

Improved parison glass handling with servo-electric invert mechanism (SEI)



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*Smooth motion with high repeatability and consistency is an important demand on mechanisms that directly handle glass in IS machines. Poor handling can negatively impact container quality even in the early stages of forming. Dr Matthias Kümmerle and Dipl-Ing Leo Diehm**



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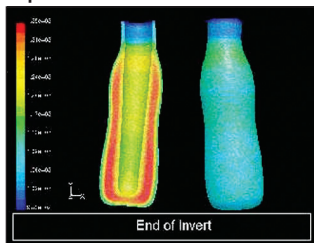
show the importance of controlling motion during the invert process, and propose a solution that can reduce critical defects.

The key to an optimum, highly productive glass container forming process is the controlled handling of glass flow through the IS section. A smooth flow avoids stressing of the glass, which could reduce or prevent defects – mainly critical defects of the finish. Thus, the factor determining and limiting speed is not the mechanical handling of the glass by the section mechanisms, but rather the necessary process time. The process time requirement is determined by the thermal properties of the glass and by the physical limitations of the forming process. In order to further increase the productivity of the IS machine, mechanical handling times need to be minimised. Consequently the speed, the precision, the controllability and the repeatability of motion within section mechanisms need to be improved. Within the scope of these growing demands, servo-electric drives are increasingly replacing the pneumatically driven mechanisms that still represent the standard in glass container forming machines.

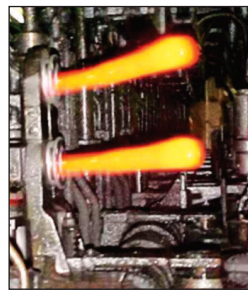
Specific demands on invert mechanisms

Although the invert mechanism is not directly involved in the forming process, its contribution to container quality is crucial. Due to inertial forces, the 180° rotation induces unwanted bending and mechanical stressing of the parison. **Fig 1** shows a typical picture of two parisons during their invert motion. The quality of the invert motion is inversely proportional to the torque acting on the neck of the container during the invert. It is this torque that actually leads to stresses in the neck area and to bending of the parison.

▼ **Fig 3.** Simulation of deformation of parisons at end of invert motion.

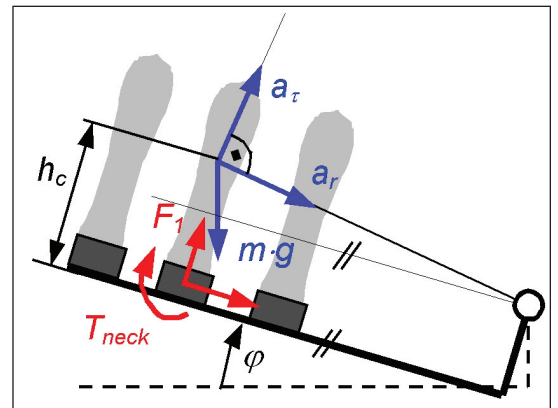


Using a simple dynamic model (**Fig 2**), the neck



▲ **Fig 1.** Photo of parisons during invert motion.

▶ **Fig 2.** Simplified dynamic model.



torque can be expressed as function of the geometry (parison shape, neckring holder offset, etc.) and of the motion profile:

$$T_{neck} = f(\text{geometry}, \varphi, \dot{\varphi}, \ddot{\varphi})$$

It is important to note that, since the parison is always being rotated by 180°, every invert motion leads to neck torques. But the resulting torque amplitudes, and in particular the resulting jerk, are directly influenced by the motion profile. Velocity, acceleration and jerk (the first derivative of torque) can effectively be minimised as a function of motion time.

Taking a step beyond this simple dynamic model, Finite Element Modelling (FEM) simulations have been carried out to examine the deformations of the parisons during different stages of a typical invert motion (**Fig 3**).

The strong deformations of both parisons in the neck area (especially in the middle of the invert motion cycle, and to a lesser extent at the end of the motion) underscore the sensitivity of this phase of the process.

