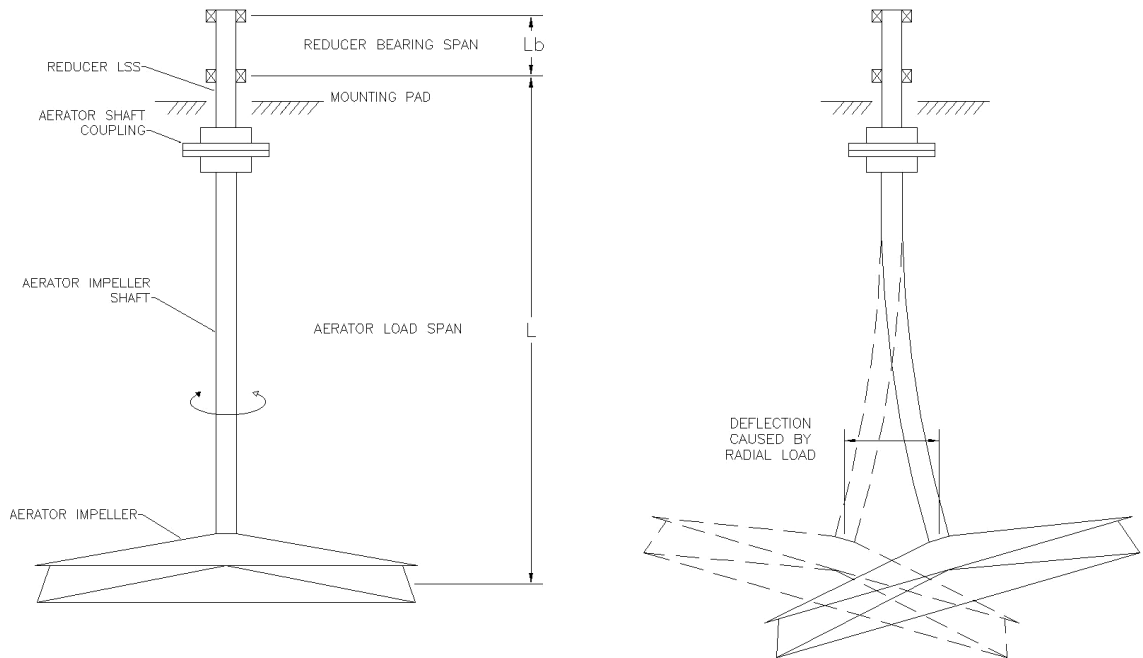
Figure 5. Effects of Radial Load on Impeller Shaft

The variations of available bearings by bearing manufacturers offer the gearbox manufacturer many options in compensating for the given load conditions. Some bearings are best suited for high thrust and low radial, while others are better suited for high radial and low thrust. Because of the typical nature of aerator drives and the combined high thrust and radial loads, spherical rollers provide a unique ability to handle the conditions and loads imposed by most aerator drives. Please note that not all aerator drives are equal. Therefore, the high radial and thrust load conditions described as typical do not *always* apply. If operating at a reduced load, the gearbox manufacturer should approve the conditions. If the aerator impeller is in pure thrust, then spherical roller bearings (SRB) would have to be reconfirmed as the appropriate selection for the given application conditions. *Figure 6* shows SRB, which was heavily loaded, in the red (left) side. The blue (right) side was hardly loaded, suggesting pure thrust load. In this case, a SRB may not be the optimum choice.

Figure 6. Unique Load Conditions

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Application Impact on Gearboxes

The uniquely high radial and axial loads produced by the aeration application have the greatest effect on the low speed shaft bearings. This is why aerator specifications usually require a higher L_{10} bearing life for the low speed shaft assembly, compared to the intermediate and high-speed shaft assemblies. In older specifications, it is not uncommon to see gearbox service factor (SF) requirements of 2.5 to 3 applied to the motor power. The basis for this is to increase the bearing life.

Gearing made to AGMA 6010-E88 Standards or later with a minimum 2.0 Service factor applied to the motor power is generally sufficient to withstand the operating conditions of the aerator. Gearing made to these standards would have a capacity of 200% the gearbox rating for momentary overloads. This is normally more than adequate to sustain continuous operation without damage. However, to meet the bearing life requirements set forth in the specification with the load conditions imposed by the Aerator OEM, the bearings have to be sized accordingly.

