Fundamentals
M7
MAINTENANCE PRACTICES

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M7.8
Riveting

EASA Part-66
CAT B1

Training Manual

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M7 MAINTENANCE PRACTICES

M7.8 RIVETING

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RIVETED JOINTS, RIVET SPACING AND PITCH

Riveted Joints

Introduction

Aircraft structure consists of various components manufactured separately and subsequently joined together. Commonly used are adhesive, weld, screw and rivet joints.

Since rivet joints are non-detachable, generally structural parts are connected with this method, which do not have to be detached during maintenance.

The material type, the material thickness of the parts that are going to be connected and the sheer strength of the rivet itself affect the selection of the rivet.

Design of riveted joints

Rivet joints are designed in such a way that a single rivet can not fail by fatigue in normal flight operation. This means that during dynamic loads fatigue always first affects the structural element.

The fatigue resistance of a rivet joint depends on the distance between the rivets and on the number of rivet rows.

In a two-row lap joint every row carries 50% of the load.

In a three-row joint the outer rows are stressed with 40% and the inner row is stressed with only 20% of the load.

Types of riveted Joints

Lap Joint

The structural parts that are joined, e.g. two skin panels, overlap each other and are joined together with a minimum of two or normally three-rivet rows.

This is a single shear connection since the rivet is only stressed with shear in a single location.

Butt Joint

The two elements, like e.g. two fuselage sections, are connected with an inner lug and two- to four-row rivet joints per side. Also this connection is single shear due to the already described reasons.

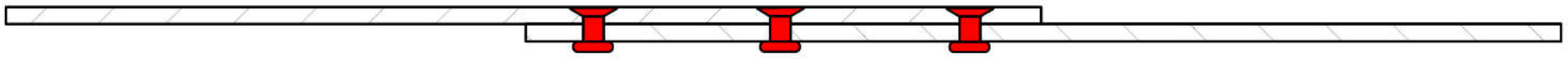
Overlapped/lugged two-shear connection

Looking at the strength of a connection, a two-shear connection is preferable to a single shear connection. Here e.g. the butt joint is reinforced outside with a second lug.

However, this technique increases the weight of a connection and decreases the aerodynamic efficiency. So the designer often does not choose this variant but leave it open for possible repairs.

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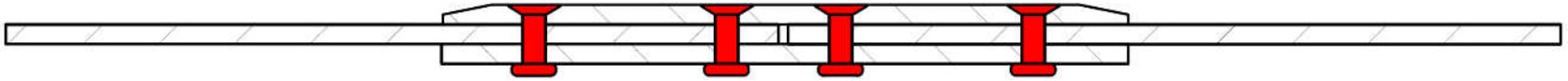
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Lap Joint, single shear



Butt Joint, single shear



Butt Joint, double shear (repair solution)

Figure 1 Riveted Joints

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Rivet Selection

General

The rivet selection regarding to material, head and diameter is influenced by factors like e.g.:

- Material type of the to be connected elements
- Installation location of the component
- Amount of transmitted loads
- Material thickness of the structural element.

Rivet Diameter

The rivet diameter depends on the minimum thickness of the connected elements. Generally a rivet diameter of 2,5–4 times the thinnest sheet thickness is selected.

The margins between rivets and to the element's edge have high influence on the fatigue strength of the rivet joint. For this reason it is important to follow the minimum and/or maximum margins of the rivet defined in SRM Chapter 51.

Rivet spacing and pitch

Edge Margin/Edge Distance

The bolt and pin hole edge distance values are from the center of one fastener hole to the nearest edge of the component. The minimum or maximum distance does not only depend on the rivet diameter but additionally on the rivet type itself. For a solid rivet the edge distance is normally 2–2,5 times the rivet diameter.

Annotation: Edge Margin/Edge Distance

The application of the denominations Edge Margin and Edge Distance depends on the aircraft manufacturer.

Airbus uses the denomination **Edge Distance** for the distance between rivet center and the element's edge.

Boeing uses the denomination **Edge Margin** for the distance between the rivet center and the element's edge. **Edge Distance** describes the distance between the fastener hole wall and the edge of the component.

Spacing or Row Spacing

Spacing is the distance between fastener rows, taken from the hole centers. Use 4 to 5 D as a rule of thumb.

Pitch

The bolt and pin hole pitch values are from the center of one fastener hole to the center of the next fastener hole in a row and are quoted in terms of the fastener nominal shank diameter 'D'. Generally the pitch is 4–5 times the rivet diameter.

