A new 'hoist unit' system for STS cranes

A motor from a different industry, the segment motor 1FW68 from Siemens, offers interesting solutions for the design of 'hoist unit' STS crane hoist systems. Liftech has developed a few possible concepts, writes Simo Hoite, Liftech Consultants Inc*

Existing large STS crane main hoist systems typically use two hoist motors, 600 kW each, connected to a large gearbox turning two hoist wire rope drums, each with two ropes. Current generation main hoist motors operate at speeds of 900 rpm with full lifted load at a speed of 90 m/min, and 1,800 rpm with reduced load at 180 m/min. Since the ropes are all fixed to the drums and lift the four corners of the spreader, the hoist system includes hydraulic cylinders to individually move the four hoist ropes allowing trim, list and skew (TLS) motions of the lifted load.

The same TLS system cylinders typically also protect crane components against overload if the spreader snags in the ship cell guides during hoisting. In a snag event, the spreader stops nearly instantaneously while the motors and drums continue rotating and stretching the ropes. The high rotational energy of the motors and high-speed brake discs make it difficult to stop the drum before the ropes or other crane components are overloaded. The hydraulic snag protection system limits rope loads by rapidly releasing the hydraulic cylinders above a pre-set load, allowing safe dissipation of energy until the hoist brakes and motors stop the rotating machinery before components are damaged.

A new approach

The new STS 'hoist unit' concept that Liftech has developed with Siemens uses a large-diameter, low-speed, high-torque electric motor, without a gearbox, to turn the drum. Permanent magnets are mounted at one end of the drum. The drum is mounted inside the stator and is controlled directly by the drives. The hoist unit is equipped with brakes mounted against the end flange of the drum. While it can have a large diameter (more than 3m is no problem), the width of the stator is only about 0.4m. An STS hoist system can consist of one to eight hoist units.

The motors operate in the 60 rpm to 120 rpm range, greatly reducing the rotational energy of the system. Because the rotational energy is reduced by over 85% compared with a traditional hoist arrangement, a separate hydraulic snag protection system is not required.

Using a single-hoist-unit system, the TLS function can be provided by screw jacks instead of a hydraulic system and the anti-snag function by the motor and brakes. Using a four-hoist-unit system, with each wire rope individually controlled, the separate TLS function can also be eliminated.

Single-hoist-unit and four-hoist-unit systems are presented in this article. We hope to stimulate interest in this new concept, which we believe can have significant advantages in maintenance and operation due to the simplicity of the mechanical design, reduced rotating energy and losses, and improved rotor control.

Segment hoist motor

The hoist unit system uses existing technology currently found in indexing tables and large machine tooling industries. Large-diameter torque motors, composed of curved segments based on linear drive technology, are used to directly turn the hoist drum without a gearbox or couplings.

Permanent magnets on the hoist drum are turned by the stator across an air gap of up to 3mm. To increase available torque, the drum diameter at the motor is larger than at the ropes.

Radial segments

The radial segments of the segment motor are independent power units that exert a lateral force on the fixed permanent magnets. In a machine tool drive system, or on a trolley, they are used for lateral propulsion. When the segments are curved and placed in a circle, they form a segment motor.

The radial segments are independently wired, cooled, and controlled. A large number of cables with a smaller cross-section are run in parallel, so that the cabling effort is not much different to the cabling installed in today's STS crane hoist systems.

The motors are characterised by high torque and dynamic capabilities at low rpm and a low torque ripple, a measurement of torque variation per rotation. The motors are dust-proof, designed for indoor use with IP63 protection, but can also be used outside with additional protection against water ingress and contamination by corrosive agents.

Even at large torques, the motors can make a full torque reversal in less than 50 ms. In a snag event, because of the reduction in rotating energy, the motors, combined with the effect of the ropes and brakes, can stop the rope drum from full speed in a very short time without overloading the wire ropes.

Siemens torque motor segments, with 300mm active length in the direction of the drum axis, are rated for a continuous force of 10.8 kN. Multiplying the number of segments by this force and the air gap radius gives the rated motor torque. The motors have this unique and simple characteristic: it is possible to increase the motor radius, with the same number of motor segments, and increase the torque. A larger circle also means more segments can be used, further increasing the available torque.

The motors are water cooled and suitable for continuous operation at rated torque. Maximum torque is 1.67 times rated torque, which is nearly equivalent to traditional hoist motors.

