LOCTITE®

3D PRINTING
BONDING GUIDE

Henkel

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ADHESIVE BONDING

The technology of adhesive bonding has made significant advances in recent years – often driven by the challenge to combine new and high-performance materials in more and more demanding end-use applications. In the next pages, we want to help you with realizing your bonding application, especially regarding 3D printed parts. We compare adhesive bonding with other joining technologies, explain the advantages for additive manufacturing (AM), advice you how to design bonding lines and help you to select the right adhesive. At the end of this document you will find a use case, where we have successfully implemented bonding.

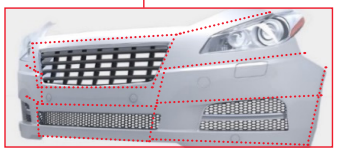
JOINING TECHNOLOGIES IN COMPARISON

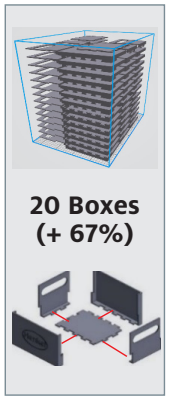
The graphic below compares different joining technologies regarding range of material, stress, appearance and ease of use:

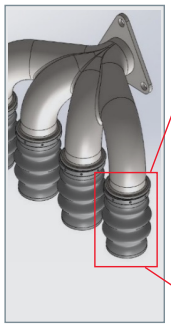
	LOCTITE ADHESIVES	WELDING	SOLVENT BONDING	MECHANICAL FASTENERS	SNAP FITTING JOINTS
					
VERSATILE FOR PLASTICS, ELASTOMERS AND METALS	☑			☑	
JOINS DISSIMILAR MATERIALS	☑			☑	☑
DISTRIBUTES JOINT STRESS EVENLY	☑	☑	☑		
SEALS JOINTS	☑	☑	☑		
AESTHETIC JOINTS	☑	☑	☑		☑
SCALLABLE PROCESS EQUIPMENT	☑			☑	

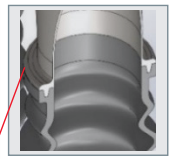
ADVANTAGES OF ADHESIVE BONDING

The high degree of design complexity, offered with 3D printing, is appealing, but the practical limitations of slow print speed, build space and the need for post-processing of printed parts are challenging. Adhesive bonding plays an important role in improving the overall process efficiency. The advantages of bonding regarding AM are the following:









OPTIMIZE BUILD SPACE

Total chassis enabled by bonding of sliced components

Optimizing packing density

OPTIMIZE PRINT ORIENTATION

Adjust print orientation

Decrease thermal stress

INCREASE DESIGN FLEXIBILITY

OPTIMIZE PART

Assembly into final product

✓ OPTIMIZE BUILD SPACE

With adhesive bonding, you can enable the creation of parts which are larger than the build volume of your printer: By “cutting” 3D models into printable subcomponents,

1. you can achieve higher packing density to increase productivity.
2. it is possible to create structures larger than the available build space of your printer.

✓ OPTIMIZE PRINT ORIENTATION

With adhesive bonding, you can enable the creation of AM parts with optimized performance:
The mechanical performance of the printed part depends on the print orientation. By “cutting” 3D models and printing in the preferred orientation, it is possible to optimize the overall performance of the final assembly. Printing smaller components can reduced the material distortion and increase the accuracy of the printed part.

✓ INCREASE DESIGN FLEXIBILITY

With adhesive bonding, you can join dissimilar materials, which gives you the freedom to select the optimal material for your application and combine your 3D printed part also with a conventional manufactured part.

Second, adhesives ensure a uniform distribution of the load over the entire contact area and therefore allow the use of thin-walls and lightweight materials without compromising the aesthetics of the final assembly.

✓ OPTIMIZE PART

Adhesives may add the following features to your 3D printed part:

1. Hermetic seal to protect internal components
2. Thermal, electrical or acoustic properties
3. Repair solution instead of reprinting, which reduces scrap and increases your output

