Belts and planetary gearboxes add up to reliable parts-handling

JOE BROWN, Associate Editor

Conventional wisdom says that heavy-duty parts handlers need ball screw or rack-and-pinion actuators. But this builder uses belt drives to prove otherwise.

Belt drives supposedly can't handle the high inertial loads of heavy-duty parts handlers on automated production lines. In recent years, however, belt-driven shuttles were developed that carry parts weighing up to 10,000 lb, moving them at velocities up to 170 in./sec and accelerations to 400 in./sec^2. These shuttle drives span distances up to 40 ft at up to 18 cycles/min.

The new shuttles are built by ISI Robotics, a Fraser, Mich. manufacturer of part transfer systems for global automotive and appliance markets. Defying conventional wisdom, the company uses the belt-driven shuttles on heavy-duty automated parts handlers, Figure 1, to achieve longer mean time between failures, easier and less-frequent maintenance, higher energy efficiency, and lower capital cost compared to ball screw or rack-and-pinion systems. The longer the travel, the larger the cost savings.

One key to the success of these belt-driven shuttles is the use of stiff (high response) servomotor drives, up to 12 hp, that enable high positioning accuracy.

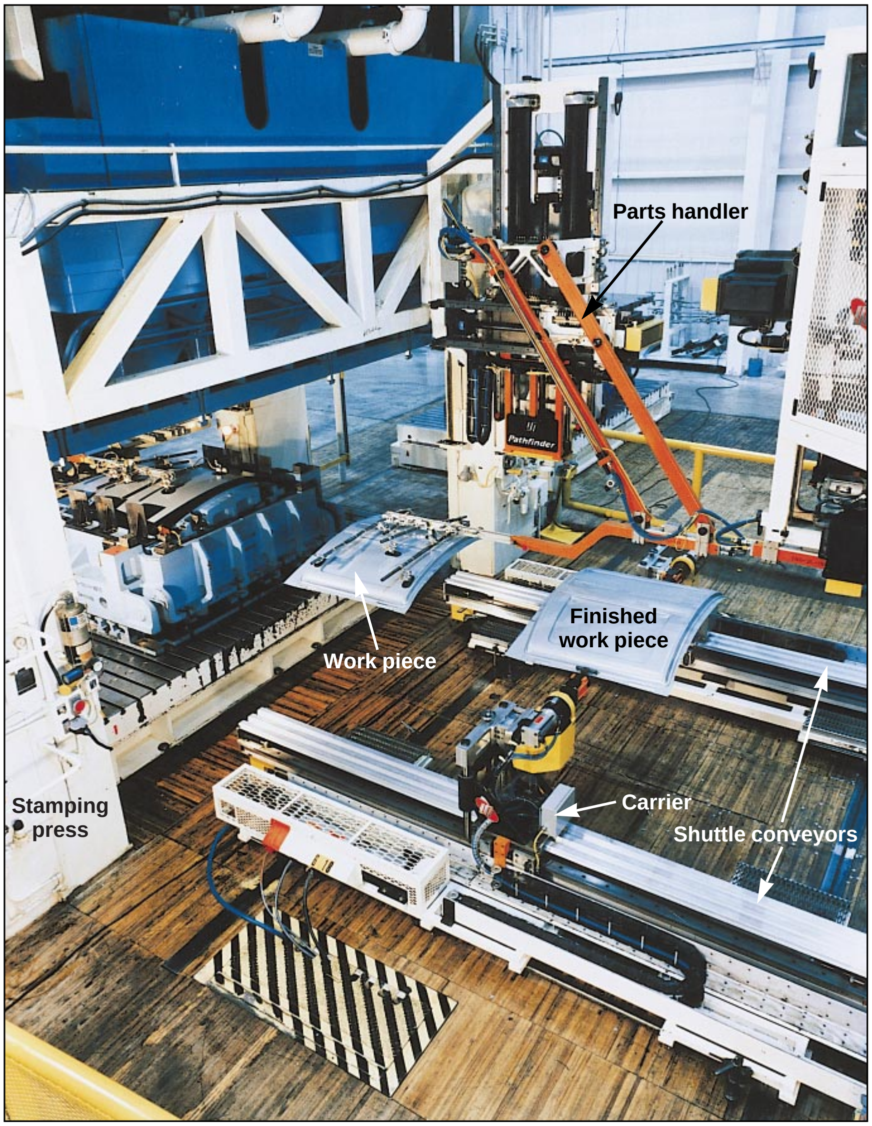

Figure 1 — Shuttle conveyor in a busy stamping press room typifies the system recently installed in China. Pathfinder parts handler (top) transfers work piece from one shuttle (middle) to the press at the left while the carrier on another shuttle (bottom) takes a finished piece to the next press, which is out of sight to the right. Motors, gearboxes, and belt drives are located below the shuttles and are not visible in this photo.

