Mechanically Adjustable Speed Drive for AC Motor Applications to Eliminate Vibrations Without Additional Harmonics

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1. INTRODUCTION:

With the advent of high performance permanent magnets, there is a new non-eddy-current option to achieving adjustable speed control when matching the AC motor output speed to the requirements of the load. This option is cheaper to install, maintain and operate without introducing damaging harmonic frequencies to the motor.

The Flux Drive® technology utilizes portions of induction motor theory and combines it with recent improvements in permanent magnets to develop a simple but unique magnetic adjustable speed drive (ASD) and a soft-start coupling.

The following Sections will outline the technology and describe two applications in which this drive was installed.

2. TECHNOLOGY OVERVIEW:

This technology demonstrates the efficient use of the highest energy rare earth magnetic materials available (i.e., Neodymium-iron-boron). The robust design is characterized by a primary member populated by easily assembled permanent magnets, and a secondary member relying on casting techniques of an aluminum cage that have been highly refined over a century of induction motor development.

The Flux Drive® ASD, shown in Figure 1, achieves adjustable speed of the output shaft, by controlling the overlap of a "Can" containing an optimized array of rare earth magnets, as it spins around a magneto-conductive "Rotor". As the Can and Rotor are disengaged, slip increases, thus allowing the output speed to decrease proportionally. Conversely, greater alignment between the Can and Rotor allows for greater transfer of torque and change in speed as the Rotor enters into the Can.

