

## **THE USE OF CAD PROGRAMS FOR DESIGNING SPECIAL INSTRUMENTATION IN ADHESIVE TECHNOLOGIES**

*Jacek Tomasz Ogrodniczek<sup>1✉</sup>, Adrian Pyda<sup>2</sup>, Mariusz Kłonica<sup>3</sup>*

<sup>1✉</sup> Lublin University of Technology, Faculty of Mechanical Engineering, Department of Production Engineering, 36 Nadbystrzycka Str., 20-618 Lublin, Poland, email: [eggy94@wp.pl](mailto:eggy94@wp.pl)

<sup>2</sup> Lublin University of Technology, Faculty of Mechanical Engineering, Department of Production Engineering, 36 Nadbystrzycka Str., 20-618 Lublin, Poland, email: [adrian.pyda@onet.com.pl](mailto:adrian.pyda@onet.com.pl)

<sup>3</sup> Lublin University of Technology, Faculty of Mechanical Engineering, Department of Production Engineering, 36 Nadbystrzycka Str., 20-618 Lublin, Poland, [orcid.org/0000-0001-6149-1710](https://orcid.org/0000-0001-6149-1710), email: [m.klonica@pollub.pl](mailto:m.klonica@pollub.pl)

*Submitted: 2017-12-19 / Accepted: 2017-12-28 / Published: 2018-01-15*

### **ABSTRACT**

The role of adhesive technology in industry has increased significantly in recent times. The need to transfer ever-greater stresses while reducing the mass of devices causes difficulties in engineering. The use of dissimilar materials prioritise this technology. Special equipment is required to ensure the right technological conditions. CAD software facilitates the creation of a virtual design to meet the formulated requirements. This article presents the method of designing the instrumentation allowing to conduct the study of adhesives cured by UV rays.

**KEYWORDS:** CAD programs, UV, adhesive joints, cohesion

### **1. Introduction**

Currently, advanced technology and the desire for miniaturization raises the bar high for engineers. The traditional methods of joining elements such as welding or riveting do not always meet the imposed demands. Bonding technology is the solution for the industry [1].

Thanks to the development of chemistry and research devoted to adhesive joints, better and better types of adhesives have been obtained and their properties have been significantly improved. The ease of use, as well as their weight, make engineers and technologists decide to choose this technology [2]. However, the gluing process itself, for which specialized equipment is required, may turn out to be a problem. Therefore CAD software is implemented to design and check the adhesive devices by means of the so-called "Virtual reality".

### **2. Adhesion technologies**

Gluing is the main type of adhesive bond which permanently join two elements. It is used in many industries such as: automotive, aviation, construction or in medicine. The major factor that gives this technology an advantage over e.g. welding and determines its choice is the possibility of combining dissimilar elements [2].

The basic phenomena connected with this technology, such as: adhesion, cohesion and wettability are worth to be mentioned. The term adhesion is not well-specified. The standard defines it as "a state in which two surfaces are held together by means of interphase bonds". Hence it is

a surface phenomenon of binding two bodies. One of the divisions of adhesion is into mechanical and specific adhesion [3].

The second factor affecting the adhesive bond is cohesion. It is the action of the intermolecular forces of a given object counteracting the load changes [3].