"Beginning with stiff drive packages, we deliver parts-handling shuttles with 4 to 1 ratios between reflected load inertia and motor-rotor inertia. Moreover, the systems offer positioning accuracy within ±0.005 in.," says Dave Tomlin, ISI Robotics mechanical engineering manager. "That's a lot higher performance than is normally thought possible for belt-type shuttles."

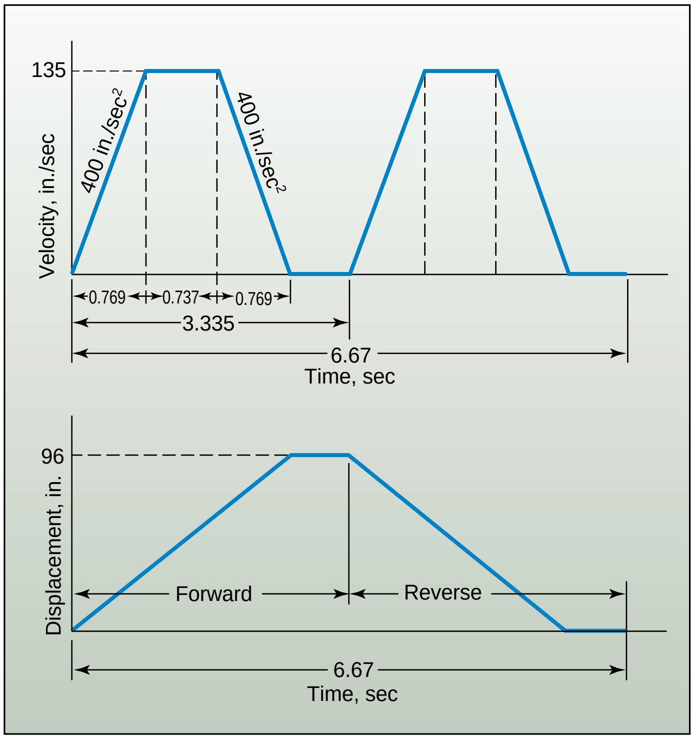

Figure 2 — Heavy-duty shuttles operating in a Chinese auto body stamping plant must accelerate parts to a speed of 135 in./sec and then decelerate to a stop in less than 3 sec. while moving parts a distance of 8 ft. This duty cycle generates inertial forces approaching 1 g.

Stamping plant

A recent application of the new shuttles is a parts-handling system built for the Chang An automotive parts stamping plant in Sichiuan province, mainland China. This operation started in November 1994, with five shuttles transferring 50-lb auto body panels over 8-ft distances at a rate of 9 panels/min. This duty cycle requires a maximum velocity of 135 in./sec and maximum acceleration of 400 in./sec^2, producing inertial forces up to about 1g, Figure 2. Though each part weighs about 50 lb, the total weight of the part and its belt-mounted carrier is closer to 350 lb, which causes high inertial forces.

The shuttles operate between five heavy-duty stamping presses, each equipped with parts handers from ISI Robotics that load and unload the presses. In a typical operation, Figure 1, a belt-mounted carrier on the shuttle picks up a stamped part from the parts handler at one press, travels 8 ft and hands the part off to another parts handler at the next press. Then the carrier returns to pick up another part. The same cycle is repeated between each of the five presses. Whether full or empty, the carrier is accelerating or decelerating most of the time. It spends very little time at maximum speed or stopped at either end. The system provides ±0.005 in. placement accuracy at pickup and delivery points.

