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# EQUIPMENT FOR SEMI-AUTOMATIC ASSEMBLING OF ELEMENTS

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*ABSTRACT: This work resolves a real problem of assembling the hold-on component unit with the main product item by closing the riveting operation integrated in the manufacturing process. The finalized component will be used for assembling the newest model power switch in production of this corporation. In this diploma work some possible variants will be provided. The workable solution of the best one will be suggested as a final mechanical problem resolution with detailed description of construction description, component selection and skeleton program design to build a special purpose machinery.*
*KEYWORDS: Automation, CAD/CAM, fixation, tool, CATIA*

## INTRODUCTION

*The main goal of the article is to show the proposal of mechanical construction of equipment, which will be able to fix flexible element onto complicated snapped "contact blade", so that it will conform to conditions of technological tests. The equipment has to be designed so, that it will be possible to add new technological equipment, which will extend functions of above mentioned unit. Although the equipment will be used as single-purpose equipment, it is favourable to design it so, that if will be possible to use it for other production or for production of similar components after modest reconfiguration (or also after small reconstruction). From the construction view, the article is based on use of modular components and also on components made by company itself, which allows to use existing components for construction of new equipment or for decrease of entry investment.*

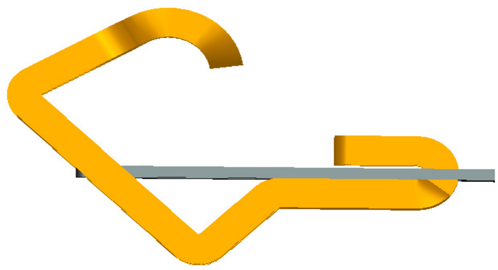

*Figure 1. Fixation – required result of operation*

## OPERATION – BEND WITH FIXATION

*This operation follows the operation of pre-bending and the result is definitive securing of element against mutual move away (Figure 1). Relative movements (approx. 0,1 mm) are tolerated and possible only within limits given by mechanical construction of assembled elements.*

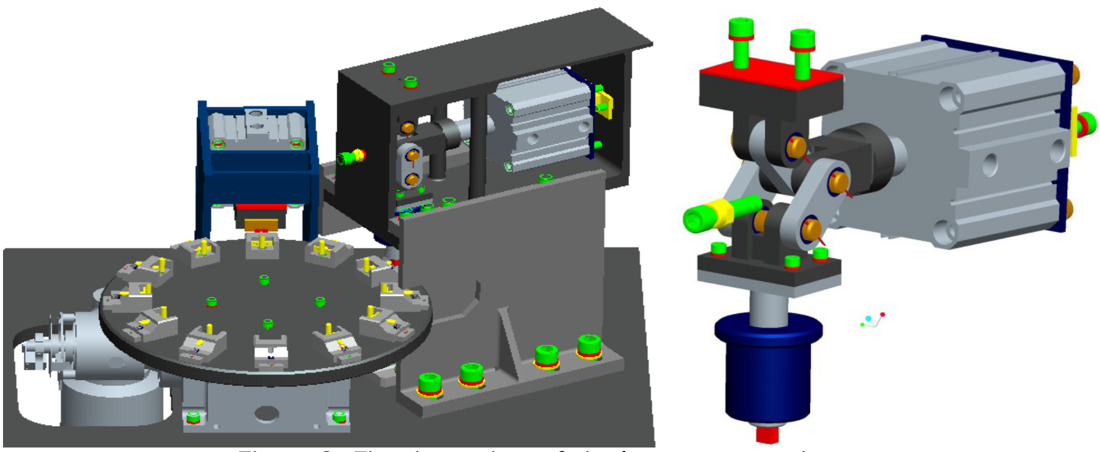

*Figure 2. Fixation – view of single-purpose equipment*

*Single-purpose pneumatic-mechanical press is used for realisation of the operation. The main function of this module is to perform resulting deformation of nib of contact leaf spring, onto which the flexible cut element is placed. Basic mathematical description of principle is given in kinematic visual presentation (Figure 3) and formulas.*

