From Fuel Line to Gas Pipe

Pipes Made of PA12 for Channeling Hydrocarbon-Containing Media

How are thin pipes made into large-volume pipes? To answer this question it is necessary to consider the entire process chain. Plastics manufacturers must develop expert knowledge of the end application if they are to deliver "well-rounded" products.

PA12 piping up to 200 m long can be rolled up. In contrast, trucks can only transport steel pipes with a maximum length of 18 m (figures: Evonik Industries)

When developing a new application, companies often like to vaunt their experience. "Decades of expertise in plastics", "Global experts" or "Backward integration as far as the monomer" are slogans often heard in this connection. But sometimes these advantages are not enough. For, expert knowledge that extends no further than the extrusion stage falls far short of the end application. Sustainable product development requires a number of additional steps.

Back in 2001, the automotive industry had already been widely using PA12 for many years. Many auto makers around the globe were installing mono-layer and multi-layer PA12 pipes in their vehicles in the form of fuel lines, air brake lines and hydraulic lines. In particular, PA12's good chemical resistance rendered it an ideal material for applications involving contact with hydrocarbon-containing media.

It occurred to Evonik Industries AG, Marl, Germany, that PA12 might lend itself to other applications involving hydrocarbon contact. One major application that had hitherto been made in steel was gas pipes. True, polyethylene (PE) had already replaced steel in domestic connections for low pressures of up to 10 bar, but it could not match steel for distribution lines and industrial connectors in the medium pressure range up to 16 bar. Steel was still the only suitable material – and the use of PA12 there was a "pipe dream".

PA12 pipes have several advantages over their steel counterparts. They can be wound onto a reel in lengths of 150 to 200 meters (**Title figure**). Steel pipes, in contrast, are restricted to 18 m, as that is the maximum length that can be transported by truck. Consequently, plastic piping has much fewer welds. This reduces both the installation time and the installation costs. In addition, maintenance is less costly, » as there is no need for cathodic corrosion protection (impressed current cathodic protection or a sacrificial anode). Consequently, given the simpler installation, easier handling and lower maintenance costs, system costs for PA12 are significantly lower than those for steel. But there is a catch: gas pipes in the medium pressure range have an outside diameter of 160 mm and more. Such pipe dimensions had never been extruded in PA12. This posed a real challenge for research and application technologists.

Optimizing Processing

As expected, initial extrusion experiments quickly showed that the material's viscosity and melt strength were too low. This made the parison difficult to handle. Parisons with irregular wall thickness distribution typically drooped after the extrusion nozzle (**Fig. 1**). A new type of PA12 therefore had to be developed. And this is where the aforementioned vaunted vast experience and backward integration really did help: through careful monomer selection and polymer modification, the right balance of viscosity and rigidity was reached in a relatively short time.

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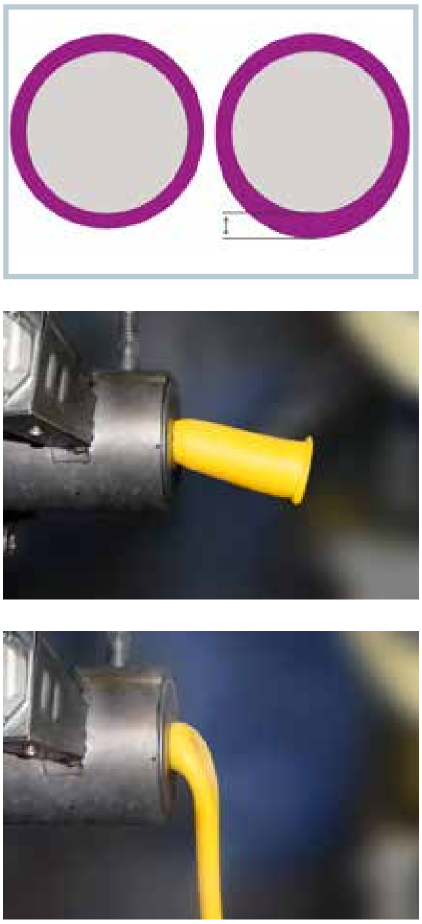

Fig. 1. Top: Schematic diagram of the impact of pipe dimension on horizontal extrusion (left: high viscosity; right: low viscosity). Center: Extrusion of material with high viscosity and/or melt strength. Bottom: Extrusion of material with low viscosity and/or melt strength

Simply adjusting the material properties, however, was not enough on its own. At the same time, it had to be ensured that the new PA12 type could be processed on standard PE extruders. The goal was to avoid expensive retrofits for plastic pipe manufacturers. After initial test runs, it was clear that, depending on the method of operation and processing conditions, throughput was lower than with PE. This is due on one hand to the increased viscosity, which causes a lot of pressure to build up in the extruder. On the other hand, melting of the pellets in the screw requires higher torque. Numerous tests conducted at converters as well as experiments with the Institute of Product Engineering (IPE), University of Duisburg-Essen, Germany, ultimately led to several advances. Not only were the processing parameters optimized, but, among others, the temperatures were significantly increased in the feed zone so as to lower the necessary torque. This more or less offset the lower throughput. Furthermore, since PA12 undergoes less shrinkage than PE, the calibration system needs to be dimensioned accordingly. This ensures that even standard PE machines are capable of producing large-volume PA12 pipes that are economic and dimensionally stable.

The product eventually saw the light of day in 2004. The new PA12 grade possessed the requisite properties, supported production of pipes with an outside diameter of up to 300 mm and was easy for plastics processors to handle – now it was time for the real work to get underway.

