Handling concept for ultra-thin glass sheets

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ABSTRACT

In this paper the concept of ultra-thin glass sheets handling is introduced. In order to investigate the implemented concept on a subject of safety of glass sheets during the handlings the concept was realized in 3-axis gantry system equipped with a suction gripper and experimentally examined. The results of the experimental investigation of the concept on a subject of safety of glass sheets during the handlings are presented in this article. The accent is made on the measurements and analysis of occurring vertical vibrations, experienced by the suction gripper along the movement, as far as on the influence of the driving pressure value on the disturbance of a glass surface during the contact with suction cups. Based on the results, the optimal design of handling gripper is proposed.

1 INTRODUCTION

Trend of the minimization and increased process speed in the Printed Circuited Boards industry set a special requirement for the production process. In frames of the research project GlassPCB - "Development of Multilayered Printed Circuit Boards based on thin-glass substrate" novel production process for the multi-layered PCBs based on the glass substrate of 145 µm thickness is developed. It brings specific advantages over synthetic-based PCBs, such as the mechanical endurance at higher temperatures. [1]

Thin-glass is a very attractive production substrate due to its high thermal stability, excellent barrier properties, and very smooth surface. Though, there are still some issues – first of all, glass is easy to break, which brings difficulties in handling flexible glass. [2]

Apart of novel concepts for non-contact handling of thin glass sheets, where sheets are being levitated with help of air bearing and being moved with the help of electrostatic force [3], the basic method of lifting glass sheets consists in applying suction force onto the glass surface with the help of vacuum gripper [4], [5], [6].

One of the most important issues in this method is the design of the suction gripper, or rather arrangement of the suction cups along the surface of the suction gripper.

This question was partially considered in [7], where the way to an optimization of gripper designs was proposed through the numerical simulation for a description of the deformation behavior of thin glass sheets. In this research occurring vibrations, experienced by the suction gripper were not taken into account as far as the influence of the value of driving pressure on the contact between suction cup and surface of glass sheet.

In presented work two mentioned above points were investigated experimentally. Therefore handling process was conditionally divided in two parts: static and dynamic.

This article is structured in following way. Section 2 presents the realized handling concept for ultra-thin glass sheets and construction of the gantry system. In section 3 static part of handling process is explained and influence of the driving vibration value on the contact between suction cups and glass sheets is examined, while section 4 represents the dynamic part of the handling and investigation of occurring vibrations. Article closes with the summary, where main steps of the performed work are overviewed.

2 IMPLEMENTED HANDLING CONCEPT

Within the research project Glass PCB, a solution for the manipulation of the thin-glass sheets, which are susceptible even to small mechanical stresses, is implemented at the Institute of transport and automation technology, Leibniz Universität Hannover.

In this approach, the 3-axis linear actuator system is equipped with the handling gripper and handling process is automated through the inboard PLC controller (Fig.1, left). Suction gripper consists of an aluminum perforated plate, which is screwed at two points to the movable part of the manipulator. On the aluminum plate four brackets for suction cups are drilled. The gripper uses vacuum, which is received through the processing the driving pressure with the help of ejector and applied to the glass sheets through the suction cups (Fig. 1, right above).

Single axis accelerometer is mounted directly on the suction cup for analyzing of dynamic part of handling (Fig. 1, right below).

Handling process of ultra-thin glass sheets consists of two steps: process of suction (static part) and process of manipulation (dynamic part). The safety of the thin-glass sheets during handling was examined at each of these two parts.

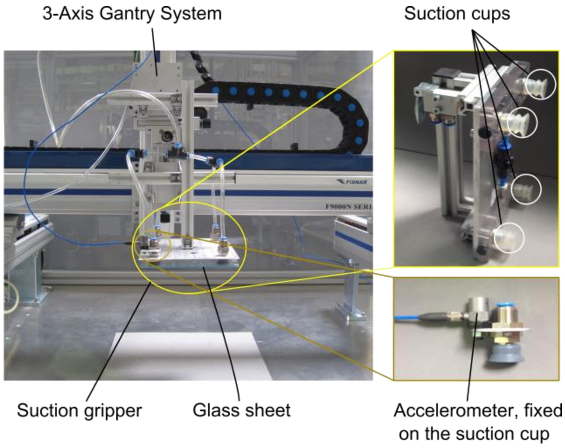

Fig. 1: Constructed Gantry System (left) is equipped with developed suction gripper with suction cups (right above) and accelerometer, fixed directly on the suction cup (right below).

3 STATIC PART OF HANDLING PROCESS

Suction process is pictured in the Figure 2. By each suction operation glass sheets deform on value Δ (1).

$$\Delta = X1 - X2 \qquad (1)$$

The task is to prevent glass breaking during this deformation, keeping this value at the sufficient level. The main factor, influencing this parameter is driving pressure in the system.

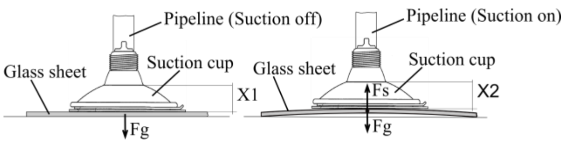

Fig. 2: Value of glass sheet deformation which caused by turning suction on should be kept at the sufficient level.