DESIGN FOR ADHESIVES

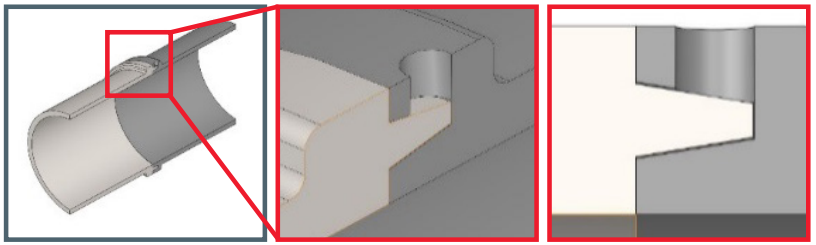
SELECTION OF BONDLINE

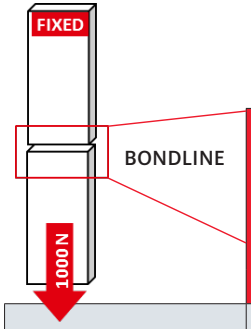
The design of the bondline is mainly determined by

- Application (load, temperature, ...)
- Substrate (stiffness, surface energy, ...)
- Adhesive (gap filling, flexible, ...)

Most 3D modeling software packages offer an automated function to “cut” a 3D model into mating parts. In its most simple form, the 2 components can be cut with a plane split-line, creating two flat-faces for bonding. But there are more bondline designs possible than a butt joint. The next graphic compares five different bondlines regarding self-alignment, bonding area and stress disruption:

USE CASE Tube bonding with tongue & groove as rigid connection



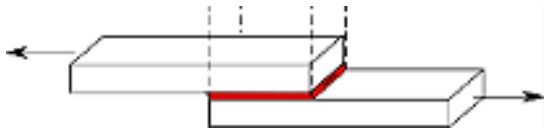


	BUTT	SCARF	STEPPED SCARF	SAW TOOTH	TONGUE & GROOVE
Self-Alignment	✗	✗	✓✓	✓✓	✓✓✓
Bond Area	✓	✓✓	✓✓	✓✓	✓✓✓
Stress Distribution	✓	✓✓	✓✓	✓✓✓	✓✓✓

BONDING GAP

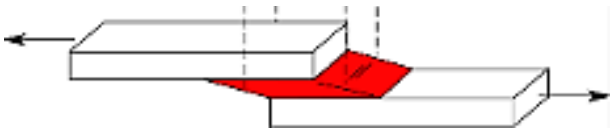
The size of the bonding gap determines whether it is a rigid or a flexible joint, independent of the adhesive:

rigid bonding: small gap (~0 mm*– 0.9 mm)



*surface roughness

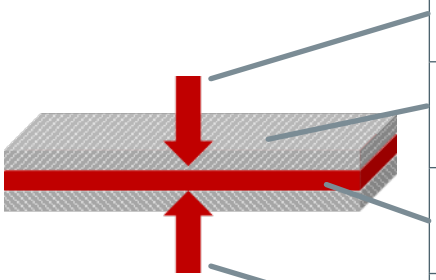
flexible bonding: large gap (~1 mm – 5 mm)



WHY elastic bonding:

- High unequal material expansion
- Vibration insulation
- High resistance to peel stress
- High resetting forces
- Noise reduction

Overview of the factors which influences the size of the bonding gap:



	DESCRIPTION	EXAMPLE
Type of stress	Environmental & mechanical impacts	100 N abrupt, 60 °C permanent, in contact with oil
Part substrate	Flexible or rigid substrate with high or low surface roughness	**elastic:** silicon – polyamid bond **rigid:** metal – metal bond
Viscosity of the adhesive	The lower the viscosity of the adhesive, the easier it is to wet the substrate surface	Water*: 1 mPa.s Oil*: 100 mPa.s *@ 20 °C
Joining procedure	It is possible to apply adhesive before or after (capillarity) assembling the part	Manual, semi-automatic or automatic application see equipment p.10

