THEORY OF PRECISION MECHANIC PANEL SCREWS

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Abstract: *Constructions belonging to precision mechanics need to be suitable for the functional conditions. The product has to perform the task reliably in its perfection in the prescribed limit of error. At the same time this aim must be reached not at any price but economically, well manufactured and in easily marketable realization. A new construction usually becomes out of date in three-four years morally deteriorates even though if it is useful in the aspect of working. This is the explanation of the fact that the standardization and the normalization in precision mechanics play a great role. During the latest decades the polymer pieces have been appearing in the different areas of the industry. Nowadays polymer and composite materials are used not only as covering but as the material of concrete mechanical elements as they have a wide workable and usability spectrum. The pieces made of polymer materials in the telecommunication industry take an honoured place. It is because they are good insulators they are light and cheaper than the metal materials. In the European Union it is a regulation that the most of the pieces must be recyclable. It means not only the reuse of the raw material but the recycle of the pieces. So the new and economical types of connection in the polymer pieces have appeared, and their examination have become important, too. The self-tapping screwed joint is suitable, too, the economical point of view and for the recycle, as it does not need any more operations after the removal of the screw.*

Keywords: SELF-TAPPING SCREWS, VOLUTION, THREAD CUTTING, TAPPING, BOLT PRELOAD

1. Introduction

During the latest times masters made an effort on optimization of geometry of the screw depending on the material of the tube. The several finite element models mean great help not only with the investigation of the physical processes during the creation of the screwed joint but the examination of mechanic behavior of the bolt joint because it makes possible the forecast the influence of the parameters on the physical process.

If there is self-tapping screwed joint there is no need for threaded boring made in advance, as the screw makes the female tread during the process of the screwing in. So the self-tapping screwed joint is the particularly economical form of the threaded bonds. The user is not often able to control the quality of the threaded bonds because of the high speed of the electrical screwdrivers. Screwdrivers used wide for the steering of the screwing in process use a simple built in torque limiter, which breaks the screwing in process if the torque departs from the posed value. The automatic control of the screwing in process is very important because of the great number of the threaded connections used in the practice. If we make a comparison between the torque-displacement graph measured during the screwing in process and the theoretic torque-angle of rotation characteristic of the threaded bonds then the producing of screwed-joints become watched over. We can reach it by the way of making comparison between the torque-distance graph on the screwing bond being shaping and the graph of a well-produced screwing connection. Insertion of measured in advance curves causes significant surplus work if we use more different screwing bonds.

Table 1: *Possibilities of fixing polymer elements with screwed joint*

Screwed joints	Without inserts			With metal insert
Nut thread	made in advance	screwed joint		
Volution		thread cutter	thread tapper/ driller	
Screw type	metric screw	screw thread with cutter edge	tapping screw (for metal or wood)	screw with metric thread
Adaption	sometimes, complicated, expensive	brittle materials: fiber-reinforced thermo-plastic polymers	tough materials: thermo-plastic polymers	often dis-mantling bonds, foamed polymers

Tab. 1 shows the screwing bond solutions of the fixing of polymer pieces.

We can distinguish two kinds of screws: forming and cutting threads. Forming threads are used as tinner screws or wooden screws. Producing this connection remarkable stress come into being in the tube, so while choosing the material it is very important that the material will be able to enlarge to avoid the polymer geol. While making the cutting threads so remarkable stress do not generate into the tube because the screw produces the nut thread by shaping.

The screws used in practice are shown in Tab. 2 and the process of producing the screw-joints are displayed on Fig. 1.