To test influence of this factor on safety of glass sheets cycles of glass suctions were performed for different configurations of the system.

Glass sheets of two thicknesses were tested: 0,5 µm and 0,145 µm. Driving pressure was increased subsequently from 0,5 to 5 Bar with the step of 0,5.

In each cycle glass sheet is gripped, lifted up and then let down. For each configuration of the system 40 such cycles were performed. During the time of experiments no visual observable breaks or cracks were noticed.

Then glass surface was observed with the help of the microscope. Suction cup's overprints of different shape and size were noticed and analyzed (Fig. 3).

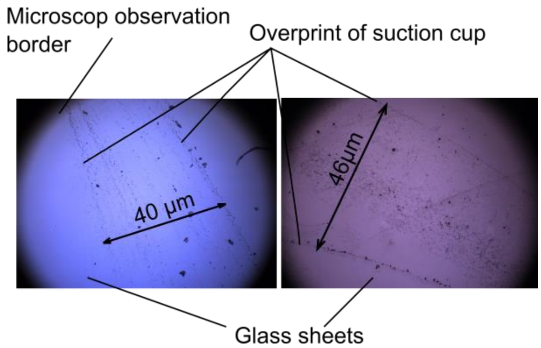

Fig: 3: Overprint on surface of the glass after contact with the suction cup with driving pressure of 3,5 Bar (left) and of 5 Bar (right)

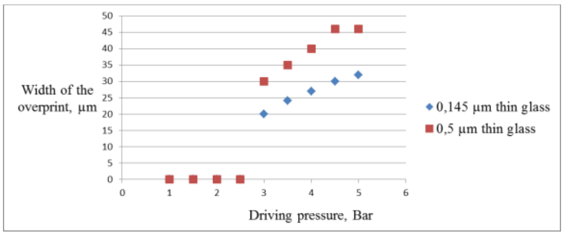

Fig. 4: Overprints width, left by the suction cup during suction process, for range of values of driving pressure

As it is represented in the Fig. 4 driving pressure lower than 3 Bar doesn't leave any overprints, but it also doesn't provide stabile gripping of the glass sheet.

Driving pressure of 4-5 Bar with the chosen type of suction cups can be used without any danger of overcoming deformation. During the performed experiment no glass sheet was damaged. Thus, taking into account the need of the clear non-contaminated glass surface, driving pressure of 3 Bar is chosen as optimal for chosen configuration of the system. It provides stabile gripping of the glass sheet and leaves the minimal overprints on glass surface.

4 DYNAMIC PART OF HANDLING PROCESS

In the performed experiment the values of occurring vibration were measured during the movement cycle, which consists of 8 subsequent iterations. For this purpose an accelerometer was integrated into the system and directly connected with the suction cup in order to minimize the tolerance.

Due to the symmetry quarter area of a suction gripper surface was chosen for an observation (Fig. 5.). 33 Points were used for the accelerometer installation in order to find the one with the lowest level of occurring vibrations during the handling process. That point would be used afterwards for installation of the suction cup in order to reduce the transmission of vibration to the glass sheet.

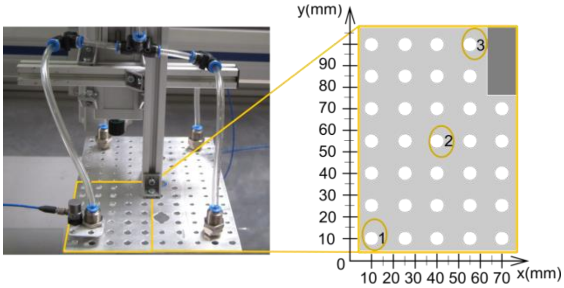

Fig. 5: Observation area of the mounted suction gripper

The movement cycle is represented visually in the Fig. 6 and each iteration is presented in the table 1 in relative coordinates. The value of the vertical acceleration occuring during the cycle was measured 10 times for each point in order to reduce the tolerance. 3 Points, which are marked in Figure 5, are used for representation of vibrations value at different parts of the gripper.

Number	Movement in relative coordinates (mm)	Suction state
1	X0, Y0, Z-160	off
2	X0, Y0, Z0	on
3	X0, Y0, Z160	on
4	X400, Y0, Z0	on
5	X0, Y300, Z0	on
6	X-400, Y-300, Z-160	on
7	X0, Y0, Z0	off
8	X0, Y0, Z160	off

Fig. 6: Cycle iterations in relative coordinates

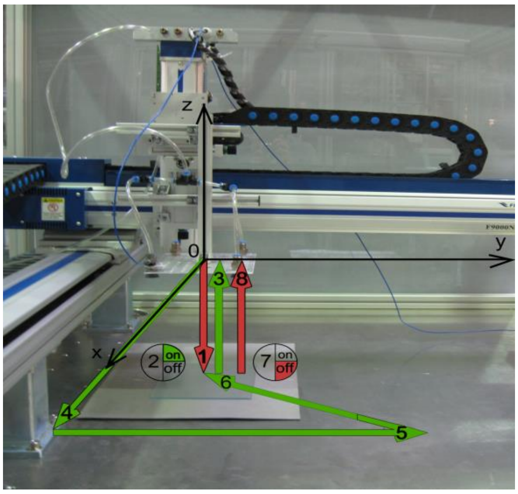

Fig. 7: The movement cycle: the arrows denote the direction of movement at each of the iterations. Green color of arrow signifies the presence of pressure at the system, red – absence.