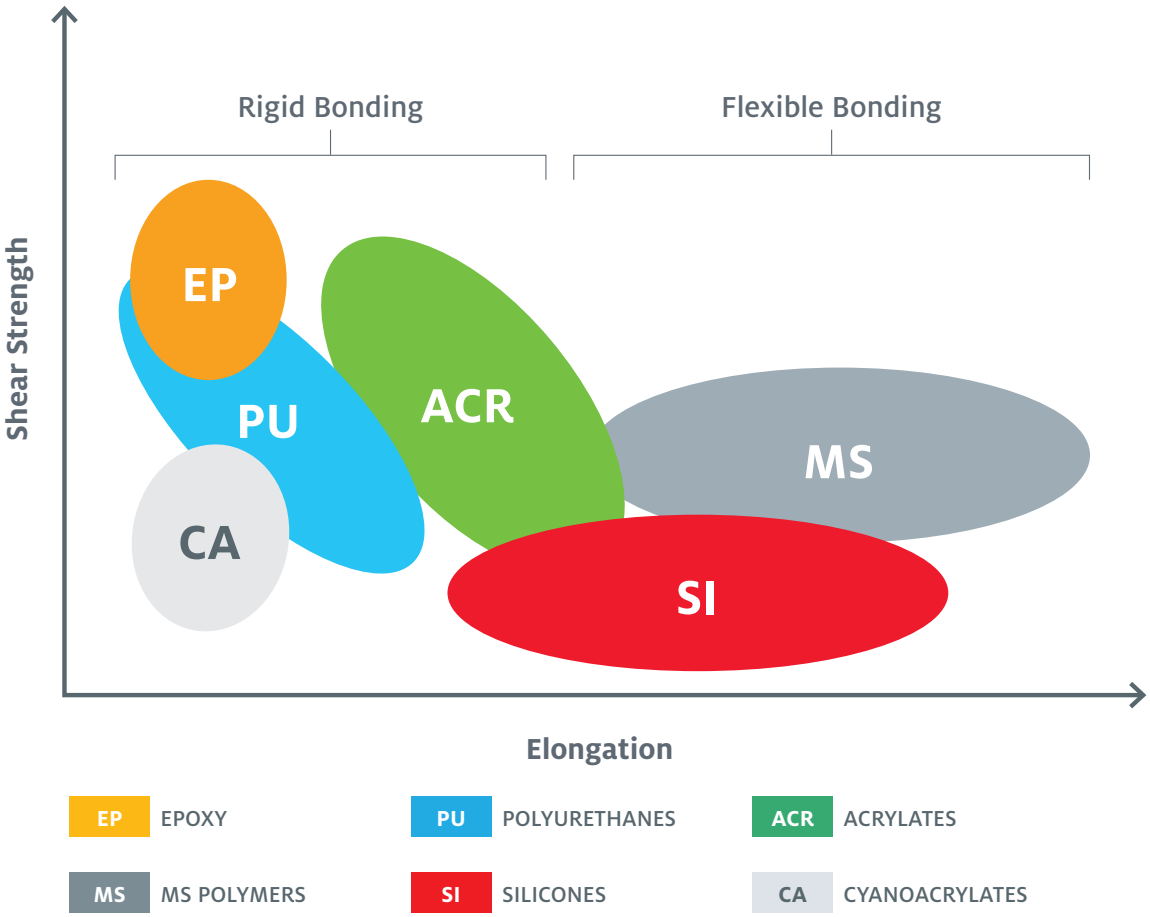
PART CLEANLINESS

For a reliable adhesive bond, the surface to be bonded must be free of contamination, like grease, dust or loose powder. Unclean or partially cleaned surfaces can affect adhesive performance. But not every cleaner is appropriate to use before bonding and can effect the adhesive cure and final strength. The following table compares three LOCTITE Cleaners, which are recommended to use before bonding.

PRODUCT	BASIS	USE CASE	SOLVES	DRYING TIME (@ 20 °C)
LOCTITE SF 7061	acetone, alcohol	metal, glass, ceramic	dirt, resins, varnish, grease, oils	fast drying time (60 s*)
LOCTITE SF 7063	isoparaffin, dimethoxymethane and ethanol blend	metal, plastics	oils, grease, waxes	fast drying time (60 s*)
LOCTITE SF 7070	hydrocarbon, monoterpene blend	plastics, elastomers, metal	oils, grease, waxes, silicone oil	slow drying time (5 min*)

CHOOSING THE RIGHT ADHESIVE TECHNOLOGY

Henkel offers a broad range of technologies to serve almost all possible application requirements.
The next graphic compares the different adhesives technologies regarding elongation and strength.



Rigid, high impact bonding
e. g. Machinery Equipment

EP ACR CA PU

Transparent bonding
e. g. Fashion, Jewelry

EP ACR MS

High temperature bonding
e. g. Transportation

EP ACR SI

Flexible bonding
e. g. Wearables

SI MS CA

SELECTING THE RIGHT ADHESIVE

To identify the most effective adhesive for your application, you have to know the following criteria:

- Type of stress
- Material of the to be bonded part
- Dimension of the part
- Bondline design and bond gap
- Process requirements (cure time <-> cycle time, degree of automation)
- Further application requirements, e. g. fire resistance

The following table helps you to choose the right adhesive for your 3D printed part substrates:

	PLA	ABS	ASA	PA6	PA12	PA12 GB	PA6.6	DLP/ SLA	PC	PP	PE	PEKK	PET	PMMA	PS	SAN	TPU	TPE	PEI
LOCTITE 3DP Instant Bonder	●	●	●	●	●	●	●	●	●	●	●	●	○	●	●	○	●	○	○
LOCTITE 3DP Universal Bonder	●	●	●	●	●	○	○		●	●	●	●	○		●	○	●	○	○
LOCTITE HY 4090		●	●	●	●	●	○	●	●	●	●	●	○	●	●	○	●	○	○
LOCTITE EA 3430		○	○	◒	●	●		◒	○	●			●	◒	○	◒	◒	○	◒
LOCTITE 3D PU Bonder		○	○	◒	●	●	●		◒	○			◒	○	◒	◒	◒	◒	
TEROSON MS 9399		●	◒	●	◒	◒		●	○	○			○	○	○	◒	○	◒	●

● Best
◒ Moderate
○ Bad
No information available

REVIEW OF ADHESIVE PERFORMANCE

Review the performance characteristics of the adhesives, especially available for bonding 3D printed materials.

Adhesive	Description	Color	Viscosity	Temperature range	Curing time		Application case
					Initial strength	Working time	
LOCTITE 3DP Instant Bonder	One component cyanoacrylate adhesive developed for high performance instant bonding on close fitting plastic and metal parts. Approved for many 3D printed materials from SLA/DLP, SLS, FFF and BJ technology.	Clear	110 mPa·s	-40 °C to +120 °C	3 to 10 s	–	For acidic surfaces such as chromated or galvanized surfaces. Also suitable for porous substrates such as wood, paper, leather, cork and fabric
LOCTITE 3DP Universal Bonder	Two component hybrid adhesive with fast fixture performance of bond gaps up to 5 mm. The gel consistency allows accurate control of adhesive flow even on vertical surfaces. It provides an excellent bonding characteristic to a wide range of 3D printed substrates.	Clear	30 mPa·s	+120 °C	5 min	4 – 5 min	Applications where complete cure of excess adhesive is required. It can be subsequently sanded.
LOCTITE HY 4090	Two component hybrid adhesive, which is designed to bond a variety of substrates including metals, most plastics and rubbers. It provides good shock resistance and a good temperature and moisture performance. The thixotropic nature makes it suitable for applications where good gap filling properties on rough and poorly fitting surfaces are required.	White to light yellow	High	-40 °C to +150 °C	4 – 6 min	3 – 5 min	For high load applications where speed, gap filling, and high environmental resistance are required Biocompatible adhesive – medical use ISO 10993
LOCTITE EA 3430	Two component, fast curing epoxy adhesive which is highly transparent	Ultra-clear	23 Pa·s	-55 °C to +100 °C	15 min	7 min	Suitable for applications requiring an optically clear bond line, e. g. bonding glass, decorative panels, displays and general repair.
LOCTITE EA 9492	Two component, high temperature epoxy adhesives with excellent chemical resistance.	White	30 Pa·s	-55 °C to +180 °C	75 min	50 min	Ideal for applications where high superior thermal shock resistance, mechanical and electrical and impact resistant properties are required
LOCTITE EA 9466	two component, universal epoxy adhesive which provides a high peel resistance and a high shear strength. The fully cured epoxy is resistant to a wide range of chemicals and solvents, and acts as an excellent electrical insulator.	Yellowish	35 Pa·s	-55 °C to +120 °C	180 min	60 min	Typical applications include general purpose industrial applications requiring extended work life for adjusting parts during assembly
LOCTITE 3D PU Bonder	Two component, fast curing polyurethane adhesive. The cured product is sandable and has a good paintability for final surface finishing.	Grey	High	-40 °C to +140 °C	6 min	150 s	The product is particularly suited for all major 3D printed materials printed with SLA/DLP, SLS, FFF, MJF and BJ. It is also suitable for standard produced metals, plastics and ceramics.
TEROSON MS 9399	Two component, elastomeric bonding adhesive that cures independently of humidity. It offers a short tack-free time, high initial strength and good fungus resistance. It is free of solvents, isocyanates and silicones and has good resistance to UV and weathering.	Grey	550 mPa·s	-40 °C to +100 °C	1.5 to 2 h	20 min	Very good to use for indoor and outdoor applications. Elastic bonding can be realized.

