TECHNICAL INFORMATION

Dipl.-Ing. (FH) Christian Niklis
(German Edition)

CONTACT SCREWS

ARCUS ELEKTROTECHNIK
ALOIS SCHIFFMANN GMBH

Foreword

Beside the method of compression the method of bolted connections has a high importance for cable connections of any kind. Advantages of bolted connections on one side are large cross sectional ranges covered with one connector, on the other side it is simple and fast installation with small and light tools.
The nuclear element in the technique of bolted connections is the contact screw, of which different screw types were generated due to a multitude of requirements.
This article is to explain the main features of contact screws and their selection criteria.

Tasks of a contact screw

Primary task of a contact screw is the generation of a contact force to create as many real contact areas as possible between two electrically conductive bodies. By deformation of one or both bodies foreign layers such as oxide skin will be destroyed. The more real contact areas are created, the lower is the contact resistance.
Another task is to hold both bodies together against appearing mechanical forces, in order to keep contact areas stable for a long period of time. For underground cable connections this means that the contact is to withstand all strain for 50 years or longer.
As the contact screw is in direct contact with at least one current carrying body, an alternating reaction between screw and this body takes place which leads to chemical and mechanical damage of the real contact areas.
For this reason the selection of the suitable contact screw is the premise for a long-term good contact.

Which contact screw is the right one ?

To define the optimum screw for contact on underground cable conductors, the most different criteria are to be considered.
First of all difference is to be made between bare and insulated cable conductors.
For bare conductors a simple pressure screw is sufficient, whilst for insulated conductors an insulation-piercing screw (1) is required which then builds up a contact force. Furthermore one needs to clarify if a simple grub screw (2) or a screws with shear-head is required.
Decision for a grub screw is right when protrusion of the screw after installation is not important or if the jointer secures the required torque by using a torque wrench, or through his experience.
Decision for a shear-head screw is right to reduce protrusion after installation to a certain level, or if the torque should not depend on jointer or tool.

Contact screws with shear-head still require a defined number of rated break points, yet these are mainly defined by cross sectional range of connected conductors as well as by admissible protrusion after installation. Further distinction for shear-head contact screws is to be made between detachable and non-detachable screws.

Detachable screws have the advantage to be re-opened in case of faulty installation.
On the other hand they have the disadvantage that after re-opening they can be reset onto the same, already deformed area of the cable conductor.
This contact is certainly worse than a contact on an un-deformed area, because less real contact areas will be created due to the already effected compaction of the conductor.
Also detachable screws may lead the jointer to eventually retightening them. For instance on stranded aluminium conductors this would lead to cutting off single strands.
On contact screws with more than one rated break point (4) one needs to distinguish between release of a certain break point to be introduced by the installation tool or through geometry of screw.
In case the selection of tool will decide about the rated break point, the jointer needs to store different installation tools for this contact screw. Another disadvantage is the remaining hole in the screw after the head broke off. In medium voltage this may lead to an undesired rise of the electric field strength and thus to partial discharges. The advantage of such screws is that the higher torque is also related to the higher cross section, whilst in determination of releasing rated break point through geometry of contact screw the highest torque is related to the smallest cross section.
Beside geometric characteristics of contact screws the materials used and properties of surface are decisive.
The following chapters will explain the different models in detail.


1


2


3


4

Construction and function

Screw head

1

2

3

The head of a screw is designed to introduce the torque into the screw by means of standard tools.
Usually a hexagonal socket and a hexagonal head are used for it.
A combination of different hexagons on a contact screw will give certain characteristics to it.
For instance single rated break points can be released specifically by relating different hexagons (1).
Also one may design one hexagon to tighten a screw and another one to detach it.
Furthermore one may offer different hexagons to facilitate installation by free tool selection (2).

It is possible to provide hexagonal socket and hexagonal head with a stopper for the installation tool by means of a punch mark, a plastic stopper or a collar to make sure that after the head of the shear-head screw broke off there still remains the lower half of the tool face so that the screw remains detachable.

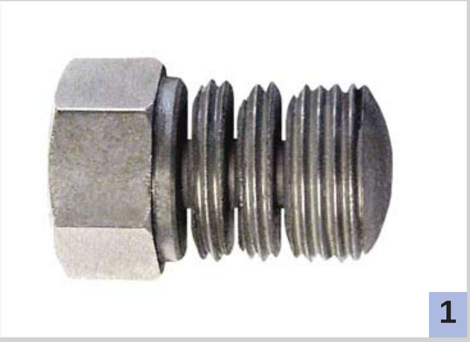
So already the choice of screw head decides about usage and function of the contact screw.