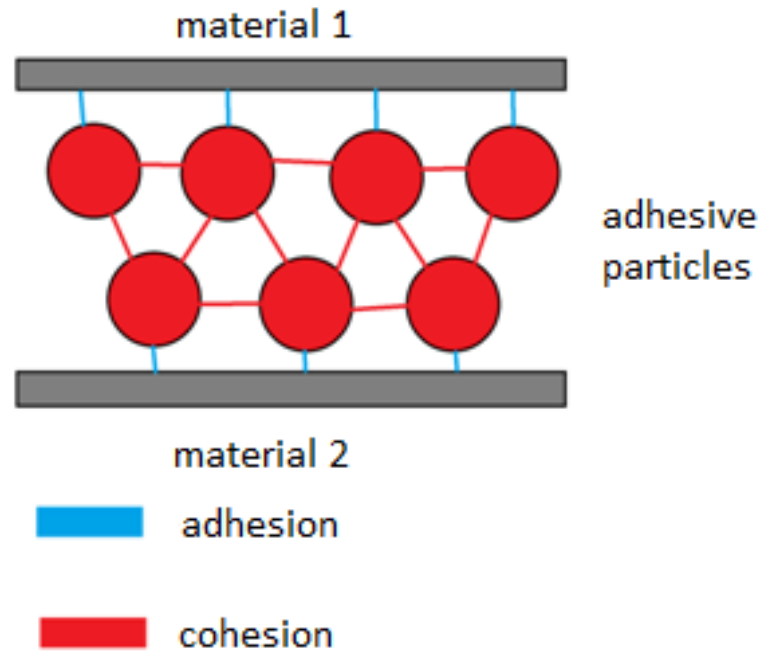


Fig. 1. Mechanism of adhesion and cohesion [4]

Figure 1 presents a diagram of the adhesive joint. Cohesion (marked in red) binds together the adhesive particles, and adhesion (shown in blue) connects the adhesive particles with the surface layer of the adhesive material [4].

The wettability is an equally important issue in this type of joint. This is a surface phenomenon where the wetting angle plays a major role [5].

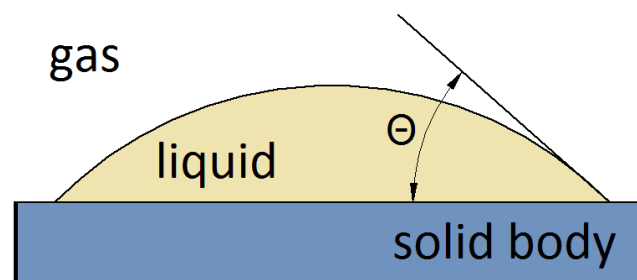


Fig. 2. The wetting [5]

The wetting angle shown in Figure 2 is described by the Greek letter  $\Theta$ . It is the angle between the solid body, to which the adhesive layer is applied and the adhesive. The proper wettability occurs when the value of the contact angle  $\Theta$  is smaller than  $90^\circ$  [6].

Adhesive connections consist of a series of operations necessary to create the right joints. These operations include [7]:

- surface preparation - removal of all impurities and corrosion, as well as ensuring proper geometry of the surface layer (surface development in the geometrical sense),

- preparation of adhesive - the operation depends on the type of adhesive and the need to use activators, foundations or promoters,
- fixing and assembling elements - the fixing of objects affects the quality and durability of the connection,
- application of adhesive,
- curing the adhesive joint - the choice of adhesive determines the choice of the method. There are many ways of tying the weld, which involve a number of gluing tools,
- finishing operations - among others removing the excess of the overflowing adhesive,
- control of joints – detection of connection errors.

Currently, there are many types of adhesive on sale that differ in their curing method. To enable the right choice of the adhesive which is suitable for a given material, the divisions are made according to [8]:

- type of gluing mechanism - adhesives based on polymeric resins (among others epoxy resins), solvent-based adhesives and mixed adhesives,
- amount of ingredients - single component, multi-ingredient.
- natural and synthetic.

### 3. Special instrumentation

Special equipment is used to ensure appropriate parameters at particular stages of gluing. These instruments or mechanisms support the creation of a given type of the adhesive joint. They are used in unit and mass production. The degree of complexity of such instrumentation depends on the specifics of the operations [9].

The main tasks of special tooling are [9]:

- dispensing and distribution of adhesive on bonded surfaces,
- maintaining proper pressure,
- hardening of the weld,
- maintaining the required temperature,
- control of the bond.

It is important to choose the instrumentation for a given connection, consequently each operation may have a different technological solution [10]. To this end, software from the CAx family are used, they enable to design an appropriate construction.

### 4. The use of CAD software

Computer Aided designing (CAD) is included in CAx software. It enables creating geometric models in 2D or 3D mode of entire assemblies of devices. In this way the software helps to visualise the idea, which is why it is widely used in industry, for example, for prototyping or reverse engineering. There is a wide range of CAD software offered by various developers, including software such as CATIA and NX [11].

CATIA, whose name is an acronym from Computer Aided Three-dimensional Interactive Application is mainly used in the automotive industry due to its capabilities. This does not mean exclusion from other industries. Boeing, representing the aviation sector, is one of the largest users of this software [12].

