Title: *Mechanical joining —Qualification of joining procedure — Form-fit blind rivet and (lock) bolt joints*

Title: *"Mechanical joining - Specification and qualification of testing procedures -- form-fit blind rivet and (lock) bolt joints"*

OR

"Mechanical joining - Form-fit blind rivet and (lock) bolt joints -- Specification and qualification of testing procedures"

Contents

Recipients of this draft are invited to submit, with their comments, notification of any relevant patent rights of which they are aware and to provide supporting documentation.

Foreword

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The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

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ISO 25239-4 was prepared by which has been approved as an international standardizing body

Requests for official interpretations of provisions in this standard should be made in writing and sent to the ISO Central Secretariat who will forward them to the IIW Secretariat for an official response.

Title: ***"Mechanical joining - Form-fit blind rivet and (lock) bolt joints - - Specification and qualification of testing procedures"***

1 Scope

This international Standard specifies the function and procedure for the testing, evaluation and qualification of form-fit blind rivet and (lock) bolt joints with a nominal diameter increasing from 1.6(?) mm. The tests shall be carried in accordance with this standard unless more severe tests are specified by the relevant specification.

Note Specific service, material or manufacturing conditions require more comprehensive testing than that specified in this standard.

Such tests may include e.g.:

- micro sections
- fatigue and/or endurance tests
- corrosion tests
- tests of components and/or complete assemblies

2 Normative references

The following normative documents contain provisions which, through references in this text …

ISO 3269: 2000, *Fasteners – Acceptance inspection*

ISO 4042: 1999, *Fasteners – Electroplated coatings*

ISO 14588:2000, *Blind rivets – Terminology and definitions*
ISO 18592:2009 *Resistance welding - Fatigue testing of multi …*
…
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3 Terms and definitions

Symbols and designations of dimensions if not specifically defined in this standard will be as specified in ISO 14588.

3.1 Form-fit blind rivet

Mechanical fastener, with the capability of joining the component parts of an assembly, such that there is no radial play between the mandrel, shank and work piece even though access for its installation and setting may be limited to one side only.

Note 1 It comprises a body containing a mandrel which, during the setting operation, expands the shank or sleeve radially bridging existing gaps between mandrel, shank and work piece bore.

Note 2 The elements of conventional and form-fit blind rivets are shown in Figure 1.

3.2 Form-fit (lock) bolts

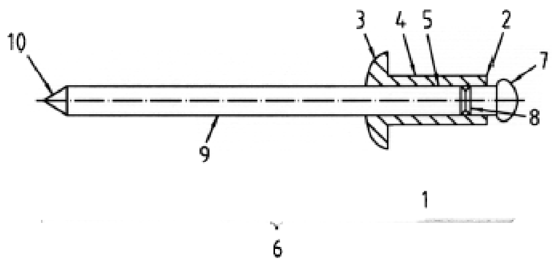
Mechanical fastener with the capability of joining the component parts of an assembly such that there is no radial play between the shaft of the (lock) bolt and the work piece bore.

Note 1 Form-fit (lock) bolts are characterized by mandrel shafts which have an interference fit with the holes in the components to be joined. The design of the bolts is such that a that a form- and force-fit joint is achieved without the mandrel prematurely fracturing at the break neck due to excessive setting force requirements

Note 2 In special cases, form-fit (lock) bolts may be used in conjunction with sleeves or shanks, see Figure 2.

Note 3 Form-fit (lock)bolts may be used in conjunction with locking collars or other mandrel retaining methods.

3.3 . . . . .



Key

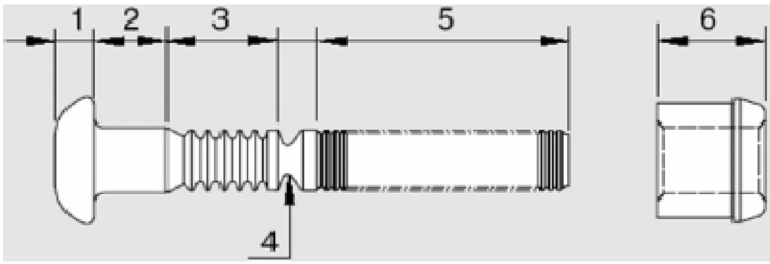
1 Blind rivet body
2 Blind rivet end
3 Blind rivet head
4 Blind rivet shank
5 Blind rivet core
6 Mandrel
7 Mandrel head
8 Break area
9 Mandrel shank
10 Mandrel end

Légende

1 Corps du rivet aveugle
2 Extrémité du corps du rivet aveugle
3 Tête du rivet aveugle
4 Fût du rivet aveugle
5 Alésage du corps du rivet aveugle
6 Tige du rivet aveugle
7 Tête de la tige
8 Amorce de rupture de la tige
9 Fût de la tige
10 Extrémité de la tige

Figure 1 — Blind rivet elements
Figure 1 — Éléments constituant un rivet aveugle

4 Blind rivet sleeve



Key
1 Brazier or countersunk head
2 Smooth section of the shaft
3 Locking grooves
4 Breaker groove or break neck
5 Pin tail for applying the pulling force
6 Collar

Figure 2?: Components of lock bolt

4 Symbols

Symbols and designations of dimensions if not specifically defined in this standard will be as specified in ISO 14588.

5. Requirements for the function of joints

5.1 Transmission of shear loads[1]

Joints made with conventional rivets are, as a rule, force fit, i.e. they rely on the clamping force, together with the friction between the sheets, for the transmission of shear loads. Form-fit joints made with either blind rivets or (lock)bolts are both form- and force fit, making use of both mechanisms for the transmission of shear loads.

because the radial play between mandrel, sleeve and work piece bore is not completely eliminated.

