RESEARCH OF EFFECTIVENESS OF ASSEMBLY DEPENDING ON THE ANGLE OF SCREW GRADIENT IN RELATION TO THE AXIS OF THE HOLE IN THE PROCESS OF AUTOMATIC SCREW DRIVING

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Abstract. The process 'automatic screw driving' is one of the most difficult and at the same time very spread because of the advantages of the threaded joints. A basic characteristic feature of the precision of the assembly process according to the classical understandings is the error in the relative disposition of the parts at the moment, right before starting the assembly – the displacement of the axes of the screw and the hole, as well as the angle of the screw gradient in relation to the hole. In the present work is described a method about measuring the angle of the screw gradient during gradually changing the displacement of the axes of the assembly parts. The results from the carried out works on a specialized device are given. The got experimental data are analyzed by a statistics program.

Keywords: automation, screw, assembly, an angle of screw gradient

1. Introduction

The process 'automatic screw driving' is one of the most difficult and at the same time very spread That's determined by the advantages of the threaded joints which provide solidity and reliability of working and a hermetic construction, a comfortable assembly and dismounting, a possibility for regulation the mutual disposition of the parts and the force of the jam.

The assembly process with the use of threading tackling parts consists of several stages [1]. The parts of the product which will be connected are settled down and oriented mutually on the assembly position. After that the threading tackling parts are fed and screwed up. Screwing includes three stages: 'adaptation' of the threading parts with subsequent fixture, driving the basic part of the thread and subsequent jam by a given moment. Four groups of factors influence the gathering of the parts in the automatic screw driving[1].

It's traditionally considered that a considerable and often determined influence upon the gathering of the parts is exerted by the geometric parameters of the assembly process or as it is called – the assembly precision. A basic characteristic feature of the precision of the assembly process according to the classical understandings is the error in the relative disposition of the parts in the moment, just before starting the assembly. In order to pass the process correctly it's necessary

$$\Delta\Sigma \leq [\Delta\Sigma] \text{ and } \beta\Sigma \leq [\beta\Sigma] \quad (1)$$

Where $\Delta\Sigma$ is the displacement of the axes of the assembled surfaces; $\beta\Sigma$ - the angle of crossing the axes of the assembled surfaces; $[\Delta\Sigma]$ and $[\beta\Sigma]$ - maximum admissible values of the errors of relative disposition, during which the starting of the assembly is possible.

For threading surfaces the definition of the $\Delta\Sigma$ limits without chamfers is done by the formula [2]:

$$\Delta\Sigma \leq 0.325 \cdot S \quad (2)$$

Where S is the threading step.

For a thread diameter of M2 – M10 the angle between the axis of the screw and that of the nut must answer the requirement

$$\mathrm{tg}\,\beta \leq \frac{0.5 \cdot S}{d} \quad (3)$$

Where d is the average thread diameter.

The above formulas are deduced on the basis of only geometric works, without taking account of the integral influence of all the factors, operating in production environment. There are some differences in the formulas about the admissible values of $[\Delta\Sigma]$ and $[\beta\Sigma]$, given by different authors. Because of that it's necessary to be constructed a device, which in conditions close to production ones, to allow the influence of the different factors on the gathering of the parts to be examined.

2. Research of the angle of crossing between the screw axes and the threading hole

To be measured the crossing between the axes the dial indicators (3) from figure 1 [1] are used. They are tackled on micrometer holders and touch the left and the right jaws of the chuck of the screw driving unit.

Before starting the measuring, the dial

indicators are put on zero according to the jaws as the mentioned above changeable control shaft is fixed and driven in the hole (7) of the device. The crossing between the axes of the screw and the hole, in which the screw will be driven, causes displacement of the chuck jaws, which is read by the micrometer dial indicators.

In the general case the angle of crossing is calculated by the formula

$$\angle\beta = \arctan\frac{l_r}{h_1} \qquad (4)$$

Where $h_1 + h_2 = h$ are the parts after separating the distance h from the chuck (the measuring line) to the threading hole by the point of the axes crossing.

