Polyethylene can be bonded too

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Plastics of all shapes and types have become indispensable in our everyday lives. If you look around, you will find that an increasing number of natural materials are being replaced by plastics. This has resulted in many technical challenges, one of the biggest being bonding.

There are numerous, well-known benefits of abandoning the use of metal in favour of plastics. Using plastics brought about significant changes in the simplicity of maintenance, as well as durability of products. This has in turn made life easier for users on a level unattainable in the past, when metals were used for the same products. Let us use our boats and their parts as an example. In most cases, plastic is lighter than metal, which means that the final product made from it is lighter as well, which makes quite the difference when you are at sea. Other

Specifications

Colour:	transparent base, blue catalyst
Mixing ratio:	10:1
Working time with a single mixer:	around 8 minutes
Open assembly time:	10 minutes
Drying time to handling strength:	60 minutes
Drying time to full strength:	24 hours

The entire boat is made from polyethylene. In the past, this type of boat could not be repaired by bonding

They used to be considered disposable tanks, but now they too can easily be repaired by bonding

characteristics of plastic materials include resistance to corrosion and chemicals. The last, and perhaps the most important aspect is their price. Today, plastic parts are mostly mass produced from molds, which significantly reduces the price of the most expensive work component, human labour. Lighter products also lead to savings, particularly in transport costs, albeit only in the long term. However, since boats are used for long periods of time, every penny saved is ultimately reflected in the rate of depreciation. But the area where every single boatsman has noticed the greatest improvement is precisely corrosion resistance. Plastic vessels do not rust, and plastic tanks will not be damaged by the corrosive fuel and become covered in rust. There is no need to paint them over, to fight corrosion, no need to worry about grounding, zincing... Simply put, there is no need for maintenance!

The “lotus effect” appears on some plastic surfaces as well, such as polyethylene, which previously prevented efficient bonding

High-density polyethylene (HDPE)

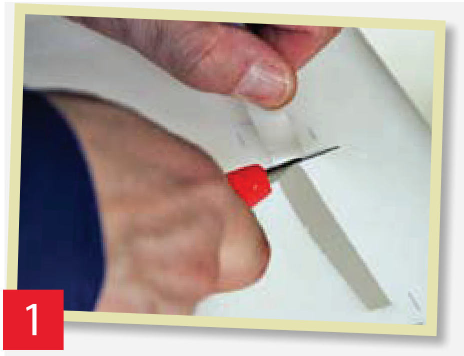
Things are great when maintenance isn’t necessary, but what happens when something needs to be repaired? In this regard, plastic components proved much more complicated in some cases. Unlike metals, which can simply be repaired by welding, riveting or adding screws, plastic materials could not be repaired as easily. The only remedy for this have been chemical compounds such as adhesives, while some plastic materials, like polyethylene, could be welded, but only by a very complex process. The low purchase price, as well as the high costs and complexity of repairs, have lead to these materials still being seen as disposable. Even when it came to valuable objects that were truly worth the effort and that should have been repaired when any kind of damage appeared. One example are the polyethylene tanks on our boats, and even entire boats such as Whally or most of the sit-on-top kayaks that can be seen along the coastline... All of these are valuable, and it would be a shame to write them off simply because they have been damaged. Unfortunately, this was often the case. Despite their excellent mechanical properties, durability and resistance to mechanical, as well as most other stresses, polyethylene parts also sustained damage, and among all plastic materials, these were the most difficult to repair.

Up until now, damage to components made from polyethylene and similar plastic materials meant one of two things: the object would either be welded if it had thicker walls, or it would be disposed of. Bonding was out of the question. Until now...

Why are some plastic materials so difficult to bond?

Most of us have at some point in our lives experienced the need to bond things together that simply would not bond. All of the adhesives that were ideal for bonding metal, leather, ceramics and even some types of plastic, proved completely ineffective

Polyethylene bonding process



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We damaged the polyethylene tank beyond repair

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The surface needs to be cleaned with alcohol before bonding

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As in many cases, it is recommended to lightly sand the surface with a Scotch Brite material and then clean it with alcohol once again

4

For the work to be done properly, you need the right tool

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Before starting, squeeze out a small amount of adhesive in order to eject any dry residue that might have formed over time, blocking the passage

