Technical and safety requirements for restraint systems for VR rides

HAWE´s hydraulic locking units (HLU*) have set standards

Content:

Roller coasters and other rides enhanced with virtual reality are gaining popularity. They open up completely new worlds of experience and thus innovative fields of application. This white paper discusses the requirements for the respective passenger restraint systems in amusement rides. It shows the standards that have been set by hydraulic locking units in this area.

Because the issue of safety has top priority, the HAWE Micro Fluid GmbH will be demonstrated as an example of how TÜV certification can be carried out; company-specific, but also product-specific. In addition, the paper highlights the benefits of such product certification, especially for ride manufacturers and operators.

* HLU = Hydraulic Locking Unit

Amusement parks discover virtual reality

Virtual reality is booming in the amusement parks. Completely new, digitally programmable worlds open up to passengers when roller coaster rides are supplemented by VR glasses.

In addition to the added fun factor, the idea is also advantageous from an economic point of view. The park operators can upgrade their older roller coasters without having to invest in completely new rides. And recreational facilities that were in the past less suitable can now add the experience to their offerings. For example, "Bolt" is the first interactive catapult roller coaster on a Carnival Cruise Line ship.

Another innovative application for VR rides are the robot simulators, whether for the leisure sector or for instruction and training. For example, critical flight manoeuvres can be imaged with a high degree of authenticity, combining repurposed industrial robots with a virtual reality application.

But whether amusement ride or robot simulator, with or without a virtual reality application, they all have one thing in common: Despite the wildest manoeuvres, the passenger has to be safely secured in the seat by a reliable and at the same time comfortable restraint system.

Fig. 1: Perceived safety also plays a role.

The forces involved can be extremely high. In some roller coasters, acceleration forces of up to 6G can occur. This is six times the Earth's gravity: even greater than the forces acting on an astronaut during a rocket launch.

Requirements of passenger restraint systems

Hydraulic locking units for passenger restraint systems have set standards in comfort and safety in recent years. Safety has the highest priority for a state-of-the-art restraint system. It must be provided 100 per cent, unconditionally and without compromise. For this reason, in addition to the actual technical safety, the perceived safety of the passenger also plays an important role. A gentle and above all quiet opening and closing of the retaining bar, in which the bar position can be continuously adjusted to the passenger, makes a contribution here. In addition, quick opening and closing of the locking mechanism is important. This minimises the time between two trips and makes a quick change of passengers possible.

Another requirement from ride operators is low wear, combined with a long lifetime of the installed parts. All components should be as low maintenance as possible. In addition, the maintenance intervals must be reliably predictable, since any standstill times have a negative impact on revenue and thus on the amortisation period of the ride. With investment totals that can reach several million euros, this is not a negligible factor.

Operators also benefit from speedy commissioning due to fast and easy TÜV approval, especially when their rides are used on festivals or fairgrounds and have to be set up and dismantled frequently.*

The ride manufacturers benefit from components that are designed using a modular design. The systems can be easily and quickly adapted to the respective project. This shortens project planning times and allows for flexible implementation of special requirements using standard components. By providing locking units as

* Note: No sale of locking units to the United States in mobile, i.e. repeatedly assembled and dissembled rides (fairground rides).

a plug-and-play solution, installation is as quick and easy as possible.

And finally, a requirement from applicable standards must be taken into account: manual opening of the restraint bar in an emergency. This function is also integrated in the system.

But first, let us look at the functional principle. The heart of the unit is a screwed double tube cylinder (1). The inner tube guides the piston rod with piston, the outer tube guides the oil of the rod side to the flanged connection block on the cylinder base (3). It supports a diaphragm accumulator (2)and an electromagnetically and manually releasable check valve (7).