On figure 1a is shown the geometric scheme by which the length of the separate parts h_1 and h_2 are calculated. In it CD = l_r, CB = $h = h_1 + h_2$, AD is the inclined axis of the screw, AB = Δ is the axis displacement between the axes of the screw and the hole, which is supposed to be already measured and known from the explanations in the article [1] scheme.

The calculation of the angle by the formula (4) in the general case is really realizable, but it's connected with a lot of calculations, which makes difficult the realization of an experiment with repeated measurements.

Much easier and faster the experiment and the necessary calculations of the angle would be realized if instead of the general case from fig. 1a a special case is realized, in which the crossing of the axes is on the level of the horizontal plane, where the beginning of the hole is (figure 1,6). It's possible if the height h is set to be approximately equal to the length of the screw. Then the angle will be calculated by the formula

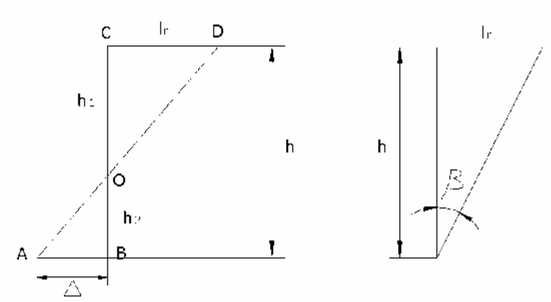
$$\angle\beta = \arctan\frac{l_r}{h} \qquad (5)$$

Where l_r is the value of the dial indicator, and h is the height from the chuck jaws to the horizontal plane from where the hole begins.

3. Results from the research of the relation of the angle of the screw inclination towards the hole axis during gradually changing the displacement between the axes of the hole and the screw driver

A known fact is that all the researchers consider the angle of the screw inclination in relation to the axis of the threading hole to be one of the factors, which influence considerably the effectiveness of the process of automatic screw driving. It's accepted, that it can't be bigger than a definite value, as otherwise the process can't be realized. The aims of that research are to be determined:

- if the angle of the screw inclination in relation to the axis of the threading hole is a factor influencing individually the effectiveness of the process of automatic screw driving and from that to be made a conclusion about the participation of that factor in the process model or not;
- if the frontier angle, when the process effectiveness decreases disastrously, got experimentally, corresponds the frontier angle got on the basis of geometrical considerations.



a)

b)

Figure 1. Measuring of the angle of the crossing of axes between the screw and the threading hole

The research is made using the possibilities of the device for researching the angle of the crossing of the screw and the hole described in [1], having in mind the following initial conditions:

- it's researched the behavior of an assembling system type 'stiff screw driver – stiff nut', in order to be got invariable position of the axes of the screw driver and the screw in the space, which will be able to be measured by existing devices, as the error, which would be got by the "searching' movements of the screw and the threading hole, is eliminated;

- the screws with the best indices about % correctly assembled parts as a result of the experimental results described in [1] are used M4×12 with an element for transferring the revolving moment in the form of a cross. Thus the errors, which would be got as a result of incorrectly produced screw, are eliminated to the highest degree;
- the axis over which the micrometer dial indicators are disposed and the axis along which the plate with the threading hole is moving coincide. Thus can be given an answer of the question how the behavior of the maximum angle of the crossing between the screw axis and the hole axis is changed, when the direction of increasing of the parallel displacement between the axes of the screw and the threading hole brings near the axis of the hole to the one dial indicator and takes it away from the other. The geometric possibilities, which provide doing the research during such a movement of the hole axis, are seen on figure 2.

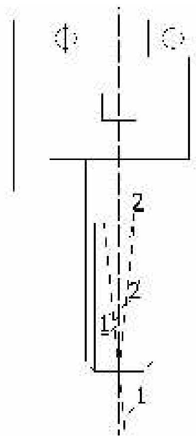


Figure 2. Possibilities about researching the angle of the screw inclination during the stage of a mutual adaptation

It’s clear from the figure, that during a movement to the right the axis of the hole remains parallel to the axis of the screw driver and the angles of a real deflection 1 and 2 remain equal to the angles which can be calculated as a result of the measuring - respectively 1′ and 2′ as adjacent angles;

- deflection is started giving step by step on one axis as a step (an interval of the changing) is equal to 0.2 mm;
- before starting the experiments setting is done as the screw driver is disposed exactly above the hole. For that purpose a pin is produced and a method already described in [1] is used;
- during every displacement after the relevant step ten control screw driving are done;
- the dial indicators used for reading the displacement of the jaws have a value of one division 0.01 mm;
- the research goes on till reaching such a boundary value of the deflection at which all the screws from the control ten are driven incorrectly;
- only the maximum angle of deflection is calculated.

