Friedrich-Alexander-Universität
Technische Fakultät

INSTITUTE OF
POLYMER TECHNOLOGY
Prof. Dr.-Ing. Dietmar Drummer

Welding of Thermoplastic Polymers

Vibration Welding, Infrared Welding, Ultrasonic Welding

Barcode zu Ansprech-partner und Infomaterialien

Motivation

The joining of polymers often takes on a central position within the manufacturing process chain. By connecting several components, it is possible to circumvent existing restrictions of the primary shaping process. The common industrially applied joining methods for thermoplastics are welding, adhesive bonding and mechanical fastening. Welding is exceptional in its possibility to produce parts with high joint strengths without the use of additives. Industrial applications can be found especially in the automotive and medical industries, in household appliances as well as in pipeline and tank construction. Fig. 1 illustrates examplary applications of industrial welding solutions.

In general, all thermoplastics are weldable. However, the production of multi-material connections is strongly restricted by the necessary material adhesion-compatibility as well as the prerequisit of similar temperature ranges of the polymers.

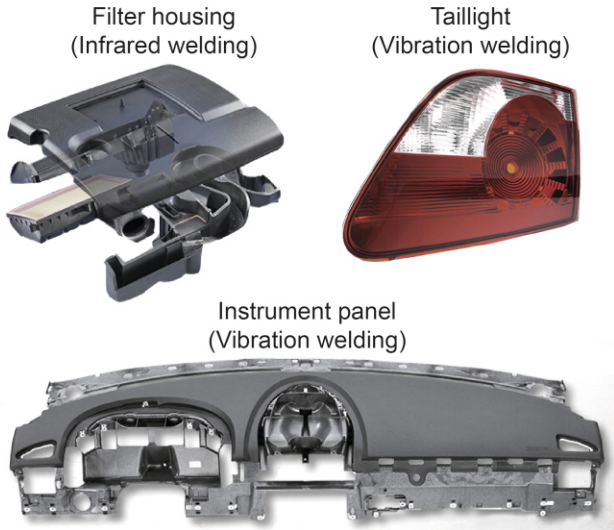

Fig. 1: Applications of welding [source: bielomatik Leuze GmbH + Co. KG]

Vibration Welding

The vibration welding process is based on an oscillating friction-relative movement of the joining partners. Due to the part movement under compression, melting (semi-crystalline) or softening (amorphous) of the polymers takes place and a welding pressure induced melt flow occurs in the joining zone. At the end of the friction-relative movement, the joining partners cool down under pressure and a connection is formed. Fundamental investigations of the process have shown a characteristic course of the resulting weld path, regardless of part geometry, material and process parameters. This course can be segmented into four typical phases, displayed in Fig. 2. Reaching of the quasi-steady phase is considered to be a quality criterion for vibration welded joints and is a prerequisite to achieve high weld strengths.

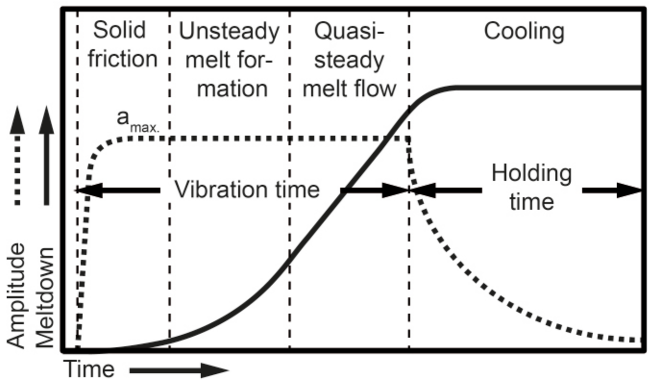

Fig. 2: Schematic process course and phase seperation of vibration welding

Ultrasonic Welding

The ultrasonic welding process is based on heating by friction and offers extremely short welding times of normally less than one second. The transformation of the induced high-frequency ultrasonic oscillation occurs mainly by internal friction by means of energy dissipation, which is caused by longitudinal oscillations due to the pressure wave load. Special seam geometries, so-called energy direction transmitters, are required for the welding process. These allow for a reduction of the contact surface leading to an only linear contact with high local pressure at the beginning of the welding process. Similar to vibration welding, ultrasonic welding can be divided into four typical phases that show a characteristic weld path, Fig. 3.

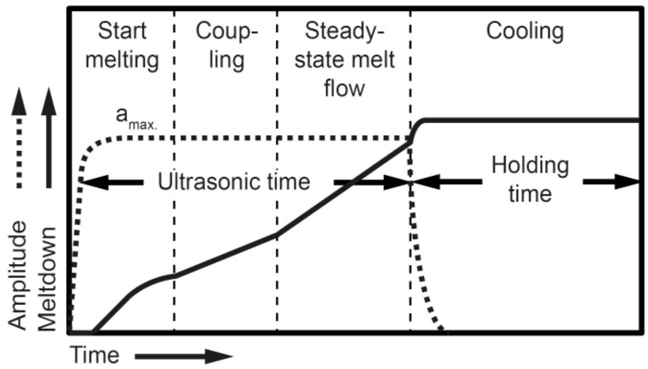

Fig. 3: Schematic process course and phase seperation of ultrasonic welding

Infrared Welding

Infrared welding s a two-step process. Heating of the joining partners takes place separately from and before the joining process. The energy required for melting or softening of the material is introduced by means of an infrared emitter. The absorption of the radiation is dependent on the wavelength of the radiator as well as the morphological and chemical structure of the polymers. The infrared welding process can be divided into three process phases, Fig. 4. At the beginning of the welding process, the joining partners are heated contactlessly by means of an infrared radiator that is placed between the partners during the heating phase. After the formation of a sufficient melt layer, the radiator is moved away and the joining partners come into contact during the changeover phase. The parts are joined and cooled under pressure.