The modules included in CATIA form the whole product life cycle (PLM), managed by the constructor. They enable creating simulations of how a given product will behave in certain conditions (FEM) or the movement of a set of parts [13].

The NX software belongs to the Siemens group. Its biggest advantage is the ability to design and manufacture machine parts in an integrated one system. NX allows you to generate the code for a machine tool operating on the Sinumerik system [14].

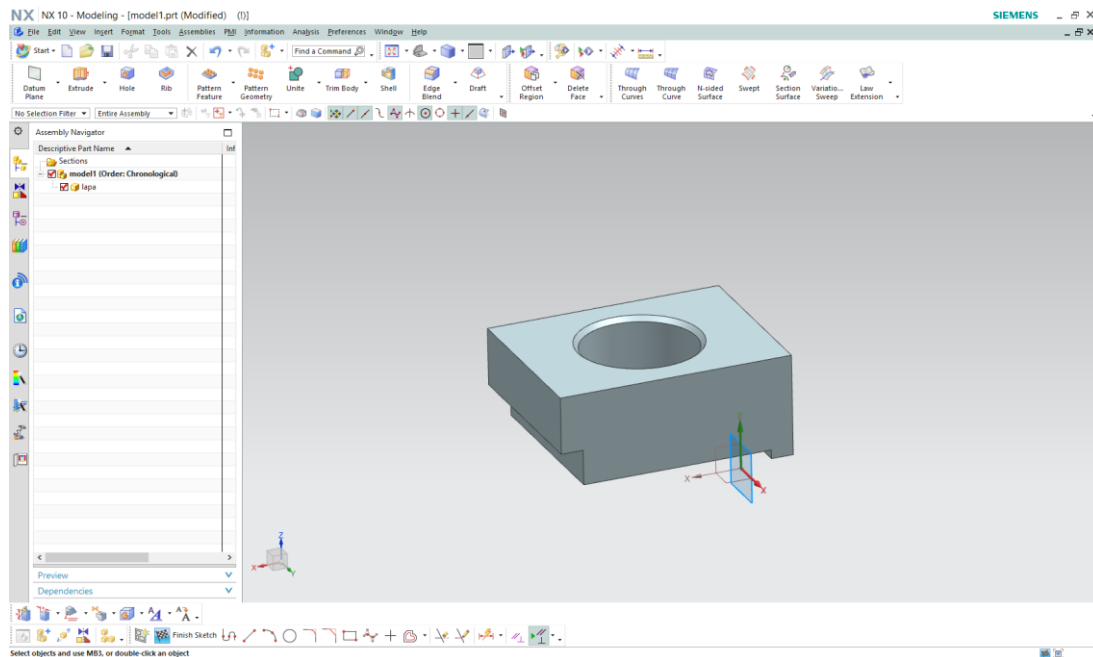


Fig. 3. Interface of NX software (own study)

Figure 3 shows the NX system interface. Most of the offered functions are in the toolbar. In order to facilitate the use, the manufacturer has placed search tools.

The operation of programmes such as NX or CATIA is not simple and requires a lot of engineering knowledge as well as software knowledge. Siemens decided to face this problem and developed the Solid Edge software [15].