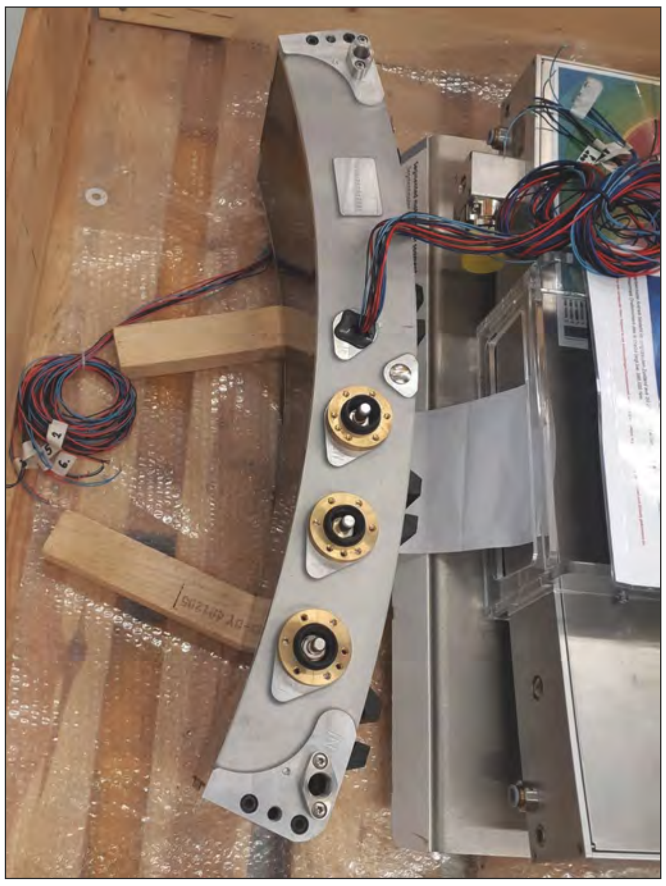
The greatest cost component of the motors is the permanent magnets. Segment motors are not viable as trolley drives on STS cranes because of the cost of magnets along the entire length of the runway.

At smaller air gap diameters, with multiple drums, the segment motor solution is more expensive because the smaller radius means more motor segments are required to achieve the required torque. There is a trade-off between the maximum viable diameter of the motors and the cost of the structure of the rotor and of the ring structure to support the motor segment stator around it. Flexibility in the number of segments and the motor radius, and varying the drum diameter, allow the selection of motors for different torques, using standard components.

The drives used to supply the stator segments with current are standard industrial servo drives, Siemens Sinamics S120. Two stator segments can be supplied by one inverter. The inverters for the different stator segment pairs are supplied from a common DC-bus and a self-commutated regenerative in-feeder. One inverter is set to operate as master, with the others to follow its output current as a slave. Due to the parallel operation of a larger number of inverters, any failure of a single inverter can be easily accommodated.

Single-unit concept

For typical rope towed trolley (RTT) STS cranes, an equivalent system to the existing main hoist consists of a single drum of 1.1m diameter, 8.5m long. The drum is supported on pillow blocks. At one end of the drum is the motor, about 0.5m long by 3.4m diameter, supported by an outer



Curved motor segment with three main leads

Other Content is Not Shown

**This article was written by Simo Hoite, with contributors: Gerhard Fischer, Siemens; Matt Plante, Virginia International Terminals; Andreas Dieges, Siemens; Gong Zhenqing, ZPMC; Michael Scheidt, Sibre; Patrick McCarthy and Nick Grebe, Liftech. The views and opinions expressed are not necessarily shared by WorldCargo News* circular steel structure. At the other end of the drum is a brake disc of 2.4m diameter fitted with four smaller drum brakes, such as Sibre SHI 162 – with springs suitable for 2M cycles of operation.

All four main hoist ropes run off the drum, which is smaller than usual. The reeving angles are tight, but still viable, if the backreach is less than 25m. The motor consists of 15 stator segments, each with three power cable connections, a thermal sensor cable and water cooling fittings.

Eight permanent magnets are mounted on the rotor for each of the 15 motor segments, making 120 magnets in total, forming a ring with an inside diameter of 3.2m.

The main differences between the new and existing hoist systems are that couplings and gearboxes are eliminated and the motor speed is reduced from 900/1,800 rpm to 52/104 rpm. As a result, the rotating energy at full hoist speed is reduced by about 85% and the motor, ropes, and brakes can stop the load in a snag event without overload. Some method of adjusting rope lengths is still required for TLS motions, but without the need for hydraulic snag protection, this could be done either with hydraulic cylinders or with electronic actuators, such as screw jacks.