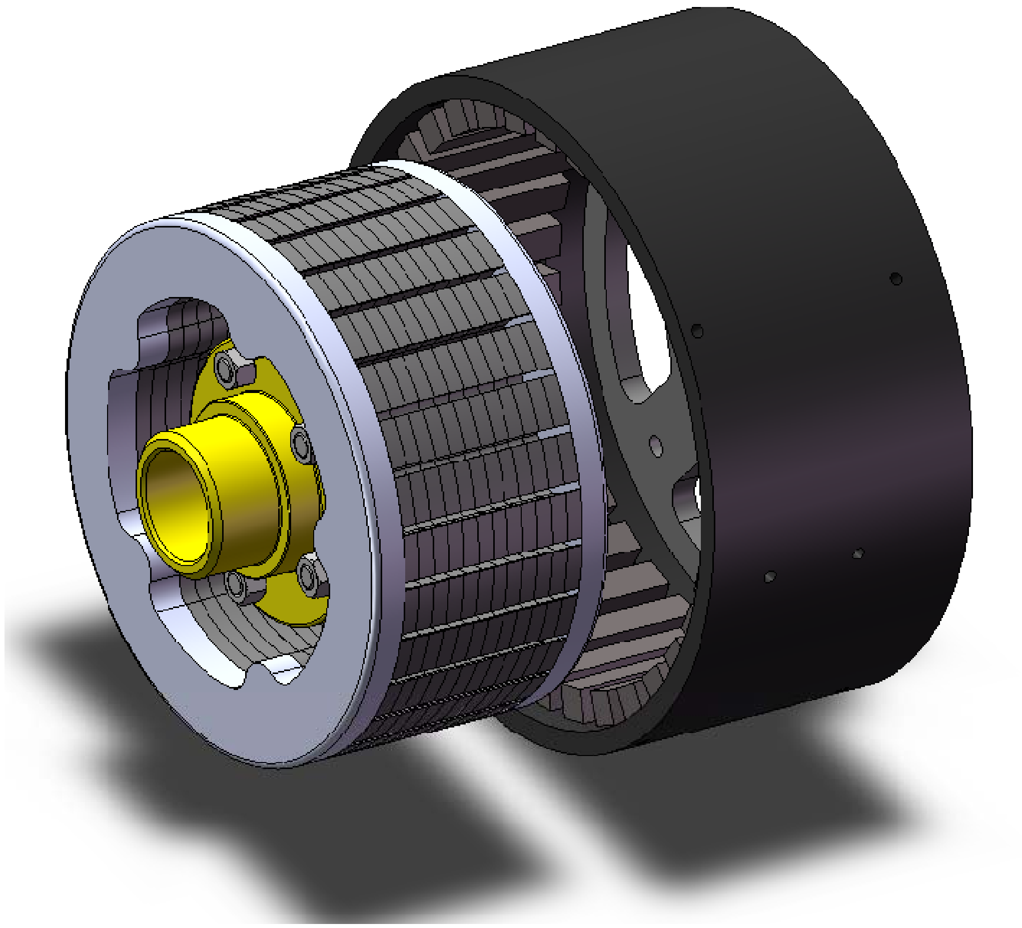

Figure 1 View of a Flux Drive® ASD

A Flux Drive coupling is configured by simply leaving the Rotor fully engaged within the magnet Can. During the motor starting event, the motor shaft commences rotation before the start-up of the Flux Drive® coupling, thereby allowing the motor to breakaway from the load and accelerate to full motor speed without a prolonged period of ‘locked rotor’ current. The motor, therefore, experiences ‘in-rush’ current for a much reduced duration due to the absence of the load.

As a result of these two time-varying events, the motor current is limited to well below the ‘locked rotor’ value. Testing of the coupling on a 25 HP motor shows that the maximum torque developed is 76 ft-lb during the start-up event. In the event that the motor experiences a sudden obstruction to the output rotor, the maximum torque that it can develop would be no more than the maximum amount that the coupling can transmit. In this case, therefore, the motor torque (and consequently, the current) is limited to the safe value of 134% of its full load rating. This unique feature of the Flux Drive®

coupling provides an added safety feature to installations that are susceptible to temporary overloads.

This feature also reduces torque 'spikes' and torsional vibration that can often be created by the load and therefore protects the motor from damage that often results from a load shaft seizure event.

3. PERFORMANCE:

In order to achieve the optimum selection of a Flux Drive® product in a particular application, it is important to be familiar with the performance characteristics of this drive's design. The following sub-sections discuss various parameters that constitute the specifications of the adjustable speed drive or coupling.

i. Speed/torque characteristics:

Both the ASD and coupling have characteristics that are similar in appearance to induction motors but are unlike those of eddy-current couplings. The speed/torque characteristics in Figure 2 were obtained from tests on a 25 HP Flux Drive® coupling. The starting and peak torque values are part of the familiar saddleback shape that can be modified with appropriate Rotor design changes, as is the case with induction motors.

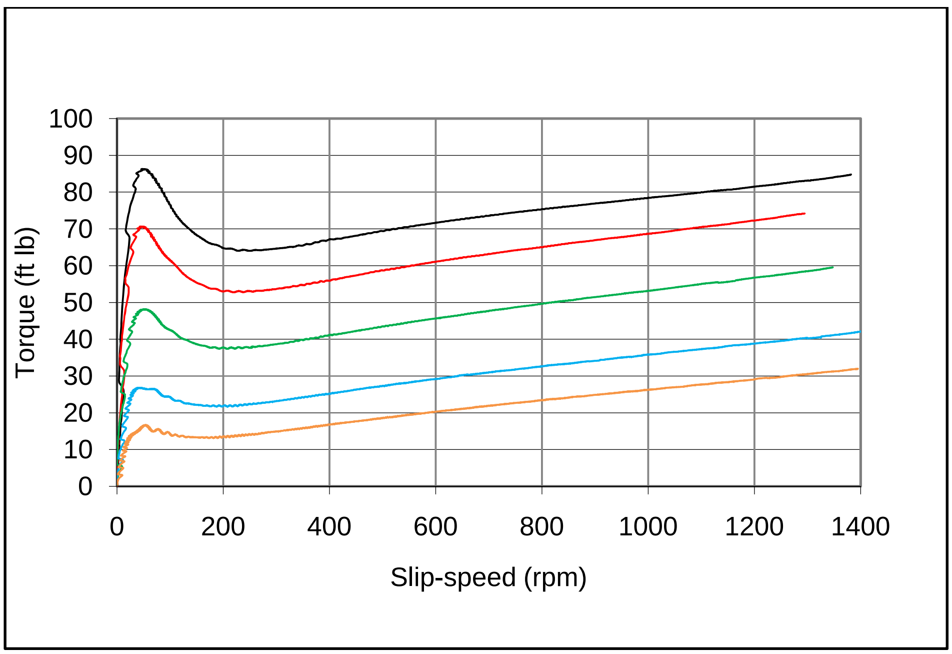

Figure 2 Experimental speed / torque characteristics of a Flux Drive® product at various engagements.