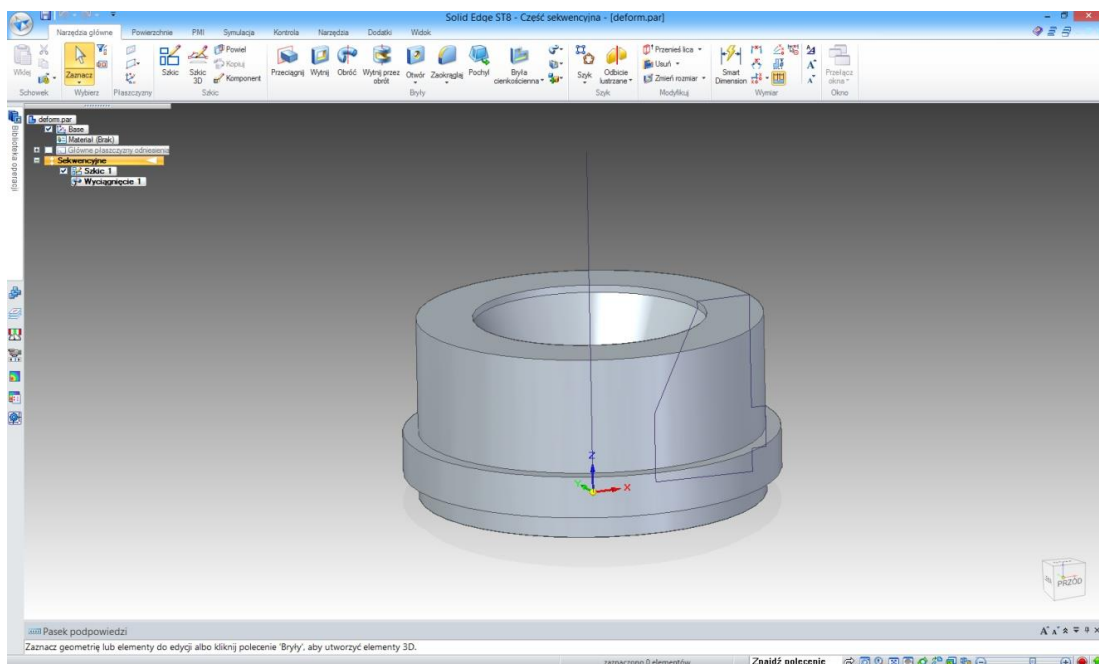


Fig. 4. Interface of Solid Edge software (own study)

The Solid Edge interface itself, shown in Figure 4, is very intuitive. It does not require advanced user skills to operate the system while maintaining all basic functions of the CAD software. Its greatest asset is the modeling environment for parts made of sheet metal [16].

Solid Edge is used in industries that do not require high computing power and where the part complexity is rather small.

## 5. Practical application of CAD in the adhesive industry

One of the ways of making adhesive joints is cross-linking with UV radiation. At present, this method plays an important role in gluing technology. It is used, among others, in dentistry to strengthen seals.

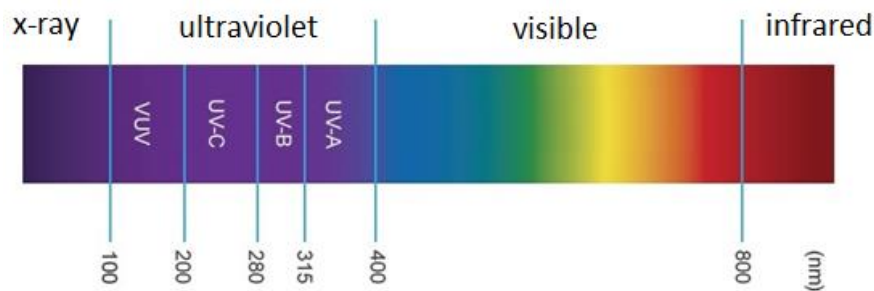


Fig. 5. Range of electromagnetic wave [17]

Figure 5 shows the range of light or electromagnetic wave. Depending on the wavelength it can have a different color. Ultraviolet radiation is divided into four categories: VUV, UVA, UVB and UVC. The radiation closely related to the visible light, whose wavelength ranges from 315 to 400 nm, is most frequently used for curing [17].

Due to the harmfulness of UVA radiation for humans, it is important to use the instrumentation to eliminate this factor. For this purpose, a chamber was constructed together with a device for adhesive the tested samples.

Design assumptions:

- adaptation of the handle to the chamber with a UV lamp,
- ensuring proper pressure of adhesive samples and the possibility of adjusting their overlaps,
- changing the position of the UV lamp in 2 planes,
- isolation of UV radiation from the environment,
- possibility of making many adhesive joints (10 pieces),
- the ability to adjust the length of the connection tab,
- possibility of making a connection on samples of different thickness and width,
- laboratory stand with the possibility of quick disassembly of the adhesive holder.

The main factor determining the dimensions of the device was a UV lamp, in relation to which it was possible to choose the dimensions of the adhesive device and the chamber itself.