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5.2 Variables related to the joint quality

The load carrying properties of riveted joints depend on two main factors: form- and force-fit. The degree of force-fit depends on the clamping force generated by the mandrel after its fracture at the break neck and ejection of the broken off mandrel. This is about 60% of the peak value at which the mandrel breaks, Figure XXX. The quality of a form-fit joint can be assessed by the contact area, in percent, between the sleeve and the work piece bore on the one hand and between the mandrel and the sleeve on the other hand. In the case of (lock)bolt joints, this is the contact area, in percent, between the mandrel and the work piece bore.

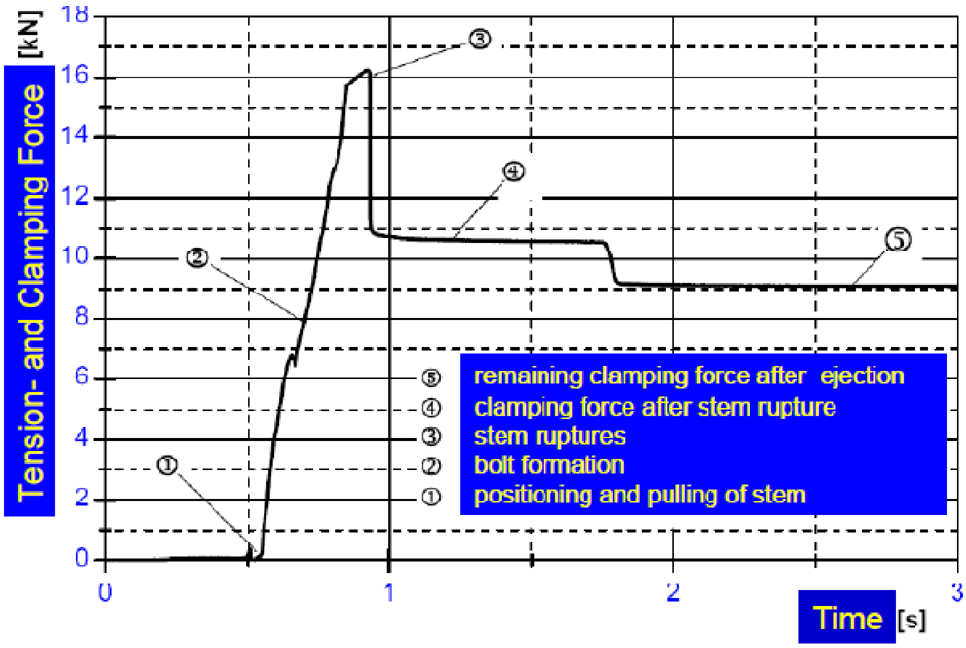


Figure XXX: Time vs. Force curve showing the clamping force at various stages of the setting process. Results apply to both blind rivets and lock bolts. (Source: Zorn, Herzog, Henkel and Al Raheb. Rostock Univ.)

The coefficient of friction depends on the material combinations(s) in the faying surface(s) and their pre-treatment, e.g. special paint or roughening treatment, e.g. through (sand)blasting.

Other important factors are the size of the rivet head (or collar) and that of the blind head.

Note[1] Rivets are regularly sold/offered as having “very good” hole fill properties without any further qualification. Such information is erroneous and misleading.

5.2.1 Blind rivets

Blind rivets are mechanical fasteners, comprising of a blind rivet body, including a sleeve, and a mandrel, with the capability of joining component parts of an assembly, even though access for their installation and setting may be limited to one side only

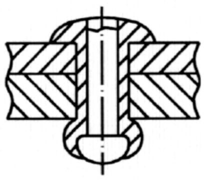


Figure ZZZ: Cross-section of structural blind rivet joint with flush break mandrel and expanded blind head. Note that different mandrel retention methods and both folding as well as expanding sleeves may be used.

Hole fill capability of form-fit rivets will vary with

- Nominal diameter of rivet; increases with the diameter
- Degree of interference fit: The bridgeable gap increases with the increases with the strength of the mandrel material and decreases with the strength of the work piece material(s) due to limits set by the increase in setting force
- Shank or sleeve material: The stronger the material, the larger the bridgeable gap, but strength requirements on the mandrel too will increase

- Thickness of work pieces: The bridgeable gap decreases with the thickness of the work piece(s)
- Material properties of work pieces: The bridgeable gap increases with the decrease in the strength of the work piece material(s)
- Strength and hardness of mandrel material: The bridgeable gap increases with the strength of the material

5.2.2 (Lock)bolts

Lock bolts are generally two-piece fasteners compromising a mandrel and a lock nut. The mandrel normally has parallel radial grooves on at least a part of the shaft. A two side access is mandatory for the use of such fasteners. During the setting process, the mouth-piece a suitably designed setting tool forces the material of the lock nut to flow into the radial grooves. At the end of the setting process the mandrel breaks off at the breaker groove or break neck, a section of the mandrel with a smaller diameter. Lock bolt joints are designed to transmit shear loads through friction locking. The transmittable load depends on the coefficient of friction at the faying surface between the sheets and the clamping force generated by the lock bolt. Typical calculated and experimentally determined clamping forces exercised by lock bolts with different diameters are given in **Tables YYY** and **ZZZ.**

Hole fill capability will vary with:

- Nominal diameter of bolt: increases with the diameter
- Work piece material: The bridgeable gap decreases with the increase in strength of the work piece material(s)
- Degree of interference fit: The bridgeable gap increase with the degree of interference fit and is limited by the required force permissible for setting
- Thickness of work piece material(s). The bridgeable gaps decrease with the thickness of the work pieces
- Mandrel: The stronger the material, the larger the bridgeable gap, but requirements on the setting force too will increase

Tabelle 3. Rechnerisch ermittelte Mindest-Scherkräfte für Schließringbolzen unterschiedlicher Durchmesser
(Calculated minimum Shear Load Values of Lockbolts with various Diameters)

Werkstoff der Bolzen	R_m / τ [MPa]	Mindest-Scherkraft [kN] (berechnet)			
		Ø SRB 4,8 mm	Ø SRB 6,4 mm	Ø SRB 8 mm	Ø SRB 9,6 mm
Stahl	800 / 530	9,6	17,1	26,6	38,4
Stahlqualität A2	500 / 400	7,2	12,9	20,1	28,9
Aluminium	420 / 240	4,3	7,7	12,1	17,4

Tabelle 4. Rechnerisch ermittelte Mindest-Scherkräfte für Schließringbolzen größerer Abmessungen
(Calculated minimum Shear Load Values of Large Diameter Lockbolts).