Table 2: *Types of self-tapping screw (used for polymers)*

Name	Screw type	Properties	Application	Schematic
AB	Thread forming	Do not contain cutting slots Do not produce chips 60^o thread angle	Materials with a modulus less than 2760MPa	
B	Thread forming	Large root diameter, finer thread pitch	Designed for wood and metal, but also used for thermoplastics	
BF	Thread cutting	Wide thread spacing can suffer clogging of the cutting slots when working with softer materials	Materials with a modulus greater than 2760MPa	
BP	Thread forming	Same dimensions as B, but has a cone point for use where holes are slightly misaligned	Materials with a modulus less than 2760MPa	
BT	Thread cutting	Most common Wide thread spacing	Materials with a modulus greater than 2760MPa	
D	Thread cutting	Good for field replacement	General use	

F	Thread cutting	Blunt tapered point Multi-cutting edges Chip cavities	Both metals and plastics	
T	Thread cutting	Fine thread spacing to reduce granulation	High modulus (greater than 7000MPa) glass reinforced materials	
Hi-Lo	Thread forming / thread cutting	Double lead screw -high thread 30^o - low thread 60^o	Designed for thermoplastics Excellent pull-out due to the increased contact with plastic between the high threads	
Trilob e	Thread forming	Triangular spaced threads -single lead - double lead Thread angles $45\text{-}48^o$	Increased resistance to loosening, ideal for vibration applications	

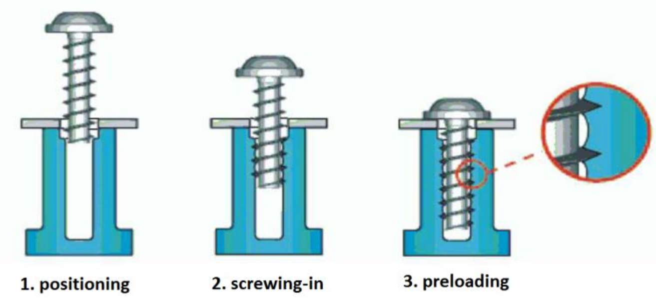

Fig. 1 Main steps of making self-tapping screw bonds

Torque on the screw during the process of screwing in devotes to the shaping of the threads and friction resistance between the screw threads and the tube. During the screwing in we have to reckon on heat generation because of local, plastic deformations and the sliding friction. Added difficulty that the force occurred during the process changes because of the behavior of the polymer (creeping, stress relaxation). The determinate elements on the quality of self-tapping screwed joint are shown in Fig. 2.

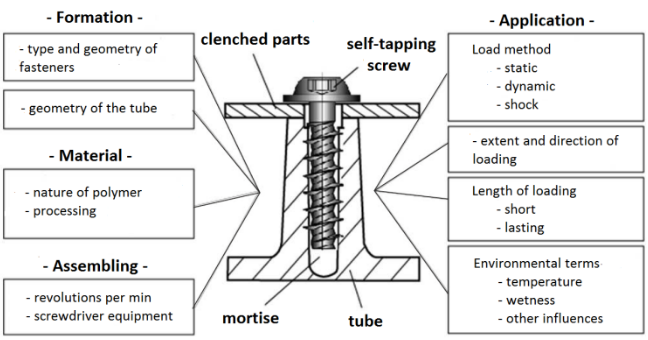

Fig. 2 Factors determining quality of self-tapping screw bonds

Screwing bonds used for the fixing of thermoplastic polymer elements make two types:

- The first group contains those bonds where the piece is fixed between the screw-head and the front of the tube. So the polymer piece will be exposed to a nearly permanent that is independent from time-change. (the synchronous stress-strain curve can be displayed by a vertical line which shows the influence of the time during the process from the pre-stress of the screw)
- In the other group an added loading influences on the bonds. A nearly permanent stress is in the polymer device.

It is worth to mention that the geometry of self-tapping screwing joints used nowadays has been developed by a continuous development work, which can be seen on the Fig. 3.

2. Directives for selection and dimensioning

Research result of this essay applies exclusively the pairing of self-tapping steel screw and polymer tube.