The basic formula for bearing life is defined in *Formula 1.*

Formula 1: $$L_{10} = \left(\frac{C}{P}\right)^{\frac{10}{3}} \times 5,000\,hours$$

Where: C = Reducer Mechanical Rating
P = Motor Power

As a general rule of thumb, the low speed gearset is the mechanically limiting components in a helical gearbox. For this reason, many people making gearbox selections assume that the reducer mechanical power ratings are equivalent to the low speed assembly capacity, including the bearings. For other applications where the operating conditions are not as severe as in the case of aerators, this is generally a satisfactory assumption.

Since service factor is the ratio of the reducer mechanical rating to the motor power, this assumption means that the SF is directly proportional to the L_{10} bearing life. See *Chart 2*, which illustrates the impact of SF on L_{10} bearing life related to the power ratio.

In actuality, the forces and direction of the gear loads, the application loads, and the distances between all of these forces affect the bearing life. These forces acting on the low speed shaft assembly are combined. The result of which is used to select proper-sized bearings, or, in the case of pre-engineered industrial gearboxes, confirming the bearing capacity and comparing to the specification requirements. The L_{10} bearing life equation (*Formula 1*) is modified as defined in *Formula 2* below.

Formula 2: $$L_{10} = \left(\frac{C}{P}\right)^{\frac{10}{3}} \times 5,000\,hours$$

Where: C = Bearing Load Rating
P = Combined Load Conditions
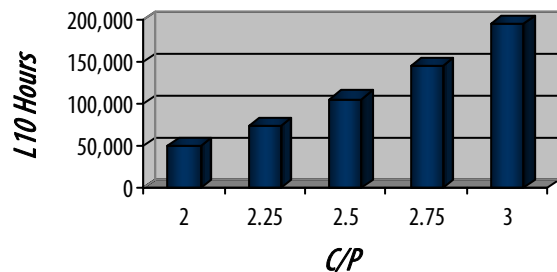
In this case, the force ratio is properly used to estimate the bearing life of the low speed gearset. Since the formula is unchanged and only the variables altered, the ratio of forces becomes more important to the bearing life than the power ratio. The distance between the reducer bearings, L_b in *Figure 3*, has a large impact on the load carrying capacity of the bearings and subsequent estimated L_{10} bearing life. As L_b increases, the value for *P* in *Equation 2* decreases. As the force ratio increases, so would the estimated L_{10} bearing life. So we can say that to obtain a specific bearing life, the distance between the reducer bearings becomes increasingly relevant.

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Properly Selected Gearboxes, based on supplied input conditions

A properly selected gearbox should follow the basic procedure outlined below:

1. Preliminary selection based on motor Hp x required SF for given output speed requirement
2. Check selection based on Load distance to gearbox vs. gearbox bearing span ratio
3. Check selection based on low speed shaft run out.

Some gearbox manufacturers have used the ratio of gearbox bearing distance, L_b, to the distance from the gearbox mounting to the load, L. Some manufacturers use a 5:1 ratio, as shown in *Formula 3*, to account for unknown or variable application conditions derived from years of experience supplying gearboxes to the aerator industry.

Formula 3 $$\frac{L}{L_b} \leq 5$$ Where: L = Distance from Load to Gearbox Bearing
                                                                                L_b = Gearbox Bearing Span

The final check is to ensure the shaft deflection produced by the radial load does not exceed the low speed shaft seal allowable run out. The average nitrile rubber seal maximum allowable run out is approximately 0.5 mm.