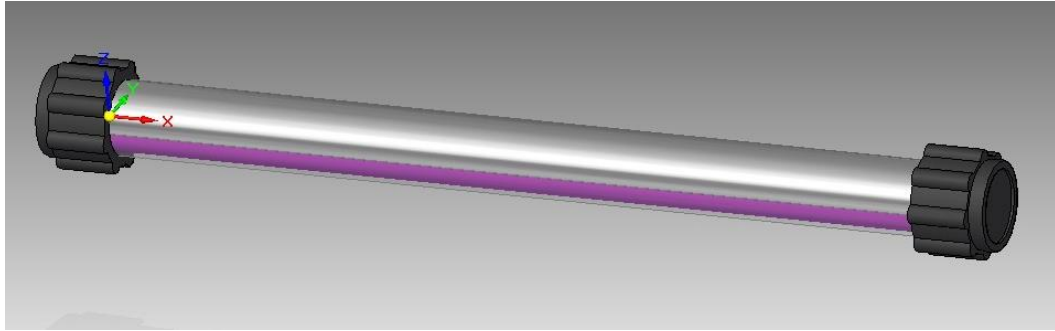


Fig. 6. Model of BOHL UVA "STAR" lamp (own study)

Using the bottom-up method, the base for all subsequent attachments was the lamp shown in Figure 6. In order to ensure movement in the assumed directions and the possibility of reaching radiation to each place, a manipulator was designed.

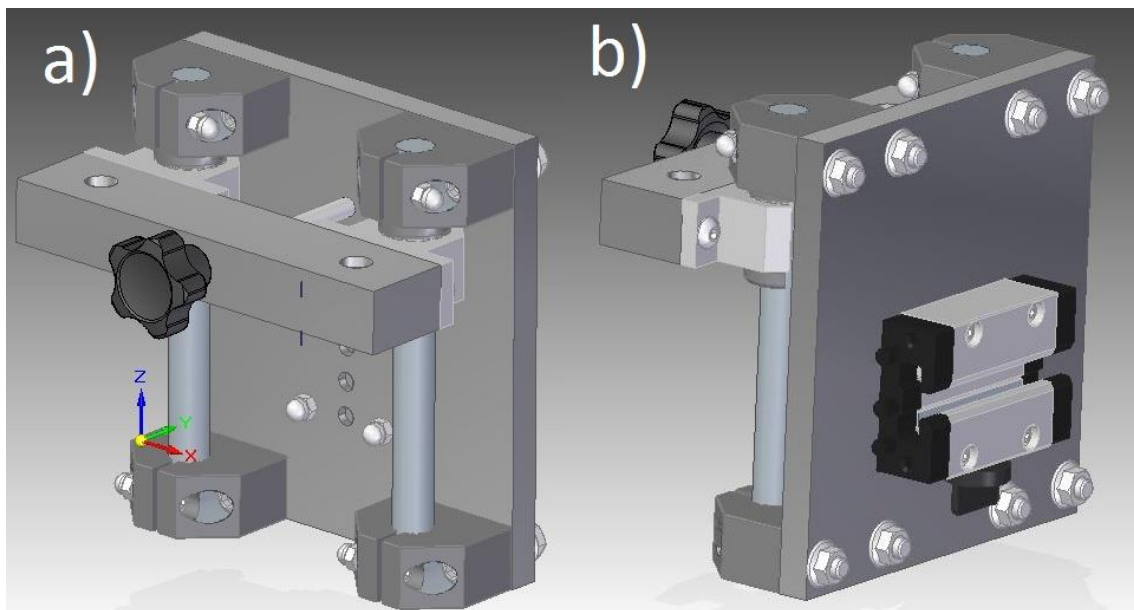
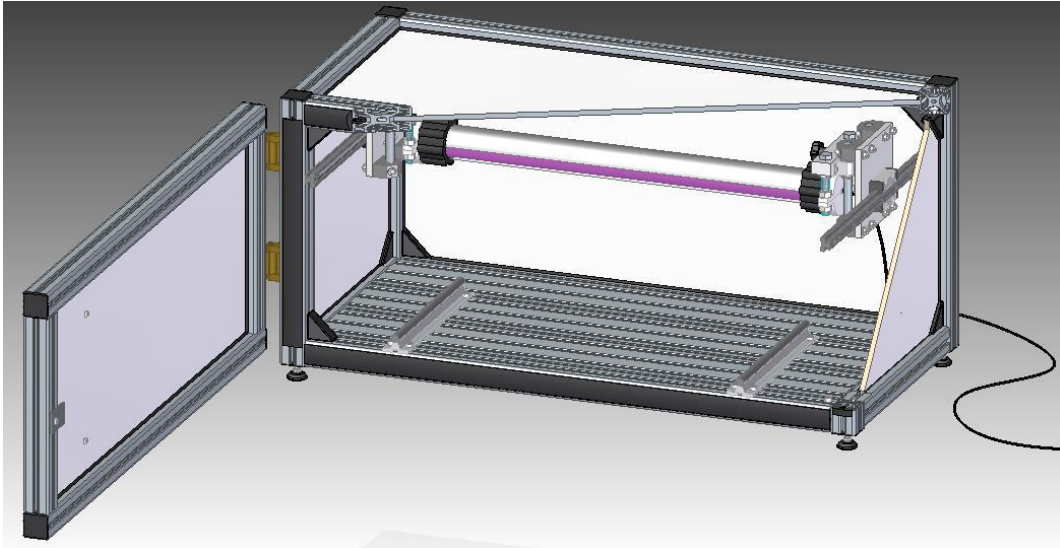