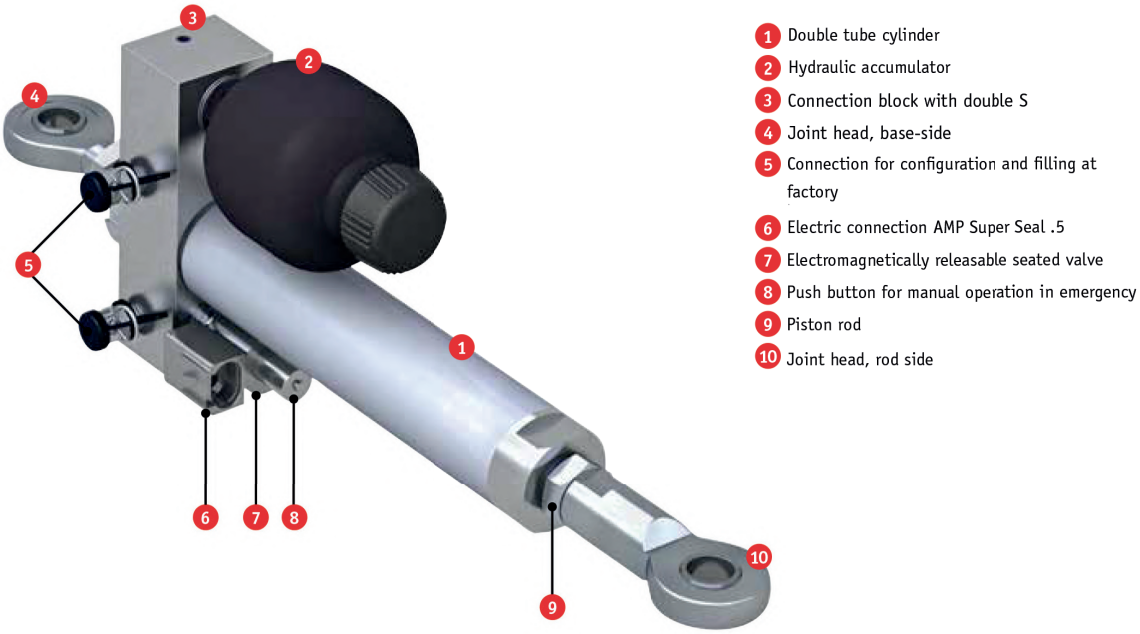

Fig. 2: The various components of a hydraulic locking unit

Functional principle of hydraulic locking units

With the hydraulic locking unit, specially developed for rides and flying apparatus, HAWE has succeeded in fully meeting the outlined requirements for a locking unit for passenger restraint systems in rides. A failure probability due to contamination with particles of less than one per billion operating hours ensures maximum safety. This value is verified by the independent and accredited test institute TÜV Süd. We will address the exact certification process later.

The diaphragm accumulator precharges the unit to a defined pressure and absorbs the oil displaced by the piston rod during retraction. Thus, it serves as an intermediate storage of energy released during the closing operation. This can then be used to open the bar. Additional gas springs, spring systems or pneumatic drives for opening the bar can thus be eliminated completely.

The electromagnetically releasable seated valve (7) allows the flow of oil only in one direction; it blocks flow in the opposite direction. Through electromagnetic actuation in normal operation or manual operation in case of failure, oil flow in both directions is possible. The special valve used for this purpose is extremely low-leakage, because it has a hardened seat edge, thus ensuring maximum reliability. So-called minimess connections (5) are used for factory oil filling and pressure configuration of the unit during assembly.

The locking unit is available in two different sizes. The smaller and lighter version HLU-LE25 with a piston diameter of 25 mm has a total length of approx. 355 mm when retracted and is designed for small to medium load requirements as well as narrow installation spaces. The slightly larger HLU-LE32 unit have a piston diameter of 32 mm and are usually 503 mm long and the preferred choice for high load requirements. Due to the very compact design, it is also possible to integrate it into novel seat designs, whether for abdominal, shoulder or lap bars.

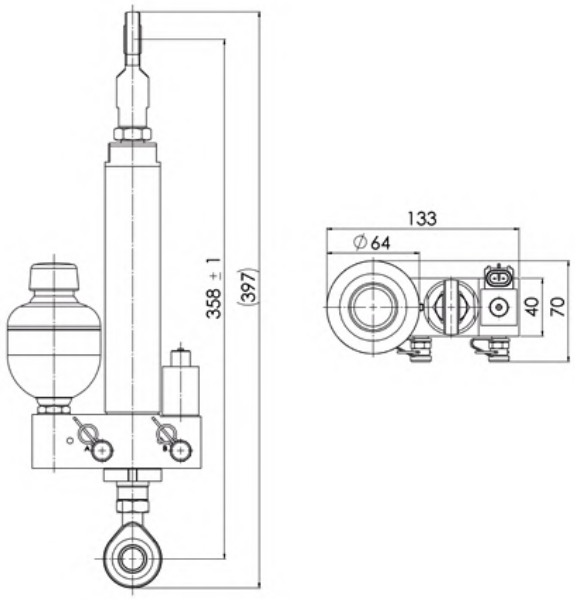

Fig. 3: Design drawing of the HLU-LE25 with 80mm hub.