Having in mind the described initial conditions are implemented experiments on the device for researching the process of automatic screw driving. The results are given in table 1.

The tables contain the following data:

I column – № of the experiment;

II column – values of the indicator at the relevant displacement. The second column is separated into left and right area, where accordingly the values of I dial indicator and II dial indicator are written down. In the columns next to them the values of the maximum angles of deflection are calculated. At the bottom under each of the columns with maximum angles the average maximum angle is calculated, when the screw driving is carried out.

4. Tabular presentation of the results of the research of the maximum angle of deflection of the screw in the process of mutual adaptation

As a result of the experiments and the calculations of the maximum angles of the axes crossing, for every step of moving apart the results from table 2 are got. They show the correspondence between the axis displacement of the axes of the screw and the hole and the average maximum angle of the crossing of their axes, to reaching the boundary value of the displacement when screw driving is not done.

5. Processing of the research results of the maximum angle of axes crossing depending on the axis displacement between the screw and the threading hole

In order to be realized one of the purposes of the research the results got (described) in the previous chapter are processed by a specialized program about statistics works “Statistika +”. The program is directed to statistics processing of data.

The program can build diagrams (histograms, linear, with areas, point, and circular). More than 80 built in functions can be used. It’s maintained generating of casual numbers and matrix operations.

Table 1 Experimental results

№ of the experi-ment	Indices of the dial indicator			
	Fixed displacement – 0.0 mm			
	I dial indicator	An angle of the screw inclination	II dial indicator	An angle of the screw inclination
1	0 ÷ 8	0.28648°	0 ÷ 20	0.71616°
2	0 ÷ 10	0.3581°	10 ÷ 10	0.3581°
3	0 ÷ 10	0.3581°	0 ÷ 12	0.4297°
4	10 ÷ 20	0.7162°	0 ÷ 30	1.0743°
5	15 ÷ 8	0.5371°	0 ÷ 25	0.8952°
6	8 ÷ 10	0.3581°	-5 ÷ 10	0.3581°
7	0 ÷ 20	0.7162°	0 ÷ 20	0.7162°
8	0 ÷ 10	0.3581°	-5 ÷ 8	0.28648°
9	-10 ÷ 5	0.3581°	-5 ÷ 10	0.3581°
10	-2 ÷ 15	0.5371°	0 ÷ 15	0.5371°
	Average maximum angle	0.458358°	Average maximum angle	0.572948°

Table 2. Experimental results by changing of the angles of the axes.

Fixed displacement		0 mm	0.2 mm	0.4 mm	0.6 mm	0.8 mm	1.0 mm	1.2 mm
Maximum average angle	**I indicator**	0.46°	0.51°	0.53°	0.59°	0.95°	1.57°	1.53°
	II indicator	0.57°	0.52°	0.65°	0.79°	0.90°	1.10°	1.33°

Fixed displacement		1.4 mm	1.6 mm	1.8 mm	2.0 mm	2.2 mm	2.4 mm	2.6 mm
Maximum average angle	**I indicator**	1.57°	1.61°	1.66°	1.64°	1.91°	2.10°	2.15°
	II indicator	1.57°	1.48°	1.66°	2.20°	2.02°	1.89°	1.88°

In that case, the option of the program to do the correlation analysis is used. The research data are introduced in the type of an electronic table as in the column A up to down are given the values of the axis displacement and in columns B and C – the values of the average maximum angle of the axis crossing of the screw and the threading hole having in mind a relative value of the axis displacement.

The results from the correlation analysis are shown in the table 3.