Rated break point

The rated break point guarantees that the screw will be tightened until the defined torque is reached, without requirement of a torque wrench.
Contact screws that have not been installed properly still show the shear-head which helps to reduce faulty installations.
With the breaking of the screw head the manufacturer takes the guarantee for the optimum contact pressure.
The shear value of a screw is defined through the diameter of a clearance groove.
Because of the latest production processes this value is determined to exactly +/- 1 Nm.
After the head broke off there may remain a rough sharp-edged surface. Shrink sleeves of shrinkable joints may be damaged during sliding or shrinking. To avoid this, contact screws with lowered break point (4) were developed. Here the break area within a rounded rim is lowered, so no sharp edges will protrude.

4

Rated break point (continued)



1

In case contact screws need to cover a larger cross sectional range and protrusion after installation is limited, several rated break points are used.
As these break points are on close distance towards each other, they need to have little expansion to obtain sufficient load-bearing thread in-between. Consequently on contact screws with multiple break points this prevents lowered break points at every rated break point.
To still obtain a break area that fulfils the demands of a joint, rated break points are provided with additional facets (1) that de-sharpen the end of the screw thread.

One more reason to manufacture contact screws with multiple break points is the de-coupling of different effects of a screw.
For instance on an insulation-piercing screw (2) the first rated break point may release as soon as the piercing process is to end. This way the initially rotating piercing plate will become a stagnant pressure plate.
When the screw is tightened further, strands of stranded conductors are compacted until breaking off the screw head finishes the installation procedure.
Such screws were developed to contact stranded conductors to TGL Standard.
For the number and width of a rated break point one needs to observe that each interruption of the screw thread reduces its load-bearing capacity. For this reason the number of break points should remain small and width should remain narrow.

Screw end

The end of the screw is in direct contact with the cable conductor, so it has great significance.
In general the screw end should contact the cable conductor on an extensive area to create as many real contact areas as possible.
This means, the thread diameter of the screw should be large enough to have the screw, for instance, fill the inside barrel in its width as much as possible.

This also has the effect that on stranded cable conductors no strand will remain aside of the screw and thus would not participate in current transmission.
The end of a screw for insulated cable conductors is to cut through the conductor insulation. This can be reached for instance by cutting slots (2), a cutting cone or a cone point. Still the screw must not be aggressive enough to damage the conductor itself (3). For this reason cutting slots are dimensioned to be filled by plastic conductor insulation after piercing, this way they have no more cutting effect.

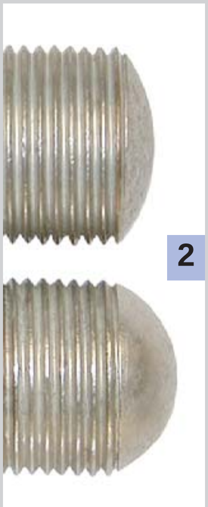
3

2

Screw end (continued)

Cutting cones (1) may be designed to upend after insulation piercing and will blunt this way.
A cone point will cut through conductor insulation relatively easy. But it is unsuitable to compact stranded conductors as the point will simply slide between the strands.
Furthermore the cone point will not disperse contact force to a larger area. This means, the number of real contact areas will not be sufficient to transmit higher currents.
The end of a contact screw for bare cable conductors will usually be shaped as a flat face or as a spherical calotte. In many applications a flat face is sufficient to compact conductors on a large area and build up contact force.
In other applications it is necessary to have the screw partially penetrate the conductor to create even more real contact areas by a larger degree of deformation.
This penetration is best obtained with a spherical calotte, and the radius of the calotte has an important influence (2).

1



2

Spherical calotte with large radius

Spherical calotte with small radius

Spherical calottes with a small radius will easily penetrate the conductor as their contact area will grow slowly with each turn of screw, by which also the face pressure will only decrease slowly.
Disadvantage of calottes with small radius is, that for instance in screw connectors the contact screw needs to be turned back to a large extent to also fit the maximum conductor into the barrel.
Then the screw may fall from the thread and with a conductor inside the barrel one may not be able to feed the screw back into the thread.
So one needs to select a radius of spherical calotte that is large enough to enable even the largest cable conductor to be introduced into the barrel.
Yet the calotte with larger radius will less penetrate the cable conductor as with each turn of screw the contact area will grow much faster and thus also the face pressure will decrease faster.
In any case the penetration of the contact screw into the cable conductor needs to be chosen in a way to avoid cutting off strands.
Furthermore the tensile strength must not fall below the required values of the valid standard.
Such values for instance are specified in IEC 61238-1 of March 2003.