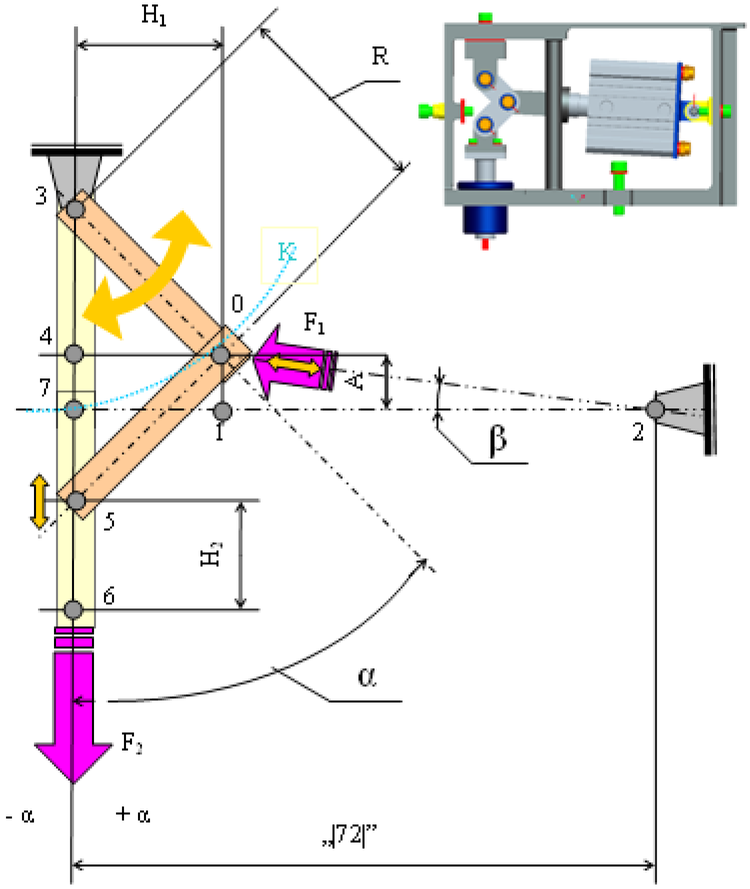


*Figure 3. Kinematic solution of fixing equipment construction*

## *Arms length „R“ of mechanism*

*It is considered the length of pivot axes of above mentioned mechanism. The required travel of tool will be at least $H_2$=20 mm.*

*Then* $A = \frac{1}{2} H_2$ *and at the same time*

$A = R - R.\cos(\alpha) = R.(1-\cos(\alpha))$ .

*From the above shown formulas we express the length of arms:*

$$R_{TEOR} = \frac{H_2}{2.(1-\cos(\alpha))} = \frac{20}{2.(1-\cos(45°))} = 34{,}14 \text{ mm.}$$

*The length R=40 mm was chosen. So, the total travel will be* $H_2 = 2.A = 2.R.(1-\cos(\alpha)) = 2.40.(1-\cos(45°) = 23{,}4$ *mm with maximal permissible angle* $a = a_{MAX} = 45°$*. It is necessary to keep the smallest working angle a, because greater angle means bigger stress perpendicularly on axis of press arm movement with tool (axis given by items 3 and 6). This stress causes increased friction impact of press arm on press arm box (risks of increased wear of press arm box). Therefore, the working angle is sufficient for achievement of required travel with arm length R=40 mm.*

$$\alpha = \arccos\left[1 - \frac{H_2}{2.R}\right] = \arccos\left[1 - \frac{20}{2.40}\right] = 41{,}41°$$

## *Selection of linear pneumatic drive*

*Considered pressure of pneumatic medium is 0,5 MPa. At the same time, the piston diameter of linear drive is 100 mm and the force will be:*

$$F_{DEF1} = p.S = 0{,}5.10^6.\pi.r^2 = 0{,}5.10^6.\pi.0{,}05^2 = 3\,927 \quad [N].$$

*Since the travel of press arm is connected with shift of point “7” to point “0” on circle “K” (Figure 3), it is necessary to consider a drive inclination - angle β. Anchoring of drive to support,* *which could be inclined, will assure meeting of working conditions - application of forces only in piston axis of drive. This will prevent damaging of component. For the travel of pneumatic piston (given by triangular - points 3, 4, 0) is valid:*

$$H_1 = |40| = |30|.\sin(\alpha) = R.\sin(\alpha) = 40.\sin(41{,}41°) = 26{,}5 \quad [mm] \tag{1}$$

