DANILO PERSICI

Cool runnings

AS DEMAND FOR LIFT-TRUCKS AND OFF-HIGHWAY MACHINERY RISES IN THE COLDER REGIONS OF THE WORLD, HIGH-QUALITY PUMP COMPONENTS ARE REQUIRED TO PREVENT A SLIPPERY SLIDE TO OBLIVION

The latest trends show higher demands on micro-pumps for low-temperature applications due to increased demand from emerging areas with adverse weather conditions, such as Mongolia or Siberia, which can reach -50°C. Marzocchi Group has acquired great experience through its collaborations with several world-leading automotive companies, which have led to the development of innovative micro-pumps for automatic clutch, directional stability control and several other applications.

Marzocchi Pompe has co-operated with the DIEM department of Bologna University for over 30 years and therefore has had ample opportunity to deepen its know-how and improve its products. Great efforts have been made to optimise the inner parts of pumps and motors, thereby improving their mechanical and volumetric efficiencies. The R&D department has therefore been equipped with experimental test benches for mechanical, hydraulic, acoustic and vibration performance analysis and durability test benches to simulate the toughest working conditions.

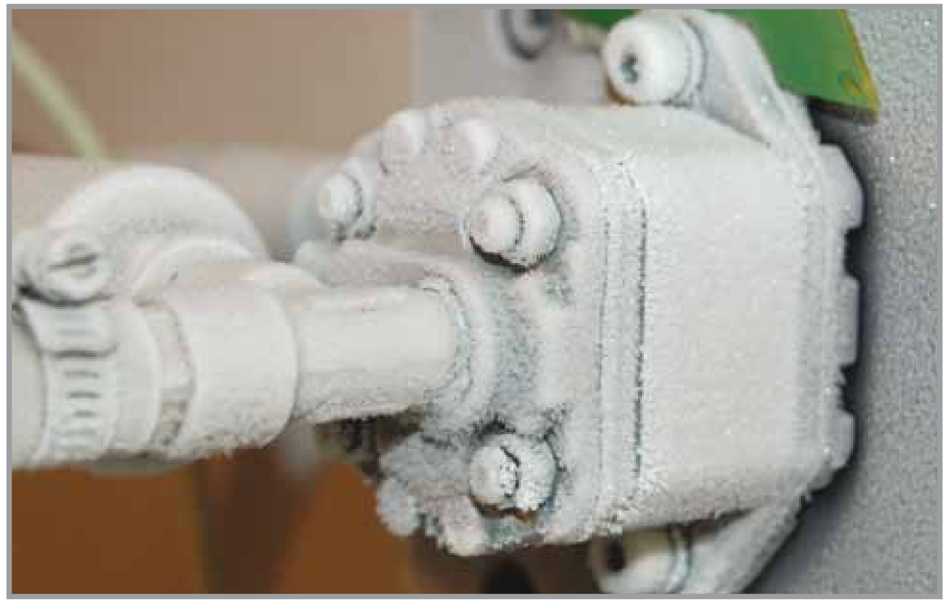

FIG. 1 **Marzocchi K0.5 Gear pump on cold-start test at -45°C**

Durability testing

The test bench is directly connected to the climatic chamber to enable the carrying out of durability testing and specific customisations on pumps, motor-pumps or complete hydraulic power units, in a temperature range between -70° and +180°C. Special software simulates the majority of working conditions, continually varying the pressure and the rotation speed. Several tests were performed to study the behaviour of the pumps at very low temperatures in the most critical operating conditions (Figure 1).

Performance in temperature spectrum: As the new test bench records the pump's mechanical and volumetric performance in a wide temperature range, it is possible to study the performance trend as the temperature, and consequently the oil viscosity, varies.

Cold-start test: This is the most severe test, and simulates the awakening of the hydraulic circuit after a long resting period under low temperatures. The purpose of the test is to verify the ability to start, to suction oil, and to pump it at low temperatures.

Durability test in temperature spectrum: This simulates an important duty cycle that is repeated a number of times relating to the normal lifetime of the pump, at variable temperatures in the whole field of use. Periodically it verifies the performance of the pump under test. This test verifies the resistance of all the components to the various working temperatures, from the lowest to the highest, where the oil used must keep adequate lubrication flow characteristics (viscosity should be less than 2,000cSt at startup).