CA HY* EP PU MS

*HY = Hybrid adhesive, contains two adhesive technologies

DISPENSING EQUIPMENT

Using the right adhesive dispensing equipment, helps you to realize an efficient joining process. Process speed can be increased, high accuracy and performance consistency are ensured and work safety is fulfilled. In the following we present you manual, semi-automatic and automatic dispensing solutions.

LOCTITE CA Volumetric Hand Pump

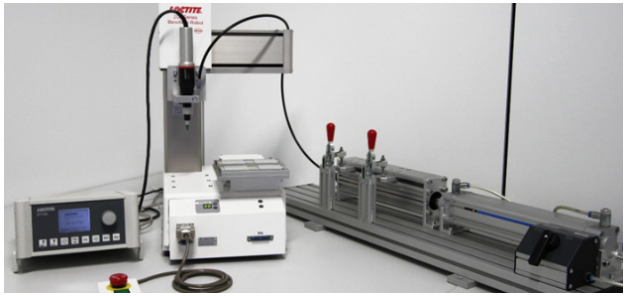
The manual handgun offers a precise, volumetric cyanoacrylate dispensing. The shot sizes are repeatable and it does not require pneumatics, battery or electrical power.

LOCTITE EQ PU20 Digital Peristaltic Dispenser

The semi-automatic solution LOCTITE® Peristaltic Dispenser provides a volumetric dispensing directly from the product bottle, like e. g. Instant Bonder. Additionally, it offers timed dispense mode and vacuum suck back to prevent dripping.

LOCTITE 50ml Dual Cartridge Manual and Pneumatic Applicator

The manual applicators are ergonomically designed to deliver adhesives directly from the original package. The simple and clean dispensing reduces waste and operator contact.



LOCTITE offers full-automatic solutions for one and two component products. The handling unit can be realized with a robot.

USE CASE – AIR DUCT SYSTEM

Challenge

In a short period of time our team should realize an air balancing duct system for a 3D printer which had to fit to the existing hot air extraction system of the laboratory ceiling. Besides the duct system had to be flexible and pass aesthetic requirements.

Solution

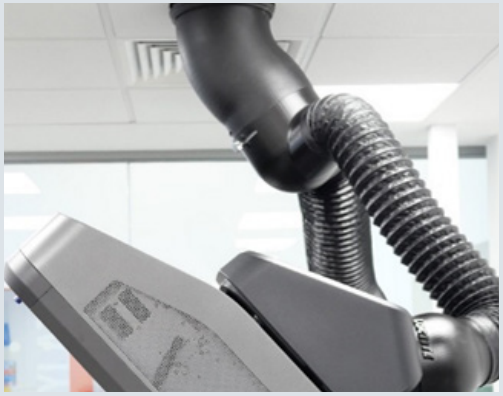
As a solution to this challenge, our team designed three PA12 parts due to the limited build space of the printer. LOCTITE 3D Printing Universal Bonder was used to assemble the final parts, because it offers a good performance on PA12. Additionally, the gap filling properties and the short curve speed were also important selection criteria for this adhesive.

Realization steps

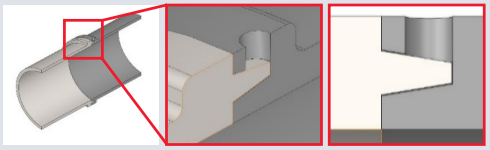
1. Tongue and groove, a self-aligning bondline was chosen to assemble the parts without additional jigs and fixtures. Furthermore, the bondline maximises the bond area and offers a good stress distribution so that a high strength joint could be realized.

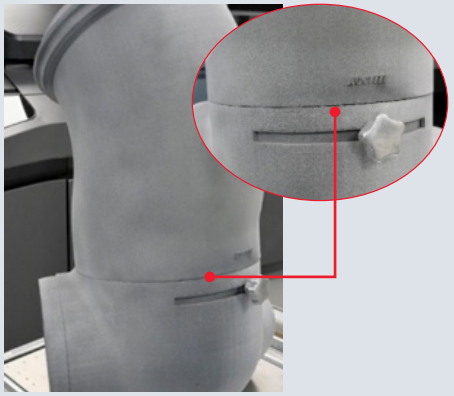
2. A small bonding gap for a rigid PA12 to PA12 bonding was used and grooves as injection holes were added to allow post assembly adhesive injection.

3. To pass the aesthetic claim, the duct surface was coated with LOCTITE 3D Printing Smooth Coat.
   >> The bonded duct system clearly illustrates the advantages such as design freedom of large 3D printed components.



tongue & groove as rigid connection





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