*In this case it is possible to neglect the influence of the drive inclination (length as well as force values) caused by movement of point "0" (pivot in arms of fixing equipment) during movement on circle "K" with radius "R" and midpoint in point "3".*

*Deviation of axis of linear pneumatic drive is given in formula (2). Therefore we can assume, that the piston travel is the same as distance $H_1$. The selected pneumatic linear drive with travel length equalling 40 mm is CDQ2B100-40D, produced by SMC (cylinder with ring magnet).*

## *Deviation of axis of linear pneumatic drive*

*From the mechanical construction and draft on Figure 3 it is given, that distance |72| corresponds to the position of press arm (achievement of bottom dead centre) and |72|=258 mm.*

*Then, if press arm with tool is in top dead centre and angle a=41,41°, the distance |12|=|72|-$H_1$=258-26,5=231,5 mm. From Figure 3 and triangle set by points 0,1,2 it is clear, that*

$$\frac{|01|}{|12|} = \tan(\beta) = \frac{A}{231{,}5} \quad \textit{and from this}$$

$$\beta = \arctan\left(\frac{A}{231{,}5}\right) = \arctan\left(\frac{\frac{1}{2}H_2}{231{,}5}\right) = \arctan\left(\frac{\frac{1}{2}20}{231{,}5}\right) = 2{,}47° \tag{2}$$

*Due to the difference in distance lengths between lengths |02| and |12|, which is lower than 0,5 mm, it could be considered that |02|=|12|. The following figures show the end positions of single purpose press. It is possible to see end positions of mechanism movements, above mentioned deviation of pneumatic drive and also top and down dead centre.*

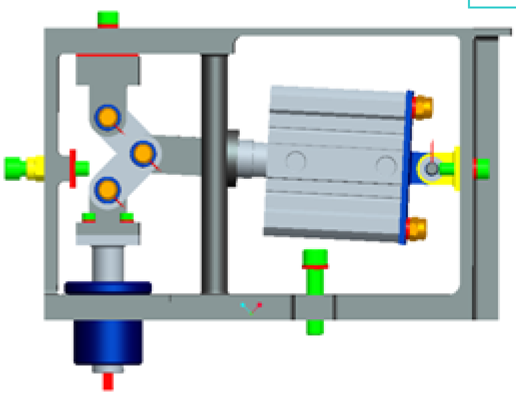

*Figure 4. Fixation module - top dead centre*

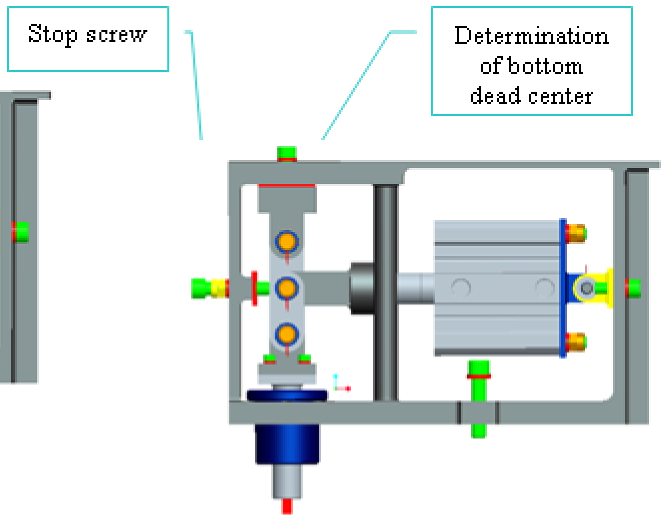


*Figure 5. Fixation module - bottom dead centre*

## *Ratio of output and input force*

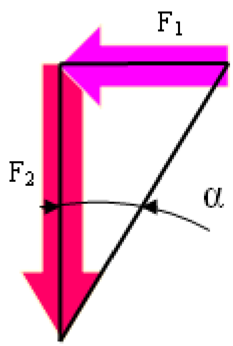


*Figure 6. Fixation - force transformation*

*This part describes the mutual relation between deformation force (output force) and input force (force of pneumatic drive) and visually describes transformation of force depending on angle of arms deviation. Practical use of increase of output force progress $F_2$ which depends on angle dip is in plastic deformation of material edge "V" in order to decrease tension, so that the nib (edge) will not unspring. This will ensure sufficient deformation tension on flexible cut element.*