The percentage engagement (i.e., overlap) of the Can with the Rotor determines the amount of torque transmitted from the motor to the load and the speed at which the load shaft will operate. This is an adaptive situation in which the motor and load achieve steady-state operation at all engagement positions. Substantial amounts of motor torque can be transmitted to the load via the Flux Drive® magnetic circuit at minimal values of slip.

The rating of a Flux Drive® ASD or coupling is based on the combination of two major parameters: 1) the maximum torque transmitted, and 2) the slip-speed corresponding to that torque. Figure 2 shows a family of speed/torque curves of a typical ASD drive at various amounts of engagement between Can and Rotor.

ii. Soft-start characteristics:

As mentioned in Section 2 above, the Flux Drive® coupling or ASD can be used to soft-start a motor's load as well as to adjust its speed. Various parameters were recorded as a 25 HP motor was started with the Flux Drive® coupling compared to a standard rigid coupling. Figure 3 shows that the duration of the high start-up current is reduced substantially and is only a fraction of the time experienced with a rigid coupling. The power input to the motor is also reduced to approximately a third of its value, as seen in Figure 4. This is primarily because of the lower amounts of current necessary to accelerate the output shaft to full speed. The power factor is also improved as seen in Figure 5. Figure 6 shows that, even though the energy transferred with the Flux Drive® coupling takes more than twice as long to complete than with a rigid coupling, the startup power to the motor is reduced during most of that time.