Werkstoff der Bolzen	R_m / τ [MPa]	Mindest-Scherkraft [kN] (berechnet)				
		Ø SRB 12,7 mm	Ø SRB 15,9 mm	Ø SRB 19,0 mm	Ø SRB 22,2 mm	Ø SRB 25,4 mm
Stahl	800 / 530	63	98	140	191	250

Tabelle 5. Im Versuch ermittelte Richtwerte für Mindest-Zugkräfte für Schließringbolzensysteme unterschiedlicher Durchmesser
(Experimental minimum Tensile Load values of Lockbolts with various diameters).

Werkstoff der Bolzen	R_m / τ [MPa]	Mindest-Zugkraft [kN] (gemessen)			
		Ø SRB 4,8 mm	Ø SRB 6,4 mm	Ø SRB 8 mm	Ø SRB 9,6 mm
Stahl	800 / 530	9,7	16,5	26,7	41,3
Stahlqualität A2	500 / 400	6,0	14,0	18,0	27,0
Aluminium	420 / 240	4,0	7,5	12,5	18,5

Tabelle 6. Im Versuch ermittelte Richtwerte für Mindest-Zugkräfte für Schließringbolzensysteme größerer Abmessungen
(Experimental minimum Tensile Load values of large diameter Lockbolts).

Werkstoff der Bolzen	R_m / τ [MPa]	Mindest-Zugkraft [kN] (gemessen)				
		Ø SRB 12,7 mm	Ø SRB 15,9 mm	Ø SRB 19,0 mm	Ø SRB 22,2 mm	Ø SRB 25,4 mm
Stahl	800 / 530	75	120	175	245	320

Tabelle 7. Im Versuch ermittelte Richtwerte für Mindest-Klemmkräfte für Schließringbolzensysteme unterschiedlicher Durchmesser *(Experimental minimum Clamp Load values of Lockbolts with various diameters).*

Werkstoff der Bolzen	R_m / τ [MPa]	Mindest-Klemmkraft [kN] (gemessen)			
		Ø SRB 4,8 mm	Ø SRB 6,4 mm	Ø SRB 8 mm	Ø SRB 9,6 mm
Stahl	800 / 530	4,5	10,0	18,6	26,6
Stahlqualität A2	500 / 400	4,5	8,0	12,5	17,5
Aluminium	420 / 240	2,0	4,0	6,5	9,5

Tabelle 8. Im Versuch ermittelte Richtwerte für Mindest-Klemmkräfte für Schließringbolzensysteme größerer Abmessungen *(Experimental minimum Clamp Load values of large diameter Lockbolts).*

Werkstoff der Bolzen	R_m / τ [MPa]	Mindest-Klemmkraft [kN] (gemessen)				
		Ø SRB 12,7 mm	Ø SRB 15,9 mm	Ø SRB 19,0 mm	Ø SRB 22,2 mm	Ø SRB 25,4 mm
Stahl	800 / 530	53 kN	85 kN	126 kN	174 kN	228 kN

5.3 Required functions of the joint

Form-fit blind rivet and (lock) bolt joints shall be both form- and force-fit, possessing superior properties, particularly when subjected to cyclic alternating loads with larger amplitudes. When subjected to quasi-static shear loads, the joints shall not show any slipping of the components, see **Figure XX,** and the yield limit **$Rp_{0.2}$** shall be 2 to approx. 6 times higher than the load at which slipping occurs in the case of conventional rivets and (lock) bolts. The degree of improvement shall increase with the strength of the coupon material. The rivets and (lock) bolts should allow the production of form-fit joints when clearance holes with tolerances as specified for state of the art rivets are used. Larger tolerances may be possible and will depend on the application. Form-fit rivets and (lock) bolts shall ensure positive locking play-free joints with a significantly longer fatigue life.

5.4 Failure criterion

Joints shall be considered as having failed when slipping or permanent setting occurs.

6. Qualification of joining procedures

6.1 General

The manufacturer shall prepare a preliminary *Specification and qualification of testing procedures" (pSQTP)* and shall ensure that it is applicable for the actual production, using experience from previous productions and the general fund of knowledge of joining technology.
A pWPS shall be used as the basis for establishing a joining procedure qualification record (JPQR) to be tested according to one of the methods listed in Clause 6 (Joining procedure test) or Clause 7 (pre-production Joining test). The rivet or (lock)bolt joint for which the joining procedure will be used in production shall be represented by making a standardized test piece or pieces, as specified in 6.2. Where the production/joint geometry requirements do not represent the standardized test pieces as shown in 6.2, the use of Clause 7 shall be required.

NOTE For some applications, it may be necessary to supplement or reduce the list.

A joining procedure specification (JPS) covers a certain range of material thickness and also covers a range of parent materials.

Ranges and tolerances, according to the relevant standard (see Clause 2) and to the manufacturer's experience, shall be specified where appropriate.