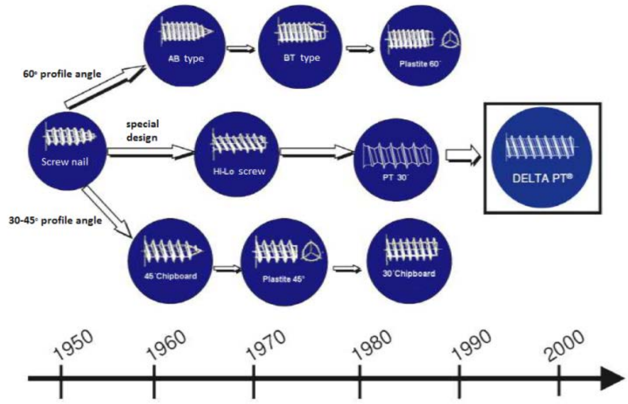

Fig. 3 Changes in the geometry of the self-tapping screws

2.1 Forming the screw

The diameter of self-tapping screws used in thermoplastic polymer devices changes 1.4-10mm. The threads are less profile angled (45^o, 40^o or 30^o) in the screws so as to be able to reduce the radial stress in the polymer tube. The thread ditches are also deeper than for example in the case of metric threads. The used thread profiles are changed by the producers.

An optimal thread has to be adequate to the following criteria:

- the radical shape-change of the tube must be small
- it has to demand small screwing-in torque
- the size of the connected hob surface must be as big as it can be
- a narrow tolerance field has to be particular to it

The cutting edge working with brittle materials has got a big importance in the lightening of screwing-in. Collar-screws are often made to minimize the stresses on the beddings of screw-heads. The Fig. 4 also displays a screw like this.

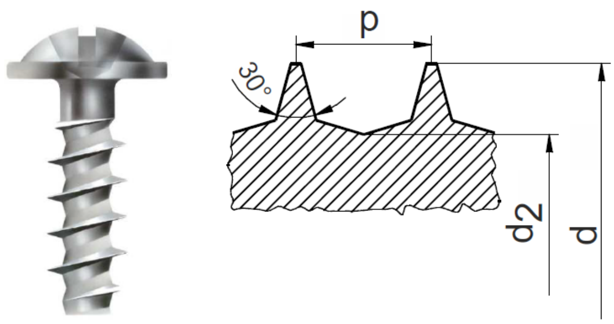

Fig. 4 PT type screw

On it we can see the threats, too. Next to the 30^o profile screw we can also see, that the geometry of screw bar is different from the traditional metric screws. This is made so that the ditch can be filled by the polymer material. By the screws used nowadays we can reach suitable pre-stress even after numerous unbinds a pre-forces. Screws used with polymer tubes are characterized by the followings:

- smaller inner diameter, bigger thread height with the metric thread
- higher thread lifting
- 30^o profile angle

2.2 Forming of tube

Fig. 5 shows the scheme of a polymer tube. On the polymer divice the fixing points are made as a cylindrical inner core (tube). The tube is lift up with 0,5-1^o taper to make the device to be capable to let the screw out of itself - an inner so called relief bore is made on the top surface of the tube – often with a bigger diameter (d_s). This bore lightens the fitting of the screw in the bore (d_s>d) and relieves the top surface from the loadings added by the threads. The best forming of the tube is the condition of achieving the maximal pre-stress force.

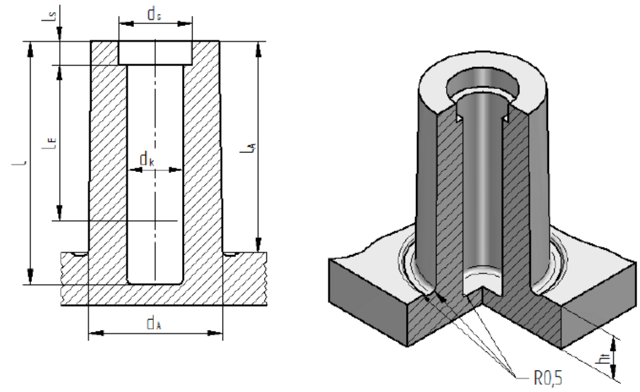

Fig. 5 *Schematic illustration of the polymer tube*

If the length of the screwing is longer the bearing of burdens of the screwing bond is growing. The solidity of the screw means the top limit of bearing of burdens. On the contrary the metal screw – metal female the metal screw – the polymer tube's each thread takes part in the load delivering, which is the result of elastic modulus of the two materials.