Initial cost of the complete one-hoist-unit system, including electronic snag protection and TLS functions, is estimated at 10% less than traditional main hoist machinery with hydraulic snag protection.

Four-unit concept

Using four drums of 0.9m diameter, each with a single rope, the required drum length is about 2.7m for a large, modern STS crane. For 32mm standard hoist ropes, the drum rope diameter ratio is 28:1.

The selected motor in our solution uses seven segments with an air gap diameter of 1.5m. The outer stator diameter is 1.7m. If a larger, slightly more expensive motor is desirable, eight segments can be used with an air gap diameter of 1.7m. In this case, the higher torque will allow a drum diameter of 1.3m.

A four-hoist-unit system, with the individual loads equalised and controlled electronically by the drives, can replace a standard STS crane hoist system, including the TLS and snag protection functions.

Initial cost of a four-hoist-unit system with a total of 28 individual motor segments is estimated at 15% more than a traditional hoist system. Since such a system would include eliminating maintenance of the gearbox, high-speed brakes, couplings, and hydraulic anti-snag system, the higher initial cost is likely to still be attractive to most owners.

Braking

Without a gearbox, the approach to braking is different from the standard STS crane design.

In a standard hoist system, two or more calliper style brakes, or similar, are used as safety brakes on the hoist drums, supplementing the thruster service brakes on the high-speed shaft. The drum safety brakes are required because in standard hoist systems, it is possible that a shaft in the gearbox can fail, resulting in free-spinning of the drum and dropping the load. Without a gearbox, this eventuality does not exist, and emergency brakes are not required.

For the hoist unit system, there will be a large-diameter brake disc mounted to the opposite end from the motor on the drum. The speed of the disc on the brake will not exceed 30 ms, which should improve the braking performance of the linings compared with existing systems.

Standard thruster holding brakes cannot be used because of the large brake disc diameter. For the single-hoist-unit system, four hydraulically released calliper brakes, such as Sibre SHI-162, will be used, with a spring package suitable for 2M cycles of operation. With a suitable hydraulic package, the brakes can be released within 0.3 seconds. The drive system will easily establish torque before the brakes release.

Applying four smaller service brakes on the single hoist unit, with a 2.4m diameter brake disc, gives about the same performance as existing systems using one holding brake and one safety brake per drum – four brakes in total. Different brake and disc size combinations are possible.

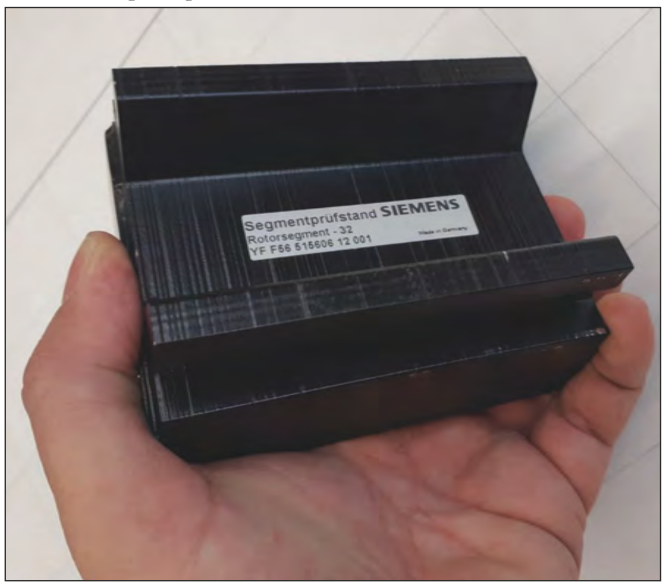
Snag

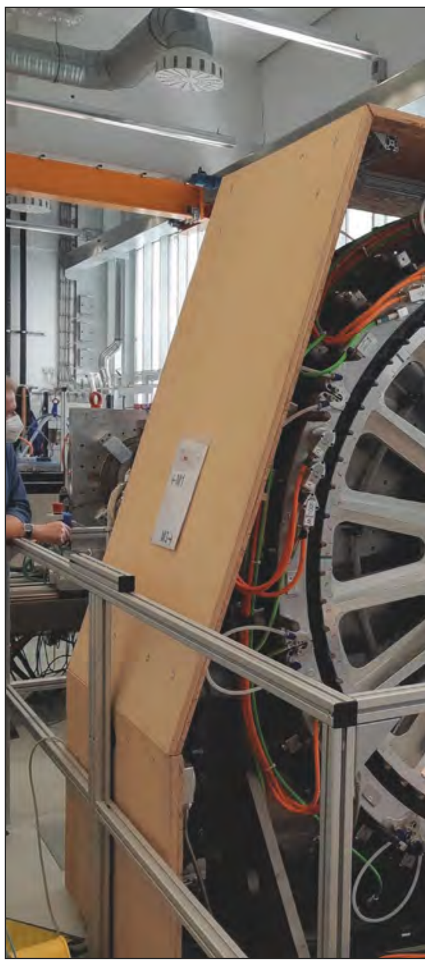
In the case of high-speed snag, the segment motor system can stop the drum rotation before the ropes, or structure, are overloaded. Due to the low inertia and fast stopping, the forces resulting from stretching of the wire ropes is the main factor stopping drum rotation, but the motor and brakes also contribute.