Sustainable Product Development

The first few years during and after development of the material were mainly about continuing to build up knowledge. National and international standardization and norms had to be considered. The key questions were: Which methods of laying gas pipes have to be evaluated? What is the best way to join the pipes to each other? What system checks are performed? In short: How does the whole system work and how does PA12 fit into it?

Part of this knowledge buildup involved intensive collaboration with nu-

Fig. 2. In the past few years, numerous test installations as well as a series of commercial installations have been realized with PA12 pipes

merous gas network operators and pipe producers and extensive liaising with standards bodies and associations. From the outset, the focus of all discussions was on safety and a long pipe service life. After all, an underground gas pipe must function reliably for 50 years.

In conjunction with various external partners and institutes, such as the Gas Technology Institute, Des Plaines, Illinois/USA, a number of material and system tests were performed: the rapid crack propagation test and the slow crack growth test, for example, confirmed the outstanding properties of PA12 piping and smooth operation at an operating pressure of up to 18 bar.

The ensuing years saw the completion of several test installations, including in Germany and the USA (**Fig. 2**). Aside from different soils and climates, various welding techniques (**Fig. 3**) and installation methods (**Fig. 4**) were tried out. Crucially, these test installations yielded a better understanding of the overall system, e.g., which connection technologies are approved and which ones are actually used. Since then, a number of commercial PA12 supply pipelines in the USA and Brazil have already gone into regular operation. This experience is also benefiting pipe manufacturers and installation companies.

Besides making processing recommendations, Evonik provides CAE support to evaluate pipe systems prior to installation. Buckling and bending angles can be simulated with a view to predicting the windability of the piping under certain external conditions, such as temperature and humidity (**Fig. 5**). Simulations can also be used to derive data for what happens underground, e.g., how piping behaves when stones or earth movements cause it to deform by more than was originally planned. Numerical methods such as finite element analysis (FEA) yield reliable predictions for making recommendations. Thus Evonik supports not only pipe and fitting manufacturers in process design, but also downstream processors in installation and assembly.

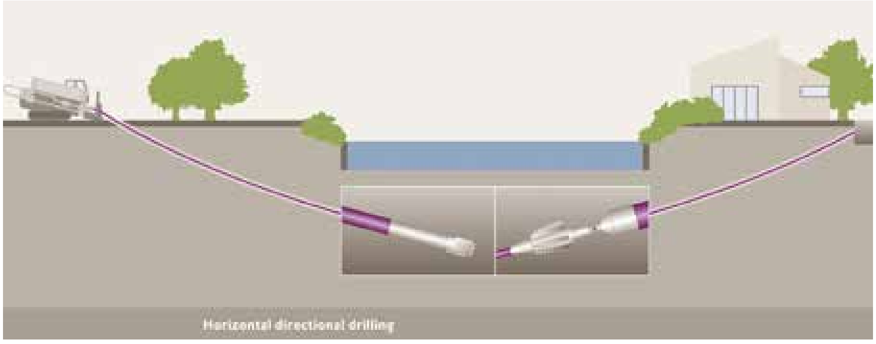

Fig. 4. Directional drilling is just one of several methods for trenchless laying of underground pipes. PA12 pipes must meet the various mechanical requirements imposed

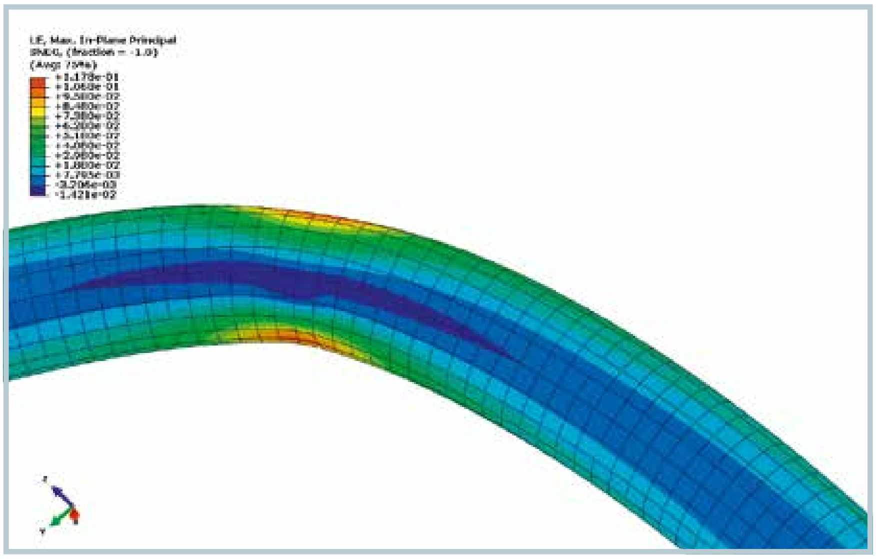

Fig. 5. FEA simulations show the mechanical stresses in bending and buckling of pipes and allow reliable predictions and recommendations to be made (shown here the buckling of a pipe under bending stress)

Fig. 3. Even as the polymer is being developed, consideration must be given to how the piping will be joined together on site

Other Areas of Application

Gas pipes are not the only large-volume pipes that can be made from the new PA12. In addition to its use in all-plastic pipes, PA12 serves as a material layer in flexible oil pipelines for oil rigs. Again, the decisive factors here are such properties as its strength and impact resistance, chemical resistance and low water absorption. PA12 can also serve as the outer shell for steel pipes or as the liner for the oil pipes on the sea floor. Each of these applications has its own standards and licensing restrictions. Accordingly, each area also requires that the appropriate expertise be acquired.

Even though development on the new PA12 grades under the brand name Vestamid NRG finished several years ago, optimization work is ongoing and aims to always offer the best possible product for every application. Sustainable product development therefore means above all: intensive knowledge buildup, close industry contacts – and sticking power. ■