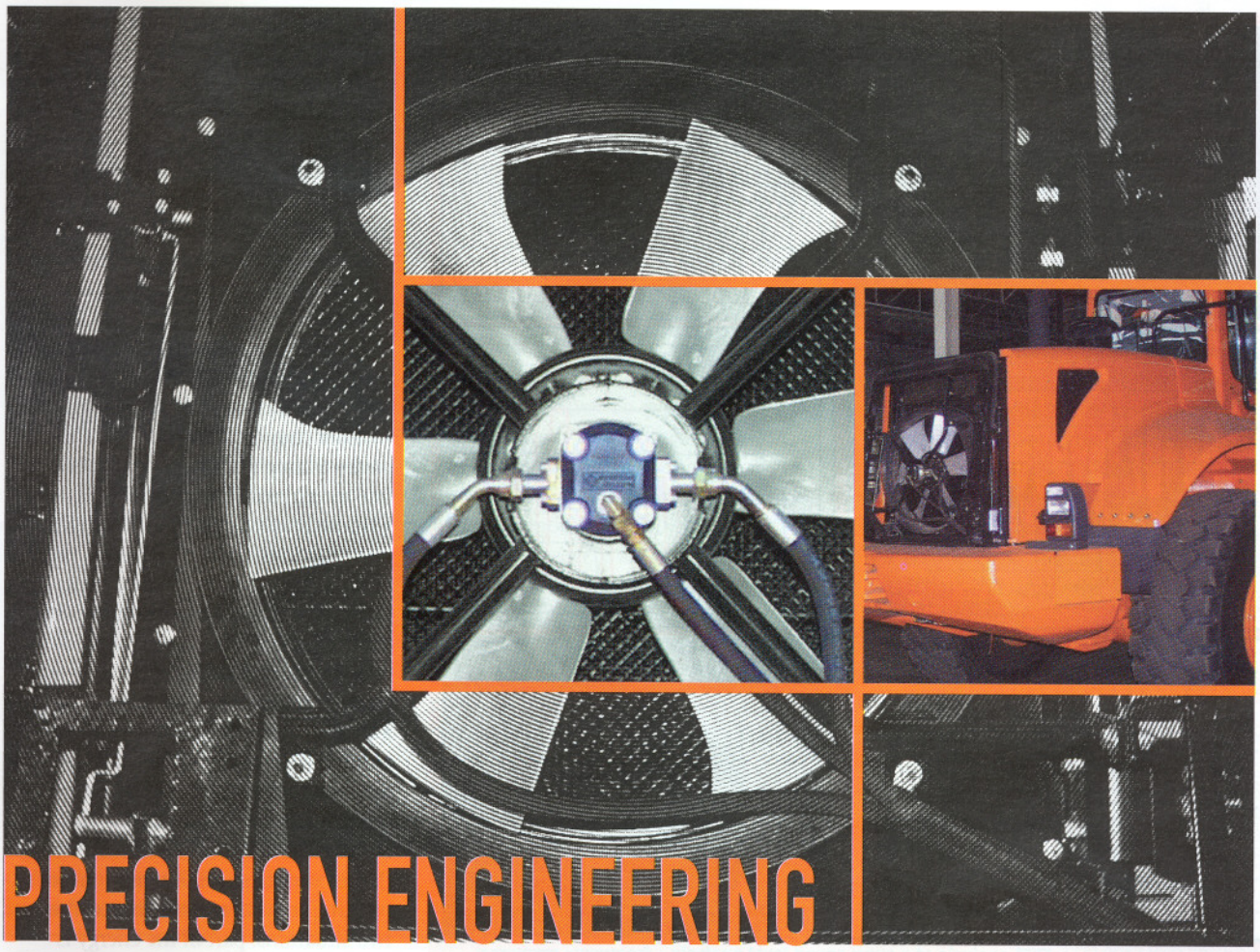
DANILO PERSICI



PRECISION ENGINEERING

The combination of FEM simulation and latest production techniques has seen one range of hydraulic systems satisfy demands for efficiency, reliability and reduced noise

