Linear Robots with Brains

New Software from Engel Compensates for External Influences in Injection Molding Handling

The vision for the smart factory is that the various components of the production cells will be permanently self-optimizing – distributed intelligence is a prominent feature of "Industry 4.0". For injection molding operations, this means that the focus is widening from just the molding machines to the entire production cell, including the automation. A new generation of linear robots is now capable of reacting to external influences in real time.

Although this is not visible from the outside, the Engel viper linear robots have undergone a significant performance boost. The key: sophisticated software and sensor technology (© Engel)

Engel Austria GmbH, Schwertberg, Austria, set the stage for the smart factory seven years ago when it launched the viper generation of linear robots (**Title figure**) for injection molding machines. Featuring optimized mechanical and drive technology, fieldbus communication up to the sensors on the gripper unit and integrated data management for robot and injection molding machine, these robots are perfect for integrating intelligent software to exploit the potential of the production cells and boost the benefits for users.

Faster Positioning for Shorter Cycle Times

It started with three software modules in 2009. These enabled even robots with long beams to adapt their movements and dynamics and so maximize their overall efficiency. The vibration control module calculated the expected oscillation of the robot that would result from each load and corresponding handling task, and compensated the oscillations in real time.

Now, Engel has gone one step further with its new "active vibration control." This controller can also handle vibrations from external influences, enabling the robot to reach a stable working position much more quickly, and shortening the cycle time in many applications. This gain in cycle time becomes especially apparent in such operations as placing of »

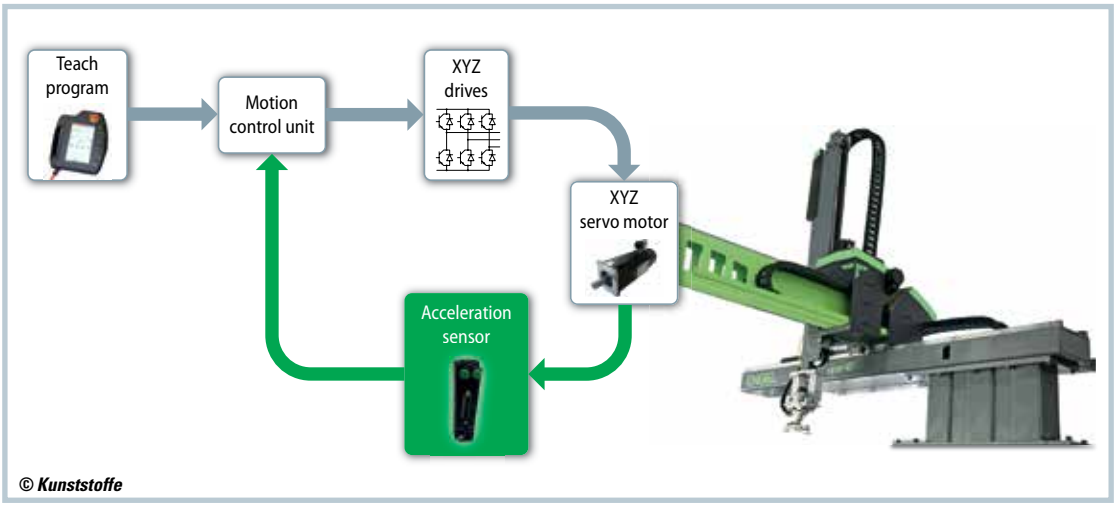

Fig. 1. Closed-loop control: A 3-D acceleration sensor detects the dynamics of the vertical arm and relays the measurements to the controller (source: Engel)

inserts and transfer of pre-molded parts. In both cases, the active vibration control directly impacts the cycle time.

By virtue of their lightweight construction and high load-bearing capacity, every Engel viper robot is a virtually undamped system. Once vibrations start, it takes a long time for them to dissipate – up to several seconds, depending on the size. The reasons for oscillations are various kinds of transmission of external forces. e. g. by ejector movements or by other production-cell components attached to the robot. The robot may also start vibrating due to movement of the wrist axis or the pneumatic cylinders. Small robots performing simple pick-and-place operations generally do not need vibration control because of their rigid, rugged construction. However, where large loads and long axes are involved, the need for optimization grows considerably.

