

The invention relates to a self-tapping drill screw with a maximum thread diameter of approximately 6 mm for screwing into a metal sheet with a maximum thickness of approximately 1 mm, comprising a head having a tool holder, a threaded shank and a cylindrical portion connected thereto which has a smaller diameter than the effective diameter of the threaded shank and which merges into a tapering drilling portion.

A screw of this kind is known from DE-C-25 37 446. In this screw, referred to as a self-tapping screw, the drilling portion serves to drill the hole later receiving the screw by machining, to which end the drilling portion narrows into a sharp point which forms the vertex of a pyramid, the edges of which serve to machine the relevant sheet portion. According to Figure 18 of this patent specification, a cylindrical portion the diameter of which is equal to or smaller than the effective diameter of the threads is arranged between the completely cylindrical threaded shank and the drilling portion shaped like a pyramid. The function of this cylindrical portion is to adapt the hole drilled to the cylindrical shape and to align it so that it is axially perpendicular to the hole so that the threaded shank can be introduced into the sheet without canting.

A further self-tapping drill screw is known from DE-C-27 32 695. This screw is also based on the principle that it first penetrates into the material of the sheet via a sharp point of its conical drilling portion and drills a guide channel therein. The drilling portion of this screw is moreover provided with a thread of large pitch, by means of which the guide channel first drilled by the sharp point is supposed to be enlarged to open into the form of a protuberance as the

screw penetrates further into the material of the sheet. In this screw, the thread of the threaded shank merges directly into the drilling portion.

Various disadvantages arise as a result of the fine machining of the sheet material when screwing in the known screws. Fine metal chips are deposited in the interior of housings and the like, where, e.g. in the case of electrical apparatus, they may form undesired and dangerous contact bridges. Moreover, fine chips are difficult to remove and, particularly in the case of the access of moisture or humid air, lead to undesired corrosion.

It is furthermore known from FR-A 1 581 931 to provide a self-tapping drill screw at its front end with a sharp conical point which is driven into a sheet portion like a nail in order to form the hole therein. However, there is then a risk that the sheet will tear in the region of the hole created, so that the thread produced when the threaded portion of the screw is screwed in may also display tears which have a considerable influence on the holding power of the sheet acting on the screw.

The aim of the invention is to design the screw described at the outset in such a manner that the problem of chips is eliminated and the screw is screwed into the metal sheet with a particularly firm seat.

This is effected according to the invention in that the threaded shank merges via a taper extending as a component of the threaded shank over approximately four threads into the cylindrical portion, the length of which corresponds

approximately to four times the sheet thickness, that the drilling portion ends in a spherical friction surface which softens the sheet by rotation and which has a radius of approximately 0.5 mm and that the entire screw is made in one piece from quenched and tempered steel with a tensile strength of up to approximately 1400 N/mm^2 or from case-hardened steel.

The screw according to the invention provides the hole in the metal sheet by friction of the spherical friction surface with respect to the metal sheet, which is heated in this manner to such an extent that the material is converted into its plastic range, in which it is so flexible radially that the hole is enlarged in the desired manner with displacement of the material to form a throat. It has been found that a radius of approximately 0.5 mm for the sphericity of the friction surface gives advantageous centring, sufficiently rapid generation of heat at a high penetration rate and good heat flow through the screw. The cylindrical portion of the screw then penetrates into the throat as the screw is screwed in further, thereby completing the formation of the hole with the throat. The taper of the threaded shank then engages the hole, as a result of which the internal thread is formed in the hole, this being correspondingly facilitated by the taper. The cylindrical portion therefore allows to a certain extent for progression of the rotational speed of the screw to be screwed in, as a substantially higher rotational speed is required for the initial formation of the hole as a result of friction than for the formation of the thread. This prevents the threads of the taper of the threaded shank already having to be engaged, e.g. during the forming process for the hole.

The heating of the metal sheet by the friction produced by the

spherical friction surface is dependent on the contact pressure by means of which the friction surface is pressed against the metal sheet. The pressure required for sufficient heating can be reduced by providing the metal sheet with a tapered countersink instead of forming the hole. In this case, and with an opening in the outer surface of the cone such that the zone of contact with the spherical friction surface is situated only in the region of the outer surface of the cone, the spherical friction surface is designed in such a manner that it has a radius of approximately 0.5 to 1 mm.