Materials

As material for contact screws different copper alloys have prevailed. Due to excellent electric conductivity, good machining properties, and unproblematic availability on the market they generally volunteer for electrically conductive parts.
One will also find aluminium alloys in contact technique. Electric conductivity of aluminium is only 2/3 of that of copper, but also aluminium is machined well and is available on the market at any time. Also aluminium is lighter and less expensive than copper.
The decision to manufacture a contact screw of aluminium alloy or of copper alloy also depends on the other materials that can be found in the contact area. Here aspect such as corrosion between copper and aluminium or cold-welding between aluminium and aluminium play a role.
In both materials alloy components such as magnesium, zinc or lead are decisive for mechanic and electric characteristics, whereat the electric properties will improve with decreasing mechanic properties and vice-versa.
So there is no contact screw made of copper alloy with the mechanic characteristics of steel and the electric properties of electrolytic copper. One needs to chose for the suitable alloy depending on prevailing electric conductivity or mechanic carrying capacity.
In applications where the screw mainly has a mechanic function, one does not need to consider electric conductivity. In this case steel contact screws are used which only have the task to press the cable conductor into its contact bed. Current will flow directly from conductor into contact bed without the screw having to carry a major part of it.

Surfaces

Coating of screws requires special attention.
Each layer on the screw will change contact resistance between screw and another body.
Composition and thickness of layer have an important role.
For contact screws of copper alloy or aluminium alloy mostly a galvanic tin-plating is chosen as corrosion protection.
On one side tin has good electric conductivity and is an economic and effective protection, on the other hand side the soft tin has the advantage that when contact is made, because of the high contact pressure, it is partially displaced. This way it forms a wall around the real contact areas which protects them against humidity or aerial oxygen. As optimum thickness of tin layer under consideration of electric conductivity, a value of approximately 5-10 µm has been proven.

To actually create real contact areas a sufficient contact pressure is required. The level of contact pressure also depends on friction in the thread and bearing surfaces of the screw.

Under disadvantageous conditions up to 90% of installation momentum may get lost through friction and only 10% will be transformed directly into contact force. Practice has shown that solid lubricants on the basis of Molybdenum-disulfide are suitable to create a low friction rate. Lubrication is thin, cohesive and flush. Due to the hand-firm film the screws are easy to handle and friction proportion is exactly defined.

Several tests also have demonstrated that the scatter of electric values at the contact area is much lower on solid lubricated contact screws than on contact screws without lubrication or with unsuitable lubricant.

Temperature range for which these lubricants are suitable is sufficiently high at -180 °C up to +300 °C.

Still one needs to point out that additional lubrication of the contact screw before or during installation is to be omitted, because this way certain lubricants may be washed out again. Furthermore an unintended chemical reaction between unsuitable lubricants and synthetics used in the joint will not be ruled out.

Installation notes

It was already mentioned that the level of contact pressure also decides about the contact resistance.
Contact pressure between screw and cable conductor is mostly defined through the parameters of geometry and surface of the screw as well as torque.
In this context the professional installation is also important. Only this way the rated torque and therewith a minimum contact resistance will be obtained.
If not only pure torsion but also bending is introduced into the screw through the tool, on one side friction in the thread increases, on the other hand side this additional bending will lead to an additional strain at the rated break point which causes breaking of the head earlier than with pure torsion.
Also sudden and irregular guidance of the tool leads to early breaking off the screw head and this way up to 10% of torque may get lost.
When selecting a contact screw with shear-head it is also important to make sure, that the cross sectional range of cable conductors will fit to the break momentum of the screw. This may mean that the cross sectional range of a screw connector with shear-head screws will be smaller than when using a screw without shear-head.
Furthermore one needs to consider that at least one rated break point may be located in the bearing area of the thread, when contact screws with several rated break points are used.
Consequently such screws will lose mechanical capacity compared to contact screws without shear-head or with only one rated break point. This especially has a negative effect on short threads, for example in thin-walled screw connectors.
There is no significant influence on the accuracy of the break values of a contact screw under different temperatures of usage.
After a number of investigations one can say that contact screws made of different copper alloys will shear off within the rated tolerance of +/- 1 Nm under temperatures of -10 °C up to +45 °C.

Final view

Summarising one can say that the constructive design of contact screws is under the influence of numerous parameters.
The selection of the suitable screw thus requires detailed knowledge about its respective application and installation procedure. Also experience and personal preferences of the end user as well as philosophies of the electric utility have an important role.

Phone
General
+49 (0) 89 / 4 36 04 - 0

Fax
General
+49 (0) 89 4 31 68 88

Fax
Sales Department
+49 (0) 89 4 36 04 - 73

Internet
www.ARCUS-Schiffmann.com
info@ARCUS-Schiffmann.com

Seat of the company
Truderinger Str. 199
D-81673 Munich

Layout: Marion Renz

Edition: 08.2008 Subject to change without notice

Copyright © ARCUS Schiffmann