3-D Acceleration Sensors Support Efficient Damping

The key to efficiently damping external vibrations that are not caused by robot movements is the use of 3-D acceleration sensors. These capture the dynamics of the vertical arm and relay the measurements to the controller in the linear robot (**Fig. 1**). There, the movements are recalculated such that the vibrations of the working point are minimized under closed-loop control by a damping counter-movement.

Thanks to active vibration control, some 90 % of oscillations induced by external influences are eliminated within the timeframe of one of the robot's ei-

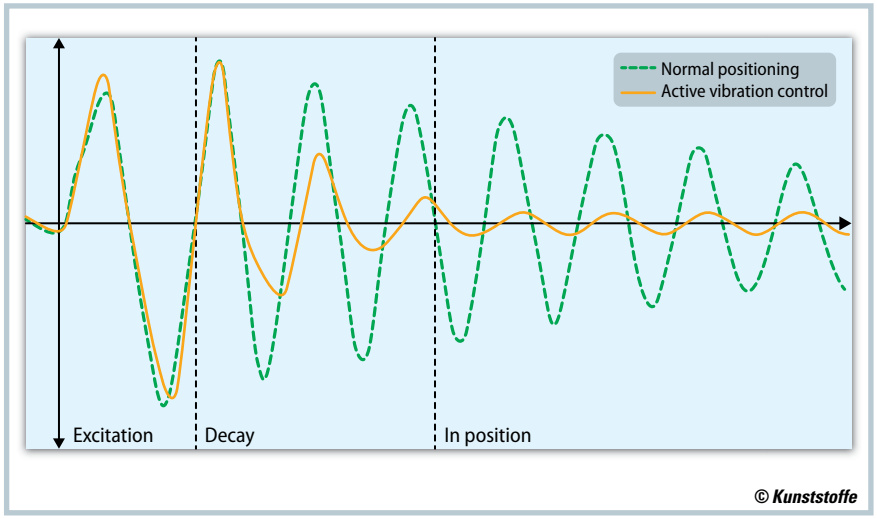

Fig. 2. Active vibration control can damp nearly any oscillation in the shortest-possible time – both at rest and in motion. It only takes a fraction of a second in the case of large machines to reduce the vibration to a barely perceptible movement (source: Engel)

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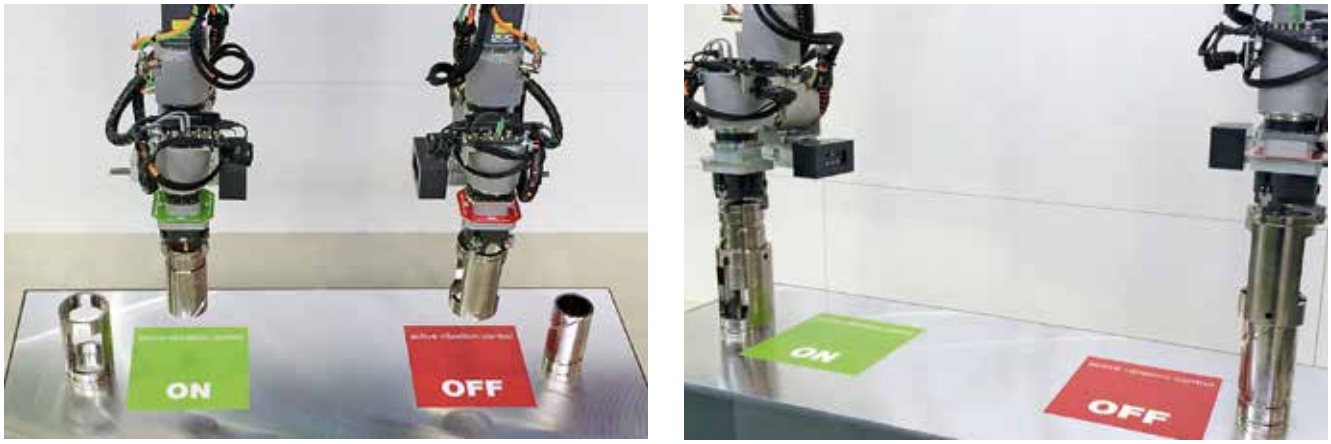