*The $F_1$ is force caused by pneumatic drive and force $F_2$ is deformation force from transformation mechanism of fixation module. Angle a is the angle of arms deviation, in this part of equipment it depends on position of pneumatic piston.*

*It is clear, that*

$$\frac{F_1}{F_2} = \tan(\alpha) \quad \textit{and} \quad F_2 = F_1.\frac{1}{\tan(\alpha)}, \tag{3}$$

*a is maximal considered angle of arms deviation from vertical position of fixation equipment as it is stated above a=41,41˚. For the height of working scope / stroke $H_{2z}$=2,5 mm (it is the height of non-pre-curved nib „V“), the angle of scope / stroke will be*

$$\alpha_Z = \arccos\left[1 - \frac{H_{2z}}{2.R}\right] = \arccos\left[1 - \frac{2{,}5}{2.40}\right] = 14{,}36°$$

*and it is clear, that the biggest opposite force of deformed material will be within 14,36˚ to 0˚(corresponds to the position in bottom edge centre) and this corresponds to the stage, where the tool deforms the material (Figure 7).*

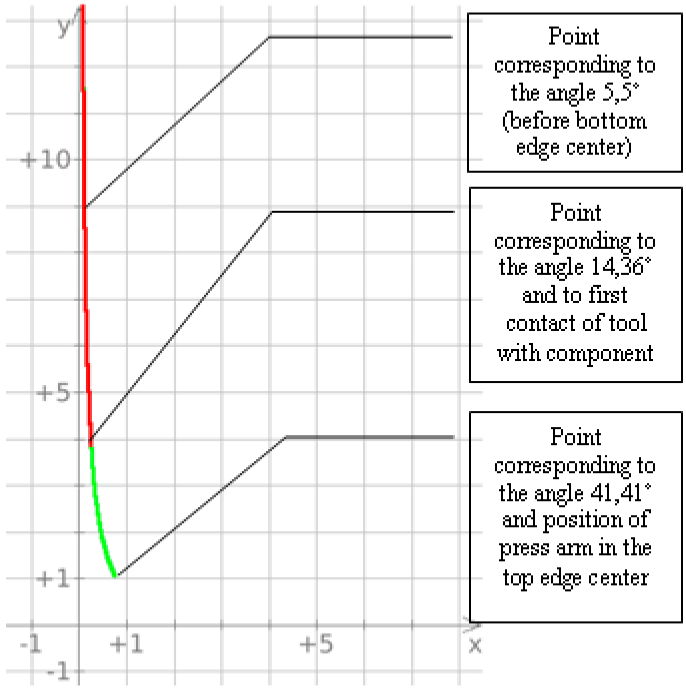


*Figure 7. Fixation - illustration of deformation force progress*
*Labels in the figure: x= a [rad] a y=$F_2$/ $F_1$.*

## Construction of fixation tool

*Plastic volumetric strain of material is by means of tool, working surface of which is finished by indentation, or tool with small knops. Pressing of small knops into the material will partly eliminate pre-stresses caused by bending of knops and also eliminate the above mentioned unspring of bended part. After plastic deformation together with material shift, better resistance against material springing is reached.*

*Nowadays experimental verifications of shape of contact area of deformation tool taking into account practical experiences of company at production of other components were performed.*

*It is possible to change working tool, if the press arm of fixation module is raised and the working table is slewed into inter-position.*

