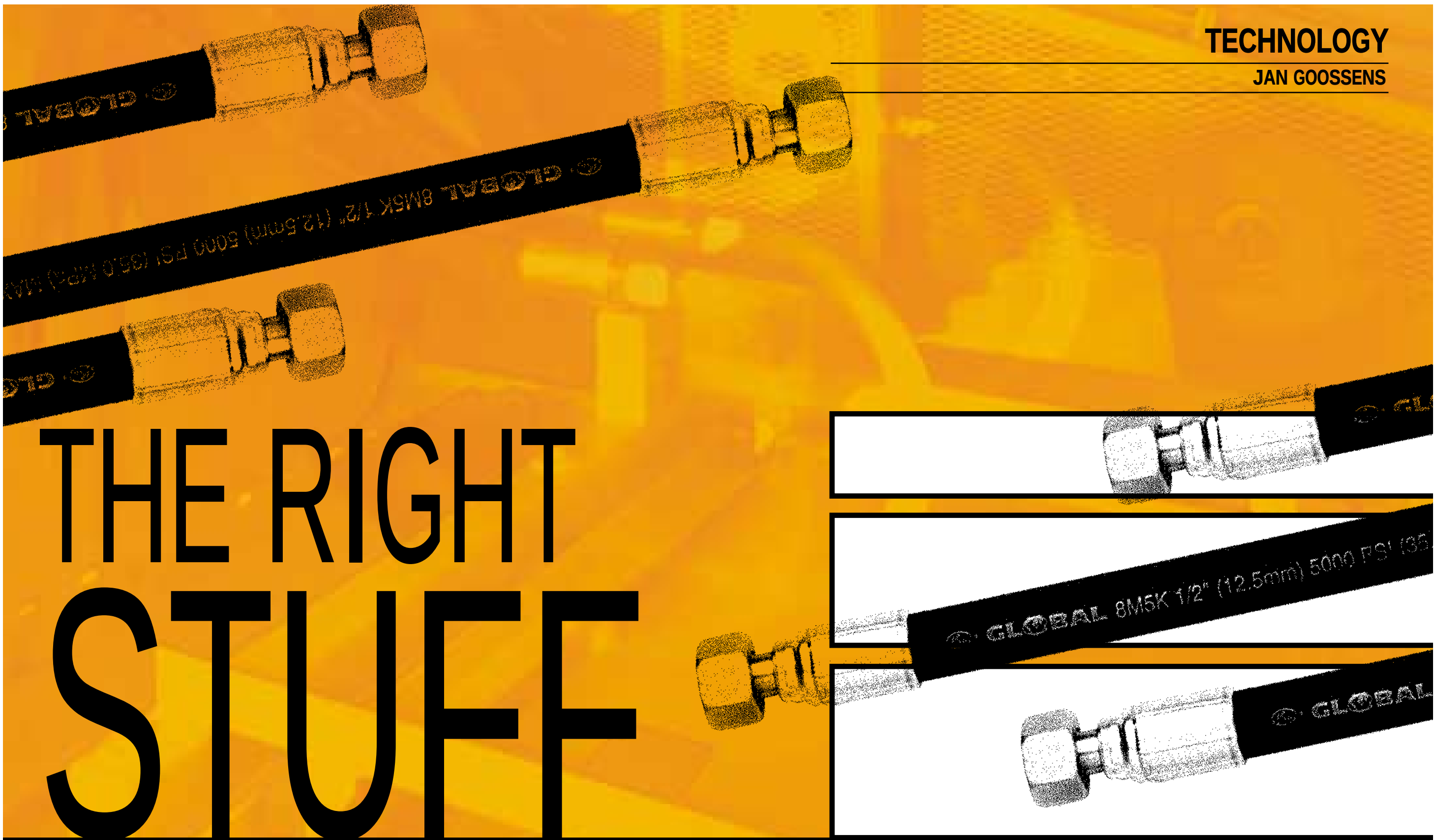
JAN GOOSSENS



THE RIGHT STUFF

If your machines are experiencing frequent downtime as a result of hydraulic hose failure, the problem could be simple: is the basic rubber compound design up to the task at hand?