2.3 Pulling torque

Fig. 6 displays the torque on the screw-head during the making the screwing joint taken as a function of the turning round the longitudinal axis of the angle.

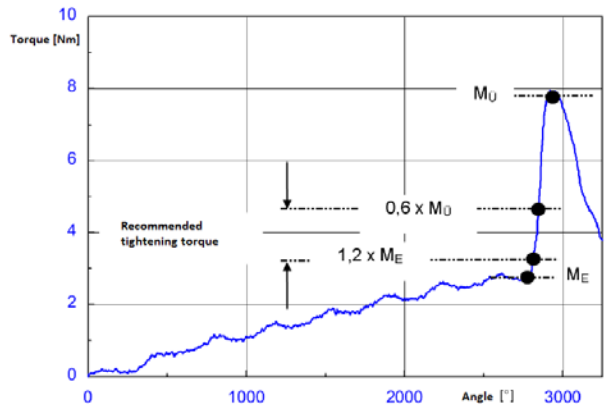

Fig. 6 *Torque effect on self-tapping screw depend on the angle*

The bigger the speed of the screwing in the smaller the torque (M_E). This influence is stronger with amorphous thermoplastic polymers than with the partly crystalline materials. This is explainable by the friction heat and as a result of it with the material softening. It is also foreseeable that the greater the biasing force the bigger the load of the polymer tube will be. The higher biasing force demands the higher relaxation at the same time. Pulling torque is

(1) $M_A = M_E + k(M_{Ü} - M_E)$

where the k's value is 0.2-0.5. By Erhard the value of k depends on the parameters of the screwing machines. Screwing in torque (M_E) is that torque, which we see when the screw-head is only set on the surface of the polymer tube, but there is not pre-stress yet. Two things make the screwing in torque forming threads and the friction. ($M_{Ü}$) is that torque which is used then when the bond deteriorates.

2.4 Biasing force

We can avoid the overloading and the too strong biasing force relaxation if we choose the value of the pre-stress very carefully. It is not effective to use too big biasing force during making screw bonds. Experiments gave evidence that with a bigger screwing-in speed (500-1000 turning/min) we can achieve bigger biasing force with give sized pulling torque than in case of smaller speed. We can normally estimate the biasing force in the joint (F_V), but the accurate value of it is must be measured. We suppose that the linear connection is between the biasing force and pulling torque. The biasing force is:

(2) $F_V = \frac{4F_A \cdot k(M_{Ü} - M_E)}{4(M_{Ü} - M_E) + F_A \cdot \mu_F \cdot (D + d_s)}$

if we consider the friction between the surfaces. If we take a steal-polymer sliding couple the friction fact is 0.2-0.3.

The biasing force in time continuously decreases because of the polymer material's time and temperature addictive behavior. Experiments demonstrate that in average working circumstances there is no need for a big biasing force decreases in bigger degree taken as a function of time than a smaller biasing force.

3. Results of discussion

We have a detailed literature connected to the screwing joint. Experts have investigated various aspects of screwing bonds for example the geometry of screw, the stability of the joint, the parameter of setting-up, the possibility of automation of setting-up, the forms of crash. These parameters have been investigated by theoretical ways and by models. On the basics of these theoretical investigations they have created connections based orientation on adoption, which present a basis for choosing the material or the measurement of the bolted joint. Nowadays experts often describe the behavior of the joint or the different work phases by numerical models.

The screwing machines in most cases have got torque limit, which undo at a given pull torque and at the same time it ensures the same pull torque to each screwing joint. During the latest decades higher and higher demand emerged on the automation of the screwdriving process, which have developed to a reliant area of research. The aim of these researches is the development of the automatic controlling and supervisory strategies in support of increase of production. The aim is to make a model, which can determine that in the case of given pull torque how big is the axial moving away of the screw.