For low maintenance, choose belts

Why pick belts for such high-inertia, close-tolerance applications? "As with many of today's automakers, engineers at Chang An insisted on a system with high reliability as well as ease of maintenance," Mr. Tomlin explains. This new requirement grew out of a reliability and maintainability (R&M) movement, led by Ford Motor Co., which is catching on throughout the automotive industry globally.

"Because both ball screws and rack-and-pinion systems must be periodically lubricated, we decided that toothed belts would be the best answer to R&M requirements," says Mr. Tomlin. "In our reliability tests, the new belt systems demonstrate a longer mean time between failure (MTBF) than previous belt systems. Mean time to repair (MTTR) is dramatically reduced with our modular bearing blocks and pulley assemblies. Also, the gearbox is easily accessible, which facilitates quick replacement in the event of failure."

Planetary gearbox — with a twist

For the Chang An project, ISI Robotics engineers specified an accurate, torsionally stiff drive package consisting of a 3,000-rpm servomotor and a modified planetary gearbox with 6:1 speed reduction ratio, Figure 3. The gearbox, from Lenze Power Transmission, Fairfield, N.J., incorporates a 354 lb-in./arc min torsional stiffness at the output shaft to enhance positioning accuracy. To obtain this high stiffness, manufacturers increased the preload on the gear teeth.

To this package, the engineers added a Brecoflex AT10 toothed drive belt (10-pitch) to which a parts carrier is clamped. The belt is pretensioned to 1,350 lb to accommodate rapid acceleration and deceleration with minimum belt elongation. With this arrangement, the motor speed control adjusts carrier speed without mechanical brakes or clutches.

Because this belt pretensioning exceeds the planetary gearbox's overhung load limit, an outboard support bearing was required. To accommodate this bearing, engineers specified a 5.63-in. long shaft, rather than the usual 3.23 in., Figure 4. The bearing, a McGill spherical roller bearing, mounts in a housing on the shuttle frame.

Why a planetary gearbox instead of he-

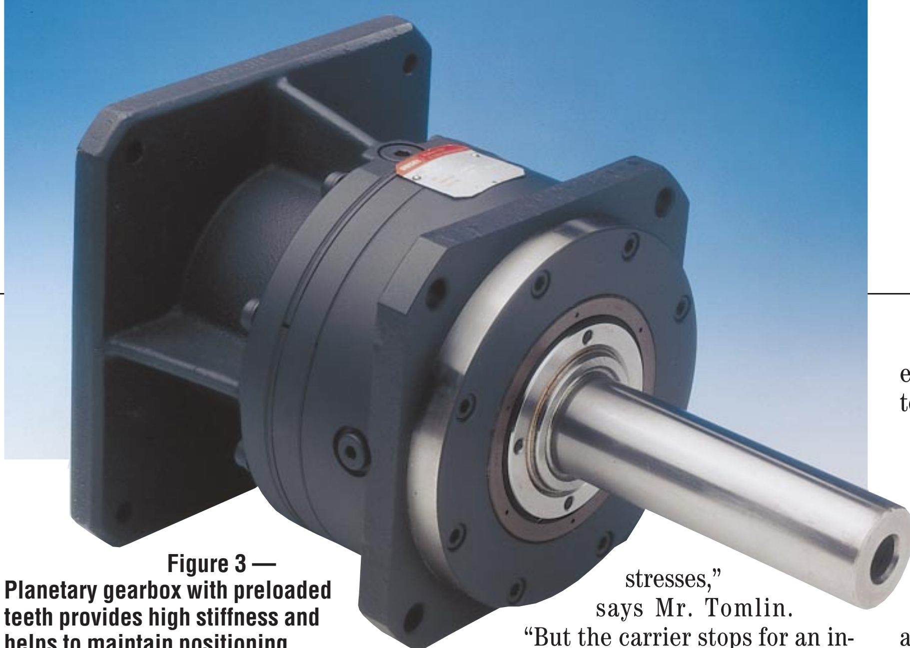

Figure 3 — Planetary gearbox with preloaded teeth provides high stiffness and helps to maintain positioning accuracy for a shuttle drive. For the Chang An shuttles, the planetary gearbox is less than half the size of a helical or worm gearbox.

lical or worm? "Mainly for its stiffness and torque-to-size ratio," reasons Mr. Tomlin. With a planetary gearbox, multiple planet gears provide more tooth contact area to share the load, thereby offering more load capacity for the gearbox size. At Chang An, each gearbox contains three planet gears. "The combination of planetary construction and gear-tooth preloading makes for a stiffer gearbox than is possible with worm or helical drives."