Servo-electric vs pneumatic invert mechanisms

Two major advantages of servo-electric actuators over pneumatic actuators are their controllability and their high repeatability.

Controllability

The primary means to control the behaviour of a pneumatic mechanism is adjustment of the airflow. However it is impossible to independently set the motion time and the velocities at specific points. Servo-electric mech-

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anisms on the other hand allow the user to select the best motion profile.

Fig 4 shows the measured velocity profile of a constant cushioner invert mechanism and of a SEI mechanism at a motion time of approximately 700ms (ie a typical invert motion). The profile of the servomechanism shown in the figure is a Freudenstein-13 cam program, and the profile of the pneumatic mechanism is the result of setting the needle valve. The velocities are scaled so that they both correspond to the motor rpm of the servo-motor. The figure clearly shows how well the SEI completes its controlled motion when compared to the pneumatic mechanism. In particular, the deceleration phase and the jerk induced by the pneumatic mechanism's end stop cushioner do not meet the requirements of smooth glass handling.

Repeatability

Fig 5 shows ten measured position profiles of ten consecutive invert motions. The single profiles are aligned in the figure such that the start-trigger for the motion is at $t=0$. The initial acceleration of the pneumatic mechanism is not very repeatable and leads to time variations at different angles of up to 50ms or angular variations at certain times of up to 25°.

The standard deviations (STD) of the time as function of the angular position are displayed for both mechanisms in **Fig 6a**. At $t=0$, the profiles still have the same position and the STD is zero. With increasing time, the STD increase and reach their maximums at approximately the halfway point of the motion time scale. Obviously, after completion of the motions, the standard deviations reach zero again. In the short term, for example over ten consecutive cycles, the maximum angular standard deviation of the pneumatic mechanism is approximately five times higher than the one for the SEI. Over longer terms (eg several days and nights) of operation, the differences will be even greater.

Fig 6b displays the STD of time as function of the angular position of the invert arm. As the angle increases, the times increasingly vary, and the STD of the pneumatic invert mechanism reaches 15ms by the end of the motion. Note that it is the first part of the motion that principally contributes to the STD for pneumatic mechanisms. In other words, it is particularly the acceleration that is not repeatable.

Improving performance through SEI mechanism

Using the simplified dynamic model as described on the previous page, the neck torque and jerk of the inner parison has been calculated for the measured motion profiles of the CC pneumatic and the SEI mechanism. **Fig 7** shows the result.

The two plots clearly demonstrate how much higher the resulting torque and jerk are during the deceleration phase of the pneumatic mechanism than during the same phase of the SEI mechanism.

Choice of Motion Profile

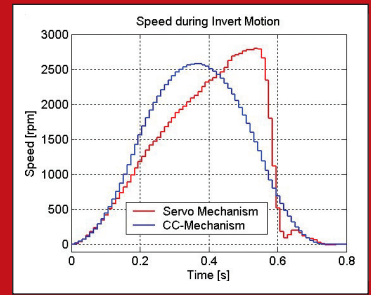
Besides uncontrolled jerkiness, the invert velocity in the vertical position is another important parameter that can negatively influence neck torque. Excessive velocities

result in unacceptable upward bending due to centrifugal forces, low velocities lead to undue downward bending due to gravity.

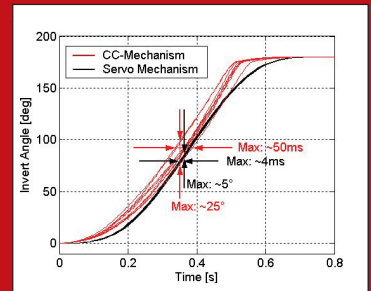
Servo-electric mechanisms allow the selection of motion profiles that control operational movements such that they occur within a specified time frame and at the optimum velocity. **Fig 8** shows various invert profiles that have maximum normalised velocities between 1.3 and 2.0 for identical motion times. This capability allows the user to optimise motion time without jeopardising motion characteristics.

Similarly, invert motions can have different motion times, but identical maximum velocities (see **Fig 9**).