Established in 1961 by Guglielmo and Stefano Marzocchi in Casalecchio di Reno (on the outskirts of Bologna), Marzocchi Pompe is today at the head of an industrial group that employs more than 400 people. Owned and led by Adriano and Paolo Marzocchi, the company operates in the field of hydraulic pumps/motors, and suspension systems for motorbikes and mountain bikes. Over the years, the company itself has expanded while at the same time increasing its product range, to the point where Marzocchi is now widely recognised as one of the most important manufacturers of external gear pumps and motors in Italy.

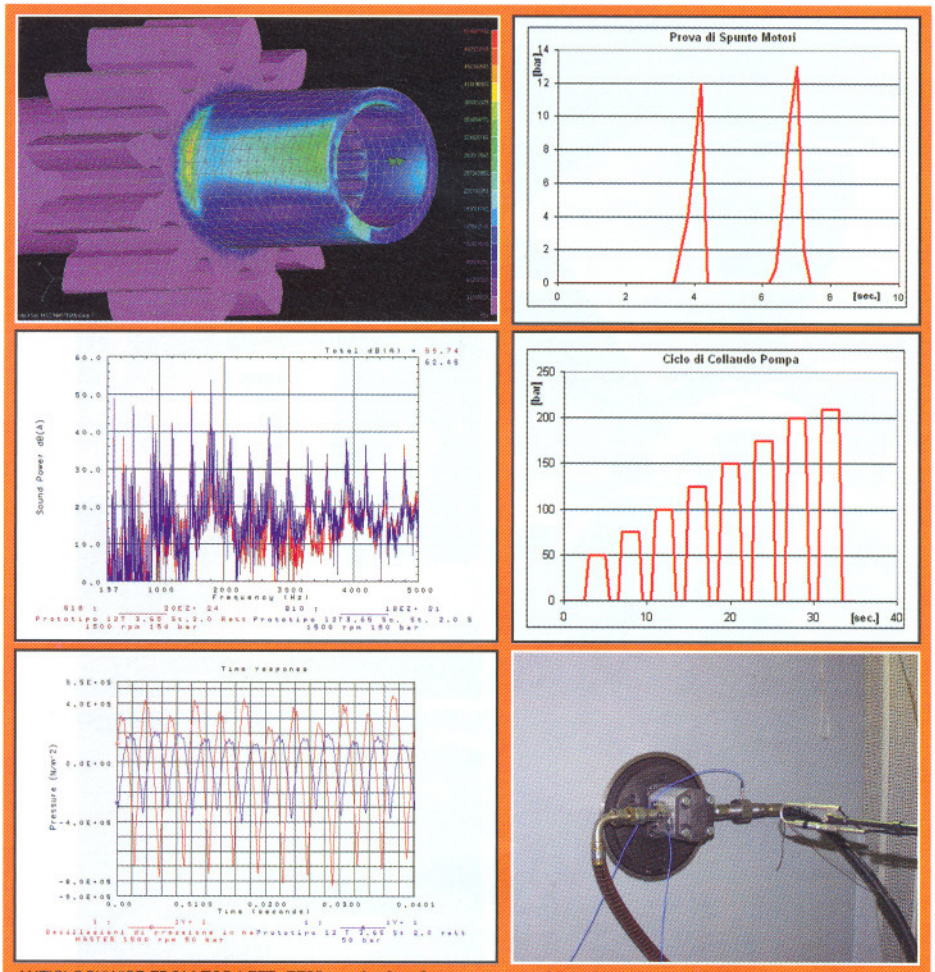
The trust and the respect that Marzocchi has accumulated over a long period of time has shored its position as a very reliable partner, able to provide customers with specific know-how, high-quality products and excellent service for all hydraulic applications.