When a hydraulic hose assembly failure can cause significant equipment downtime, choosing the hose that minimises the risk of failure becomes of extreme importance. OEM design engineers generally take performance criteria, such as pressure rating and minimum bend radii, into consideration, but many often underestimate or even overlook the importance of the rubber compound and its influence on key factors such as hose performance, reliability and lifetime.

Gates Hose and Connectors invests significant time and resources in rubber compound development and testing. As such, it is well-placed to share its expertise on ensuring that your hoses are made from the right stuff.

What is rubber?

Synthetic rubber compounds are used in the production of hydraulic hoses. Unlike natural rubber, the chemical structure of which is quite variable, a synthetic rubber compound consists of a very tightly controlled composition of man-made polymers (also sometimes known as elastomers), 'genetically' engraved with various functional groups to obtain specific properties. The polymer is the key determinant of the hose compound's physical properties and its compatibility with different media.

Once a rubber compound has been mixed, it becomes a polymer network with viscous behaviour that can then be moulded or extruded into its final shape. The rubber is then vulcanised at elevated temperatures to create chemical crosslinks between the different polymer chains, resulting in a permanent elastic structure – the hose.

The polymers that are mainly used for hydraulic hose compounds are NBR (nitrile-butadiene rubber), which is sometimes blended with PVC for ozone resistance, CR (polychloroprene rubber), CPE (chlorinated polyethylene rubber), and CSM (chlorosulphonated polyethylene rubber).

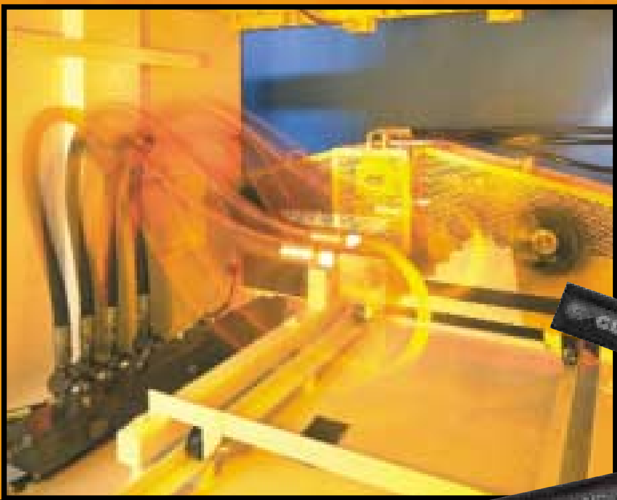
Hydraulic hoses consist of three structural elements – the inner tube to convey the fluid, a steel-wire reinforcement that withstands the hydraulic pressure, and the outer cover to protect the hose against external influences.

A schematic view of how a typical two-layer wire braid (medium-high pressure) hose is constructed and a typical spiral (high-pressure) hose construction is shown overleaf. The basic construction is similar to that of a braided hose, except that the reinforcement is spiralled around the tube and can consist of up to six layers of steel wire with additional friction layers in between.

The hose compound fulfils a different function in each of these structural elements. Firstly, the inner tube rubber compound must be compatible with a broad range of potentially aggressive hydraulic oils and has to resist high oil temperatures. It must also be strong enough to bridge any gaps in the reinforcement, formed when the hose is bent. The inner tube must also provide the required coupling hold to ensure the lifetime of the hose assembly.

Secondly, the different layers of reinforcement are interspersed with thin layers of rubber compound applied between them. This thin but vital layer of compound, called friction, transfers the load onto the different reinforcement layers and also binds them together. In addition, it also fills any gaps in the reinforcement pattern.

Finally, hose-cover compounds must have a strong resistance to potentially damaging external elements, such as



LEFT: **Gates' hydraulic hoses being tested to anything from 500,000 to one million cycles**
BELOW: **Just a selection of hydraulic hoses, manufactured by Gates. These types are flame-resistant and operate up to 35MPa**

ozone, UV light, hot air and abrasion. They must also adhere firmly to the wire reinforcement, especially so in the case of hoses intended for use with no-skive couplings.

Potential hose failure modes and their correlation with compound design

Hose performance and reliability can be drastically improved by selecting a hose made from the proper compound for the specific application and, in the event of unforeseen incidents, could even prevent end-user injury.

