AC Drives Lead the Technical Revolution of Electric Forklifts

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Forklifts can be divided into combustion forklifts and electric forklifts by drives. Electric forklifts are driven by storage batteries, are easy to operate, stable, make low noise and have zero emissions. Because of these features, users are increasing demand for electric forklifts and in developed countries electric forklifts have a much higher demand than fuel forklifts. This is closely related to environmental protection in those countries. Especially in ports, warehouses, the tobacco industry, food and textile sectors, electric forklifts are replacing fuel forklifts. Historically speaking, DC drives have been applied in such applications. However, as technology has developed AC drives have emerged as a superior alternative.

DC Motor

Up until the 1990's, DC motors drove almost all electrical vehicles. DC motors work under the following principle: direct current is transferred by brush to the commutator and then to the rotor. This kind of operation has two very apparent downsides. First, all the armature current must be transferred by the brush, making the motor performance highly dependent on the physical size and wearing status of the brush. Of course, this restricts the motor from better performance. In addition, the brush is easily broken and must be replaced regularly (every six months to 12 months) otherwise the life of the motor could be seriously affected. Considering this, the DC motor is usually equipped with a device to monitor the abrasion of the brush and to give a warning if necessary. Also, the heat is largely produced by internal elements of the DC motor, so most DC motors have a fan to reduce temperature.

3-Phase AC Motor

AC Induction Motor Drives represent newer technology developed in the nineties. A three-phase alternating current is transferred to the fixed stator windings. Rotator windings, which generate an electro-magnetic force, turn the rotator. The drive uses vector control-to-control speed and torque.

One of the features of the AC motor is that it works without the brush and can tolerate much higher peak currents as a result. This means the motor can work with more energy and larger brake torque for higher speed. In addition, the heat is largely generated by the stator windings of the motor enclosure, where the heat can easily be radiated and cooled. As AC motors require fewer elements than DC motors and have no damageable parts that need to be replaced regularly, they are more efficient and stronger, requiring no maintenance.

In the recent years, as frequency conversion technology has progressed and the speed of high power semiconductor devices and micro processors have greatly increased, AC induction motor compared to DC drives are becoming more efficient, taking less space, are lighter, simpler in structure, have a longer life and requirement no maintenance. This system has a wide range of velocity, capable of low-speed constant torque and high-speed constant power operation. They can very well satisfy the rotating velocity requirement for electrical vehicles in actual operation.

It is the fast development of semiconductors that is encouraging the technical revolution of AC motors so that they now feature much stronger controlling power. In addition, the lowering prices of electronic elements are reducing the cost of AC motor hardware. . This makes it possible for the wide application of AC drives.

Features of Forklifts Driven by AC Drives

The total cost of a forklift is not the sum of the cost of each element. It involves many other factors. For the end user, the total coast of ownership for a forklift includes purchasing cost, operation cost and maintenance cost. So, it is very important to

choose a reliable and high quality product.

By using AC drives, the forklift has a much better integrated performance, as well as a much lower frequency of malfunctions and element replacement. The forklift is more reliable and the productivity higher, while the operating and maintenance costs are lower. The user benefits the most. The details are as follows:

Low Operation and Maintenance Costs

No Maintenance Required for Life

As the AC motor has no forward/backward commutating contactor (), no brush or commutator, it is smaller, lighter and rotates faster. Regular examination and replacement of the brush is no longer required. The best thing is that this forklift motor needs little maintenance during its entire life. The forklift is therefore more reliable and stable. In addition, the design of the forklift does not have to reserve a space for maintenance. The motor even can be sealed up to make the forklift a more compacted structure.

Use Regenerative Braking to Reduce Abrasion

Regenerative braking is a non-contacting braking, much simpler than the traditional braking system. When the forklift driver uses the brake to slow or stop the vehicle or change direction, the motor acts like a generator, transferring electromagnetic torque into braking torque. This means the abrasion of brake pads will be minimum. This greatly reduces maintenance costs and minimizes operational costs.

In addition, the AC motor has higher efficiency in running and braking. When braking or changing direction, energy will be created. The more powerful the braking is, the more regenerative energy will be created. The energy will be returned to the battery to extend its working time. Although some DC driver forklifts have regenerative braking function, it can be started only during very powerful braking. This means much regenerative energy is transferred to heat during braking. However, AC drives can regenerate energy in almost all conditions, and the effect would continue till the forklift comes to a complete stop. Apparently, the energy regeneration efficiency is higher than DC motors.

Higher Productivity

Regenerative energy feeds back to the battery so that the battery can be used for a longer period of time. The energy can also be used to improve the integrated performance of the forklift. The result is that the forklift starts more quickly. The time and distance it takes to reach the maximum speed is reduced. Research shows that a forklift usually goes no more than 20 meters for most operations. The excellent accelerating ability of AC motors helps forklifts to reach full speed in such a short distance, further improving the working efficiency.