Over the past three years, however, the company has updated its product range with the creation of two new lines. The first, ALP and ALM, includes pumps and motors with aluminium flanges and covers respectively, and is the natural evolution of the previous range. The second – GHP and GHM – is a new line of products with cast-iron flanges and covers, dedicated to high-pressure applications and the mobile market.

To effect this production change internally, however, Marzocchi has had to reconfigure its entire production cycle. The Project Design department – with its 40 years' experience in this sector – has completely revised the design of the products and their production processes, revolutionising the industrialisation of all of the components. R&D has applied the latest FEM simulation techniques that – together with the new tools for the experimental mechanics – have produced specific product optimisation aimed at satisfying current market demands for top efficiency, reliability and reduced noise levels.

Much effort has been invested into the research of internal mechanical and hydraulic conditions of the pumps and motors. For this purpose, the R&D department has been equipped with new experimental test benches for mechanical, hydraulic, acoustic and vibration performance analysis and durability test benches, able to simulate the toughest working conditions. This new test equipment has led to the optimisation of the compensation geometry (used to balance the dynamic thrust caused by pressure in gear vanes), gear profiles and the undercut drain on the bushings in order to increase product reliability and reduce noise levels. These innovations were transferred to the production department following a wide-scale renewal of the run-in and test benches.

The current Marzocchi production range varies between 0.19-200.3 cm^3/rev



ANTICLOCKWISE FROM TOP LEFT: **FEM analysis of a gear; sound level analysis – frequency response; sound level analysis – pressure ripple; experimental test bench for acoustic and vibration performance measurements; pressure diagram for the pump run-in; start-up test: minimum inlet pressure at which the motor starts running**

(0.0104-12.223in³/rev) and is divided into eight groups according to gear size (0.25, 0.5, 1P, 1, 2, 3, 3.5, 4). Within each group, the different displacements are obtained by changing gear width.

A wide range of flange, shaft and coupling configurations are also available and these components can also be manufactured according to customer specifications. The cast iron versions exist in groups 1, 2 and 3. Maximum operating pressure depends on pump displacement and type and varies, on average, between 230 bar (3,300psi) on aluminium models and 280 bar (4,100psi) for cast iron versions. All products can also be supplied with Viton seals and special versions are available for temperatures between -40°C and +120°C (-40°F/+248°F).

Mono-directional and bi-directional motors are divided into three families (1, 2 and 3) covering displacements from 2.8 to 87cm³/rev (0.17/53.1in³/rev). The maximum working pressures for the motors are similar to those of the pumps and they can deliver torque up to 250Nm and power up to 60kW.

The run-in is the last stage of the manufacturing process and is one of the most important operations because it permits the optimisation and check of the product efficiencies. During run-in tests, increasingly higher pressure levels are created. The gears – inflected by the hydraulic load – act as tools machining the pump body, thereby creating the best tolerances among the parts. This process is performed under computer control.

The definition of the gradual increase of the pressure is particularly important because it establishes the machining speed of the material by the gears and therefore the dimension of the particles. These must be small enough not to interfere with the running of the product under testing and its future performance. Each motor within each group has a personalised pressure ramp so that no contaminating material remains in the circuit. This also means that the pump is immediately able to attain maximum performance levels.

Reversible motors and pumps are subject to run-in procedure on both rotations. After undergoing this process, product efficiencies are measured at fixed parameters.

Test data is automatically acquired and recorded to have updated statistics on product performances. This data can be supplied on customer request.

As far as motors are concerned, after the run-in another specific test follows on a dedicated test bench, where the following operating conditions must be reproduced:

- Under braking, when the energy of the fluid is transferred to the shaft to overcome the resisting torque;
- Under counterpressure, when the fluid passes through the motor with the shaft free to turn without load;
- Under braking, the stress distribution is similar to that which exists on the pumps. If maximum pressure exists at the inlet and discharge pressure exists at the outlet, compensation seals and rotating parts are subjected to the maximum stress according to resisting torque;
- Under counterpressure, the inlet and outlet are under the same conditions. At maximum pressure, the stress on the rotating parts is zero while the flanges, body and external seals are subjected to the maximum stress. A typical motor's working conditions are between these two situations: part of the energy is transferred to the shaft while part is used, for example, by another motor connected in series.