Options effecting the selection

Most gearbox manufactures offer a variety of options and accessories to suit the various application requirements. It becomes critical to supply accurate and realistic application data for the proper selection and the customization of the unit, to choose the most cost-effective drive to provide adequate and expected service life. These options include an extended L_b bearing span known as a drop bearing, which is often required to handle the high radial thrust load conditions of surface aerators.
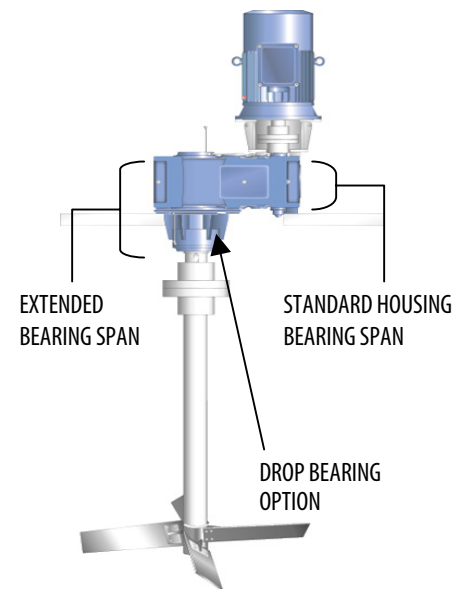
A typical Drop Bearing Aerator arrangement is shown in *Figure 7.* Note the extended housing which increases the L_b bearing span, protruding below the mounting foundation. Looking back to *Formula 3*, increasing the L_b bearing span will decrease the overall L / L_b ratio, with the target being less than 5:1.

Figure 7. Typical Drop Bearing Drive

EXTENDED BEARING SPAN

STANDARD HOUSING BEARING SPAN

DROP BEARING OPTION

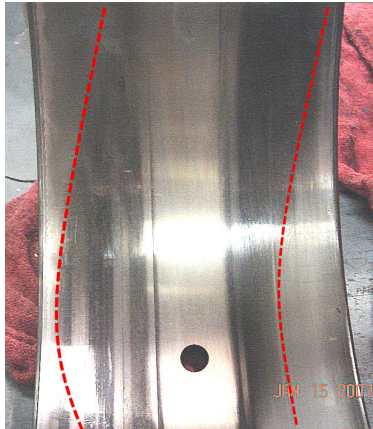## Effects of Improperly Selected Gearboxes

When the communication between aerator OEM and gearbox manufacturer break down and the application information is compromised in some way, the effects will always be borne on the condition of the gearbox. When the aerator tank and impeller are overloaded due to unknown operating conditions that differ from the original specifications, such as excessive debris in the water or improper tank water level, the gearbox is typically the magnifying point. The gearbox will often exhibit signs of overload. Some are external to the gear case housing – such as excessive vibration, a leaking low speed seal, noisy operation, and sometimes elevated operating temperatures.

Some conditions are internal, such as premature bearing or improper tooth contact wear. *Figures 8* and *9* are examples. For most aerator applications gearing SF above 1.75 is typically adequate for many years of service. Because of the high aerator shaft loads, the service factor requirement is increased to compensate for the load conditions. Most aerator gearbox failures are bearing or shaft failures due to fatigue of the overloaded low speed shaft.

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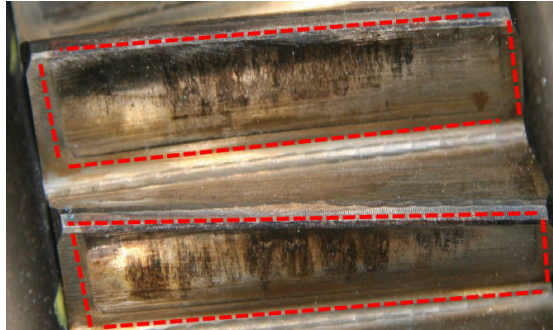f.757.485.3355   f.757.485.3193   **www.sumitomodrive.com**

(Left)   *Figure 8. Ex. Wavy Bearing*
(Bottom) *Figure 9. Ex. Premature Tooth Contact Wear*

Conclusion

Most gearbox manufactures who are members of and conform to AGMA Standards provide quality gearboxes. Likewise, most aerator OEMs who have supplied successful aerator installations are able to supply impellers and shafts which can withstand the rigors of the typical applications. With the complete and accurate supply of application information, gearbox manufactures have a variety of tools and options at their disposal to effectively manufacture and supply a gearbox to meet the intended application requirements. It is the OEMs who understand the applications and importance of supplied application data who are able to provide solutions that meet and exceed the user's expectations.

Figure 10. Example: Sumitomo PX9000 Series Aerator Drive

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