When processing metal, it is generally first necessary to cut it to specific dimensions, punch marks also often having to be provided for bores to be added later. The addition of a tapered countersink therefore does not constitute any special expenditure within the context of preparatory measures of this kind, particularly as the tapered countersink is not a through hole, i.e. it does not require a punching process with the formation of waste. By virtue of the tapered countersink, the contact zone required for heating can be considerably expanded, i.e. in an annular manner into the region of the outer surface of the cone, compared to the case described hereinabove of placing the screw via its spherical friction surface on the flat metal sheet, as a result of which a substantial reduction of the required contact pressure of the screw with respect to a metal surface becomes possible compared to placing the screw on a flat metal surface. This reduction in the contact pressure is also favourably influenced by the increase in the radius of the spherical friction surface, as by this means the radius of the annular contact zone and thus its length are correspondingly increased.

This design of the screw according to the invention gives a particularly high loosening turning moment as the heated throat shrinks around the colder threaded shank at the end of the screwing process. This gives a particularly desirable locking effect for the screwed-in screw.

Tools for forming a hole in a metal sheet which heat the sheet by friction and produce a hole with throat-like extensions by virtue of the tapered design of their end faces are known, e.g. from DE-A-25 52 665 and DE-A-28 02 229. These tools consist of a mandrel which can rotate rapidly about its axis and is applied to the sheet via a centre point or mandrel point and the material of the sheet is plasticised as a result of the frictional heat to such an extent that the tapered part of the tool adjoining the point can enlarge the hole up to the maximum diameter of the cone, to which a cylindrical mandrel portion is then connected. It is also known from FR-A 1 189 384 to round off the foremost point of a cone of this kind.

The technology of these tools has not hitherto been applied to self-tapping drill screws. The reason for this is obviously that it was feared that the considerable heating of the part of the tool striking the sheet would lead to the risk of destruction of the tool. For this reason, the tools that have become known in practice, referred to as flow drills, are made of heat-resistant materials, in particular hard metal. Materials of this kind cannot be used for the screws in question here for both financial and technical reasons, as these screws are subject above all to considerable tensile stresses for which hard metal in particular is not suitable. It has now been found that holes can be formed in metal sheets, in particular steel sheets, with a maximum thickness of 1 mm

using a drilling portion with the aforementioned spherical friction surface using the considerable frictional heat produced in this manner if quenched and tempered steel with a tensile strength of up to approximately 1400 N/mm^2 or case-hardened steel is used for the screw as a whole. Both materials are highly suitable for use as screws as a result of their tensile strength. This means that high frictional heat which cannot flow off easily in the relatively thin metal sheet is produced when the hole is formed in the metal sheet as a result of the spherical friction surface, so that there is an accumulation of heat in the metal sheet, promoting plasticisation thereof. There is still virtually no mechanical damage to the spherical friction surface as a result of the relatively small thickness of the metal sheet, so that the hole is formed at such a speed that the friction surface is virtually preserved. Even if the friction surface is affected, this plays virtually no role in the penetration of the screw, as the hole only has to be formed one single time with the screw, after which the substantially problem-free forming of the thread is effected.

The drilling portion is advantageously shaped like a cone. As a result of its geometry, the cone ensures continuous material feed both in the radial and in the axial direction.

It may be desired to prevent friction of the cone surface with respect to the material of the sheet, this being effected in that the cone is provided with a plurality of symmetrically arranged flattened portions which in cross section merge into one another in a tapering rounded manner. This facilitates deformation of the sheet material.

The material deformation can be further facilitated in that the cone and the flattened portions merge into the cylindrical portion in an axial curvature. The axial curvature results in uniform enlargement of the material to be deformed and thus advantageous material flow until the cylindrical portion is reached. The drilling portion of the screw can therefore advantageously be designed in such a manner that the taper angle is on average approximately 30° to 40° .

By virtue of the design of the throat formed by plastic deformation, internal threads having a pitch which is substantially smaller than the conventional pitch of known so-called self-tapping screws can be formed in the throat.

