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Crosslinkable Warm-melt-Polyurethanes Offer Instant-fix Characteristics

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ABSTRACT

Adhesives are becoming increasingly accepted for advanced engineering/bonding tasks. Therefore the understanding of the basic principles and the benefits of elastic bonding and structural bonding respectively is of utmost importance. Structural bonding means adhesive performance in load-bearing environments. Furthermore, the time to achieve handling strength has an impact on the economics of an assembly line. The paper gives briefly a summary about the fundamentals of elastic bonding and discusses different adhesive systems in the context of handling strength. Hereby the focus lies on the Warm Melt Technology, and its potential is compared to standard adhesives (1-part, 2-part and Booster Technology, a special 2-C system). Examples illustrate their economical benefits.

Main Points:
- The basic principles and benefits of elastic bonding
- Warm-melt Technology in comparison with standard adhesives
- Handling strength an economic issue
- Combination with Booster-Technology, a special 2-C PUR system
- Presentation of real world applications

Learning Objectives:
- Fundamentals of elastic bonding
- Warm-melt Technology: correlation between chain length and cristallinity
- Handling strength and curing speed of various systmes in comparison
- Real world applications illustrate the potential of the Warm-melt Technology

INTRODUCTION

Crosslinkable warm-melt Polyurethanes enable elastic bonding with the opportunity to realize unique production methods and find therefore increased use in recent years.

As an introduction I would like to summarize briefly the basic principles and the benefits of elastic bonding.

- **Enables Semi-structural Bonding**
  - ⇒ functional performance of the bonded part is defined by the adhesive
  - ⇒ stiffness of a bonding can be calculated

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with FEM (finite-element method) when modulus is known
⇒ lap shear strength gives a limited indication of the strength of the overall bonding
⇒ Elastic bonding copes with permanent static loads

- **Distributes of Stresses Over the Entire Bonding Area**

⇒ substrates are stressed equally, this is important for plastics and substrates sensitive to breakage (light weight constructions are possible)

- **Compensate Structure Tolerance**

⇒ joint gap bridging in the range up to 10 mm (no risk of leakage)
⇒ strength independant of the adhesive layer thickness, this in contrast to rigid adhesives

- **Different Thermal Expansion of the Substrates Can be Compensated**

⇒ adhesive layer must be sufficient thick to accomodate that movement

- **Improves Acoustic Performance**

⇒ noise and vibration deadening (e.g. low Klirr factor when bonding low speaker boxes)

- **Increases Design Possibilities with Aesthetically Improved Surfaces**

Adhesive suitable for elastic bonding can be characterized as outlined below:

- shear modulus: 1 to 3 MPa
- elongation at break: 200 to 600 %
- tensile strength: 6 to 10 MPa
- lap shear strength: 2 to 6 MPa
- permanent static load: 3 % of lap shear strength

WARM MELT TECHNOLOGY IN COMPARISON WITH STANDARD ADHESIVES

With warm melts we understand adhesives based on 1C-Polyurethane which are applied between 50 to 95℃ and are still plastic formable after cooling. This characteristic enables a prolonged wettability and hence the adhesion build-up beyond the cooling and leads therefore to a longer open time for assemblability compared to standard hot melts.

Elastic adhesives based on moisture-reactive 1C-Polyurethanes are well introduced world-wide. They have proven to be robust during application, to show adhesion on various substrates which may be pretreated with the corresponding activator or primer and to guarantee a long life performance e.g. for direct-glazing of vehicles (cars, bus, trucks or rails) over the last 20 years.

Besides these benefits the standard 1C-PUR-adhesives have the drawback when used in a production line that they require too long curing time to achieve handling strength and therefore also too long fixation time. This means an effort regarding investment and time.

To reduce the time for fixation rapid curing 2C-PUR adhesives with a pot life time of 2 to 3 minutes were implemented. However, in order to achieve the target final properties, 2-C systems need an exact stochiometric mixing and a long static mixer up to a length of 45 cm which has to be replaced at each short interruption (<5 min.)-a costly matter.