Temperature change test: Tested samples are subjected statically to numerous variations in temperature between the provided minimum and maximum. The performance of start and end of test are then compared. The test is meant to check for any physical modification in the internal and external seals. These tests, often carried out in collaboration with customers, can be particularly useful in the selection of the oil application, both in terms of viscosity and chemical compatibility of components.

Mechanical spectroscopic analysis: In cold applications, particular attention has been taken in the choice of the seal rings, because at low temperatures – due to the high viscosity of the oil – intake pressure is lower than atmospheric pressure (0.6-0.7 bar absolute). Seal ring material in these conditions begins to stiffen and lose its elastic properties, and consequently it could not guarantee the hydraulic sealing, resulting in the drawing in of air and emulsifying of the oil.

In collaboration with Bologna University, Marzocchi Pompe has thoroughly tested the behaviour of some commercial seal rings at low temperature under parameters such as glass transition temperature, trend of the intrinsic damping and the elastic modules, as the temperature changes. Different compounds belonging to three types of seal material were subjected to testing: NBR (nitrile-butadiene rubber)' HNBR (hydrogenated nitrile-butadiene rubber), and a third compound, LNBR (a special nitrile-butadiene rubber compound designed for operation at low temperatures).

Through these tests, it was possible to find the limits of each type of compound and related seal rings. Their use as a seal ring requires the polymer to exhibit high flexibility and elasticity, which are lost below the transition temperature, *Tg* (Figure 2). This temperature is therefore the limit of usability, usually specified by the manufacturer, and it can vary between *T* = 0°C and *T* = -45°C as a function of the acrylonitrile content.

FIGURE 6 (LEFT): **Marzocchi 0.25-0.5 gear micro-pumps, with displacements from 0.19-1.50cc/rev**

TABLE 1 (BELOW): **Recommended lower working limits of seal materials**

Compound type	Minimum operating temp
NBR	-15°C
HNBR	-40°C
LNBR	-45°C

These considerations led to the performing of measurements via mechanical spectroscopy techniques to determine the minimum working temperature of the seals. The mechanical analyser used is a device that allows measurements in a dynamic regime, the modulus of elasticity and the coefficient of intrinsic damping (internal friction, as indicated in the graphs by *Q-1*) of materials (Figures 3 & 4). The inherent damping is provided by the logarithmic decrement of the damped free oscillations, while the dynamic elastic modulus is proportional to the square of the resonance frequency, *f2* (Figure 5).

The experimental values were normalised so that the elastic modulus always has a value equal to 1 at a temperature of -60°C, and the inherent damping a value of 1 in correspondence with the peak. The module values are shown as f^2/f_0^2, where f_0 is the frequency at -60°C, and those of damping as $Q\text{-}1/Q\text{-}1_{MAX}$ with $Q\text{-}1_{MAX}$ being the dissipation value at the peak. From in-depth analysis, it was possible to determine the flow characteristics and physical properties of compounds, choosing such seal rings according to the terms of usage. Table 1 shows the lower working limits recommended.

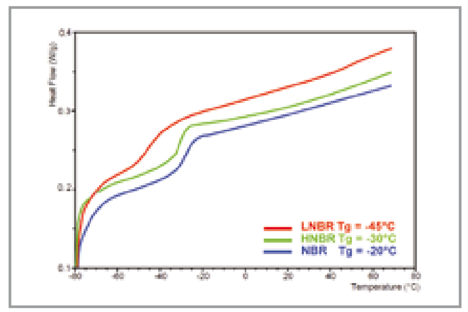

FIGURE 2: **Graph showing compound comparison on glass transition temperature *Tg***