Therefore, on the Marzocchi motors' test bench, the final control is divided in three phases:

Braking phase: At an established rotation speed, a resisting torque is applied to the motor shaft. The application of this torque creates a variation in the fluid's inlet speed and pressure. The test bench control system stabilises the motor in fixed conditions during which running parameters are acquired, such as volumetric and mechanical performances and draining flow rate.

Counterpressure phase: A fixed amount of oil goes through the motor without any resisting torque being applied to the shaft. The outlet line is kept closed and therefore a bi-lateral pressure is established. The drain-flow rate is measured at these conditions.

Start-up phase: Without any resisting torque applied to the shaft, the start-up torque is determined by measuring the minimum inlet pressure at which the motor starts running.

In the case of bi-directional motors, the three phases are performed for both rotations. After this test, the motor is

delivered to the customer perfectly run-in and controlled. In fact, its extreme reliability makes it suitable for use even under extreme conditions.

The following application example presented was developed in collaboration with the Elasis research centre in Lecce, Italy, and concerns the fan-drive hydraulic system employed to cool the engine compartment of the new Fiat-Kobelco wheeled loader range.

To make motor maintenance easier (the W270LB in the Evolution range is mounted with a Cummins six-cylinder, 10.8-litre direct-injection diesel, featuring a 202kW turbo-air after-cooler), the rear section of the vehicle can be opened. This incorporates the fan directly connected to the Marzocchi gear motor and the air conveyor, thereby permitting bi-lateral access to the radiant mass. The rotation direction of the fan is reversible, providing perfect self-cleaning action of the radiators.

This operation can be activated using an appropriate switch located in the cab on the control dashboard. The fan is driven by an aluminium reversible motor (type ALM2BK1-R-20-T4-T-H, 14.1 cm^3/rev displacement), equipped with support bearing and specific seals for a wide temperature range. The 7kg aluminium fan takes hot air in from the engine compartment, with the hydraulic motor working temperature being approximately 70-80°C (158-176°F).

The hydraulic motor is also subjected to vibration due to the wide swings of the rear side of the machine, which occur when the bucket is rapidly moving. Under extreme conditions, acceleration up to 7*g* is possible.

Normally, the motor performs with an inlet pressure of 200 bar and 50 bar in outlet pressure. To ensure the best temperature control, the fan rotation speed is independent of the motor running speed. For project validation, the hydraulic motor was subjected to an internal Marzocchi approval procedure (to which all new/special products are subjected) and to a test performed directly by the customer.

Internal approval includes various endurance tests in which the components are checked on the test benches in the R&D department. They are subjected to on/off pressure cycles at the maximum allowed pressure and periodically, an inspection is made in order to check the condition of the components. Where necessary, tests have been performed in the past with similar operating conditions to those that would be experienced in the destined application, such as same pressure cycles, temperature, oil type, etc.

Once the endurance test has been completed, a comparison is made between the initial and final product performances, and a deep analysis of each component is performed to identify any possible failure. To achieve a successful validation, no failure and no performance degradation higher than the internal specifications must occur.

The test performed by Elasis is composed from a first cycle under continuous pressure at 210 bar (3,050psi) at a temperature of 110°C (230°F), followed by a second cycle at pulsating pressure (0-210 bar) and under the same temperature conditions.

Gear pumps and motors are volumetric machines widely used in hydraulic system design. They feature a simple construction, compact size, are reliable, and offer a top cost/performance quality ratio. Over 40 years of Marzocchi experience offers plenty of support for the choice of these products. ***iVT***

✎ *Danilo Persici is an engineer within Marzocchi Pompe's R&D department*