The polymer is the key determinant of the hose compound's physical properties and its compatibility with different media

Inner tube compound-related hose failures can take on many forms but nearly always come back to one root cause – inadequate compatibility with hydraulic fluids. If your hose compound is not designed and tested for use with certain fluids, you are at risk from this type of failure. At its worldwide technical headquarters in Denver, USA, and its European lab in Erembodegem, Belgium, Gates maintains an extensive global database of commercially available hydraulic oils and their effect on tube compounds. This database is continually expanded with new trials and ongoing development work.

Some typical failure modes linked to inner tube compound are listed below.

Coupling leaks: These are not only caused by incorrect crimping, but can also be the result of inner tube cracks. Potential root causes of inner tube cracking are:

• Compound incompatibility with fluids. Incompatible fluids can extract the anti-oxidants and the plasticizer from the inner tube compound, causing shrinkage of the tube, or they can attack the chemical bonds in the rubber – resulting in oxidation.

• Excessively high oil temperature can harden the inner tube compound rubber due to oxidation and crosslinking or evaporation of the plasticizer. This will cause the rubber to crack more easily, thereby creating possible leak paths.

• Poor compound design or mixing. One of the most important characteristics of a rubber compound is its 'compression set' – i.e. its ability to return to its original shape when pressure is released. If the compression set of a compound is too high, it will not offer enough resistance when coupling force is applied and will lose sealing capability. On the other hand, if the compression set is too low, weeping at the coupling and even tube cracks can occur. It is therefore necessary to find a balance between both extremes. At Gates these parameters are tested and optimised.

Unresponsive equipment: Sluggish performance can sometimes be due to excessive swelling of the inner tube. Swelling occurs because of the incompatibility of the inner tube compound with the hydraulic fluid. The inner tube absorbs and retains molecules of the fluid or softens due to oxidation (also known as chain cleavage).

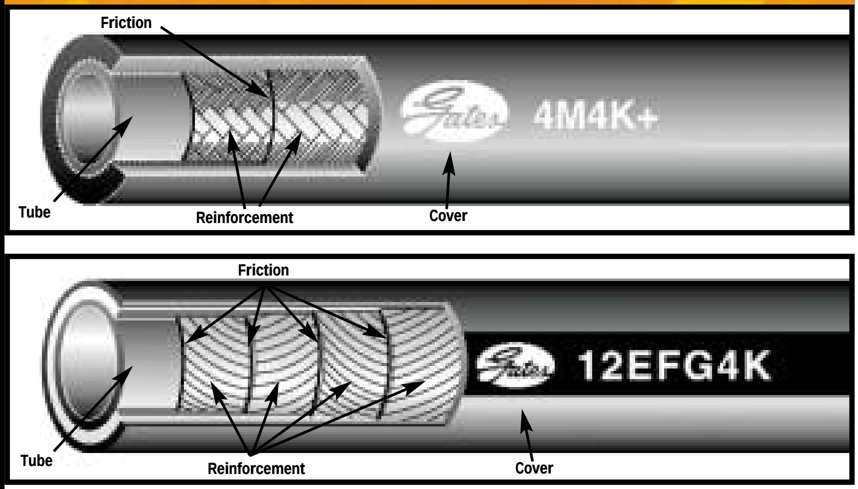
Cover blisters: This is another potential consequence of incompatibility. The incompatible fluid permeates the inner tube and collects under the cover, causing it to develop ugly blisters.

Gates' recently launched EnviroFluid hydraulic hose is an example of superior tube compound design. This is built with a special nitrile stock that prevents even the most aggressive fluids (such as environmentally friendly oils) from seeping through the tube and blistering the cover. The tube is compatible across the spectrum of hydraulic fluids, from those that are petroleum-based all the way to biodegradable oils.

Pinholes: Although it is the hose's high-tensile wire-reinforcement structure that bears the brunt of the pressure, the inner tube itself has to bridge the gaps in the braid, formed when the hose is bent and stressed. If the compound is not strong enough (tensile at break not high enough) it will be blown through these windows in the braid, which can cause a 'scissoring' effect and cut a hole in the tube, causing a leak, or 'pinhole'.