Easy Programming, Better Control

Fast development in semiconductor technology has brought breakthroughs to frequency converter velocity modulation, which can now provide real time control to AC motor rotating. The superior control of AC motors allows them to provide improved velocity adjustment performance as compared with DC motors. AC driving uses speed-torque for more sensitive control and better operation efficiency of the forklift. The function of speedup-panel-release-brake is used (i.e., when the forklift is running, a little release of the accelerator panel would start the regenerative braking) to make a smooth transition to from forward to reverse. Therefore, the forklift is more stable and reliable. In addition, CAN bus is used (CAN is one of the field bus types). The benefits are: distributed nodes are not restricted by installation location; system expansion is easier due to its modular structure so that the function features can be added or changed seamlessly; bus interface is standardized to achieve simpler system integration and flexible unit design.

More Comfortable Operation

AC drives make operating forklifts a uniquely comfortable experience. Because the AC motor is smaller and lighter, the forklift is more flexible. 7FB electric forklifts are of this design to reduce driver tiredness and improve comfort.

The following table compares the electric balance forklift of German Jungheinrich to display the differences between AC motor forklifts and DC motor forklifts of the same model.

Maintenance Costs (5 years)

Elements & Service	DC Motor	AC Motor
Change the brush on the motor	3 x = $1,175	None
Maintenance of the driving motor	$1,375	None
Commutator on the driving motor	1 x = $370	None
Change the brush on the lifting motor	3 x = $1,200	None
Commutator on the lifting motor	1 x = $120	None
Change the contactor	2 x = $1,130	None
Total	$5,370	None

Efficiency Difference (Take the example of electric balance forklifts of German Jungheinrich)

Storage Battery 48V/550Ah	EFG-V 20 AC	EFG-V 20 DC	Difference
Total Width	1120 mm	1120 mm	0
Turn Radius	2020 mm	2020 mm	0
Aisle Width	3570 mm	3570 mm	0
Travel Speed (no load)	17 km/h	16 km/h	+ 6%
Travel Speed (full load)	17 km/h	15 km/h	+ 13%
Lifting Speed (no load)	0.56 m/s	0.48 m/s	+ 16%
Lifting Speed (full load)	0.40 m/s	0.36 m/s	+ 11%
Accelerating (no load)	3.5 s	3.8 s	- 7%
Accelerating (full load)	4.0 s	4.5 s	- 11%
MAX. Grade ability (no load)	35%	28%	+ 25%
MAX. Grade ability (full load)	24%	17%	+ 41%
Energy Recharge Efficiency During Braking	30%	15%	+ 100%
Load Handled per Hour（L：100m，H：3m）	52 Pallet	39 Pallet	+ 33%

Other Comparison (Take the example of electric balance forklifts of German Jungheinrich)

	EFG-Vac 20（AC）	EFG-V 20（DC）
Internal Environment	No dust produced by the brush, clean, longer life for electrical components.	Dust is produced by brush abrasion. Over abrasion may burn the motor.
Motor	Sealed up structure, dust and humidity proof. Heat is produced on the enclosure during operation, quick cooling, suited for long time operation.	The motor is not sealed. Heat is produced within the motor. Heat is not easily radiated. It is not suited for long time operation.
Energy Recharge	The recharge efficiency while braking is nearly 30%. Greatly improves the continuous working life of storage battery and extend its life.	Only 15% while braking

The application of new electronic elements and high performance micro-processors and developments in control technology continually increase the performance-price ratio of controllers and also makes them smaller. Leading the development trend of future technology, Danaher Motion is doing research on high performance PMAC motors for application in the electric forklift sector. PMAC motors have a 10-15% higher efficiency than induction motors, are smaller and weigh less. PMAC motors also avoid the defects of commutator and brush in the DC motor. Now, PMAC motors are only applied in some low power electrical vehicles because of the high cost of PM material. However, PMAC synchronous motors are the next step in the development of electric motor vehicles.

Application of AC Drives in Forklift Industry

As an example, Toyota has produced different models of AC driven electric forklifts. Many functions of the latest 7FBE three-wheel forklift are reinforced on the basis of AC drives, which provide excellent controls different from any other product before. For example, the power control it provides enables 7FBE forklift to fully utilize the full recharge potential of the battery. So far, all the electric forklifts have the experience of deteriorating performance along with the consumption of battery life. However, Toyota 7FEB driver can always enjoy the feeling of "just recharged" because the forklift includes the power maintenance function. The time is about 40% longer than existing models.

AC drives are a revolutionary technology for electric forklifts, affecting the technology, production sales, market share, profit and the vision for innovation of forklift enterprises. The higher technology will also have a wider application. Those possessing the new technology will win more in the future market and gain a better position.

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