6.1 Geometry of the test specimens

The dimensions of the specimens shall be as follows:

Coupon width b_t: 8 x **d**
Overlap a: 6 x **d**

Where **d** is the nominal diameter of the rivet or (lock)bolt

Length of single coupon l_E: ≥120mm

Minimum length of the clamped area: ≥50mm.
Specimen length between grips l_g : *3 x a*

These dimensions for the specimen width and the overlap have been specified to ensure that strength data generated is usable for design purposes. Smaller widths and overlap could result in lower values and thus give misleading information.
Shorter coupons may be used depending on the clamps of the testing equipment. The specimen length between the clamps shall not be changed.

6.2 Recommended geometry of rivets

The diameters and gripping range of the blind rivets and (lock) bolts shall be selected in accordance with the demands of the application. The standard dimensions are given in Annex A.

1. Nominal diameters of the rivets remain unchanged, see **Table 1 ISO 15 979**
2. Wall thickness of shank or sleeve t_S ≥ 0.3mm; limited by the length of shank and the formability of the sleeve material
3. Distance of break neck groove from bottom of head: $\mathbf{l_{BN} = 2t_S =+l_G +k}$ where
   - $\mathbf{t_S}$ = wall thickness of shank or sleeve
   - $\mathbf{l_G}$ = Grip length
   - **k** = Head height

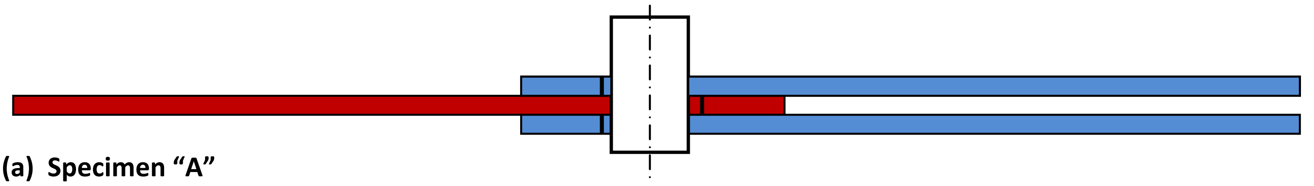
4. Mandrel or bolt diameter $\mathbf{d_m}$[1] ≤ (**d** - 0.6)mm; larger mandrel diameters are possible and must be agreed upon between manufacturer and user
5. Mandrel type: Structural[2], positive lock, flush break mandrel
6. Mandrel type: multi-grip[2], positive lock type, flush break mandrel

[1]**Note** The diameters of the mandrels of form-fit rivets are generally larger than those of conventional rivets, because form-fit rivets, unlike conventional rivets, rely on both form-fit and force-fit for the transmission of shear loads. Conventional rivets primarily depend on the clamping force generated by the sleeve or shank for the transmission of loads. Force-fit is not a property associated with state of the art blind rivet joints.

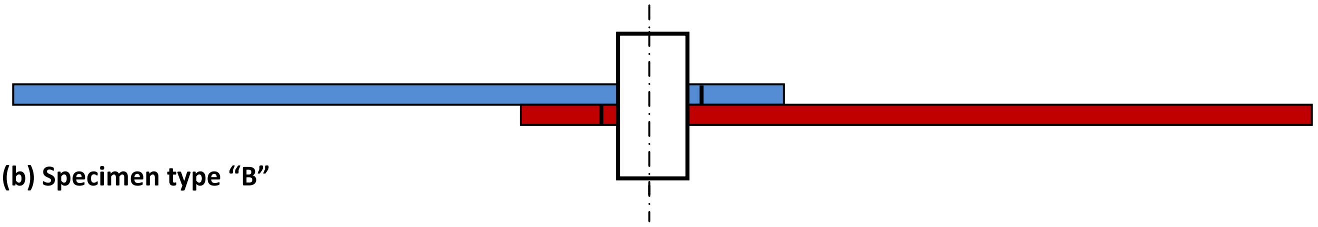
[2]**Note** All form-fit rivets and (lock) bolts are essentially suitable for structural applications

6.3 Selection of the test specimens

The verification of form-fit or positive locking in joints shall be carried out using lap shear specimens subjected to shear loads. Specimen type "A" should be given preference over specimen type "B" where possible. Exceptions may be made in the case of rivet and (lock) bolts with small grip ranges.



(a) Specimen "A"



(b) Specimen type "B"

Figure XX: Geometry of the single shear and two-shear lap specimens

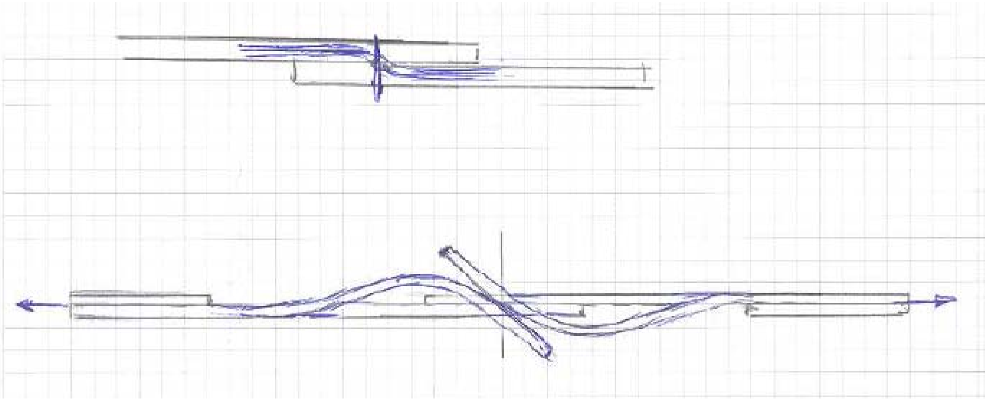


Figure YY: Schematic illustration of the deformation of a single shear lap specimen under tensile load

The reason for giving preference to specimen type “A” is to be seen in **Figure “YY”.** Due to the change in direction of the force, the specimen is deformed in the manner shown above, so that the fastener experiences both a shear and a cross tension load. Due to the deformation of the specimen, the slipping in the joint itself is more difficult to observe.