Standard hot melts (applied above 130℃) are thermoplastic systems and tend therefore to creep in particular at increased temperature. On the other hand moisture-reactive hot melts tend to sag and are

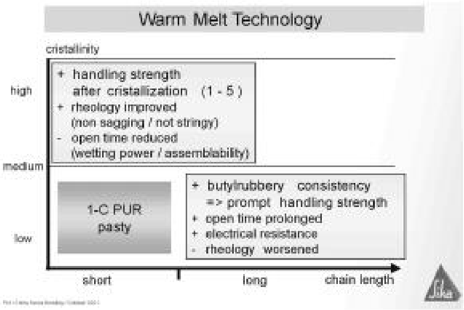

Figure 1. Correlation between chaine length and cristallinity.

therefore not suitable for application with large gaps. Furthermore, their high cristallinic characteristics demand a fast assembling which is often not feasable when bonding bigger parts.

The warm melt technology was developed by combining the experience of three main technology areas: 1C-PUR, hot melts and butylrubbers. Crosslinkable warm melts are attractive in terms of ecology and economics.

At high level of cristallinity of the warm melt, the rheology for the application and the handling strength after cristallization is improved, but the open time for assembling is reduced.

On the other hand, systems with long chain prepolymer containing a high portion of soft segments have butylrubbery consistency. The risk of contamination is reduced, the open time is prolonged, the handling strength is reached instantly and the applicability is slightly worsen. Since the warm melts are crosslinking with moisture the creep behaviour is reduced.

Different moisture-reactive warm melt products were formulated in order to meet the specific application requirements.

HANDLING STRENGTH AN ECONOMIC ISSUE

The handling strength respectively load bearing strength enables a transportation or a following operation of the bonded parts and plays in particular for production line an important economic role because it defines the production speed. Depending on the process, handling strength can mean: tack-free (no risk of contamination), move assembled parts to next station, quality control is feasable, packaging and delivery is feasable etc. For example direct glazing with a lap shear strength of 4 to 6 MPa requires a strength of 0.4 MPa to ensure a safe fixation of the windshield.

The above diagram illustrates different adhesive systems with different speed of strength build-up. It can be seen that physical hardening through high cristallinity results in a faster strength-build than through chemical reaction.

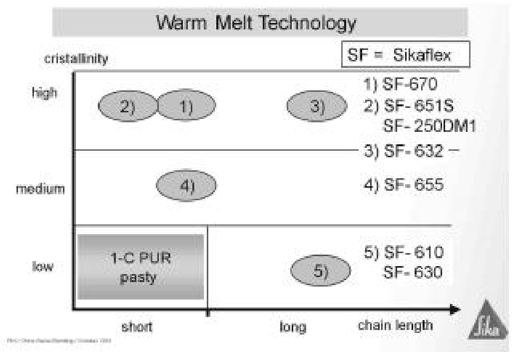

Figure 2. Positioning of Sikaflex adhesives regarding cristallinity.

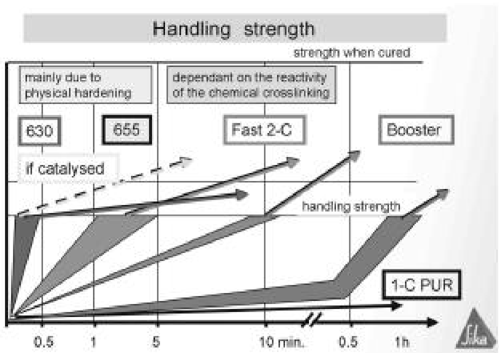

Figure 3. Handling strength and curing speed of various systems in comparison.