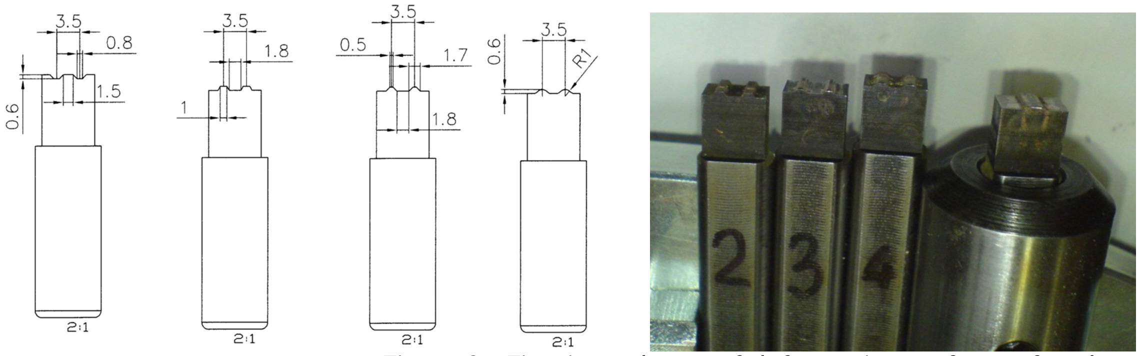


*Figure 8. Fixation - shapes of deformation surfaces of tool*

*On Figure 8 are shown experimental shapes of deformation surfaces of tool, which were tested. The material was deformed into required shape, but in some cases the material was so pressed, that tool divided (mashed) a material by press. In order to eliminate mashing (by elevation of top edge centre), the bended part of component was unspring and also after deformation the component has an unfavourable shape. By experimental tests the final shape of tool was found out. The working end of the tools is shown on Figure 9.*

*The material of tool was chosen according to STN 19 436 / X210Cr12 1.2080 (according to older-exerted manner and new, put into practice, manner of labelling). The material is high-alloy chrome steel for hardening in oil and air, with high through-hardening and resistance against wearing, well shapable if heated, well workable and the material is also suitable for tools, which are used for cold compression moulding, simple tools for moulding and cutting, i.e. tools, where no additional stress for bending occurs. The material is also used for tools for pulling,*

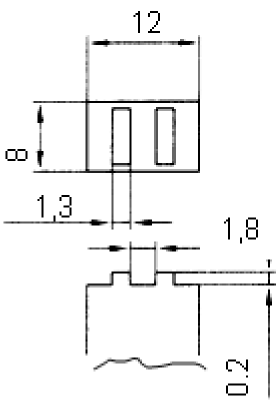


*Figure 9. Fixation - final shape of end of working tool*

*smaller bearers, tools for extrusion or pushing or threaded cylinders for thread rolling. Hardness of the material is approx. 63 HRC and class of waste is 024.*

## *Setting up of tool position*

*In case of any construction it is necessary to take into account also imprecision during production. Fixation is an operation, which requires high accuracy, because this module generates high deformation force and in case of non-correct position of end of tool (deformation surface affecting the element), the entire equipment could be damaged.*

*The entire module is designed so, that the construction may be the simplest with possible corrections in each direction within 5 mm, which is necessary for the equipment accuracy.*

*According to the importance, it is possible to arrange correction shifts in this way and at the same time in this order perform assembly of the module (Figure 10):*

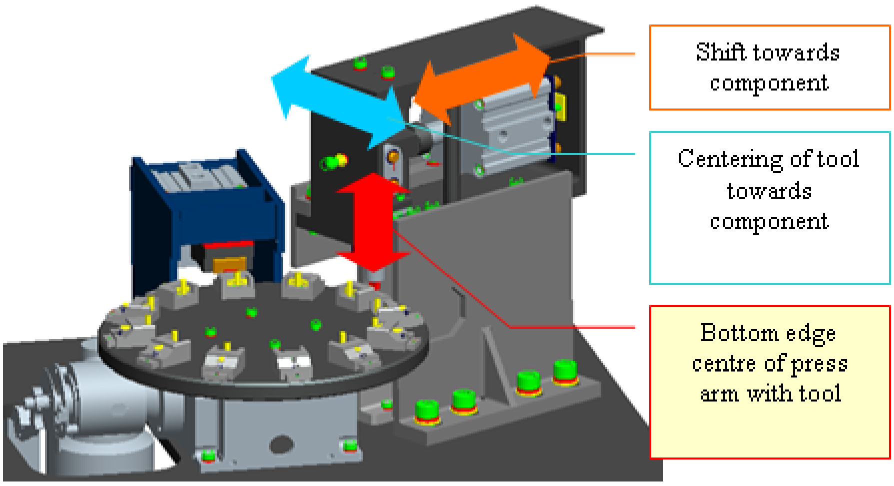


*Figure 10. Fixation - setting up of position of tool*

- ***Centring of tool towards component*** *- it is the least important, because it is positioning of knops of tool in respect of deformed knops „V" of component. It is possible to realize this correction shift by means of slot holes for screws in fastening part of stand of module, see colour resolution given in Figure 11.*