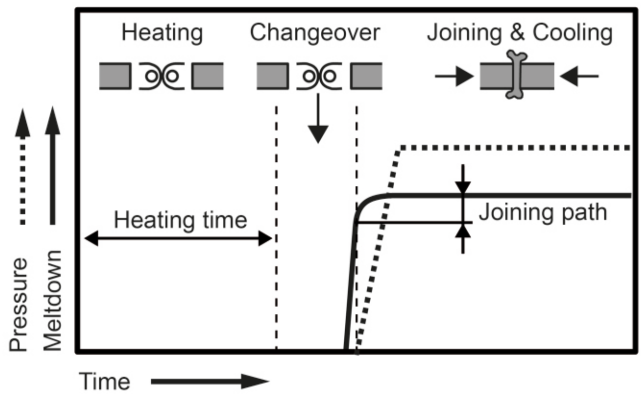

Fig. 4: *Schematic process course and phase seperation of infrared welding*

Influences on Welding Processes

Besides the material combination, the process parameters are one of the main influences on the welding process. Welding pressure, welding time and the amplitude determine the resulting process sequence during vibration and ultrasonic welding. Assuming the third process phase is reached, higher strengths are achieved with lower joining pressures in vibration welding, for example. The amplitude only has a minor effect on the bond quality, but it influences the temperature in the joining zone and thus the resulting process time significantly.

In infrared welding, the joint quality is mainly affected by the heating time and the joining pressure. Lower joining pressure leads to higher bond strengths. The heating time must be selected in such a way that a sufficient melt film is generated in the joining zone before joining. In addition to this process-specific effects, part properties like the color and the joining surface or the humidity of the joining parts can have a decisive influence on the bond quality.

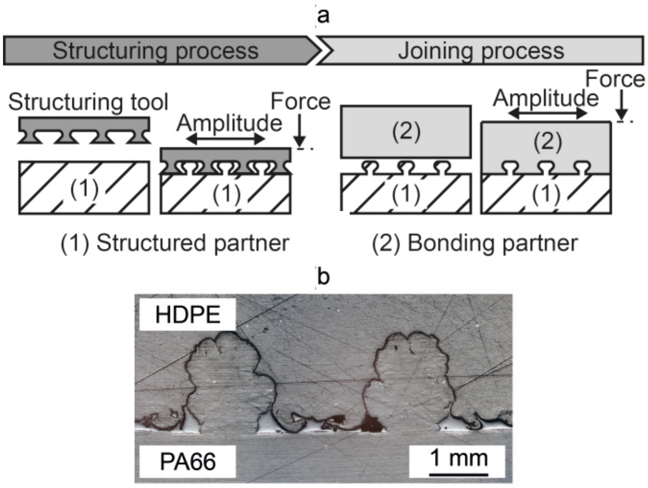

Fig. 5: *Incompatible multi-material combination based on form-fit by using the vibration welding technology*
a) Process schema of joining by form-fit
b) Micrograph of generated multi-material joint

Multi-Material Combinations

In terms of sustainable and resource-saving production, the trend is moving towards intelligent multi-material solutions and locally resolved part properties. The complex interaction of material and process currently leads to a limited spectrum of possible material combinations in welding. For this reason, activities of the Institute of Polymer Technology (LKT) focus on the development of new processes for adhesion-incompatible multi-material joints. The use of pinlike structures offers the potential to extend the spectrum of combinable polymers. For this purpose, a two-stage process is used that is carried out using the vibration welding technology, Fig. 5 (a). By means of structuring, pins are generated, which are subsequently joined to generate a form-fitting connection. Fig. 5 (b) shows an adhesion-incompatible multi-material connection between Polyethylen (HDPE) and Polyamid 66 (PA 66) produced in this way.

Furthermore, welding is transferred to new manufacturing processes like selctive laser sintering (SLS). Such processes offer the possibility to individualize serial components by customer-individualized SLS parts. SLS-specific influences, such as changes in porosity and morphology as well as the complex surface roughness, have a significant influence on the welding process. For this reason, studies on vibration and infrared welding of SLS components are carried out at the LKT, Fig. 6. In addition, the aim is to bond SLS components to injection-molded serial components.

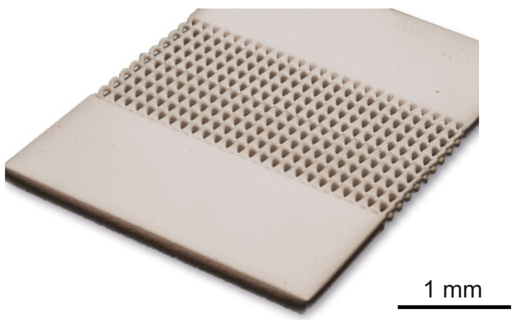

Fig. 6: Welding of selective laser sintered parts

Research Objects and Service for Industry

- Vibration, infrared and ultrasonic welding
- Multi-material combinations
- Adhesive-incompatible polymer joints
- Welding of radiation crosslinked polymers
- Testing of polymer joints

| Institute of Polymer Technology | Am Weichselgarten 10 | 91058 Erlangen-Tennenlohe, Germany
| Phone: +49 9131 85 710 00 | Fax: +49 9131 85 710 07 | Mail: lkt-info@fau.de
| https://www.lkt.tf.fau.eu/