COMBINATION WITH BOOSTER-TECHNOLOGY

Another way to overcome the drawbacks of 1C-PUR systems regarding through curing of thick bondlines between water-tight substrates and complete crosslinking at high speed of 1C-PUR systems is the use of the Booster-Technology which is on the market since 1995. With this technology a small amount of a hardener paste is added by means of a shortened static mixer. The mixing is carried out intentionally inhomogeneous and results in a layer-type arrangement of the two components. The hardening happens through water diffusion from many interfaces of the layers in a short time. This special 2C-PUR system is robust since mixing ratio and mixing quality do not need to be absolutely accurate hence do not have to be in a small tolerance band. The combination of the Booster-Technology with moisture-reactive warm-melt systems leads to high performing systems offering instant-fix characteristics and fast through-curing.

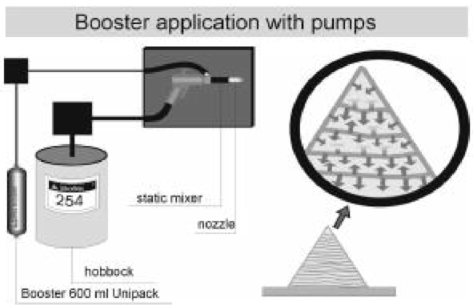

Figure 4. Booster application with pump.

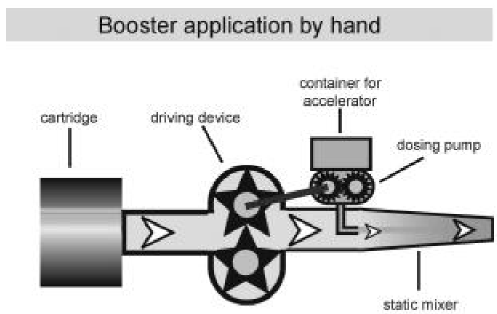

Figure 5. Booster application by hand.

EXAMPLES

- **Direct Glazing**
  - ⇒ open time: 5 minutes (depends on increasing force for assembling)
  - ⇒ some cristallinic characteristics in order to withstand permanent stress load without any fixation
  - ⇒ skinning time: 30 minutes
  - ⇒ short cut-off string
- **Bonding of Bus Floors**
  - ⇒ preformed PUR-profile with heating wire
  - ⇒ touchable
  - ⇒ manually applied like butyl rubbers
  - ⇒ heated with heating wire for viscosity reduction
  - ⇒ after cooling immediate fit to stand on floor
- **Bonding of Head Lights**
  - ⇒ replacement of fast 2-C systems
  - ⇒ on-line leakage test (30 mbar)
  - ⇒ no risk of contaminations because touchable like butyl rubber
  - ⇒ no clamps are required due to high performing adhesive bonds

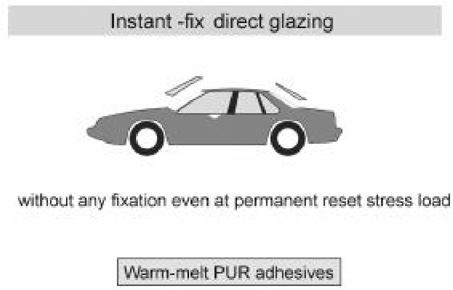

Figure 6. Direct glazing.

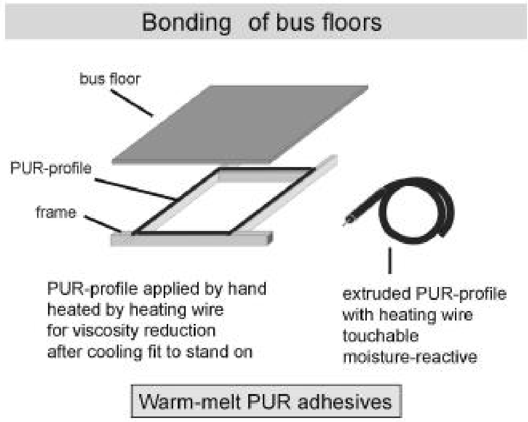

Figure 7. Bonding of bus floors.