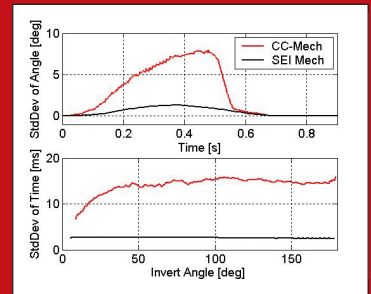
This flexibility has great practical significance. Today, skilled and attentive machine operators usually adjust pneumatic mechanisms such that the bending of the parisons during the invert motion is within acceptable limits. The motion time then is a result of these adjusted settings. A servo-electric invert mechanism allows motion time and velocity to be set independently. In other words, with comparable velocities, it is possible to achieve faster controlled invert times than with a pneumatic mechanism with less attention from operators.



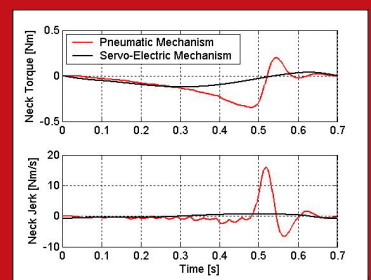
▲ Fig 4. Measurement of invert velocity for servo-electric and pneumatic mechanism.



▲ Fig 5. Repeatability of 10 consecutive invert motions for servo-electric and pneumatic mechanism.

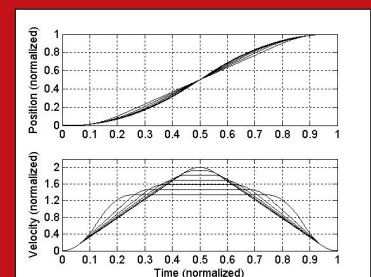


▲ Figs 6a and 6b. Standard deviation of time and of position during invert.



▲ Fig 7. Neck torque and jerk during invert motion for pneumatic mechanism and SEI.

▼ Fig 8. Invert profiles with various speeds and constant motion time.



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Advantages of Emhart Glass implementation

In addition to the glass handling benefits, the Emhart Glass SEI mechanism offers important features that should facilitate the decision to switch to servo technology. Motion profiles can be loaded to the job and be retrieved at later points in time. The system comes with a safety device that locks the neck ring mechanism in any position and thus allows the safe changing of neck ring holders. Retro-compatibility was considered an important design constraint, and therefore the system is

▼ Table I. Reasons to switch to Emhart Glass SEI Servo Technology.

- Smooth parison handling results in fewer critical defects
- Controlled invert motion
- Less variance of invert kinematics
- Identical motion on each section and cycle
- Many different profiles allow motion optimisation for each parison type (has a library with many different symmetrical and asymmetrical velocity and acceleration profiles)
- Motion profile loaded to the job
- Very fast, consistent revert motion
- Safety device for neck ring change
- Simple conversion, fits into existing sections
- Compatible with Emhart Glass neck ring mechanisms
- Leads toward elimination of the constant cushion

compatible with Emhart Glass neck ring mechanisms and fits into existing sections.

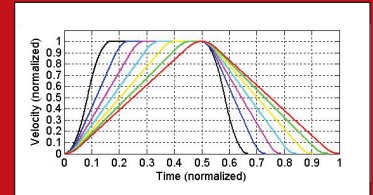
Finally, the slim design (low inertia) and the high-performance servo-motor allow very fast revert motions that are comparable with those of CC mechanisms.

Conclusion

Inverting the parisons from the blank side to the blow side is a critical phase in the container forming cycle. It has been shown that uncontrolled invert motion profiles can lead to high neck torques, and can ultimately cause critical defects of the finish. Servo-electric invert mechanisms meet the requirements of smooth, controlled and repeatable glass handling and therefore contribute to a higher container quality. In addition to the improved parison handling, the Emhart Glass SEI mechanism offers important features such as retro-compatibility, safety devices and fast revert motions. For these reasons, SEI mechanisms represent an important improvement to conventional pneumatic invert mechanisms.



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▲ Fig 9. Invert profiles with various motion times and constant velocity.