Curvature of mean vibration values occurring during the moving cycle is represented in the Fig. 7. 6 local maximums belong to 6 moving iterations and the global maximum belongs to the first iteration (vertical movement with the negative vector).

In the experiment the system performs twice the same movement of a gripper (3 and 8): one with the driving pressure on and one with the driving pressure off. This fact is used in order to evaluate, how the pressure in the system influence on the value of the vibration, occurring during the experiment cycle.

Three points were chosen for the preliminary evaluation – they are marked in the Fig. 5. Results for point 1 are represented in the Fig. 7 (right) – it shows, that there is not any valuable difference in the mean vibration between the movement 3 and 8. Using the maximum of 10 measurements vibration value for each period of time the following figure is received (Fig. 8).

Absolute maximum in this case belongs to the iteration 3 and 8.

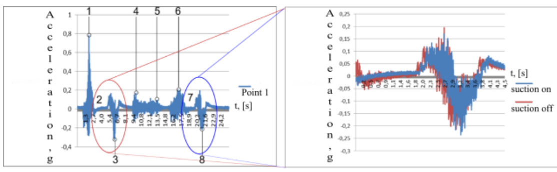

Fig. 8: Mean values of vibrations during the 3 Axis moving, measured at 1.

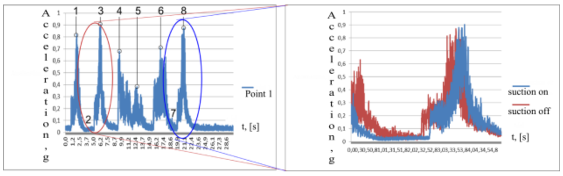

Fig. 9: Image of the maximum vibration values at 1st point and pressure influence on the vibration maximum value

Experiment results for the points 2 and 3 are represented in the Figures 9 and 10. The difference between the vibration values of these two working modes is even less noticeable.

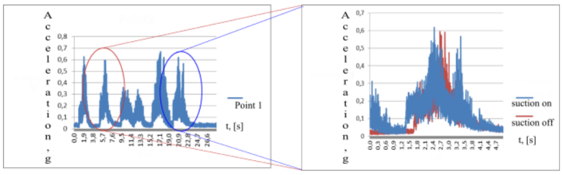

Fig. 10: Image of the maximum vibration values at 2nd point and pressure influence on the vibration maximum value

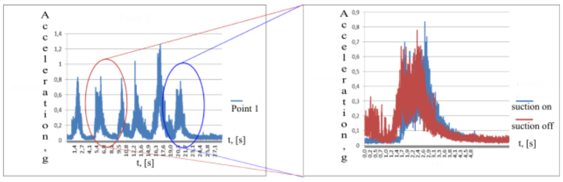

Fig. 11: Image of the maximum vibration values at 3rd point and pressure influence on the vibration maximum value

As not any meaningful difference between the moving with driving pressure on and off is noticed, further conclusion can be made: driving pressure in the system does not influence significantly the vertical value of the vibrations occurring during the transportation process.

During all the measurements for 33 points no glass breaking was noticed. The representation of absolute maximum vibration values for each of the points is presented in the Figure 9. Using the symmetry of the gripper resulting image was overlapped on whole gripper surface. Area pointed with the orange colour presents the most shaking gripper area. Desired areas for suction cup placement are represented in this picture with the blue colour – placing them in these areas will reduce the value of vibrations which are transferred to the thin-glass sheets.

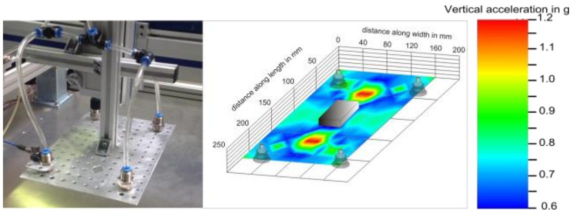

Fig. 12: Maximum vibrations values occurring at the gripper surface

Although with the used in experiments thickness of glass no breaks of glass sheets were noticed, further thinning of glass sheets, which is dictated by a trend of minimization in production industry, will make the appropriate arrangement of the suction cups on the suction gripper an essential requirement for the handling systems development.

5 SUMMARY

In this paper a concept of ultra-thin glass sheets handling concept was represented. Developed concept was experimentally investigated on a subject of safety of glass sheets during the handling and based on the results optimal configuration of the gantry system is proposed. As one of the significant outcomes, the fact that working pressure does not have an influence on the value of vertical vibrations of the gripper can be underlined.

6 ACKNOWLEDGMENT

The research project GlassPCB is supported by the The Central Innovation Program SME (ZIM) of the German state.

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