Watson-Marlow Bredel Hose Pumps invests in advanced grinding machinery

Specialist pump manufacturer Bredel Hose Pumps BV designed the high-pressure hose pump in 1973, and since then has successfully completed more than 65 000 installations in industries as diverse as chemical processing, food processing, brewing, paper manufacturing, mining, and waste and water treatment. The company recently invested €2.2 million in custom-built automatic grinding equipment. In this article from the Netherlands, Tiemen Postma, Development Engineer Rubber & Hose Technology, explains the importance of the grinding process for the reliable operation and longevity of Watson-Marlow Bredel's hose pumps.

In a hose pump, a composite, reinforced hose is enclosed within a casing that is flanged at both ends. The flanges are connected to the suction and discharge lines of the system (Figure 1). The principle of operation is as simple as it is reliable. Within the casing is a rotor with two pressing shoes opposite each other across its centre line and mounted on a shaft supported on its own bearings. As the rotor rotates the hose is totally compressed by the shoes and the product within the hose is pushed forward (Figure 2).


Figure 1. The SPX series from Watson-Marlow Bredel Hose Pumps.

The hose: the heart of the matter

So, the hose (Figure 3) is the heart of the hose pump. If it does not function correctly the pump will not have optimal performance. In cooperation with the company's hose manufacturing division, Watson-Marlow Bredel has some 30 years of experience in developing, designing and producing hoses for the hose pump.

Traditionally, development of new rubber-related products is done by 'trial-and-error' methods. This can often be a time-consuming process. To shorten development time, and therefore save material and money, Watson-Marlow Bredel developed a finite element analysis (FEA) simulation model (Figure 4). The model can for instance be used to determine the optimal geometry by looking for the best stress-strain distribution and a minimum of hysteresis (heat development).

Of course, rubber is a material that is hard to model due to its non-linear behaviour. Watson-Marlow Bredel realizes that such a FEA model is only a reflection of reality and will have its discrepancies. Therefore practical tests are still necessary to back up the calculations and guarantee a satisfactory service life of the hose.

Fully automated grinding machinery

Numerous hoses are available on the market in various qualities for industrial hose pump applications. One of the first obvious differences between these hoses is the outer surface: ground or non-ground. From the mechanical point of view, Watson-Marlow Bredel believes strongly that ground hoses are of higher quality. Since quality is an important issue for Watson-Marlow Bredel, all hoses are ground before they leave the factory.

Up till now the hoses were ground according to traditional methods. It is only thanks to the experience and the dedication of the operators of the company's original machinery that the hoses were ground within satisfactory tolerances. Convinced as the company is of the significance of the accurate grinding of hoses, an investment of €2.2 million was made to design and build completely new, fully automated,

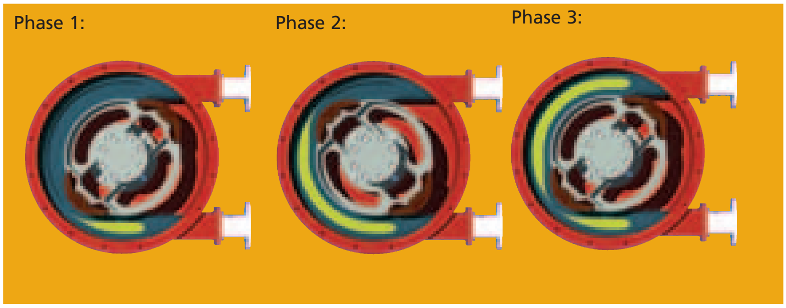

Figure 2. Principle of operation of a Watson-Marlow Bredel hose pump.

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grinding machinery according to its specifications (Figure 5). In this article it will be outlined why it is important to grind the hoses before they are mounted in a hose pump.

Constant quality control

The production of a patented Watson-Marlow Bredel hose is a multi-step process. First of all, the specific rubber compounds are prepared by mixing them in an internal mixer controlled by a computer. This way the right amount of ingredients is added and the right mixing conditions are assured. Control is carried out afterwards by checking some key properties of the rubber compound, these being the processing behaviour (Mooney viscosity), curing behaviour (rheogram) and mechanical properties – the hardness and density of the vulcanized compound. Only after the rubber compound has passed these tests is clearance given for its use in the production department.