Alex Himmelberg of Lenze Power Transmission, which makes all three types of gearboxes, adds "planetary gearboxes also provide more permanent accuracy than do worm gear drives. They retain their stiffness and positioning accuracy longer without adjustment for tooth wear. The gearboxes' high tooth contact area also enables them to handle more severe accelerations and decelerations."

Engineers say that the planetary gearbox used in Chang An takes up less than half the volume of a helical or worm type gearbox of comparable torque rating. Gearbox efficiency is 96%. With this high efficiency, there is less friction and wear, translating into energy savings and longer service life.

Managing system deflections

Because of the high inertial forces expected in the Chang An parts shuttles, engineers were concerned about elongation of the drive belts. "Elongation occurs during maximum acceleration and deceleration because of the added tensile stresses," says Mr. Tomlin.

"But the carrier stops for an instant at each end of its travel. The belt returns to its statically pretensioned length for that instant. So we get the required positioning accuracy at the two points in the cycle where we need it most. This has been proven on dozens of heavy-duty belt shuttle applications."

He added that belt stiffness along with stiffness of the support bearing, gearbox, and mounting comprise total system stiffness, or resistance to deflection. Because of its long length, the belt typically contributes the most deflection. But the use of pretensioning to get accurate positioning where it's needed gets around that problem.

Cell-based control

The parts handlers and shuttles are located in cells, one cell per press, each controlled by a VME-based five-axis controller. To coordinate the operation between cells, each controller has an I/O "handshake" interface with adjacent units and presses. The entire press line operates asynchronously to minimize idle press time and boost throughput. Cell-based control enables each cell to do the next task as soon as it is safe to do so within that cell.

An operator writes part-handling programs via a touch screen and keypad. To generate a program, the operator keys in coordinates along the carrier path including start and end points. Alternately, the operator can "teach" the cell controller by manually moving the carrier to each desired position and pressing a key to record that point.

Shuttle economics

Comparing the cost of belt-driven shuttle systems vs. ball screw or rack-and-pinion types, ISI Robotics engineers estimate that the material costs are comparable for systems that travel up to 5 or 6 ft. Belt-driven systems have lower material costs, and they require less labor to assemble because of fewer components. But, these savings are offset by the added cost of the gearbox, which isn't needed in the other two designs. At travels longer than 6 ft, the cost advantage of belt-drives increases because machined racks and ball screws cost more per foot than belts.

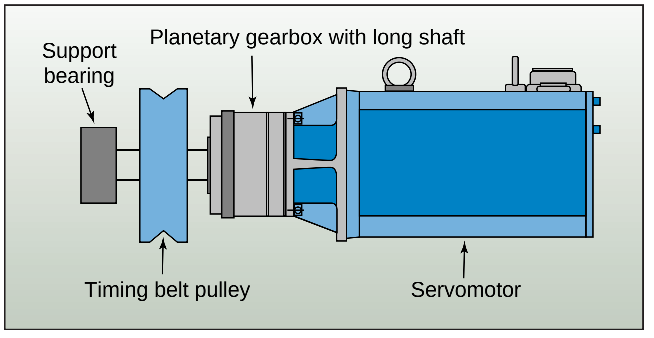

Figure 4 — Outboard support bearing on a long output shaft enables the planetary gearbox to handle high overhung loads caused by a pretensioned belt.

"We've built all types over the years," says Mr. Tomlin. "But today's belt-driven shuttles handle higher inertial loads than previous belt units, and they meet stringent positional accuracy requirements. We feel they are the best answer for today's reliability and low-maintenance requirements, even at part loads up to 5 tons and load-to-motor-rotor inertia ratios up to 4 to 1." ■