Fig. 7. Manipulator of lamp a) front view b) view from behind (own study)

The position of the lamp is changed by means of linear bearings and sliding carriages, as shown in Figure 7. The plug secures the lamp from sliding down of the manipulator. Linear bearings are mounted on linear guides, which allows smooth movement. A sliding carriage equipped with a lock was used. This solution sets the lamp in a specific position.



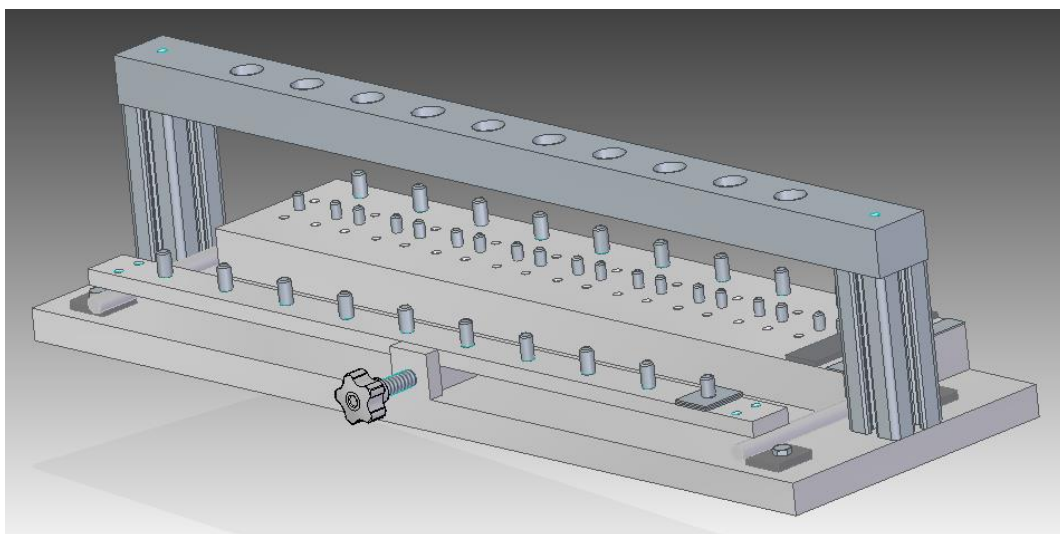
**Fig. 8. Intersection of the chamber (own study)**

The skeleton of the chamber is made of 2 types of mounting profiles whose dimensions are 40x40 and 40x120, as shown in Figure 8. To connect them, apart from the mounting screws themselves, brackets connecting vertical and horizontal profiles were used, and gaskets were applied on all inner edges.

“Dibond” composite panels have been applied to create the walls of the device. These panels are made of two layers of aluminum between which there is a thin layer of polymer. The door was made of the same materials as the entire chamber. A magnet allows to close the chamber tightly, and the gap between the door and the chamber is reduced by a gasket on the profile surface.