Fig. 3. The new module was presented for the first time at Fakuma 2015. The robot equipped with active vibration control reached a stable working position much faster and performed its handling task – picking up the sleeve placed on the outside – in less time than the robot with inactive vibration control (© Engel)

genfrequency (**Fig. 2**). Depending on the application and the size of the robot, only a fraction of a second may be needed. Without vibration control, the robot would oscillate for at least 10 times as long. It is important that vibration control can handle the robot's peculiarities especially that the own vibration frequency depends in a nonlinear manner on the vertical position of the gripper. This is important over the entire dynamic phase when position changes fast.

Engel integrated the sensor technology by developing a sensor with a fieldbus connection mounted at the end of the vertical axis. The sensor contains two separate acceleration sensors in different orientations. This redundancy prevents outages and increases the robot's availability.

Engel presented the new module for the first time at Fakuma 2015, where the grippers of an Engel viper 40 double robot held a sleeve and a corresponding core. The two robots with a common Z-axis turned the two parts together, inserting one inside the other and separating them again, repeating this multiple times. To emphasize the performance boost provided by the new software module, the vibration control was activated on just one of the robots. That robot reached a stable working position more quickly, significantly shortening the cycle time (**Fig. 3**).

The viper at the tradeshow demonstrated the safe handling of two parts by moving them precisely into each other with a tolerance less than one tenth of an inch without getting in contact with each other. Of course, contact between parts is a common occurrence in practice, e.g. when parts are inserted, picked up and deposited. When the vibration control is active, the handling robot automatically detects such situations, thereby protecting its own robotic structure, the mold and peripheral equipment.

Calculating the Expected Cycle Time in Advance

In upgrading its linear robot series, Engel not only increased the positioning speed, but also boosted the overall performance and efficiency. The robots are now even better at automatically adapting their dynamics to the real weight load. Moreover, the "efficiency control" feature also takes the cycle of the injection mold into account. The movement profile is adjusted fully automatically in the first cycle and these settings are then refined. By the time the second cycle is complete, the robots have achieved the optimum dynamics for the injection molding process.

In this regard, the absolute speed is not just dependent on the actual load; stroke length, motor temperature and timing within the process sequence have an influence. Demolding always takes place at maximum speed, because it directly determines the cycle time. When cooling times are long, though, the robot reduces the speed of the movements occurring outside the mold space.

Ultimately, users are more concerned about cycle time than about the robot's speed and dynamics. The cycle time calculator in the CC300 controller of Engel injection molding machines can calculate the expected total cycle time for each application in advance with great precision. This has been achieved by fully integrating the RC300 controller of the viper linear robots as a subsystem into the CC300 controller.

Such automatic optimization of the robot dynamics not only minimizes the cycle times, but simultaneously boosts energy efficiency and protects the mechanical components, thereby extending the overall service life. This allows maintenance intervals to be widened and uptime to be increased as part of a predictive maintenance program.

Outlook – Use of Sensors Is Paving the Way to further Smart Features

The new active vibration control first saw the light of day at Fakuma 2015. Since then, it has been gradually rolled out across the viper series starting with the viper 20 to the viper 120. By 2017, it will feature in the largest viper robots with a maximum load-bearing capacity of 120 kg. The software module configures itself each time, automatically adapting to new circumstances, such as changes of payloads, and making the overall process much easier to manage.

The sensor technology opens up scope for further advances in robots. If the robot's tool-center-point can be kept stable by means of closed-loop control, larger robots capable of moving even higher loads will be possible in the future, despite being constructed in progressively slimmer and lighter designs. However, it is the intelligent sensor technology combined with smart software that will bring the greatest benefits. With its various connectivity and control options, it is paving the way for the smart factory. ■