Material of the plate used for producing the female was ABS (acrylic-butadiene-styrene) and PC (polycarbonate). Using the model we need data of the geometry of screwing joint (parts we need to fix), the characteristics of the material, friction facts, the diameter of the pilot hole and the geometric measures of the screw. On the Fig. 8 we can see the theoretical torque-turning away curve belonging to the PC female. The numbers on the table show the characteristic linear phases of the graph.

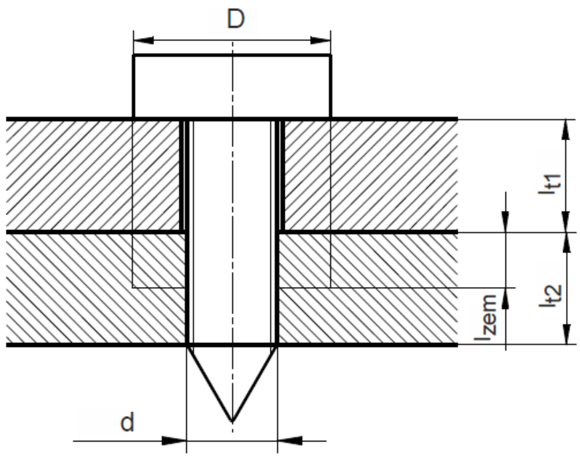

Fig. 7 *Model of self-tapping screw joint with abutment screw head*

Phase 1: The cone-shaped end of the screw is touching the pilot hole of the female (Fig. 9 T0). Then the screw is going into the female by the time when its tang touches the pilot-hole (Fig. 9 TE). The first step of the screwing-in process, the screw is snatching at the female. The torque which influences on the screw is devoting to the overcoming of the resistance caused by the making thread and the friction.

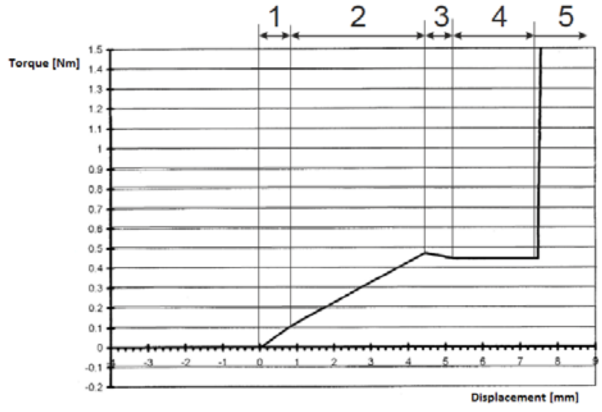

Fig. 8 *Theoretical displacement-torque graph of polycarbonate female (l_{t1}=0mm, l_{t2}=3mm, E=2.3GPa, p=1.1mm, D=5.03mm, d=2,87mm)*

Phase 2: The screw is continuously going in the pilot-hole (Fig. 9 TP). The torque on the screw is now devoting to the overcoming of the resistance of the thread making by the cutting edge and the friction between the screw and the female thread. The thread in the female is growing and it causes more and more friction resistance.

Phase 3: The cone-shaped and of the screw is turning up at the end of the pilot-hole (Fig. 9 TB), then it is emerging step by step till the cylindrical part of the screw is at the end of the pilot hole. In this phase there is thread-making and friction yet. The ready thread made in the female at the end of this phase achieves its final length.

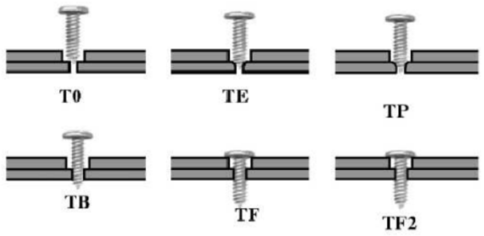

Fig. 9 *Phases of making self-tapping screw joint*

Phase 4: The cylindrical part of the screw is turning up at the end of the in and out pilot-hole (Fig. 9 TF), then it is coming out. In this phase there is no thread-making, the torque on the screw is totally devoted to overcoming the resistance of the friction on the threads. The torque is the same, because the length of the thread in this phase does not change, so the friction resistance remains the same, too.