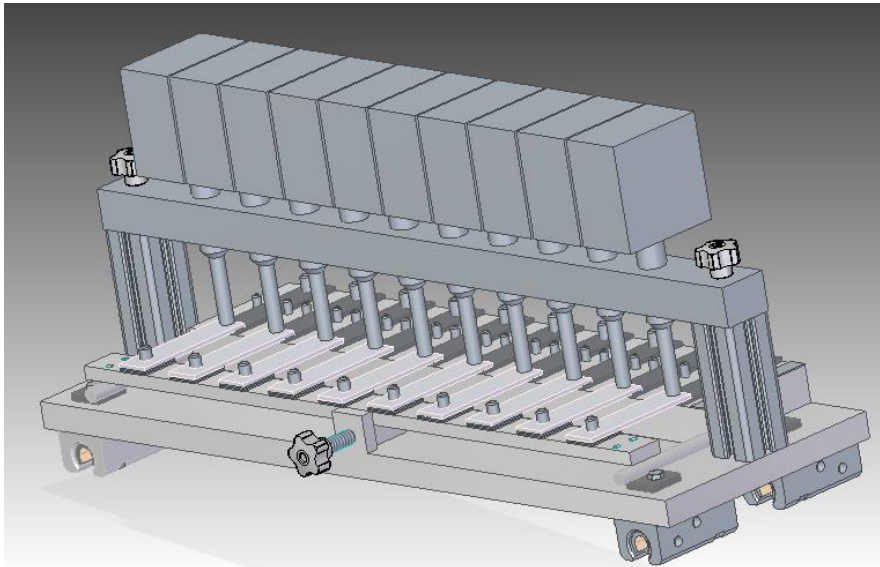
The next step was to design the construction of the adhesive holder. On the basis of the construction assumptions and calculations, a holder was designed to accommodate 10 samples with dimensions of 25x100 mm. The base of the holder was designed in accordance with the spacing between the samples. It ensures the stability of the entire structure and the change in the length of the overlap connection.

In order to avoid changing the position of the samples, a retaining dowel system was used. At the ends of the adhesive elements there is an opening that takes away degrees of freedom and prevents movement without human intervention.



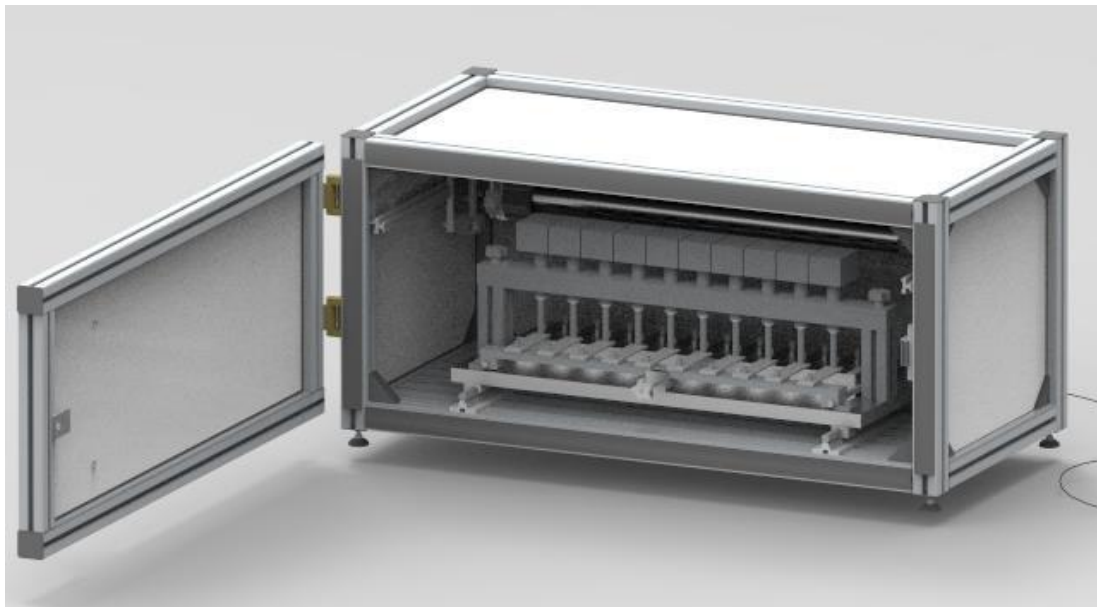
**Fig. 9. The base of the holder (own study)**

Figure 9 shows the base of the holder with the beam attached to the profiles, it positions the pressure bolts with the load. Changing the distance of the tab is done by sliding the front bar which moves on linear bearings.