Hose failures related to the design of the cover compound

The cover or outer layer provides protection for the hose. It has to resist weathering conditions, abrasion and



ABOVE AND TOP: **Gates' 12EFG4K four-layer spiral hose construction and the 4M4K+ two-layer wire braid hose construction**

external elements in general. An under-performing cover compound can lead to several types of hose failure.

Cover cracks: Cracks in the hose cover can result from ozone attack or excessive heat if the resistance of the cover compound against ozone is not high enough. This is because ozone attacks and breaks the polymer chains inside the rubber, resulting in cracks that could eventually expose the wire reinforcement.

Exposed hose reinforcement: This can be susceptible to rust and accelerated damage leading to premature hose failure. If the cover's abrasion resistance is too low, or if it does not resist aggressive fluids, it will wear down prematurely and expose the reinforcement. Gates XtraTuff and MegaTuff hose covers are two excellent examples of compounds developed to prevent exposed reinforcement. Testing to ISO 6945 standards shows that the XtraTuff covering resists abrasion 25 times longer than standard hose covers – the MegaTuff hose cover even resists abrasion up to 300 times longer than standard hose covers. In addition to their abrasion resistance, they are also highly resistant to ozone and UV rays.

Coupling blow-off: Bonding of the cover compound to the wire reinforcement is very important for coupling hold. If the adhesion is not good enough, the coupling might be blown off. This could also result from a high compression set as outlined in the section on inner tube-related coupling leaks.

Mixing for performance

Mixing technologically advanced rubber compounds requires a high degree of skill and an uncompromising commitment to quality. Gates' highly skilled and trained processing engineers combine state-of-the-art mixing equipment with a perfectionist mixing approach to formulate some of the highest performance hoses in the market.

This is also an expensive and time-consuming process. Control testing of every mixed batch is a vital element of Gates quality. When there is even the slightest doubt about a compound mix sample, the entire batch is rejected. This stringent approach enables Gates to identify and eliminate any potential material-related issues, before hose production even begins.

Developing new compounds

The development of new hydraulic compound formulations requires several iterations of studies and trials. Gates' compound programme typically includes the following types of tests:

- Tensile testing;
- Ageing trials in different types of oil;
- Heat ageing;
- Compression-set resistance;
- Tear strength;
- Ozone resistance;
- Cold flexibility tests;
- Mixing behaviour;
- Processing behaviour.

Furthermore, because Gates wire-braid hoses are designed and manufactured to withstand impulse testing to 600,000 cycles (rather than the 200,000 cycles prescribed by most standards, such as EN) and spiral hoses to one million cycles (as opposed to 400,000 cycles in most standards), compound development can have a significant impact on time to market.

In order to maximize compound quality and minimize batch-to-batch variances, Gates uses a rigorous and standardised process right from the beginning, at the raw material stage. The company maintains a global sourcing 'approved-material list' which describes all specifications and sources for every raw material. All raw materials must go through extensive testing before they can be added to this list.

Such a global approach – supported by close contacts between the different members of the Gates technical community worldwide – ensures that customers can rely on Gates' products for consistently superior quality, regardless of the production plant where they are manufactured.

Basic questions

While performance criteria (such as pressure rating and bend radii) are frequently considered in hose selection, the hose compound is an often overlooked and 'invisible' determinant of hydraulic hose assembly safety and reliability. To help reduce the risk of compound-related hose assembly failures, there are six basic questions that OEM design engineers should ask:

- Does the hose supplier mix its own compounds?
- If not, does the supplier purchase standard off-the-shelf or specially formulated compounds?
- Does the supplier use a consistent list of raw materials/compounds suppliers or does the source vary?
- Do all the technical compound specifications and characteristics conform with the needs of the required applications?
- If not, is the hose tested to the limit to exclude all potential failures due to poor compound design?
- In the design phase, what are the hose testing criteria? Are they based on compliance to minimum requirements or do they contain a safety margin?

Gates has formed a reputation for building high-quality products catered towards a very demanding industry. Through innovation, an intense employee training programme, huge investment in R&D and tight controls on raw materials sourcing, Gates has therefore been able to remain at the forefront of technology and product performance. ***iVT***

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