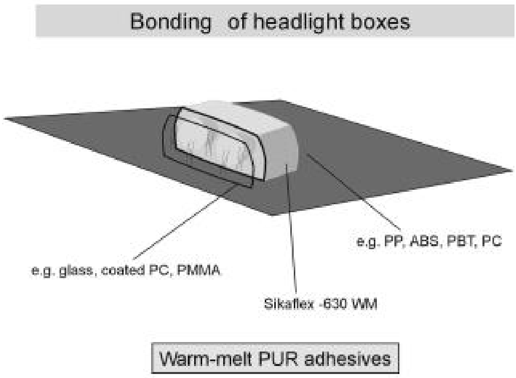

Figure 8. Bonding of headlight boxes.

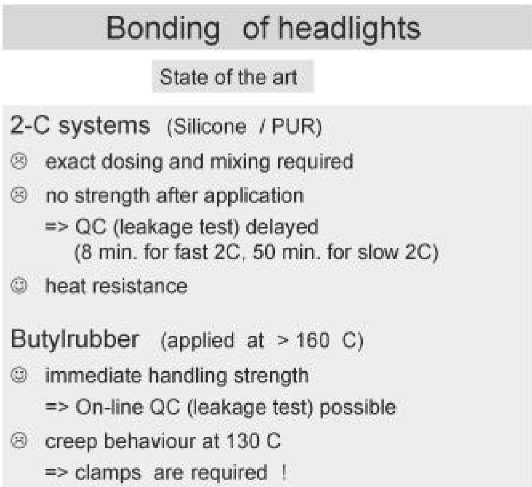

Figure 9. State of the art regarding bonding of headlight boxes.

• Seam Sealing in Car Production

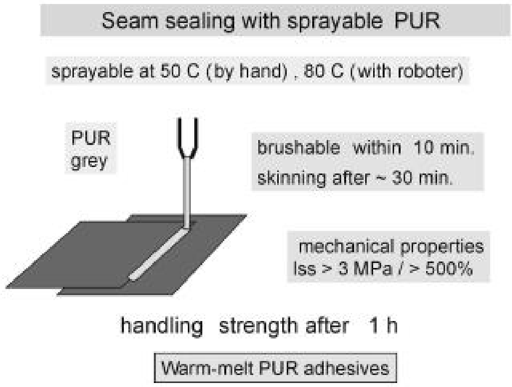

Figure 10. Seam sealing in car production.

• Seam Sealing of Profiles at High Production Speed

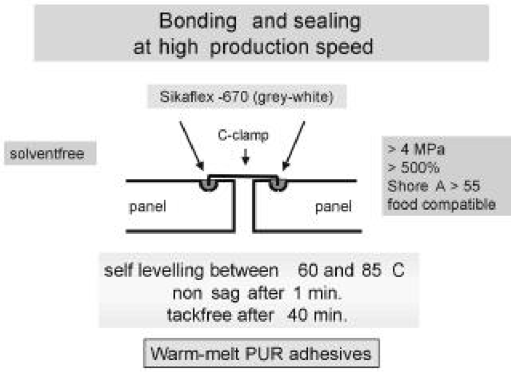

Figure 11. Seam sealing of profiles at high production speed.

These examples demonstrate the many possibilities well-designed moisture-reactive Warm-melt-Polyurethanes can offer. The benefits can only be achieved when the joint is designed consequently for bonding and when the involved partners (adhesive supplier, application engineers, designers) are working as a team.

OUTLOOK

It is obvious that there are still a lot of opportunities for bonding tasks with moisture-cured adhesives. Adhesives are becoming increasingly accepted for advanced engineering/bonding tasks. The mechanical behaviours of such adhesives can be predicted by means of FEM-calculations for which shear modulus, static loadability, creep behaviour, elasticity etc. are the basic parameters. Furthermore, the Warm Melt Tecnology in combination with the Booster-Technology offers additional options for adapting the application of the adhesive to the production process.

The benefits of the bonding technology can be utilized best when the adhesive manufacturer-having the necessary formulation skills-will get the opportunity to fine tune the adhesive to the application technique used as well as to the optimal joint design.

Also careful definition of the durability requirements, substrate selection, and process control, will help to ensure the final assembly fulfills the requirements.