The screw can therefore advantageously be designed in such a manner that the pitch P of the thread in relation to its outer diameter d corresponds to the formula $P = 0.15$ to $0.20 d$.

If it is desired not to press in this collar when tightening the screw, the head of the screw is advantageously designed in such a manner that it has an annular groove on its underside directed towards the threaded shank, the inner wall of said annular groove having a radius essentially corresponding to the radius of the thread flanks and receiving the front end of a throat formed when the screw penetrates into the metal sheet, i.e. the collar mentioned hereinbefore.

Pressing in the collar with a screw via the smooth underside of its screw head often results in the fact that the collar is machined to a certain circumference. Metal chips of this kind are undesired on account of contamination and subsequent corrosion, and when the screw is used in connection with

electrical apparatus, metal chips can also lead to electrical complications, in particular short circuits.

The annular groove can be given a rectangular cross section. To this end, the annular groove is pressed into the screw head during the manufacture of the screw.

It is also possible to allow the outer wall of the annular groove to slope outwards from its base. In this case, the sloping annular groove can press the collar inwards when it is placed on the sloping wall. By virtue of this design, the collar can in particular press against the thread, to which end the annular groove is given a depth such that the front end of the throat is pressed in the direction of the threaded shank when the screw is tightened. This results, on the one hand, in particularly good sealing between the throat and the thread of the screw and, on the other hand, in locking of the screw, by means of which its loosening turning moment can be considerably increased.

One embodiment of the invention is illustrated in the accompanying drawings, in which:

Figure 1 is a side view of the screw according to the invention;

Figure 2 is a section along the line A-A of Figure 1 on an enlarged scale;

Figures 3 to 5 show individual phases of screwing a screw into a metal sheet;

- Figure 6 is a side view of the screw with a rectangular annular groove in its head;
- Figure 7 is a section along the line B-B of Figure 1;
- Figure 8 shows the screw screwed into a sheet;
- Figure 9 shows the screw screwed into a sheet with the front end of the throat pressed against the thread;
- Figures 10a and b show the screw opposite a metal sheet provided with a tapered countersink;
- Figure 11 shows the cooperation between the screw and the tapered countersink, and
- Figure 12 shows a tapered countersink applied to the centre of a recess.

The screw shown in Figure 1 has the head 1, which in this case is provided with the cross recess 2 which serves as a tool holder. The threaded shank 3 is connected to the head 1 and has the taper 4 on its side remote from the head 1. This taper extends in this case over four threads. It is of course also possible to slightly increase or reduce the number of threads. The taper is produced by reducing the outer diameter of the relevant threads. The thread of the threaded portion 3 is preferably rolled.

The cylindrical portion 5 is connected to the threaded shank 3 via the taper 4, its diameter corresponding to the core

diameter of the threaded shank 3. The diameter of the cylindrical portion 5 can also be selected to be slightly greater or smaller. However, it should be less than the effective diameter of the threaded portion 3. The axial length of the cylindrical portion 5 corresponds approximately to four times the sheet thickness if it is assumed that the screw is to be introduced into two sheets each having a thickness of 1 mm, wherein it should also be ensured that one throat is formed per sheet, the length of which is also in the region of 1 mm.

The drilling portion 6 is connected to the cylindrical portion 5, and ends in the spherical friction surface 7, the sphericity of which has a radius R of approximately 0.5 mm.

It is clear from Figure 1 that the drilling portion is shaped like a cone which merges into the cylindrical portion 5 in an axial curvature 9.

It is clear from Figure 2, which shows a section along the line A-A of Figure 1, that four symmetrical flattened portions 10 extend along the drilling portion 6, so that more sharply defined curvatures 11 are produced with respect to the flattened portions 10, which, when the drilling portion 6 is screwed into a metal sheet 12 (in Figures 3 to 5), push away its material both in the radial and in the axial direction.

Screwing the screw into a metal sheet 12, e.g. a steel sheet, will now be described with reference to Figures 3, 4 and 5.