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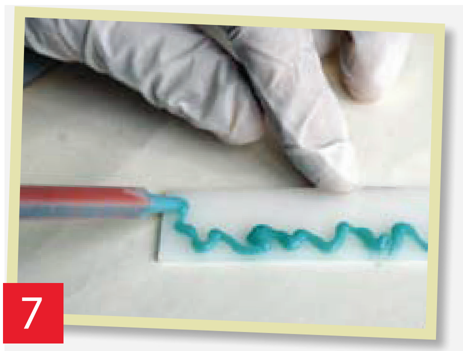
The nozzle is also the mixer for the two components



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The adhesive is applied to one of the surfaces to be bonded

8

Wipe off any excess glue right away

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The bonded parts need to be pressed hard. In this example, this was not possible as the polyethylene was too soft

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3M DP 8010 can also bond different materials with very low surface energy

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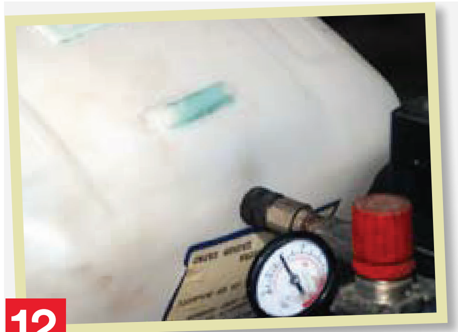
When using the adhesive on vertical surfaces, it is recommended that the parts be secured with adhesive tape to prevent them from slipping before the adhesive takes effect



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The tank was tested after 72 hours by being compressed up to 4 bar, which is when the patch yielded. Had we been able to press down harder on the joint, it would have probably been even stronger!

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We loaded another joint with a 1.4 kg weight suspended on a lever

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Even 6 kg wasn't enough to break the bond

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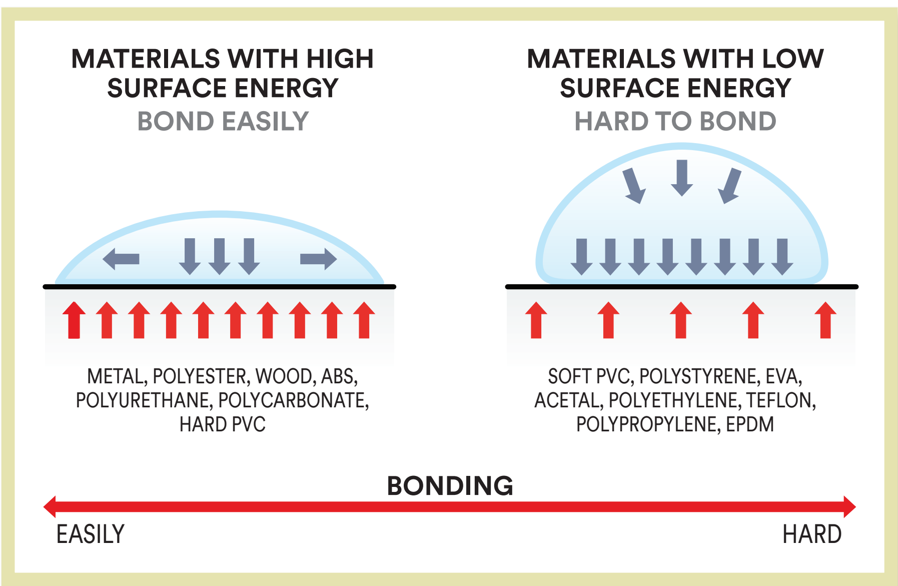
Finally, we had to put a lot of effort into breaking off the bonded piece of plastic

on some surfaces. What was the problem? All of these surfaces that are difficult to bond have the same property – low surface energy.

Surface energy is energy created as a result of the materials' surface tension. The stronger the interaction between atoms on the surface, the higher the surface energy. What is interesting is that the surface energy of solid surfaces cannot be measured directly, but can be determined by a very simple empirical method – the so-called wetting method. The experiment is simple. A drop of water is placed on the surface and the contact angle between the drop and the surface is measured. The larger the angle, the lower the energy. When it comes to polyethylene, the drop will take the shape of a bead whose wall will form an angle of 72° with the surface. When it comes into contact with glass, the same drop will spread over a much larger surface, and its edge will rise to an angle of 5° relative to the surface. Experience shows that, on the molecular level, these materials behave in the same manner with other liquids as well. In other words, the contact surface between the adhesive and low surface energy material will be limited, as will be their adhesion.

Many call this low surface energy effect the "lotus effect", although us shoremen are more familiar with collard greens, from whose surface water, paint and other liquids simply slide off,



leaving no residue. Thermoplastic olefin (TPO), polypropylene (PP), and high-density polyethylene (HDPE) exhibit the same property.

