Adhesive Bonding of High Performance and Composite Plastic Products

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Abstract: The paper presents the special requirements for the adhesive bonding of high performance and composite plastic semifinished products. Field of application: machine engineering, nuclear and chemical industry, equipment manufacturing, die making, vehicle manufacturing, railway service, maintenance and repair.

Keywords: high performance and composite plastic bonding

1. INTRODUCTION

Beside meeting the various engineering requirements on the market of semifinished plastic products an ever greater role is played by high performance (HPM) and composite polymers. Quite often machinery elements or assemblies made of engineering plastics will find their final form, shape by bonding methods. Due to the different surface particularities of certain materials the adhesive bonding characteristics of many plastic and composite items may significantly vary.

2. SPECIAL REQUIREMENTS FOR THE ADHESIVE BONDING

The different chemical structure and hence, their differing physical properties of the given plastics represent the most important parameters for the adhesive technology.

As for all materials to be bonded, two preconditions must be satisfied:
1. the adhesive must wet the plastic, i.e. the surface energy of the plastic must be greater than equal than the surface tension of the adhesive.
2. the surface of the plastic must be favorable for adhesion, which means that chemical and physical interactions have to occur in the boundary layer between the adhesive and the surface.

If one of these conditions is not satisfied, the plastic in question is often unsuitable for adhesive bonding. If none of the conditions are satisfied, the plastic cannot be bonded without preliminary treatment.

2.1. The effects of plastic surfaces

In the case of plastics, it is a frequent problem that volumetric properties (the individual properties of the base material) do not correspond to the surface properties. This can be deduced to the chemical composition and/or the manufacturing process. An energy-deficient surface layer results in the low solidity of the adhesive bond, independent of the applied adhesive material.

2.2. Surface properties depending on the finishing process

During the shaping of plastic components, surface structures, hence “surface properties” different from the properties of the “base material” can arise. These are referred to as injection molded surface, which are highly smooth and compact, usually with internal tensions. The stronger is this injection molded surface, the less favorable are the adhesion properties. Its effects are similar to hose of a protective coating applied to the base material. The simplest and most effective pre-treatment is the destruction, or mechanical removal of this surface layer, e.g. by abrasion and polishing.

2.3. Crack formation due to tension in thermoplasts

When contacted by certain liquids (solvents), amorphous thermoplastics free of filling materials tend to form cracks. This is frequently referred to “tension crack corrosion”. Plastics that show the greatest tendency to this phenomenon are polycarbonates (PC), polymethyl-metacrilate (PMMA), acrylonitrile-butadiene-styrene-copolymer (ABS) and polystyrene (PS). From its name, it follows that the crack is formed as a result of two simultaneous conditions. Plastic components have some internal tensions. In most plastic components, these are present in the form of tensions “frozen” during processing, or they arise as a result of external forces. Small molecule materials have an effect on plastics (e.g. acetone, alcohol).

Adhesive materials – which are in liquid state – can give rise to tension cracks corrosion.

<table>
<thead>
<tr>
<th>Undesirable properties during adhesion</th>
<th>Surface treatment process</th>
</tr>
</thead>
<tbody>
<tr>
<td>Small molecule components on the surface</td>
<td>Cleaning with a suitable solvent and/or cleaning material mechanical removal (abrasion or polishing)</td>
</tr>
<tr>
<td>Internal die separating materials on the surface</td>
<td>Cleaning with an aqueous, basic agent</td>
</tr>
<tr>
<td>External die separating materials on the surface</td>
<td>Mechanical removal (abrasion or polishing) removal with appropriate solvents</td>
</tr>
<tr>
<td>Injection molded layer</td>
<td>Mechanical removal</td>
</tr>
</tbody>
</table>
2.4. Option to avoid crack formation

Using the technology described below or selecting another plastic, the crack formation in plastics arising during adhesion can be largely avoided:

- Softening (tempering) plastic components, as a result of which tensions will be relieved;
- Parts must not be squeezed, pressed or deformed during joining, because they can cause tensions of external origin;
- Application of rapidly settings adhesives, which decrease the solvent effect of the liquid adhesive, thus crack corrosion caused by tension will be minimized;
- Adding the adhesive sparingly using cyanoacrilate adhesives in such a way that no excess adhesive builds up on the edges of the adhesive joint, or applying an activator for the hardening of excess adhesive;
- When applying an UV-hardened adhesive, UV-induced hardening in the adhesive joint has to occur immediately after applying the adhesive. Shielded areas, where the adhesive would remain liquid, must be avoided;
- Anaerobic adhesives must be selected for bonding amorphous thermoplastics whitout filling materials.

3. GENERAL TECHNOLOGICAL STEPS OF ADHESIVE BONDING

The sticked bounds can be pulled, pressed, trimmed, stripped, bend open, often the combination of these. The toughness of the bound is strongest in case of trimming and pressing, but sticking is not the best solution if we talk about stripping. It’s recommended to project it in a way to avoid stripping.

3.1. Surface preparation

The toughness of stuck bound is greatly determined by:
- the inner cohesive strongness of the sticking material;
- the strongness of adhesic adration between glue and sticking surface.

The inner cohesive strongness is a characteristic of the sticking material’s type. The degree of adhesic adration is changeable by electrostatic and chemical effects, but mainly depends on the preparation of sticking surface.

Preparing the surface in a proper manner is paramount for reaching good binding toughness. After precise surface preparation it’s recommended to make the sticking as soon as possible, in this way being assured a proper surface and avoided the forcomming pollution.