Since the purpose of this test is to evaluate the properties of the joint, it is recommended that specimen type “A” is used for these tests, because due to the much smaller deformation of the coupons of the specimen, it is much easier to observe the load at which slipping occurs.

6.4 Preparation of the test specimens

Drill holes in the specimens at the centre of the overlapping area using a drill with the maximum permissible diameter as given in **Table X, “clearance hole diameters”**.

Table X

Table 2 — Clearance hole diameters

Dimensions in millimetres

d nom.	d_m min.	d_m max.
2,4	2,5	2,6
3	3,1	3,2
3,2	3,3	3,4
4	4,1	4,2
4,8	4,9	5,0
5	5,1	5,2
6	6,1	6,2
6,4	6,5	6,6

Non-conformance to the values listed in Table 2 may result in assembly difficulties and/or reduction in the shear and tensile loads specified in Table 3.

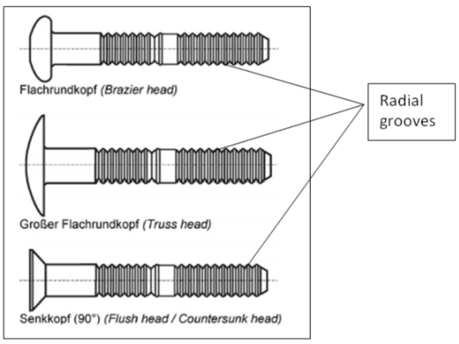


Figure ZZZ: Experimental clamping loads of large diameter lock bolts

All coupons of a specimen shall be drilled in one clamping. The use of suitable templates as well as the de-burring of the holes is recommended. In the case of holes with a diameter larger than 5mm, the holes shall be drilled in at least three steps, the diameter of the last but one drill not being smaller than 0.5mm of the final diameter.

When joining the specimen, position the coupons as shown in **Figure "XX".** Insert the rivet or (lock) bolt through the drilled holes and apply a low force opposing the direction of the force applied during the test, so that the walls of the work piece hole are in contact on opposing sides of the shank/sleeve, see **Figure XX**. Apply adhesive tape to fix the coupons in this position and set the rivet or (lock) bolt using the equipment specified by the rivet manufacturer.

Due to their hole-fill properties, suitable rivets and (lock) bolts for making form-fit joints will, when bridging the existing gaps, automatically "centre" themselves in the holes and easily overcome the resistance posed by the adhesive tape.

Gaps between rivet shank and hole, as specified for state of the art blind rivets, can be bridged with standard form-fit blind rivets and (lock) bolts. The diameters of the holes in the specimens shall be in accordance with the clearance hole diameters given in **Table 2.** Improved gap bridging and load carrying properties will generally be possible and depend on the substrate materials and thicknesses. In the case of such requirements, the selection of the appropriate form-fit rivet should be made in close collaboration with the rivet manufacturer. It is recommended to perform corresponding qualifying tests.

Clearance hole diameter = dN + $^{+0.2}_{+0.1}$

Note The mandrel shaft may be smooth or have radial grooves in order to be able to exert higher pulling forces. At least a part of the mandrel shaft, between the break neck and the head, will have a diameter larger than the core diameter.

6.5 Equipment for the joining

In most cases, standard setting equipment may be used. In special cases, the recommendations of the rivet manufacturer should be followed.

6.5 Joining procedure/ Joining processes

6.5.1 Blind rivets

6.5.1.1 Setting operation – state of the art blind rivets

During the setting operation, the blind rivet is inserted into the common hole in the specimen, the rivet body coming to bear on the accessible sheet surface. The specimen is prepared as specified under **§6.4.** The mandrel is inserted into the nose piece of the setting tool which applies a pulling force to it. The mandrel head is pulled into the rivet sleeve, expanding it and at the same time clamping the sheets together. The setting force increases with the pulling action till such time that the mandrel fractures at the neck breaker and the broken off mandrel is disposed of. The setting operation is completed.

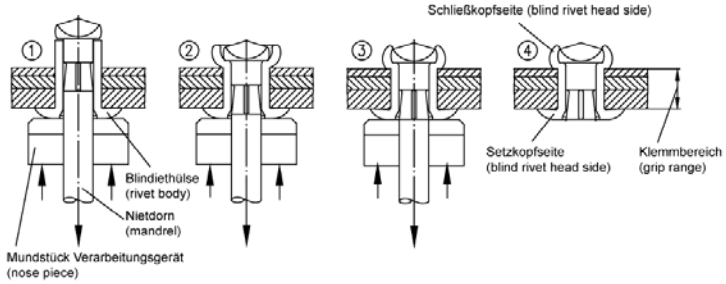


Figure ZZZ: Blind rivet setting operation (3rd picture: rivet head visible side)

6.5.1.2 Setting operation - Form-fit blind rivets

Form-fit rivets employ a mandrel, a part of which, adjacent to the head, has an interference fit with the inner diameter of the body of the shank or sleeve. During the setting operation, the mandrel is drawn through the bore in the body of the rivet, radially expanding the rivet shank or sleeve and thus positively bridging the existing gaps between shank and component bore/holes. On making contact with the walls of the work piece holes, provision must be made for “surplus” or “excess” material to be displaced without the setting force exceeding preset limits and thus prematurely fracturing the mandrel at the break neck the location of which is approximately flush with the rivet head on the visible side. The broken off mandrel id disposed of in the conventional manner.

The bolt or mandrel may be secured or retained, in addition, by any measure(s) according to the state of the art.

