NEW "CLEAN-EDGE" IMPELLER DESIGN OVERCOMES RAGGING IN WASTEWATER BIOREACTORS

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NEW "CLEAN-EDGE" IMPELLER DESIGN OVERCOMES RAGGING IN WASTEWATER BIOREACTORS

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ABSTRACT

Mechanical agitators are used in various applications within a wastewater treatment plant, including in Anoxic/Anaerobic/De-nitrification Mixing Tanks, Sludge Mixing Tanks and Equalization/Neutralization Tanks. However in many instances, the presence of fibrous solids leads to an entangled "rag build-up" on the impeller which, over time, results in both mechanical and electrical overload leading to possible failure of the machine if adequate removal of the rag build-up is not maintained.

A new impeller design (*LIGHTNIN* Clean-Edge) has been recently developed to yield the same process result as a traditional three-bladed high-efficiency hydrofoil impeller without rag build-up during operation. This new design impeller will draw equivalent power at the same speed and is therefore easily retro-fitted to existing equipment. Benefits include: reduced electrical energy usage; reduced repair bills; reduced maintenance costs and increased plant availability.

KEY WORDS

Clean-Edge Impeller, Hydrofoil Impeller, Rag Build-up, Ragging, Bio-reactors, Mechanical Agitators, fibrous solids.

1.0 INTRODUCTION

For over 50 years mechanical mixers (agitators) have been successfully utilised in municipal wastewater treatment plants for a wide range of mixing applications including rapid mixing, flocculation, chemical make-up and storage, equalisation, neutralisation, aeration, solids suspension, sludge holding and sludge digester mixing. The role of the agitator is to provide suspension of the solids within the vessel and to thoroughly blend the process liquor with reagents or to prepare and maintain reagents for process application. These mixing tanks vary widely in size starting from approximately 5m3 but are often very large, ranging up to 1000m3 and beyond. It is therefore prudent to ensure that highly efficient mixing impellers are employed to minimize the power consumed by the process. Historically a variety of impellers types have been used for these applications, these ultimately being replaced in the 1980's by what is now recognized throughout the industry as the high-efficiency hydrofoil impeller. This impeller yielded the same or better process results compared with previous impeller designs using no more than half the installed horsepower.

2.0 DISCUSSION

2.1 The Problem

Whilst a great improvement in mixing efficiency for many applications, the hydrofoil impeller has experienced a varying degree of success when applied in municipal bio-reactors containing fibrous solids including hair, lint, paper and, on occasions, plastic bags. Effective screening plays an important role in minimising the amount of fibrous solids within the bio-reactor, however it is not possible to exclude all of this material and it must therefore be considered when designing an efficient mixing impeller.

The effect of this fibrous material over time on a hydrofoil impeller is that a small amount of it clings to the leading edge of the blades or to the hub and then weaves together with other fibres, growing larger and larger until a huge matted clump of fibrous, rope-like material, resembling some type of monster from the deep, becomes securely fixed to the impeller (see figure 1 below). The weight of some rag clumps removed from impellers in *LIGHTNIN's* US trials have been measured at up to 230kg (500lbs). This large added mass rotating with the impeller creates the following issues:

- the efficiency of the flow generated by the impeller is severely reduced, resulting in potential settling of solids in the tank as the flow not only diminishes but also becomes more radial rather than axial.
- increased drag on the motor (up to 100% above design kW) and gearbox results in motor overload as well higher wear on gearing and bearings with subsequent premature failure.
- magnified dynamic (fluctuating) out-of-balance hydraulic loads acting against the impeller and agitator shaft resulting in potential blade and shaft failure through fatigue and gearbox failure through bending moment well above design limits.

Figure 1: ***Fouled impeller***

To date, the only way of effectively dealing with the problem of impeller ragging has been to periodically remove the rag build-up by either draining the tank or raising the mixer and then manually tearing the mass from the impeller (refer figure 2 below). Periodic reversing of the agitator provides some relief, however this has not proven successful in the long term, particularly once the rags entwine on the impeller hub.

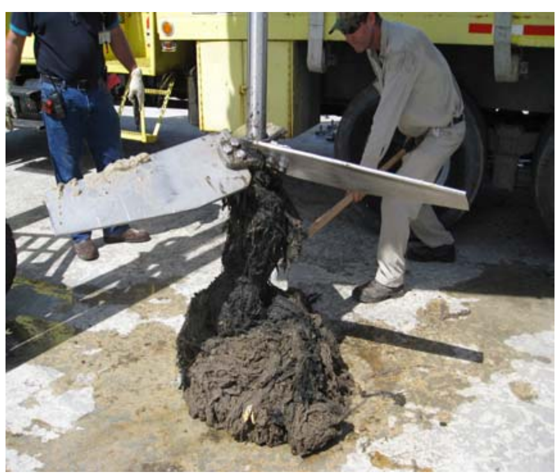

Figure 2: ***Clearing the impeller***

Submersible mixers have been viewed as a partial solution to the problem, however they also suffer from rag build-up and require periodic lifting and manual cleaning to maintain flow efficiency and avoid damage. It is worth noting that an efficient submersible mixer is no match for a well designed vertical shaft agitator as far as the flow pattern generated for a given power per unit volume. They have essentially been favoured over vertical shaft agitators because it is a simpler matter to remove the rag build-up by winching the mixer out of the water.