The drilling portion 6 is first pressed via its friction surface 7 against the sheet 12 and is rotated at a speed of approximately 4000 rpm. It is assumed that the metal sheet 12

has a thickness of 1 mm and the screw has a cylindrical portion with a diameter of 5 mm. As a result of the pressure of the friction surface 7 on the sheet 12 and the high rotational speed, such considerable frictional heat is produced between the friction surface 7 and the surface of the sheet 12 contacted that the material of the sheet 12 is plasticised, yielding both in the direction of and away from the screw, and finally, as shown in Figure 4, forming the throat 13 which extends both above and below the sheet 12. The taper angle of the drilling portion 6 is in this case 35° . With this angle the lengths of the throat 13 formed above and below the sheet 12 differ in such a manner that the length below the sheet 12 is approximately double the length above the sheet 12. Consequently, with a decreasing taper angle, the length of the throat 13 below the sheet 12 is further extended with respect to the length above the sheet 12.

The process of plastic deformation of the sheet 12 with the throat 13 then continues until the throat 13 has reached the cylindrical portion 5, where the taper 4 of the threaded shank 3 then penetrates into the throat 13. A sharply increasing turning moment is already produced for the further penetration of the screw in the region of the axial curvature 9, so that with an appropriately dimensioned driving element for the turning tool the latter reduces its rotational speed and then the taper 4 of the threaded shank 3 penetrates into the throat 13 and cuts the corresponding thread therein. This process leads to further penetration of the threaded shank 3 into the throat 13 (Figure 5) until finally (not shown) the throat 13 runs against the head 1 shown in Figure 1. The screw is thus completely screwed into the sheet 12 with its throat 13. The head 1 thus forms a seal with respect to the throat 13, as the

latter can be deformed relatively easily by the underside of the head 1 and is correspondingly adapted to the head.

The screw shown in Figure 6 has the head 1, which in this case is designed as a hexagonal head. In these embodiments, the head 1 has the shoulder 14, into the underside 22 of which the annular groove 15 is worked. The annular groove 15 is advantageously pressed into the shoulder 14 and in this case it has a rectangular cross section. The thread 3 is connected to the shoulder 14, then is followed by the further components shown in Figure 6 of the main patent.

Figure 7 shows a section through the screw according to Figure 6 along the line B-B. It is clear from Figure 7 that the inner wall 23 of the annular groove 15 has a radius lying in this case between the radii of the base 24 and the crest 25 of the thread 3, shown in Figure 7 by a dash-dotted line, i.e. corresponding to the radius of the thread flanks.

Figure 8 shows the screw with the head 1 tightened with respect to the sheet 12, the front end 18 of the throat 13 being completely received by the annular groove 16. The front end 18 is thus preserved when the head 1 of the screw is tightened. The annular groove 16 has a wall 17 sloping outwards from its base. By virtue of this design of the wall 17, in the case of contact between the front end 18 and the wall 17, the front end 18 tends to press inwards in the direction of the thread.

This effect is shown in Figure 9. In the embodiment according to Figure 9, the annular groove 16 is not pressed as far into the head 1, so that the front end 18 of the throat 13 runs against the sloping wall 19 when the head 1 is tightened and

thus is squeezed radially inwards towards the thread, as a result of which the front end 18 rests firmly against the thread, so as to provide a seal and moreover the screw is locked in the throat 13.

The embodiment according to Figure 9 shows a laminated sheet consisting of the two layers 20 and 21 which lie on top of one another when the screw is screwed in and in which a through throat 13 with a front end 18 is formed in the same manner as in the embodiment according to Figure 8, in which the material from the two layers 20 and 21 merges together. When forming the screw hole in superimposed sheets, it is possible to increase the overall thickness slightly with respect to the thickness of an individual sheet to be worked, e.g. to 1.8 mm.

The use of the screw according to the invention in connection with screwing it into a metal sheet with a tapered countersink will now be described with reference to Figures 10 to 12.