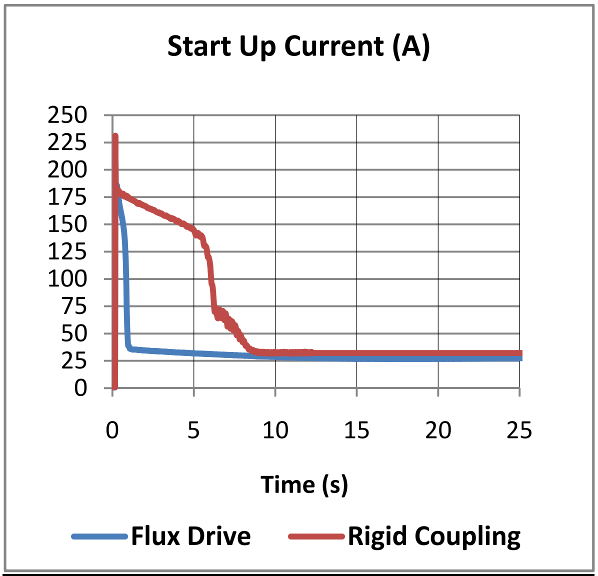

Figure 3 Start-up current with two couplings

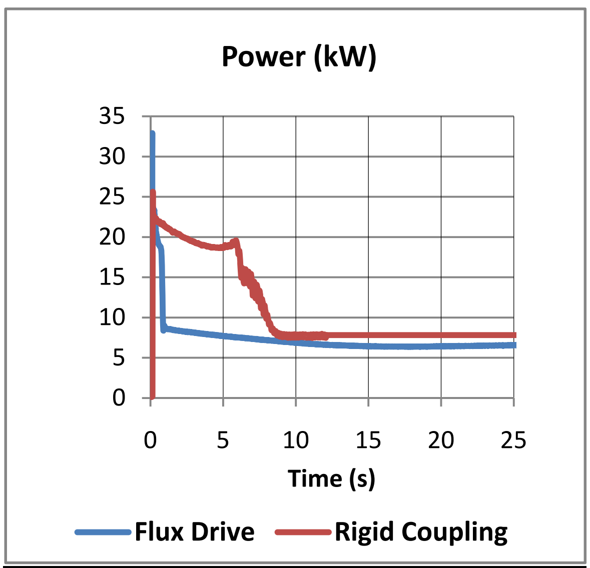

Figure 4 Input power with two couplings

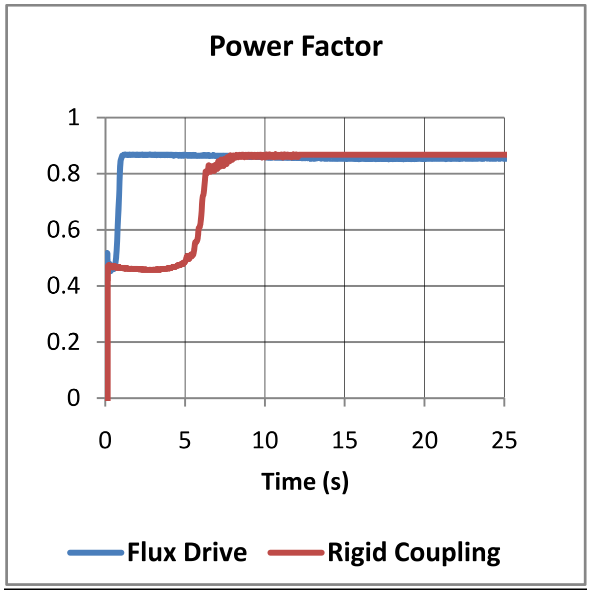

Figure 5 Power factor with two couplings

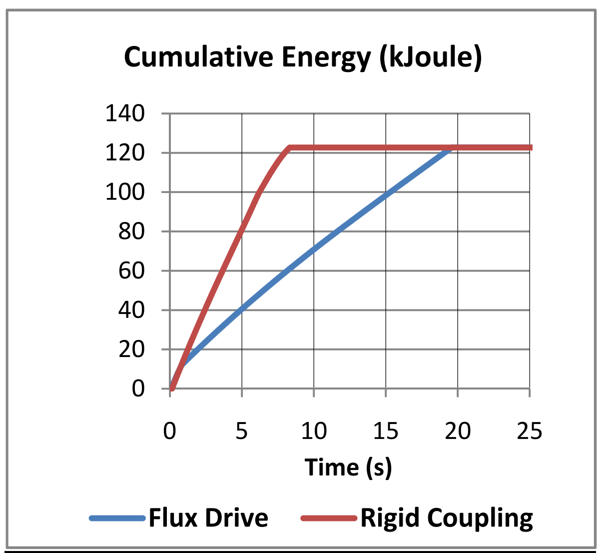

Figure 6 Shaft energy required to start load

iv. Affinity Laws:

Centrifugal loads follow what are called 'affinity laws'. According to these laws, the changes in fluid-flow are proportional to speed. However, the required torque is proportional to the square of the change in speed and the horsepower is proportional to the cube of the change in speed. These relationships are confirmed by test as part of the performance of a Flux Drive® product as seen in the following Figure 8.