The second distinguishing feature is the locking direction. This refers to the direction of movement blocked using valve technology. In the safe, de-energised state, the valve blocks the flow of oil and prevents the extension of the piston rod during travel. In the station, the bar can be opened using the extension force of the cylinder (bar actuation).

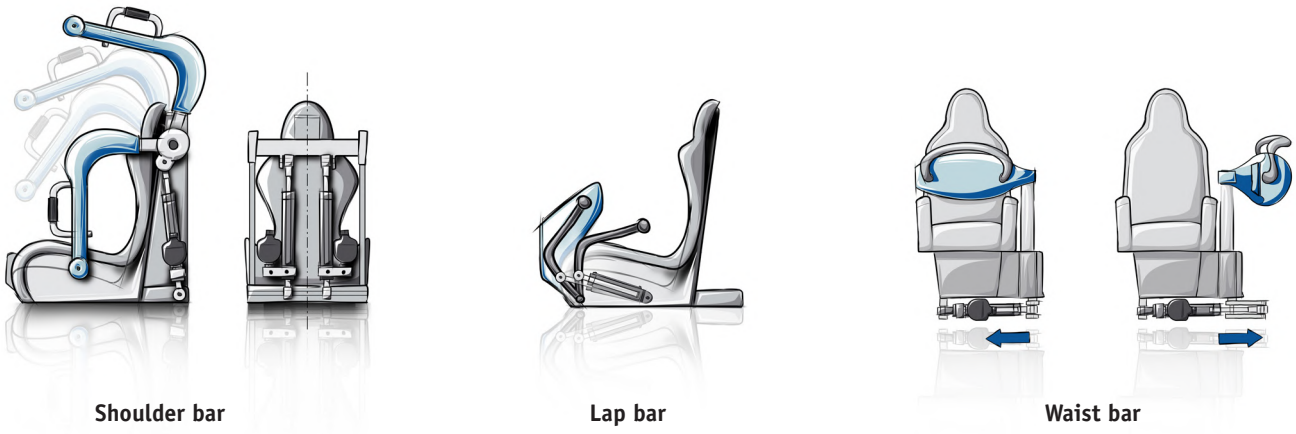

Fig. 4: Different bar types

In the inverse configuration, the valve prevents the retraction of the cylinder during travel. In this version, however, the bar actuation function is not physically possible.
Optionally, a "comfort lock" can be installed. In this case, an additional valve prevents retraction of the cylinder in the open state. The open bar can thus be used by the passenger as a handhold.

Compared to classic, mechanically locking units, hydraulic locking units thus ensure continuous adjustment to meet the passenger's needs. At the same time they are low maintenance and are not subject to the mechanical wear of a ratcheting system.

Another special feature of HAWE's hydraulic locking units is that they are designed as plug-and-play solutions. The units are completely filled with oil and tested at the factory. As a result, they can be installed directly on the customer system.

The hydraulic components follow a modular system, which ensures fast configuration. In addition, the versatile adjustment options with regard to insertion forces and pressure configuration allow tailor-made fitting to the target design on the manufacturer's side, depending on the design of the seat and retaining bar.

As already mentioned, reliability and safety is the central requirement for a locking unit. This is why HAWE has paid special attention to this criterion and had the HLU certified by TÜV Süd, a recognised partner in the industry.

TÜV certification for companies and products

HAWE locking units are thus the first and only that have been fully certified by TÜV Süd worldwide.

The question rightly arises of the meaningfulness of such a certification, considering how complex the process is. At HAWE, for example, the certification took a good three years and countless hours of work. Therefore, let us take a closer look at the product certification process.
The basic procedure consists of essentially three building blocks. On the one hand, the design itself is examined to see whether it can withstand all foreseeable loads, both in normal standard operation and in an emergency.

Fig. 5: The larger HLU-LE32 with comfort lock

This was done on the basis of the design, i.e. the detailed design calculations including the FEM data. Next, the materials used are tested.