The basics of bonding

For an adhesive to be effective, it has to closely adhere to the surface, which, as previously mentioned, depends on a material's surface energy. In order to bond well, an adhesive has to closely adhere to the surface, and to be able to do that, the surface has to allow good contact with the adhesive, which is something that low surface energy materials don't do.

The method of bonding low surface energy materials that was used in the past involved modifying the surface in order to increase its surface energy. This was usually done by heating, whether by means of open flames or plasma, etching with various acids, or using different solvents. Unfortunately, this often led to unwanted changes in material properties.

Luckily, modern chemistry finally found a solution to this challenge, with structural adhesives being made to bond even materials with low surface energy, without the need to prepare the surface in any specific way. The golden rule for any type of bonding applies here as well: the surface must be free of grease and dust, clean and dry.

Testing the 3M Scotch-Weld DP8010 Structural Plastic Adhesive

The 3M Scotch-Weld DP8010 Structural Plastic Adhesive is a two-part acrylic adhesive specially formulated to bond many low surface energy materials, but it performs equally well with other materials with higher surface energy. What is especially important with this type of adhesive is that the surface does not need any special pretreatment. It only needs to be cleaned from any dirt and degreased using alcohol if necessary.

The nozzle is also the mixer for the two components

The adhesive is applied to one of the surfaces to be bonded

The adhesive itself comes in convenient packaging that prevents contact between the two components before it is necessary. The only real challenge with such two-component adhesives in separate chambers is that a special "plunger", or an applicator gun, is needed to ensure their proper use, but once you buy the applicator and plastic plungers that squeeze out the components in the desired ratio, you will never have to worry about it again and you will be ready to use any adhesive packaged in this way.

After that, the adhesive is applied to the surfaces that are to be bonded. It is actually only applied on one of the sides, whichever one is more convenient. If possible, the bonded surfaces should be pressed together hard, either by a weight or using clamps. This will enable the adhesive to spread evenly over the entire surface, and any excess glue will be squeezed out.

A hundred and one plastics

When talking about plastics, we are actually using a term that covers a wide variety of synthetic and semi-synthetic organic compounds. What is interesting is that only a small portion of plastic materials is based on petrochemicals, while most are made from renewable resources such as polyacrylate, which is derived from corn or cotton.

- PE (polyethylene) is a thermoplastic compound made from the polymerisation of ethylene. There are many types of polyethylene, the most commonly used ones being:
- Low-density polyethylene (LDPE)
- High-density polyethylene (HDPE) In both cases, density is always under 1 g/cm³, which means they float on water.
- Surface energy: 31 mN/m
- PP (polypropylene) is an opaque, elastic, heat-resistant plastic used in heat-resistant plastic cups, and since it is a good sealant, it is also used in the production of bottle caps
- Surface energy: 31 mN/m
- PTFE (polytetrafluoroethylene), also known as teflon, is most famous for its extremely low coefficient of friction and very high melting point. Today it is mostly used as a sealing foil for water and gas pipes, as well as for coating kitchen utensils.
- Surface energy: 18.5 mN/m
- PS (polystyrene) is actually a completely transparent plastic, but most people know it as white Styrofoam, which is its expanded version used for thermal insulation and protective packaging. The non-expanded version can be found in school bags because it is used to make plastic cups, small transparent boxes, rulers and geometry sets.
- Surface energy: 33 mN/m
- PET (polyethylene terephthalate) is mostly used for packaging.
- ABS (acrylonitrile butadiene styrene) is a tough, durable plastic used to make computer cases, monitors, printers...
- PMMA (polymethyl methacrylate) is an artificial (acrylic) glass, also know as Plexiglas or Perspex. It is a type of transparent plastic with a density of around 1.1 g/cm³ and better physical properties than ordinary glass in every respect, except temperature resistance, as it becomes elastic and flexible at 200°C. It is used as a substitute for glass. It can be bonded with cyanoacrylate. PMMA burns completely. In other words, it transforms into water vapour and carbon dioxide, leaving no trace behind.
- PVC (polyvinyl chloride) is a rigid plastic usually mixed with softening agents.
- Surface energy: 39 mN/m
- Bakelite was the world’s first synthetic plastic, developed in 1907.
- PA (polyamide), better known as nylon, is a plastic material invented in 1939 and used as a substitute for natural materials such as parachute silk due to its great strength and flexibility
- Rubber, both natural and synthetic, is also a plastic material

When compared to materials with low surface energy, aluminium has a surface energy of around 500 mN/m, while the surface energy of glass is around 1,000 mN/m.