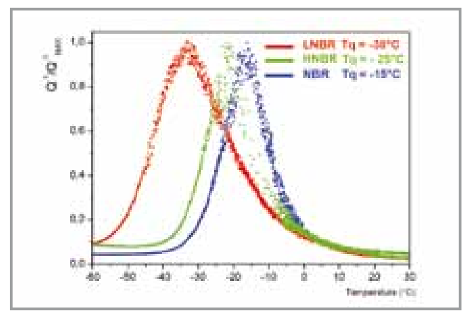

FIGURE 4: **Graph showing compound comparison on variation of intrinsic damping ($Q\text{-}1/Q\text{-}1_{MAX}$)**

Contamination issues

All 0.25/0.5 series micro-pumps with displacement from 0.19-1.5cc/rev (Figure 6) are specially developed to be mounted on mini hydraulic power packs for industrial and automotive applications. With its decades of experience in the automotive sector, Marzocchi Pompe is very wary about contamination problems and takes great care to wash all components before assembly. Following assembly, all gear pumps go through a run-in and testing phase on dedicated test benches. The run-in is the final stage of the manufacturing process and one of the most important operations because it allows the optimisation and checking of product efficiencies.

During this phase, increasingly higher pressure levels are applied under computer control; the gears, inflected by the hydraulic load, act as tools machining the pump body, thereby creating the best possible tolerances of the parts. The definition of the gradual increase of the pressure is particularly important as it establishes the machining speed of the material by the gears and therefore the particles' dimensions; the particles must be small enough not to interfere with the running of the product under testing and its future performance. Reversible motors and pumps follow a run-in procedure for each rotation.

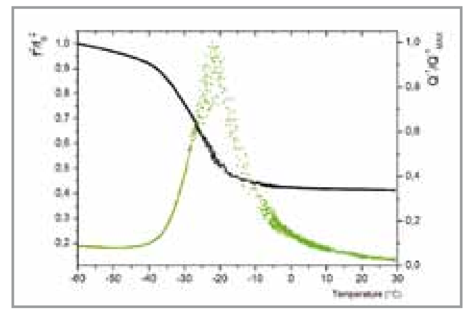

FIGURE 3: **Graph showing HNBR compound: variation of intrinsic damping ($Q\text{-}1/Q\text{-}1_{MAX}$) and variation of elastic modules (f^2/f_0^2)**

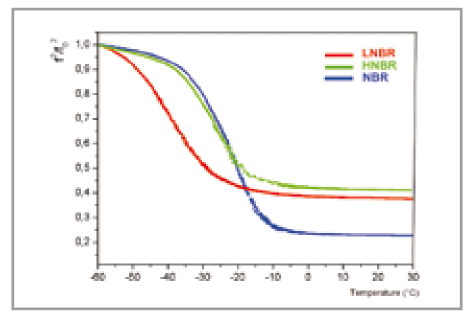

FIGURE 5: **Graph showing variation of elastic modules (f^2/f_0^2)**

After these phases, product efficiencies are measured at certain parameters. At the end of the run-in process the test phase takes place and efficiencies, performances, flow, temperature, torque and absorbed power are measured and recorded in the system to provide updated statistics on product performances. If the measured values do not comply with the limits of acceptance set in the test bench, the pump is discarded and sent to the repair department for revision. Data can be provided upon customer request years after the pump was manufactured.

A further test operation is carried out to ensure complete cleanliness and prevent any release of contaminants into the end user's hydraulic circuit. During testing there is a specific phase where the oil flows through the pump to remove contaminant particles produced during the run-in phase.

All 0.25/0.5 series pumps are able to withstand a high continuous pressure of 190 bar and a peak of 230 bar for the standard version. The pumps are also available in an RO version which, due to their run-in, can withstand continuous pressure up to 230 bar, and 270 bar of peak pressure. The feasibility of such micro gear pumps has been made possible mainly due to the introduction of automated production systems that can ensure high repeatability and therefore maintain high quality levels throughout the entire process.

The reason for this is that high efficiencies, high pressures and high reliability – especially for micro-pumps – are not just an added bonus but are the minimum requirements that must be achieved. As a result of the trust and the respect it has gained over a long period of time, Marzocchi Pompe is seen as a very reliable partner on the market, one that is able to provide its customers with specific know-how, high-quality products and excellent service for all hydraulic applications. **ALT**

Danilo Persici leads test, FEA and CFD analysis in Marzocchi Pompe's R&D department