6.5.2 (Lock) bolts

6.5.2.1 Setting operation – conventional lock bolts

During the setting operation, the mandrel of the lock bolt is inserted into the common hole in the specimen and the lock nut, if applicable, slipped over the opposite end of the mandrel. The nose piece of the setting tool grips the grooved portion of the mandrel and applies a pulling force, so that the mandrel is drawn into the bore hole in the specimen, clamping the sheets of the specimen with a high clamping force. When the force is high enough, the mandrel suffers elastic elongation, the nose piece forcing the material of the lock nut to flow into the grooves of the mandrel shaft. When the pulling force is high enough, the mandrel fractures at the break neck and the setting operation is completed.

6.5.2.2 Setting operation – form fit (lock) bolts

The setting operation of form-fit (lock) bolts is similar to that of conventional lock bolts. In the case of form-fit (lock) bolts, a section of the mandrel shaft, adjacent to the mandrel head an interference fit with the holes in the specimen. When the mandrel is drawn into the hole in the specimen, the interference fit section of the mandrel displaces “surplus” specimen material. The design of the mandrel is such, that the setting operation can be completed, ensuring a form- and force fit joint, without the mandrel prematurely fracturing at the break neck due to excessive force requirements. The use of a lock nut is not mandatory in the case of form-fit (lock) bolts because the mandrel is retained in the specimen through form- and force fit. However, any state of the art methods for retaining or securing the mandrel and exercising high clamping loads may be applied.

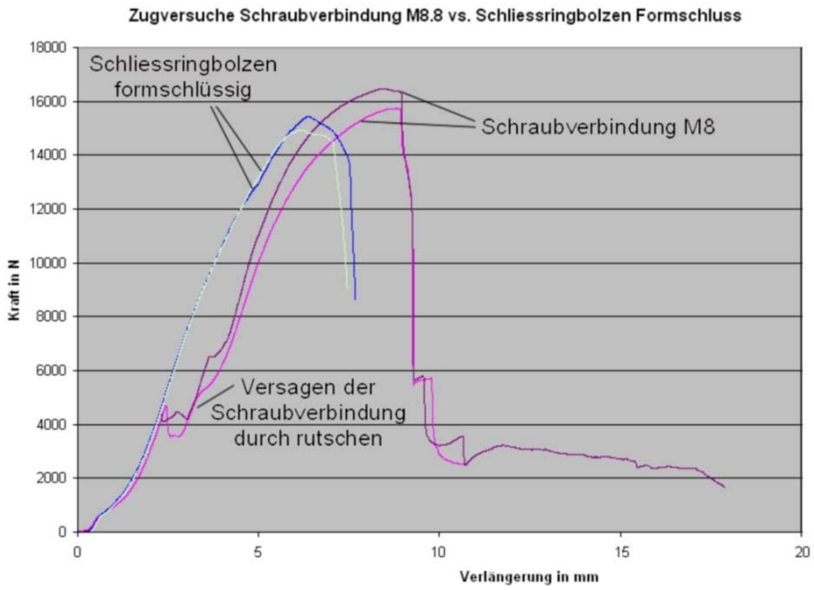
7. Qualification of joints

7.1 Type of tests

Only tests in which the joint experiences a shear or a tensile shear load will be specified, because the existence of gaps, between the rivet and the work piece hole, will readily be noticed under these types of loads.

7.2 Tensile shear tests

Perform a tensile shear test with the specimen as prepared above and record the force vs. displacement diagram. Joints made with form-fit rivets and (lock) bolts shall show no setting or relative movements of the coupons. The occurrence of slipping is shown in the force vs. displacement diagram by an increase in the displacement, without a corresponding increase in force, or by a sudden drop in force followed by an increase in displacement, without reaching the previous level of force, immediately, **see Figure Y.** Typical force vs. displacement diagrams of riveted or (lock) bolt joints with gaps are shown in **Figure Y.**



(New figure: s with results of tensile shear tests of state of the art riveted specimens)