The construction of the hose starts with extruding a homogeneous resilient rubber inner layer upon typically a 40-metre mandrel. The compound used for the inner layer determines the area of application of the finished hose, since this material needs to be chemically resistant towards the medium to be pumped. The available compounds and their area of application are listed in Table 1. Then the reinforcement layers are fitted by winding dyed nylon cords around the inner layer, each of the four layers separated by a thin layer of rubber preventing the cords of the individual layers touching each other (Figure 6). This reinforcement is needed to increase the maximum operating pressure and to secure the hoses' recovery. The construction of the cords and the cord layers is of great importance for the functioning of the hose. Due to the high strength and stiffness of the cords compared to the rubber, inaccurate construction can result in dimensional changes of the hose under dynamic loading and internal pressure. These unnecessary deformations of the hose cause a shorter lifetime, capacity loss or backflow. The final hose construction step is the extrusion of the outer layer, which is tough, but still has very good dynamical properties. During all these construction steps there is regular checking on the geometry to be sure that the production is still within the specified tolerances.

The hose is now ready for the vulcanization. Before the actual vulcanization reaction the hose is wrapped with a bandage to prevent the rubber from flowing away at the beginning of this reaction. Since the vulcanization of rubber is a form-determining reaction, the surface roughness of the bandaging is printed upon the outer surface of the finished hose. Finally the hoses are sawn into the right lengths.

A part of the finished vulcanized hose will go to the laboratory for the final control checks. At this stage the mechanical properties of the rubber, the bonding between the cords and the rubber as well as all the geometrical characteristics of the hose are checked. Only when the results of this control conform to the specifications are the hoses sent to the grinding division.

Figure 3. The 'heart' of the hose pump.

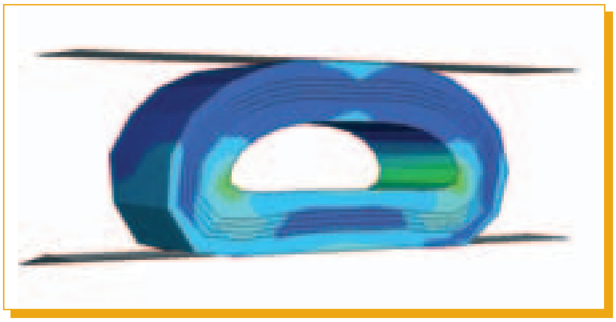

Figure 4. Finite element analysis (FEA) of a hose under moderate compression.

Other hose manufacturers producing reinforced hoses often do so in a somewhat different fashion. But the most important similarity in all hose manufacturing processes, as far as the scope of this article is concerned, is that band-

Figure 5. Watson-Marlow Bredel Hose Pumps has recently invested in new, fully automated grinding machinery.

TABLE 1: INNER LAYER MATERIALS AVAILABLE FOR WATSON-MARLOW BREDEL HOSES AND THEIR AREAS OF APPLICATION

	Natural rubber (NR)	**Acrylonitrile-butadiene rubber (NBR)**	**Ethylene propylene diene terpolymer (EPDM)**	**Chlorosulphonyl polyethylene (Hypalon®/CSM)**
General properties	Highly resilient; excellent abrasion resistance and mechanical strength	Highly abrasion and wear resistant	Good chemical resistance to a wide range of fluids	Excellent chemical resistance, extending the range of applications
Applications	Diluted acids and alcohols	Oils, fats, alkalis and detergents	Concentrated acids and alkalis	Concentrated acids and alkalis
Examples	–	Food handling: FDA and 3A approved	Weakly polar solvents	Strong oxidizing products
Temperature range	-20 to 80 °C	-10 to 80 °C	-10 to 90 °C	-10 to 80 °C

Figure 6. The layered construction of a typical hose.

aging is used during the vulcanization process and that a print is therefore left behind on the finished hoses.

The right balance in compression

For the working of a hose pump in general and its positive displacement characteristic, the hose needs to be compressed to full closure. One can imagine that the force needed to squeeze the hose flat steadily increases during this movement.

However, the force increases dramatically when the hose is compressed beyond the point of full closure. This is shown in the force-displacement curve (Figure 7) made by compressing a SP(X)40 hose using a hydraulic press. In the vicinity of complete closure, around 26 mm in this example, a millimetre extra compression leads to an increase of a few kiloNewtons in compression force. Due to the incompressibility characteristic of rubber, high stresses are formed inside the hose. With increasing compression internal frictions also increase, resulting in a higher hose temperature and a shorter fatigue lifetime. The pressing shoes and the rotor deliver the counterforce needed to compress the hose. Too much compression can give an unacceptable load on the bearings of the rotor. Also the pump casing and the rotor shaft can be damaged.