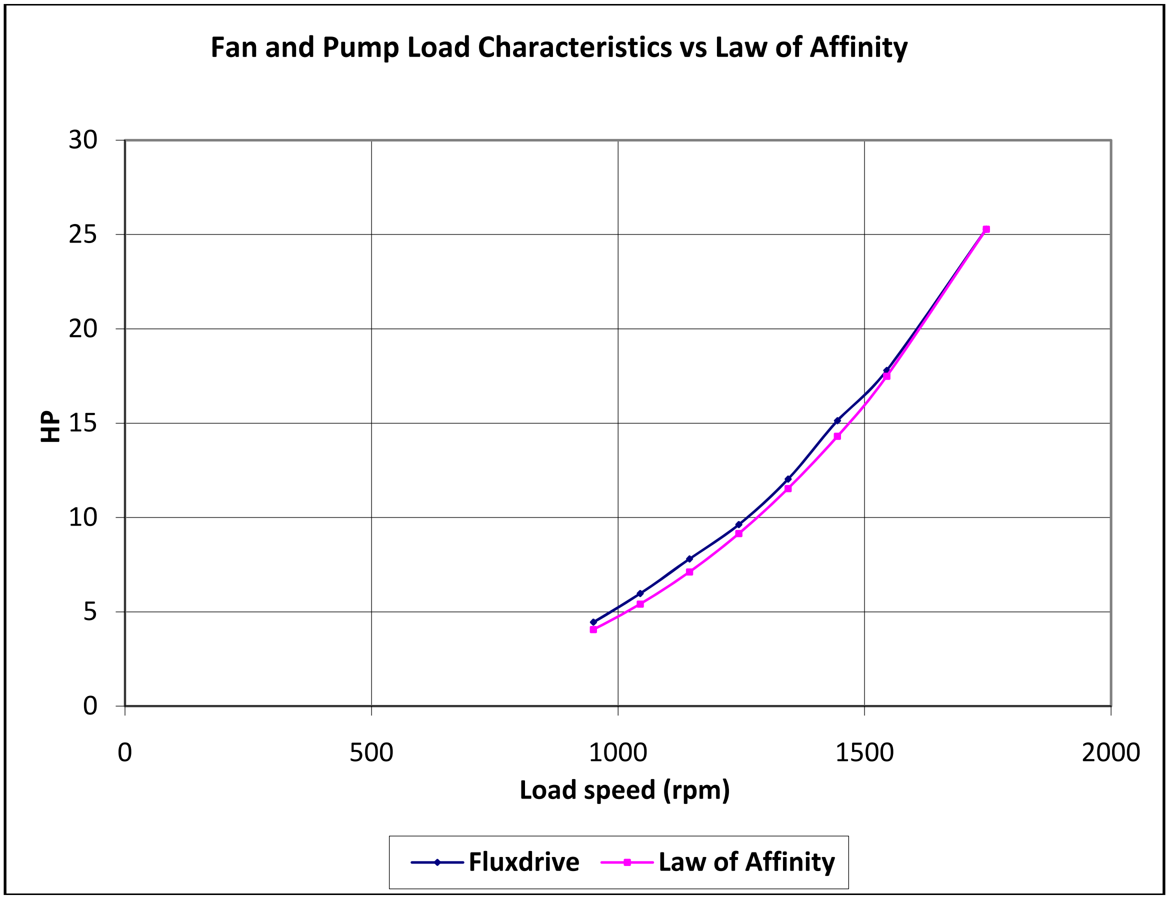

Figure 8 Flux Drive® vs. Laws of affinity

4. CASE STUDIES:

Flux Drive® products have been installed in locations where they are relied upon for continuous operation after having shown measurable improvement in the performance compared to previously installed drives.

i. Blower Application:

A Flux Drive® coupling was installed between a motor and a blower in a 30-year-old boiler room. Figure 9 below shows the replacement Flux Drive® installation. This application is a 20 HP, 1750 rpm motor driving a Forced Draft Fan for a small boiler through a fluid drive for speed control. The fluid drive is controlled by a pneumatic actuator that regulates the fan speed and airflow to the boiler.

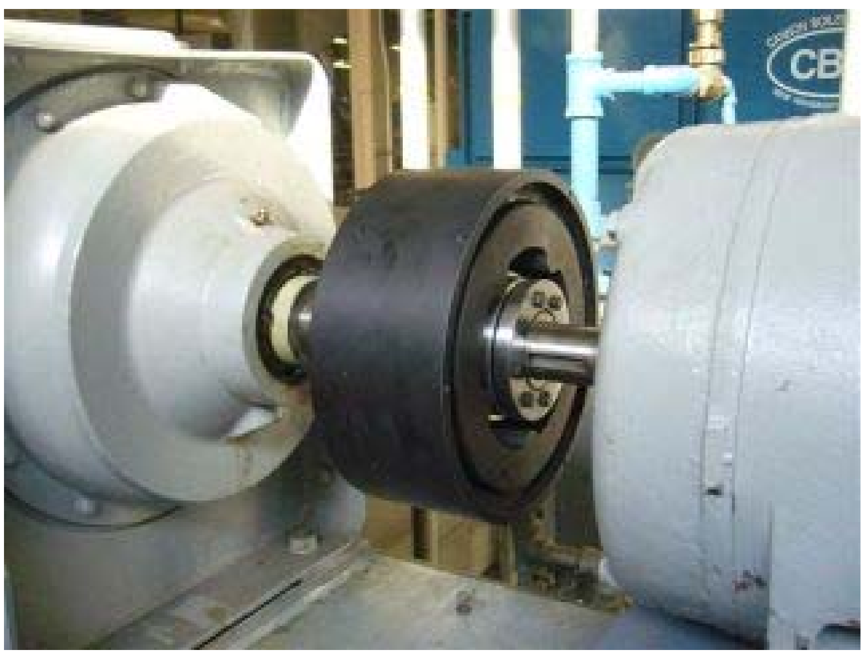

Figure 9 Flux Drive® coupling

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ii. Pump Application:

A Flux Drive® ASD was installed between a 20 HP motor and a pump at an aquarium. Figures 10 below show the replacement Flux Drive® installation. The pump serves to circulate saltwater to an underwater dome exhibiting marine life that requires reliable operation.