7.3 Fatigue tests under quasi-static and cyclic loads

7.3.1 Quasi-static load test

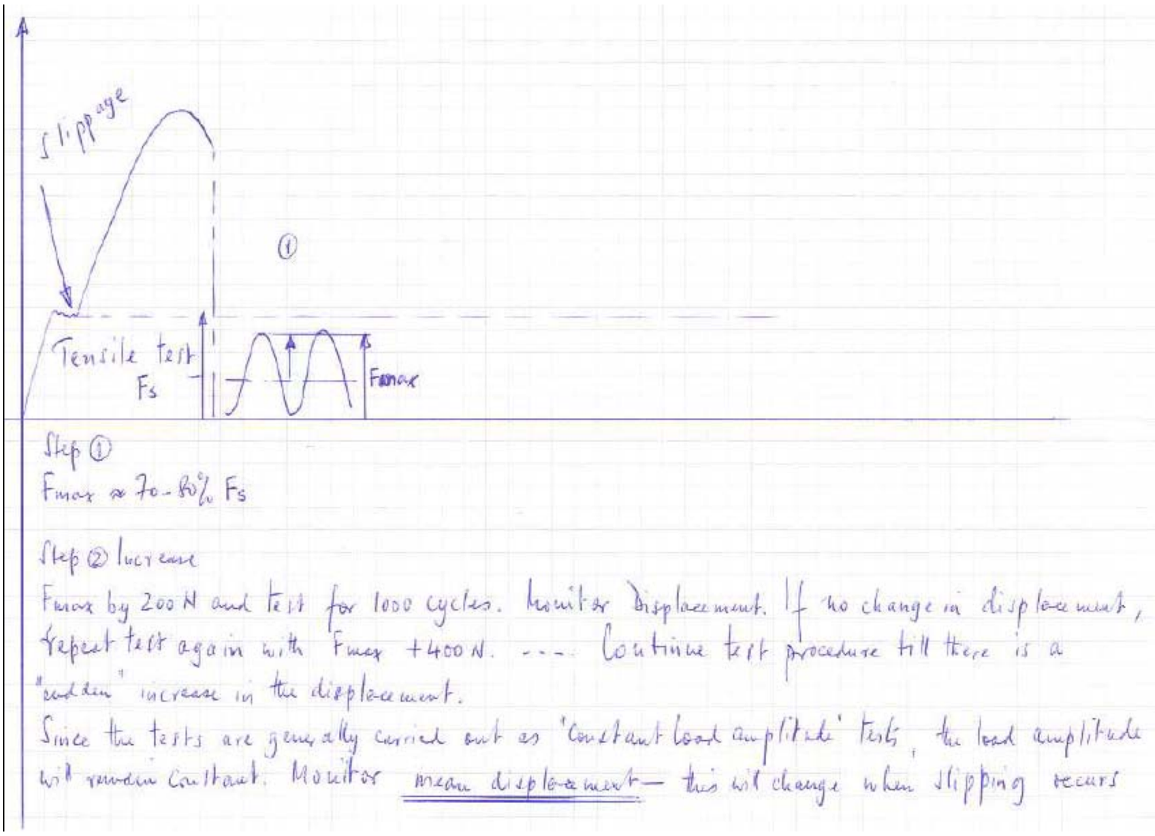


Figure X: Static loading – Step 1/Cyclic loading Step - 2

Force vs. displacement diagram of a tensile shear test specimen showing the occurrence of slipping and a cyclic load in which the maximum load $\mathbf{F_{max}}$ is lower than the slipping load.

Explanatory text for the above diagrams:

Step 1
Perform quasi-static tensile shear test with the preferred specimen and note slipping load F_S.

7.3.2 Cyclic load tests

Step 2 (See above diagram)
Using a new specimen, apply a cyclic load such that $\mathbf{F_{max}}$ is 70% of the slipping load F_S.
Test the specimen for 1000cycles. If no slipping is registered, repeat test with $\mathbf{F_{max}}$ +200N and repeat test again for 1000 cycles. If no slipping is registered, repeat test till such time that slipping occurs within 1000 cycles. Note the test data, including $\mathbf{F_{max}}$, $\mathbf{F_a}$ and the number of load cycles at which failure occurred.
The test shall be repeated with at least three test specimens. If the variation in the results is greater than 5% of the mean value, then the minimum number of specimens to be tested shall greater than 7.

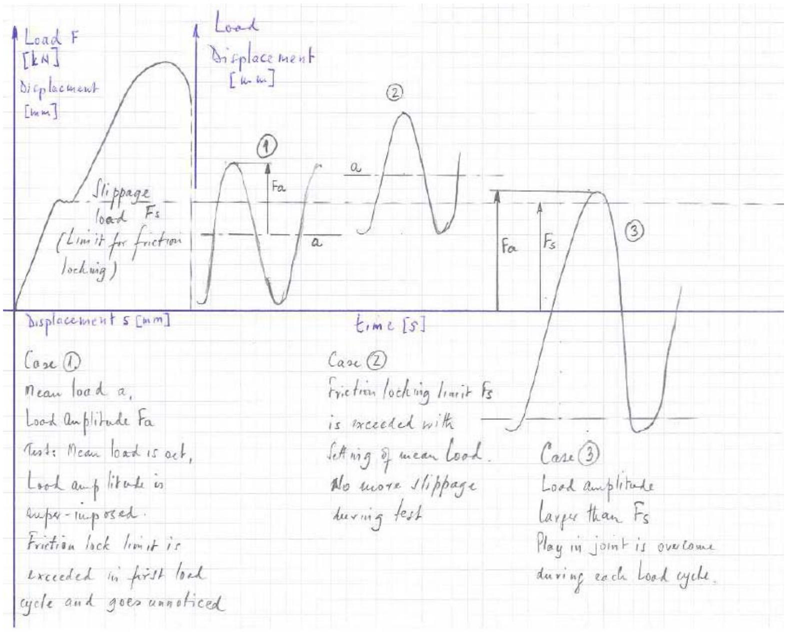


Figure Y: Cyclic loading

Case 1: Load Ratio R = 0.1
Mean load: $\mathbf{F_m}$
Load amplitude: $\mathbf{F_a}$

Test:
Mean load is applied and then the load amplitude is super-imposed.
During the actual cyclic test, the friction load level $\mathbf{F_s}$ is exceeded in the first load cycle and goes unnoticed.

Case 2: Load ratio = 0.6
Friction locking limit is exceeded during the application of the mean load $\mathbf{F_m}$.
During the cyclic test no further slipping is registered and is therefore not registered

Case 3: R = -1
The load amplitude $\mathbf{F_a}$ is greater than the slipping load $\mathbf{F_s}$
Play is overcome in each load cycle, because both the negative $\mathbf{F_a}$ and the positive load amplitudes **($-\mathbf{F_a}$; $+\mathbf{F_a}$)** are greater than the slipping load $\mathbf{F_s}$.

If a magnetically actuated resonance type testing machine is used for the tests, the test will generally be terminated by the machine, because the controls cannot ensure constant load amplitudes when slipping occurs.

If servo-hydraulic or mechanically actuated testing machines are used, the test will not be terminated automatically if slipping occurs. This will however be accompanied by an excessive noise level which will increase rapidly.

In order to obtain universally applicable test results, independent of the type of testing equipment, the use of a failure criterion applicable on all types of testing equipment is recommended, e. g. stiffness loss which shows a very good correlation with the deterioration of the integrity of the joint during testing.

7.4 Metallographic investigation / Macro- and micro etching tests

The form-fit characteristics of blind rivet and (lock) bolt joints can be ascertained with macrographs of cross-sections of such joints. Towards this purpose sections, normal to the rivet axis, shall be made 0.5mm from the faying surface or in the middle of the sheet thickness, whichever is smaller. The sections shall show that there is no radial play between the components of the rivet and the work piece hole. Typical examples are shown in the figures below.