On the other hand, incomplete closing of the hose causes (high velocity) backflow. Especially with abrasive media, severe wear of the inner layer can occur. From experience it is known that a minimum over-compression is far less harmful for the hose than under-compression. Under the influence of internal (system) pressure, rotor speed and temperature, different displacements are necessary to completely close the hose. For this shims can be put underneath the pressing shoes to increase the total diameter of the rotor, just to the point where there is no more backflow. Shimming curves per pump type are available for the right selection. Since, after grinding, twice the tolerance on the wall thickness of the Watson-Marlow Bredel hoses is smaller than the thickness of one shim (0.5 mm), the shimming does

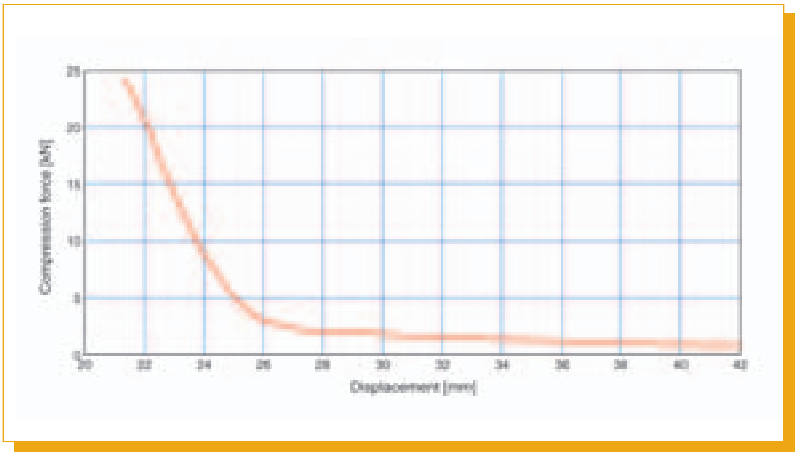

Figure 7. Force-displacement curve of a 40 mm Watson-Marlow Bredel hose with a wall thickness of 13.2 mm, measured with a hydraulic press.

not need to be adapted after hose exchange.

Smallest possible tolerances required

Keeping the importance of the right amount of compression in mind and then going back to how the produced hoses look, the question must arise if such a hose can function optimally. Looking at the outer surface of a newly produced hose the print of the wrapping is visible. Height differences of this print are measured to values exceeding 1.0 mm. Secondly there is a tolerance on the inner as well as on the outer diameter of a hose. Adding up the tolerances gives a significant difference between a hose produced in the low tolerance area and one produced in the high tolerance area. The solution for interchanging all these tolerances with a smaller new one is as simple as it is effective: grinding the outer surface of the hose to a uniform wall thickness (Figure 8).

The effects of the grinding process on the dimensional tolerances and the over-compression of the hose are shown in Table 2. In order to prevent backflow for any produced hose that is used, the compression should be high enough to compress a hose with a high tolerance inner diameter and a low tolerance outer diameter. The worst-case scenario is when a hose is used with the opposite dimensional tolerances. It shows that over-compression of non-ground hoses can have values from 2.4 up to peaks of 3.5 mm due to the height of the wrapping (Figure 9). When the data of Table 2 are coupled to Figure 7, it is found that the compression force of the ground Watson-Marlow Bredel 40 mm hose is approximately 4 to 5 kN. However, the compression force on the non-ground hoses can vary between 4 and 16 kN. This is very harmful for hose life. That ground hoses have a surface with a considerable reduction in friction is an extra, but significant, benefit.