We considered a traditional STS snag event with lift system at a speed of 180 m/min, assuming four loaded standard ropes of 32mm diameter, 220m long; motors rise to max torque and then trigger a snag event, reversing torque and applying the brakes.

For both one-hoist-unit and four-hoist-unit systems, we found the drum can be stopped before the rope load reaches 25% of ultimate capacity with symmetric snag.

Permanent magnet segment as used in the test motor




Siemens test motor in Munich, Germany

In the case of one corner snagging, or one side, the build-up of motor torque to emergency stop takes longer, while the ropes continue to be stretched. If the event is detected by Sibre's SLP system, within normal parameters, the drum can be stopped before the maximum rope load reaches 38% of maximum, which should be acceptable.

Maintenance

For the single-drum system, the weight of the drum/rotor is about 13t. For removal from a standard machinery house, the drum could consist of two or three sections bolted together.

Maintenance of the main hoist gearbox, special drum couplings, high-speed brakes and high-speed couplings are all eliminated, along with the hydraulic snag protection system. With a four-hoist-unit system, maintenance of the hydraulic TLS and hydraulic snag protection system is also eliminated.

The hoist unit system offers a simplified solution for crane hoisting. The single-hoist-unit solution has 15 independent segments, several of which can fail in service with the hoist system continuing to operate at reduced torque. Therefore, the reliability of the electrical main hoist drive is significantly improved.

Elimination of two drum couplings, two high-speed couplings, the gearbox, and two high-speed brakes means that there are fewer parts that can fail. If the hydraulic TLS and snag protection system is also eliminated, reliability is further improved.

MOT considerations

The segment motor design can make machinery-on-trolley (MOT) cranes more viable at large crane sizes. The MOT design eliminates tensioners, catenary trolleys and tow ropes, trolley tow ropes, and rope protection pads and rollers spread over the crane structure. It also requires much less hoist rope length. It provides better load control, due to direct drive control of the trolley, albeit typically at lower trolley accelerations. The hoist ropes are much shorter and have reduced rope wear. There are also far fewer ropes to inspect, maintain, and replace.

The main disadvantage is the weight of the trolley. MOT trolley STS cranes are rarely used today because the heavy trolley, combined with the large size of today's cranes, results in excessive wheel loads on the wharf. Other issues observed with MOT cranes include increased wear on the trolley wheel and rail, due to the greater trolley weight, and the possibility of structural problems with the trolley if it is not designed to be flexible to accommodate an uneven runway surface.

Our preliminary investigations show that MOT trolleys weighing 65t or less can be practical with four-hoist-unit or six-hoist-unit solutions. This is less weight than recent MOT trolleys, which typically weigh about 85t (or more). We developed a concept that allows fast disconnect of individual hoist units at the trolley and on the headblock so that the entire hoist unit can be swapped out for maintenance. The individual hoist units would have a cover, but no machinery house. Rail wear issues can be addressed by adequate sizing of wheels and rails.

Conclusions

Hoist unit systems – allowing the elimination of the main hoist gearbox and other mechanical components, the snag protection system, and the TLS system – may present a significant advance in hoist systems, offering lower cost, improved reliability, and significantly reduced maintenance costs.

Hoist unit systems may also make MOT cranes more viable by allowing the construction of a lighter MOT trolley. MOT cranes offer improved load control with shorter ropes, direct trolley drive, and better feel for some operators. They can also offer significant reductions in maintenance cost because of the shorter ropes and simpler overall crane design.

In addition to the advantages offered for traditional cranes, the segment motor design, combined with the balance crane design, may make large MOT cranes viable again. ❑

Other Content is Not Shown

MOT concept featuring four independent hoist units (motors and drums) for an under-hung MOT trolley. The under-hung hoist units can be individually disconnected and swapped out for service in the workshop