Phase 5: The head of the screw lies on the piece (Fig. 9 TF-TF2). The torque on the screw is devoted to the overcoming of the resistance friction on the surface of the screw-head.

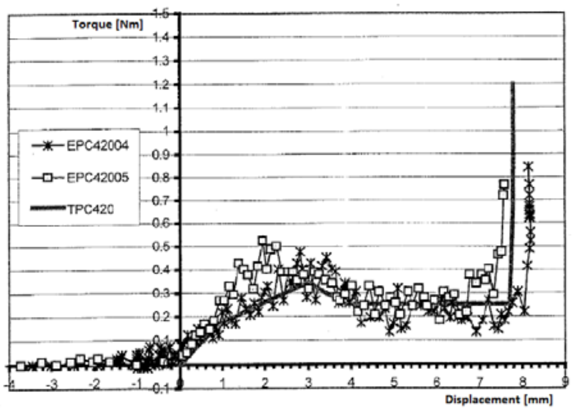

Fig. 10 *Theoretical (unmarked graph) and measured (graphs with symbol) torque-displacement graphs in case of polycarbonate female*

The different conditions of the 5 phases are well seen on the Fig. 9. And at last the comparison of the estimated and the measure torque-moving-away graph is on Fig. 10. The results show good conformities, which support the usefulness of the model.

4. Conclusion

Seneviratne and his fellows report graphs given with survey data torque-moving away. These measures prove the truth of the presence of the 5 phases in the theoretical models.

Althoefer and his fellows presented a new method for the supervision of the screwing joints. The elaborated theoretical built on the torque-moving away graph artificial neural network can distinguish the well or badly made screwed joints. By the authors the torque-displacement graph using the model depends on the geometric and mechanic characters of the fixing pieces and the screw that join them each other. The curve depends on the strength modulus, the friction fact, the solidity of the materials, the thickness of the pieces which are joined each other, the diameter of the pilot-hole and the measures of the screw. The graphs connected to the different pilot-hole diameter can be seen on Fig. 11. The comparison of the theoretical model and the torque-displacement graphs definite by measure is shown on the Fig. 12.

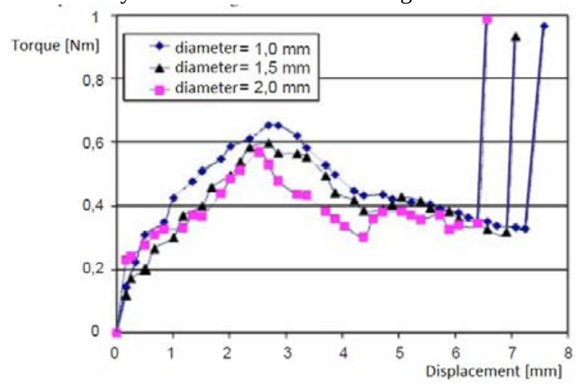

Fig. 11 *Torque-displacement graphs for different pilot-hole diameters*

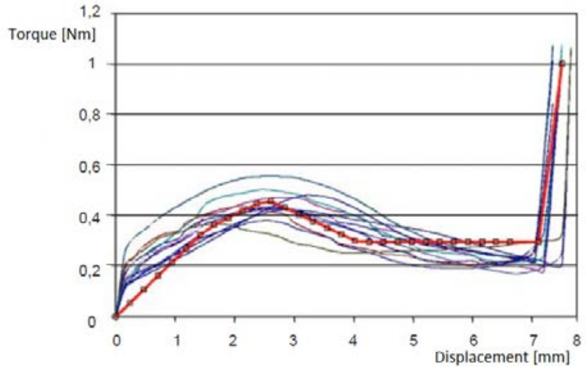

Fig. 12 *Comparison of measured (thin lines) and calculated (thick lines) torque-displacement graphs*

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