It's obvious, that the Pirson's coefficient of correlation between the axis displacement and the angle of axis crossing of the screw and the threading hole for the first I dial indicator is 0.95187, and for the second II – 0.02293. The zero hypotheses, that there isn't correlation dependence (5%) between the two parameters are rejected. The strong correlation connection between the two parameters is obvious from the diagrams of the dependence average maximum angle – axis displacement shown on figure 3 for the dial indicator I and on figure 4 for the dial indicator II.

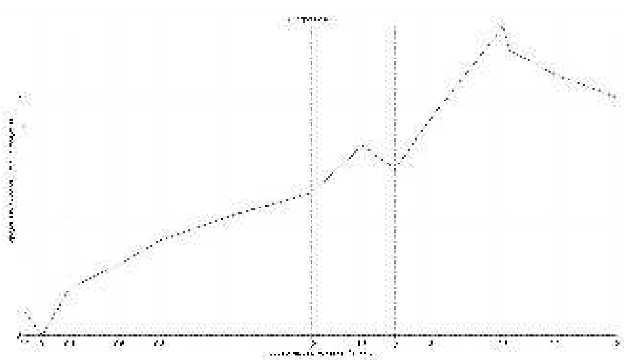


Figure 3. Dependence between the axis displacement and the average maximum angle – I indicator

Table 3. Results from the correlation analysis by the program "Statistika"

Matrix of correlation coefficients

Excerpt size	14	*Critical value (5%)* 2.178813		
		Row #1	*Row #2*	*Row #3*
Row #1	***Pirson's correlation coefficient***	**1**		
	Standard error R			
	t			
	Level of importance			
	Zero hypothesis Ho (5%)			
Row #2	***Pirson's correlation coefficient***	**0.951874**	**1**	
	Standard error R	0.007828		
	t	10.7585		
	Level of importance	1.62E-07		
	Zero hypothesis Ho (5%)	*rejected*		
Row #3	***Pirson's correlation coefficient***	**0.86469**	**0.841356**	**1**
	Standard error R	0.022937	0.026556	
	t	5.963258	5.392505	
	Level of importance	6.58E-05	0.000162	
	Zero hypothesis Ho (5%)	*rejected*	*rejected*	

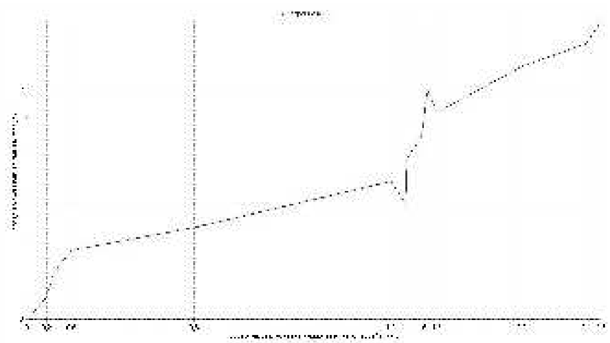


Figure 4. Dependence between the axis displacement and the average maximum angle – II indicator

6. Analysis of the research results

The analysis of the research results and their subsequent processing by a statistics program show that the correlation coefficient between the axis displacement of the screw and the threading hole and the angle of the axis crossing is bigger than zero and is close to one. That shows that there is a strong correlation connection between the two parameters.

It makes impression that there is a difference between the correlation coefficients between the axis displacement and the angles measured by relatively I and II dial indicators. Obviously that is due to the fact that during the removing of the screw axis from the II dial indicator the crossing of the axes is done much downwards the vertical axis, the dimensions of the triangle, formed by the axes and the dial indicator deflection increases and the small errors in reading the linear measurement influence more strongly the value of the angle. The standard error R is satisfactory. The rejecting of the zero hypotheses (5%), that the correlation connection between the two parameters doesn't exist, means that in 5% from the findings it's possible to exist a connection because of a real coincidence. The angle of the axes crossing between the screw and the threading hole, when the gathering decreases disastrously, is a sharp division. That means that when there is a relative moving the screw inclines so that suddenly every turning is unsuccessful.

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