Watson-Marlow Bredel emphasizes the importance of grinding the rubber hoses used for hose pumps. This way only one geometrical tolerance is introduced, which can be controlled very accurately. A regular outer surface is created as well as a uniform wall thickness ensuring a constant compression force without peak values. The constant load on the hose and the pump results in their longevity, a synergy that symbolizes the quality of the Watson-Marlow Bredel products. ■

TABLE 2: WORST-CASE SCENARIOS FOR CUMULATIVE TOLERANCES ON THE COMPRESSION OF A 40 MM GROUND HOSE AND OF A NON-WATSON-MARLOW BREDEL HOSE (NOT GROUND)

Dimensions (mm)	Watson-Marlow Bredel Hose SP(X)40	Non-ground 40 mm hose
Min. inner diameter, ID_{min}	N/A	39.5
Max. inner diameter, ID_{max}	N/A	40.5
Min. outer diameter, OD_{min}	N/A	66.3
Max. outer diameter, OD_{max}	N/A	67.7
Min. wall thickness, d_{min}	13.0	12.9
Max. wall thickness, d_{max}	13.4	14.1
2 x min. wall thickness, $2d_{min}$	26.0	25.8
2 x max. wall thickness, $2d_{max}$	26.8	28.2
$2d_{max} - 2d_{min}$	0.8	2.4
Height of bandaging*	N/A	1.1
Surplus of rubber (over compression)	0.8	3.5

Data are from available specifications of Watson-Marlow Bredel and leaflets of other hose pump manufacturers.
N/A: not applicable.
* Measured from a non- Watson-Marlow Bredel hose.

Figure 9. The print left by the bandaging is clearly visible on this finished non-Watson-Marlow Bredel hose.

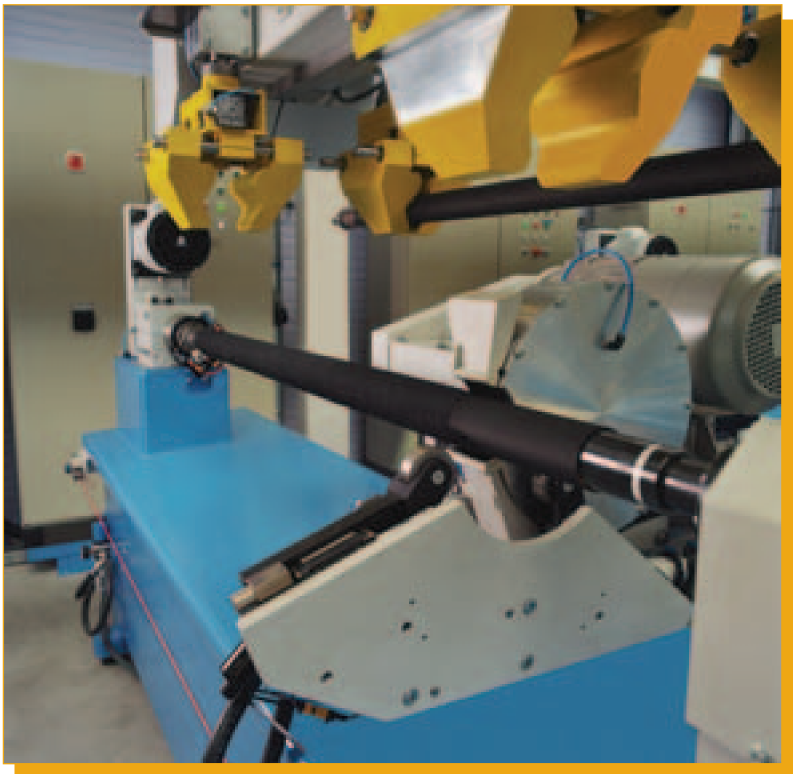

Figure 8. The outer surface of Watson-Marlow Bredel's hoses are ground to a uniform wall thickness.

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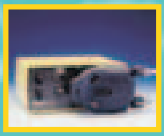
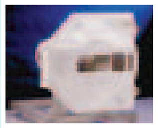
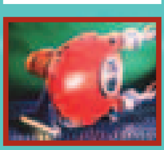
600	IP55 mid-flow industrial pumps. Fixed or variable speed.	50ml/min - 18.3 litre/min	624U	
700	IP55 industrial pumps with manual or auto control, single or twin channel.	1.6 litre/min - 66 litre/min	704U	
800	High flow hygienic pumps with full CIP and SIP capability.	2 litre/min - 133 litre/min	840	
SPX	Bredel: High flow industrial pumps operating at pressures up to 16 bar (230 psi).	0.3 litre/min 80m^3/hr	SPX40	

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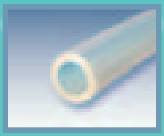
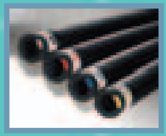
Tubing



Hoses



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