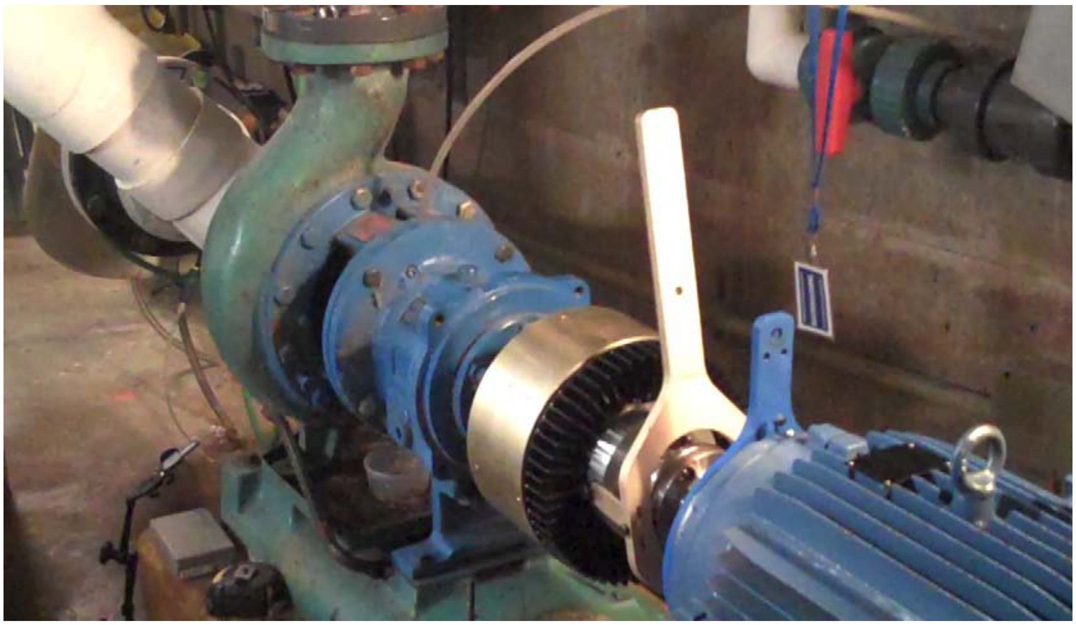

Figure 10 Flux Drive® ASD

5. CONCLUSION:

The goal in developing the Flux Drive® technology was to provide an alternative to present speed control options with similar or better performance. The result is a coupling and ASD with the following features:

- Reduce power required to operate machinery at variable speeds compared to VFDs and eddy current couplings,
- Eliminate introducing harmonic frequencies that cause distortion in the electrical systems
- Eliminate the need to install complex electronic filtering systems to reduce %THD to acceptable levels
- Reduce the ambient noise associated with VFDs and other competitive products,
- Reduce the life cycle costs of replacing and repairing expensive electronic components of other drives,
- Reduce peripheral costs (e.g., separate Filter rooms and air conditioning) involved with introducing a single (or multiple) VFDs to a system requiring speed control,
- Provide cost effective operations in harsh environments (saltwater, gases, etc.).
- Allow medium and high voltage applications to have an ASD that does not increase in price dramatically due to the higher voltage requirement of electronic drive products.

6. REFERENCES:

[1] *Product Testing: Magna Drive*, Motor Systems Resource Facility, Oregon State University, Report #00-048, March 2000.

[2] *Technology Demonstration of Magnetically-Coupled Adjustable Speed Drive Systems*, Pacific Northwest National Laboratory, PNNL-13879, June 2002.