In order to be able to ensure consistently high quality, HAWE must be able to assign each purchased material not just to a production batch, but rather to a specific product serial number, with direct access to the test certificate of the incoming-goods inspection and the respective supplier.
And in a third step, the production processes are scrutinised. Consistent and transparent processes ensure that no contamination occurs during assembly.

Process improvement as a result of the certification

Taking into account these high safety standards, some improvement measures have been introduced. For example, more stringent packaging specifications have been provided to the supplying manufacturers. The incoming-goods inspections were expanded to include a microscope examination of parts that transport oil. Also, additional individual part cleaning and further rinsing cycles were integrated into the production process in order to ensure the highest level of cleanliness of the locking units.

Fig. 6: In a specially developed test bench, a burn-in test is performed for each locking system.

In addition, investments were made in new test benches. An end-of-line-test bench tests each individual locking unit for all functional and safety-relevant system details, such as length and stroke, underlying force parameters, maximum load (leak test) and operation of the emergency actuation.
And every single locking unit to be delivered undergoes a final burn-in test. Each hydraulic locking unit is tested for 1,050 cycles at a predefined load. Only a specific extension or retraction movement of the piston rod may take place under load.

Process improvements were also made to the packaging concept. The main objective was to ensure safe and environmentally friendly shipping of goods, while at the same time facilitating handling for shipping and logistics. To this end, a own packaging design was developed that was also tested in the laboratory for its reliability.
For packaging materials, HAWE relies primarily on environmentally friendly cardboard. If undamaged, it can also be used for the returns or re-shipping. Overall, up to 25% CO_2 savings are achieved per box. Wooden boards and metal screws were completely eliminated. This also simplifies disposal at the customer side.

Fig. 7: Safe worldwide shipping can be ensured by the optimised transport packaging.

Since all products are shipped in uniform carton packaging, this standardises the shipping processes. In the case of the carton size, care was taken to ensure that even very small quantities can be sent by post inexpensively. The uniform packaging sizes also make storage more efficient.

The components are secured in the shipping carton using shrink film, which provides additional corrosion protection, so that even in overseas shipments or storage under difficult conditions, product safety can be ensured. Cardboard labelling with material, serial and order numbers, in capital letters and with QR codes, ensures the identifiability of the goods across the entire logistics chain.

Final evaluation of the TÜV certification

And now to the final question: Was this effort justified? At HAWE, our answer is a clear "yes", because it provides significant benefit to both manufacturers and ride operators.

Both benefit from a very low failure rate. Also every delivered and certified unit is classified according to Performance Level e ready (prEN13814:2016).

DIN EN 13814:2500 specifies a life cycle of 35,000 hours, which corresponds to about five million load cycles. The service life of HAWE locking units is 7 years.

Within these seven years – apart from the activities listed in the operating and maintenance manual – usually no maintenance measures are foreseen. Interventions in the closed hydraulic system are avoided, eliminating potential risks of failure.

That is why HAWE does not offer any repairs, because there can be no cleaning measures which should always work reliably - regardless of the degree of soiling. Every used system has different contamination scenarios and even the smallest particles can prevent the correct closing of valves and endanger operational safety. The majority of hydraulic failures are therefore due to contamination.

All in all, this leads to more planning security for ride operators with regard to maintenance intervals. In addition, certification brings simplified operating procedures on the customer side, which in turn lead to faster and easier TÜV approvals.

Advantages of HAWE locking units:

- TÜV Süd product certification
- Closed, low-maintenance hydraulic system
- Continuously adjustable, noiseless bar adjustment (increased ride comfort)
- System without attached components
- Manual emergency operation
- Plug & play
- Suitable for roller coasters, VR rides, 4D cinemas and simulators
- Available in different versions

Conclusions

Hydraulic locking units (for passenger restraint systems) have in recent years set standards in terms of safety and comfort, whether for shoulder, abdominal or lap bars. Safety is a requirement for which no compromises can be accepted. The quiet, gentle opening and closing, which allows the bar position to be infinitely adjusted to the passenger's size, increases the perceived safety on the part of the passenger. Hydraulic locking units from HAWE allow fast passenger changes, are low-maintenance and wear-resistant and have a long lifetime. The locking units, which are certified in accordance with current DIN standards, also have extremely low failure rates.
They represent the pinnacle in terms of reliability (Performance Level e ready PLe). This provides cost advantages in terms of maintenance and repair and enables faster and easier TÜV approval. This is another benefit, which is primarily an advantage for operators of portable rides.

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