**Fig. 10. The adhesive holder (own study)**

The support plates mounted on the front bar are used to keep the entire adhesive sample on an even level, as shown in Figure 10. The samples are pressed by the polycarbonate mandrel whose transparency is important when curing with UV radiation. Such a solution allows for an even transition of radiation to the adhesive material.



**Fig. 11. The assembled adhesive device (own study)**

Figure 11 shows the assembled adhesive device with all its components. This real life model will allow to study the behavior of the UV-cured adhesive while changing the load of adhesive surfaces or the intensity of light.



## 6. Summary

Changes in connection technology result from the need to reduce costs and the mass of mechanisms. Currently, engineers are working on improving the quality of the adhesive substances and the ways of their applications.

The use of CAD software for gluing technology allows the engineer to determine the range of possibilities of the designed operation. 2D drawings do not allow such assessment.

The work presents special equipment constructed in the Solid Edge software. The chamber together with the handle meets all technological assumptions. The advantage of this design is the possibility to test different samples under the same light intensity. Samples can have variable thickness, which allows you to check the strength of irradiated materials that have been cured in the same conditions. The tightness of the chamber makes it safe for the operator.

## 7. References

- [1] A. Rudawska, *Wybrane zagadnienia konstruowania połączeń adhezyjnych jednorodnych i hybrydowych*. Lublin: Politechnika Lubelska, 2013.
- [2] Z. Mirski and T. Piwowarczyk, „Podstawy klejenia, kleje i ich właściwości”, *Przegląd spawalnictwa*, vol. 8, pp. 12-21, 2008.
- [3] J. Szabelski, *Badania wpływu obróbki cieplnej doczołowych połączeń klejowych na ich wytrzymałość statyczną*. Lublin: Politechnika Lubelska, 2014.
- [4] W. Wielgoński, *Poradnik serwisowy*, vol. 3, pp. 238 – 241, 2002.
- [5] M. Kłonica, *Badania stanu energetycznego warstwy wierzchniej wybranych materiałów konstrukcyjnych po ozonowaniu*. Lublin: Politechnika Lubelska, 2014.
- [6] M. Kłonica and J. Kuczmaszewski, “Determining the value of surface free energy on the basis of the contact angle”, *Advances in Science and Technology Research Journal*, vol. 11, no. 1, pp. 66-74, 2017.
- [7] J. Kuczmaszewski, *Fundamentals of metal-metal adhesive joint design*. Lublin: Politechnika Lubelska, 2006.
- [8] <http://www.loctite.pl/produkty-wedlug-zastosowania-6442.htm>.
- [9] A. Rudawska, *Oprządkowanie w technologii klejenia*. Lublin, Politechnika Lubelska, 2013.
- [10] M. Kwiatkowski, M. Kłonica, J. Kuczmaszewski and S. Satoh, “Comparative analysis of energetic properties of Ti6Al4V titanium and EN-AW-2017A(PA6) aluminum alloy surface layers for an adhesive bonding application”, *Ozone-Science & Engineering*, vol. 35, no. 3, pp. 220-228, 2013.
- [11] M. Sydor, *Wprowadzenie do CAD. Podstawy Komputerowo Wspomagane Projektowania*. Wydawnictwo Naukowe PWN, 2009.
- [12] C. Burton and W. Marosz, “The Construction and Uses of CATIA, a Computerized Mathematics Testbank”, *The Two-Year College Mathematics Journal*, vol. 8, no. 4, pp. 212-216, 1977.
- [13] <https://www.3ds.com/products-services/catia/>.
- [14] <https://camdivision.pl/pl/produkty/nx-cad>.
- [15] [https://www.plm.automation.siemens.com/en\\_pl/Images/10\\_powodow\\_tcm801-79972.pdf](https://www.plm.automation.siemens.com/en_pl/Images/10_powodow_tcm801-79972.pdf).
- [16] Siemens PLMS, „10 powodów, dla których warto wybrać Solid Edge”, *Mechanik* vol. 3, 2009.
- [17] <http://barwyszklapl/klejenie-szkla-uv/>.