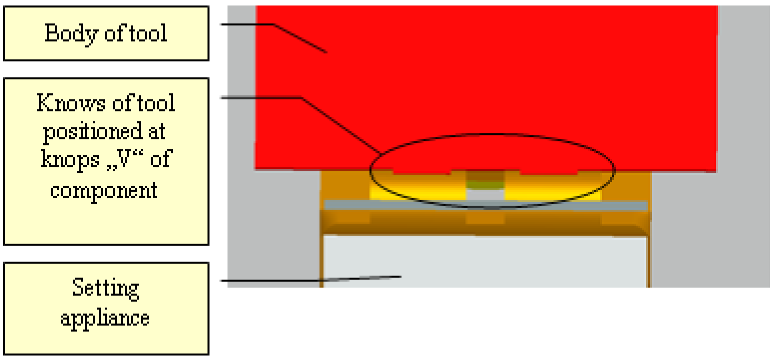


*Figure 11. Fixation - Centring of tool towards component*

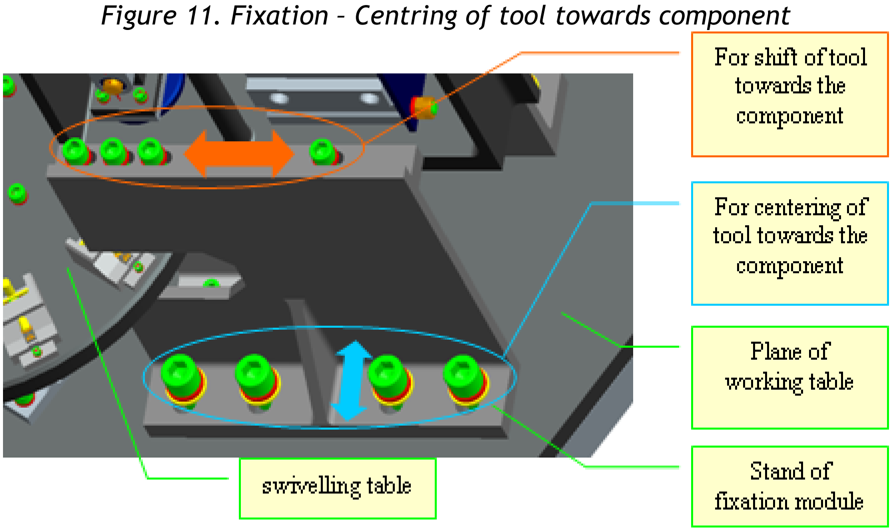


*Figure 12. Fixation - Possible tool corrections in horizontal plane*

- ***Shift toward components*** *– it is realised by slot holes for screws as in previous case. Purpose and solution are shown on Figure 12 and Figure 13.*


*Figure 13. Fixation – shift of tool toward component, required position*

- ***Bottom edge centre with tool –*** *it is the most important correction of tool position of this module. This problem will be described in the following part.*

## POSITION OF PRESS ARM AT BOTTOM EDGE CENTRE

*In order to secure both parts against significant change of relative (mutual) position and also to ensure required pressure of flexible element, it is necessary that the tool has to press on bended nib until it reaches bottom edge centre of fixation equipment. The position of bottom edge centre is set by distance elements. Stop screw sets end position of arm of transformation mechanism and stop block sets the position of bottom edge centre of press arm with tool of this module. Stop block is adjusted by precise grinding to required thickness. During adjustment of module function, the position of bottom edge centre is limited by stop screw. After final grinding of stop block, the screw will assure a stop for throwing of pneumatic linear drive of this module.*

*Unique and reliable indication of reaching of bottom edge centre is possible by means of pushing of arms to stop screw so, that arms reach negative angle a (**Error! Reference source not found**.3). The press arm with tool undergone the bottom edge centre (the plain defining vertical direction) and occurs small back travel (approx. 0.1 – 0.3 mm) slightly about the bottom edge centre. It is possible to realize it via contact sensor.*

## CONCLUSIONS

*In practice is it advisable to fix to a stop screw a thin damping stripe (e.g. rubber) supported by metal plated to damp shocks. It is also possible to use micro-switch, placed under the plate so, that it will signal increased pressure on damping stripe in case of pushed arms. The original / default position of this module is at top edge centre, the pneumatic linear drive is engaged position.*

## ACKNOWLEDGEMENT

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