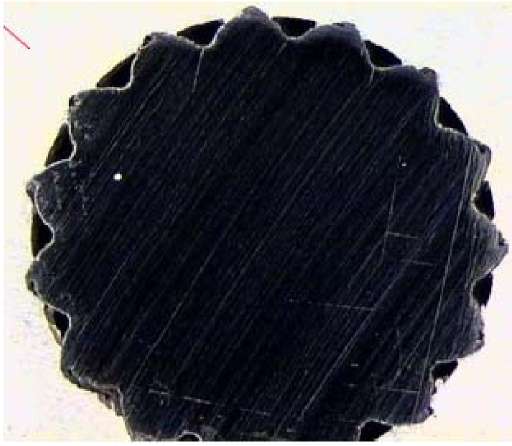



Figure ZZZ: Macro-sections of a blind rivet joint and a (lock)bolt joint with typical form-fit characteristics. Note that inspite of the presence of gaps, there is no radial play between the components.

7.5 Evaluation of test results

The evaluation of the tests shall consider the results of the quasi-static tests, noting the yield force and the maximum force, the results of the cyclic tests noting the material specific endurance strength, the slope of the F –N curve and the scatter in the results and the failure criterion applied.

8. Bibliography

Annex A (Normative)

Joining procedure qualification record / Record of test results

Materials
Thicknesses
Specimen dimensions
Rivet type
Dimensions
Designation
Manufacturer
Hole dimensions and specimen preparation
Type of test
Testing machine
Data acquisition: transducer resolution etc.
Test frequency
Failure criterion
Testing conditions: Temperature, humidity etc.
……
……
……..

ANNEX B (Normative)

Recommended geometry of rivets for mechanical joining

. . . .

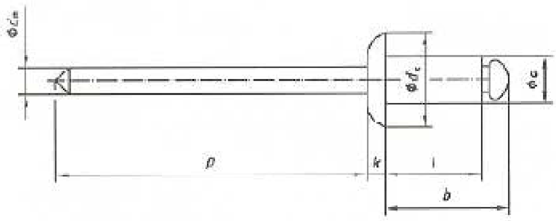


Figure 1 — Rivet dimensions

Table 1 — Rivet dimensions

Dimensions in millimetres

Rivet body	d	nom.	2,4	3	3,2	4	4,8	5	6	6,4
		max.	2,48	3,08	3,28	4,08	4,88	5,08	6,08	6,48
		min.	2,25	2,85	3,05	3,85	4,65	4,85	5,85	6,25
	d_k	max.	5,0	6,3	6,7	8,4	10,1	10,5	12,6	13,4
		min.	4,2	5,4	5,9	6,9	8,3	8,7	10,8	11,6
	k	max.	1	1,3	1,3	1,7	2	2,1	2,5	2,7
Mandrel	d_m	max.	1,5	2,15	2,15	2,8	3,5	3,5	3,4	4
	p	min.	25	25	25	27	27	27	27	27
Blind length	b	max.	$l_{max} + 3,5$	$l_{max} + 3,5$	$l_{max} + 4$	$l_{max} + 4$	$l_{max} + 4,5$	$l_{max} + 4,5$	$l_{max} + 5$	$l_{max} + 5,5$
Rivet length l[b] nom. = min.		max.	Recommended grip ranges[a]							
6		7	0,5 to 3,5	0,5 to 3,0		1 to 3	—		—	—
8		9	3,5 to 5,5	3 to 5		3 to 5	2,5 to 4,0		—	—
10		11	—	5,0 to 6,5		5,0 to 6,5	4 to 6		3 to 4	3 to 4
12		13	5,5 to 9,5	6,5 to 8,0		6,5 to 9,0	6 to 8		4 to 6	4 to 6
16		17	—	8 to 12		9 to 12	8 to 11		6 to 10	6 to 9
20		21	—	12 to 16		12 to 16	11 to 15		10 to 14	9 to 13
25		26	—	—		—	15,0 to 19,5		14 to 19	13 to 19
30		31	—	—		16 to 25	19,5 to 25,0		19 to 24	19 to 24

NOTE The rivet body dimensions are generated from the design formula as specified in annex A.

[a] The grip ranges of rivets with dimensions as given in Table 1, with the material combination as given in clause 4, are specified by the minimum and maximum grip lengths. The minimum grip lengths are given as a recommendation only. It may be possible to go into individual cases below the minimum values.

[b] Nominal lengths greater than 30 mm shall be specified in 5 mm increments. For availability and grip range refer to manufacturer.

Note Depending on the design of the rivet, the dimension "b" can vary and will in some cases be larger

Table YYY
Experimental clamping loads of lock bolts with various diameters

Werkstoff der Bolzen	R_m / τ [MPa]	Mindest-Klemmkraft [kN] (gemessen)			
		Ø SRB 4,8 mm	Ø SRB 6,4 mm	Ø SRB 8 mm	Ø SRB 9,6 mm
Stahl	800 / 530	4,5	10,0	18,6	26,6
Stahlqualität A2	500 / 400	4,5	8,0	12,5	17,5
Aluminium	420 / 240	2,0	4,0	6,5	9,5

Tabelle 8. Im Versuch ermittelte Richtwerte für Mindest-Klemmkräfte für Schließringbolzensysteme größerer Abmessungen
(Experimental minimum Clamp Load values of large diameter Lockbolts).

Werkstoff der Bolzen	R_m / τ [MPa]	Mindest-Klemmkraft [kN] (gemessen)				
		Ø SRB 12,7 mm	Ø SRB 15,9 mm	Ø SRB 19,0 mm	Ø SRB 22,2 mm	Ø SRB 25,4 mm
Stahl	800 / 530	53 kN	85 kN	126 kN	174 kN	228 kN