Figure 10a shows the cylindrical portion 5 with the adjoining drilling portion 6 and the spherical friction surface 7 of the self-tapping screw, in which the radius R is in the region of approximately 0.5 to 1 mm. This screw cooperates with the metal sheet 12 provided with the tapered countersink 26 according to Figure 10b. The taper angle α of the countersink 26 is in this case 54° . The spherical friction surface 7 is introduced into this countersink 26 and thus forms the contact zone 27 which can be seen in Figure 11, enclosing the spherical friction surface 7 in an annular manner. The front end 28 (see Figure 11) of the spherical friction surface 7 is held at a short distance from the base 29 of the countersink 26, so that there is contact with the metal sheet 12 only in the region of

the outer surface 30 of the cone of the countersink 26 and, according to Figure 11, below the edge 32 of the outer surface 30 of the cone. However, it is also possible to allow the spherical friction surface 7 to rest on the edge 32, although this is slightly less advantageous with respect to the friction produced. The contact pressure acting on the screw therefore only produces friction in the region of the contact zone 27 which, as a result of the considerable surface expansion of the contact zone 27, leads to the required heating of the material of the metal sheet 12, even with relatively low contact pressure. In the case of a screw provided with an M5 thread, a contact pressure of approximately 150 N is produced.

Particularly in the case of small screws, e.g. with an M3 thread, the large diameter of the tapered countersink 26 is approximately 1 mm. A small tapered countersink of this kind is in some cases difficult for the screw to be screwed into the relevant sheet to find. Consequently, it may be advantageous to provide the tapered countersink at the end of a recess, as shown in Figure 12. According to this figure, the recess 31 is pressed into the metal sheet 12 and the tapered countersink 26 is pressed into the centre of its base without breaking through the metal sheet 12. A screw guided in the direction of the recess 31 is then guided automatically into the countersink 26 by the wall of the recess 31, where it then works in the same manner described with reference to Figure 11.

The heating of the material of the metal sheet produced via the contact zone 27 then results in deformation as described hereinabove with reference to Figures 3, 4 and 5.

CLAIMS

1. Self-tapping drill screw with a maximum thread diameter of approximately 6 mm for screwing into a metal sheet with a maximum thickness of approximately 1 mm, comprising a head (1) having a tool holder, a threaded shank (3) and a cylindrical portion (5) connected thereto which has a smaller diameter than the effective diameter of the threaded shank (3) and which merges into a tapering drilling portion (6), characterised in that the threaded shank (3) merges via a taper (4) extending as a component of the threaded shank (3) over approximately four threads into the cylindrical portion (5), the length of which corresponds approximately to four times the sheet thickness, that the drilling portion (6) ends in a spherical friction surface (7) which softens the sheet (12) by rotation and which has a radius (R) of approximately 0.5 mm and that the entire screw is made in one piece from quenched and tempered steel with a tensile strength of up to approximately 1400 N/mm^2 or from case-hardened steel.
2. Screw according to claim 1 for screwing into a metal sheet with a tapered countersink, characterised in that given a taper angle (α) of the countersink (26) of approximately 50° to 70° and a zone (27) of contact with the spherical friction surface (7) situated only in the region of the outer surface (30) of the cone, the said friction surface has a radius of approximately 0.5 to 1 mm.
3. Screw according to claim 1 or claim 2, characterised in that the drilling portion (6) is shaped like a cone.



4. Screw according to claim 3, characterised in that the cone is provided with a plurality of symmetrically arranged flattened portions (10) which in cross section merge into one another in a tapering rounded manner.
5. Screw according to claim 3 or claim 4, characterised in that the cone and the flattened portions (10) merge into the cylindrical portion (5) in an axial curvature (9).
6. Screw according to one of claims 1 to 5, characterised in that the taper angle is on average approximately 30° to 40° .
7. Screw according to one of claims 1 to 6, characterised in that the pitch P of the thread in relation to its outer diameter d corresponds to the formula

$$P = 0.15 \text{ to } 0.20 \text{ d.}$$

8. Screw according to one of claims 1 to 7, characterised in that the head (1) has an annular groove (15, 16) on its underside (22) directed towards the threaded shank, the inner wall of said annular groove having a radius essentially corresponding to the radius of the thread flanks and receiving the front end (18) of a throat (13) formed when the screw penetrates into the metal sheet (12; 20, 21).
9. Screw according to claim 8, characterised in that the annular groove (15) has a rectangular cross section.
10. Screw according to claim 8, characterised in that the outer



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11. Screw according to one of claims 8 to 10, characterised in that the annular groove (16) has a depth such that the front end (18) of the throat (13) is pressed in the direction of the threaded shank (3) when the screw is tightened.