2.2 The Solution

So the challenge has been around for many years to design an impeller that will:

- avoid the problems associated with ragging in wastewater applications
- be highly efficient – similar to the current hydrofoil impellers
- be easily retro-fitted to existing agitators already in the field
- be manufactured to a cost effective design

LIGHTNIN's engineers set about to develop an impeller in early 2008 that would overcome the tendency for fibrous solids to adhere to the leading edge of the impeller and in so doing would avoid the possibility for fibres to attach and entangle themselves at any point. In addition, they looked to match both the power number (Np) and pump number (Nq) of their high-efficiency A510 hydrofoil impeller, so that retro-fitting many of the agitators already in operation around the world would be a simple and relatively inexpensive procedure.

The basic design involves a wide swept-back blade leading to an angled tip that produces an axial flow (refer figure 3). This patented design combines two features which eliminate the build up of rags. The first is a wide central blade. The width of the blade makes it very difficult for material to wrap itself around the blade as it is with the standard axial flow design. In addition to the wide blade, the design is swept back. This feature allows the rag material to slip easily off the blade. If a piece of rag should get caught up on the narrower portion of the blade, in the low velocity zone close to the hub, as it tries to attach itself the swept back feature allows the material to slide towards the outside of the blade and into the high velocity zone. Here the blade is wider and the velocity is higher. The material cannot wrap and the higher velocity throws it off.

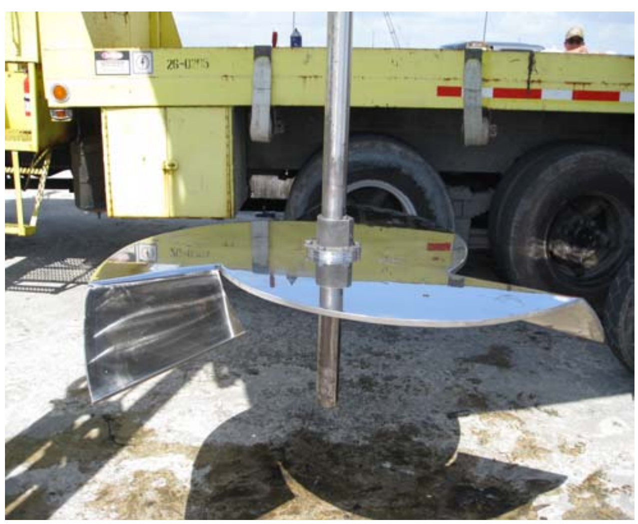

Figure 3: ***New swept-back blade and angled tip that produces an axial flow***

2.3 Test Work

Extensive laboratory trials were conducted over a 6 month period. Various designs and configurations were examined in an effort to validate the design. Once the design was verified in test lab scale, it was further tested at larger diameter in the *LIGHTNIN* factory. In both cases the impeller successfully shed materials used to simulate rags and maintained the flow and power characteristics of its high efficiency predecessor.

2.4 Full-scale Trials

Finally, the first Clean-Edge impeller was installed in large municipal facility in the Southeast United States (refer figure 5). Like many facilities this plant had learned to live with the issues that the standard hydrofoil impellers offered. This included increased power, elevated fluid forces and finally equipment failure. As this equipment was a conversion from an aerator to an anoxic mixer, the gearbox, motor and shaft design was greatly overdesigned for the anoxic application. As a result, the mode of failure was first power fluctuation and then finally blade failure (refer figure 4 below). Because this was a conversion from larger equipment, blade failure did not occur until after many cycles of build-up of material as high as 230kg on the blades. The Clean-Edge was then installed in August of 2008 and has operated continuously to date since that time. Motor power drawn started out at the same level as the previously installed A510 hydrofoil impeller and has remained at that level without fluctuation or variation.


<u>**Figures 4 & 5:**</u> ***The first Clean-Edge impeller installed in STP in USA***

A number of Clean-Edge impellers were then retro-fitted by the Tweed Shire Council to agitators at the Banora Point WWTP in Northern NSW on anoxic/anaerobic duty. This plant had experienced repeated blade failure and motor overload over many years, with the need to drain and manually remove the rags every 3 to 4 months. Daily reversing of the agitators was also performed in an attempt to shed the rags from the blades, however this was only partially successful.


<u>**Figures 6 & 7:**</u> ***The new impellers at the Banora Point plant***

So the opportunity to retrofit the new design Clean-Edge impellers was considered a worthwhile upgrade. The new impellers were then operated for 3-4 months and the tanks then drained. The photos above (figures 6 & 7) show the condition of the Clean-Edge impellers with no rags attached. Also shown alongside are some of the old hydrofoil impellers with rags hanging from the impeller hub. The trial was considered a complete success and another six (6) impellers are currently being manufactured to enable a full retro-fit at the Banora Point plant.

3.0 CONCLUSION

The *LIGHTNIN* Clean Edge impeller was designed to overcome ragging in municipal wastewater applications and address each of the following aspects of wastewater mixing:

- reduce maintenance (impeller cleaning) costs.
- reduce repair costs from overloaded (damaged) equipment
- reduce power consumption from inefficient operation
- increase impeller flow (process) efficiency
- increase plant productivity

All five (5) objectives have now been achieved with this new design impeller and conclusively demonstrated at both the US and Australian (Banora Point) wastewater treatment plants. Impeller load is now constant and within design limits. The drives no longer rock or vibrate due to excessively high out-of-balance loads acting against the impellers. Solids are uniformly suspended throughout the mixing zone. The most significant improvements (cost benefits) relate to continuous plant operation eliminating the need to take the plant off-line to either clean ragged impellers or repair equipment damaged as a result of impeller ragging.

The new Clean-Edge impeller has certainly met the need for improved plant operation. Water Authorities can be confident that any investment dollars spent in replacing their old inefficient impeller technology will be quickly repaid through a reduced maintenance requirement and increased plant productivity.

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