The most often used surface preparation’s methods are the following:

1. cleaning, degreasing:
   - the gross pollution, grease, paint hardens good adhesic aderation, so they must be cleaned.
2. cleaning, degreasing, surface hardening with medium pore (80-150) blasting paper:
   - the artificial surface hardening increases the surface sticking.
3. cleaning, degreasing, chemical preparation:
   - with chemical solvents the surface activity can be increased in order to grow the level of adhesic aderation.

3.2. Adhesives choosing

When we chose the best adhesives we should acknowledge not just their quality but also numerous other factors and affects – like:

- the bond’s elasticity: an important parameter if we stick together two materials with different heat expanding factor and factory heat levels may significantly vary;
- environmental conditions: temperature, humidity, effects of chemicals;
- gap’s distance between surfaces to be stick together: for big gaps high viscosity, for small gaps reduced viscosity type adhesives;
- color of adhesive;
- environment factor: it’s more simple to use one component adhesive than two component ones. It’s necessary to follow strict security rules when dealing with poisonous, dangerous materials;
- hardening, bounding time: the fast hardening adhesives need immediately, sharply made assembling, which is not suitable for big surfaces, later made positioning is not possible.

4. EXPERIMENTAL RESEARCHES

The purpose of measuring series conducted by the University of Szent István, Gödöllő, Machinery Engineering Faculty was to make comparing measurements for some polymer based adhesives suggested by adhesive producers and distributors. This way the users get some practical picture – as a comparing platform – about the characteristics of certain types of adhesives and polymer combinations binding toughness, elasticity and wearing downs.

Experiments were conducted in four phases:
a. Test body preparation for certain measure.

b. Surface preparation and making of stuck together bounds. Three identical test bodies, two glued surface

c. Stripping down probes on Instron tearing machine, into stripping apparatus

d. Results: stripping power, stripping toughness, elasticity, wearing down.
  Databases, conclusion

The following types of HPM and composite materials have been used for testing the adhesive bonding:

- **POM-H polyoxymethylene-homopolymer.** This version has greater mechanical strength, rigidity, smaller format expansion and better wear resistance that the POM-C.
- **PA66-GF30 polyamide66 with 30% glass fiber filling.** Due to glass fiber reinforcing, it has a greater degree of rigidity, dimensional stability and creep resistance. The maximum allowed operating temperature is higher, as well.
- **PETP/PTFE polyethyleneterephthalate with solid lubricant (PTFE).** Due the evenly distributed lubricant component, not only its wear resistance is better, but even its sliding characteristics stand out among the other technical plastics.
- **PC polycarbonate.** Thermoplastic, amorphous polymer with optical quality, eliminates the unfavorable properties of plexiglass. Extremely hardy material, suitable for safety glasses, as well.
- **PVDF polyvinylidene-fluoride.** Crystalline, unreinforced polymer with excellent mechanical, heat and electric properties, its resistance to chemicals is outstanding.
- **PPS/GF/oil polypheniliesulphone with glass fiber reinforcing and oil filling.** Reinforced, filled, amorphous polymer, with very good mechanical, electrical and chemical properties and high resistance to energy radiation.
- **HGW fabric-filled phenolics.** Cresol formaldehyde resin and textile fabric, generally readily applicable in situations where the dimensional stability and compressive strength of general engineering thermoplastic polymers are not satisfactory.

There have been used the following types of adhesives:

- instant adhesives: LOCTITE 406 and NICRO BOND V-5
- two components epoxi adhesives: LOCTITE 9461 and NICRO BOND 32-02N

The results of measuring series are presented in table number 1.

### Table 1. Trimming hardness for the adhesive/polymer combinations

<table>
<thead>
<tr>
<th>Trimming hardness (MPa)</th>
<th>Instant adhesives</th>
<th>Two components adhesives</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>LOCTITE 406</td>
<td>NICRO BOND V-5</td>
</tr>
<tr>
<td>POM-H</td>
<td>2,887</td>
<td>2,050</td>
</tr>
<tr>
<td>PA66-GF30</td>
<td>14,107</td>
<td>2,753</td>
</tr>
<tr>
<td>PETP/PTFE</td>
<td>6,054</td>
<td>3,525</td>
</tr>
<tr>
<td>PC</td>
<td>4,053</td>
<td>18,090</td>
</tr>
<tr>
<td>PVDF</td>
<td>4,919</td>
<td>8,905</td>
</tr>
<tr>
<td>PPS/GF/oil</td>
<td>2,075</td>
<td>3,730</td>
</tr>
<tr>
<td>HGW</td>
<td>12,645</td>
<td>5,486</td>
</tr>
</tbody>
</table>
4. CONCLUSION

The table number 2 presents the characteristic damage occurred under trimming effect for the different polymer/adhesive combinations.

<table>
<thead>
<tr>
<th>Plastics</th>
<th>LOCTITE 406</th>
<th>LOCTITE 9461</th>
<th>NICRO BOND 32-02N</th>
<th>NICRO BOND V-5</th>
</tr>
</thead>
<tbody>
<tr>
<td>POM-H</td>
<td>+</td>
<td>-</td>
<td>+</td>
<td>-</td>
</tr>
<tr>
<td>PA66-GF30</td>
<td>+</td>
<td>-</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>PETP/PTFE</td>
<td>0</td>
<td>+</td>
<td>+</td>
<td>-</td>
</tr>
<tr>
<td>PC</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>PVDF</td>
<td>-</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>PPS/GF/oil</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>HGW</td>
<td>+</td>
<td>+</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

+ Trimming of internal cohesion of adhesive layer
- Trimming of surface adhesion
0 Mixed damage, intermittent trimming

REFERENCES


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