ATTENTION: Consider that for the installation of countersunk head rivets special margins (Edge Margin, Pitch u. Spacing) in accordance with the manufacturer and the SRM do exist, which have to be followed implicitly. Generally the described „rules of thumb" **are only** guide values. **The instructions in the SRM have absolute priority!**

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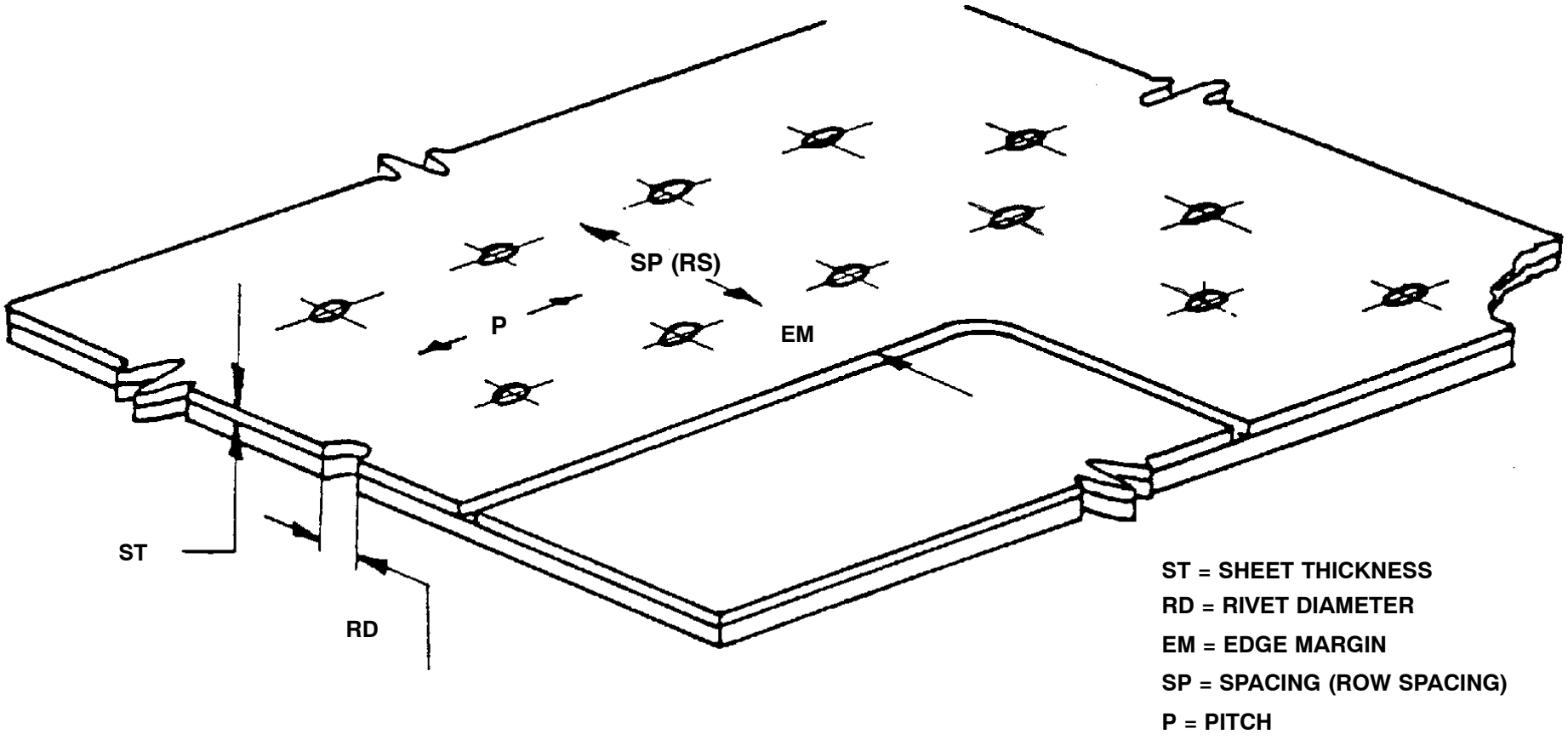


Figure 2 Fastener Spacing

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Rivet Length

For a correct rivet joint it is necessary to determine the right rivet length. This can be estimated with the thickness of the parts that have to be connected, and a so called rivet length allowance.

The rivet length allowance is needed for forming the rivet with the desired tolerances of the manufacturer (Airbus or Boeing).

The allowance depends on the rivet material. That means that rivets made out of soft material (e.g. AA 2117) are more deformed than rivets out of hard material (e.g. AA 2017). Therefore a larger allowance is needed.

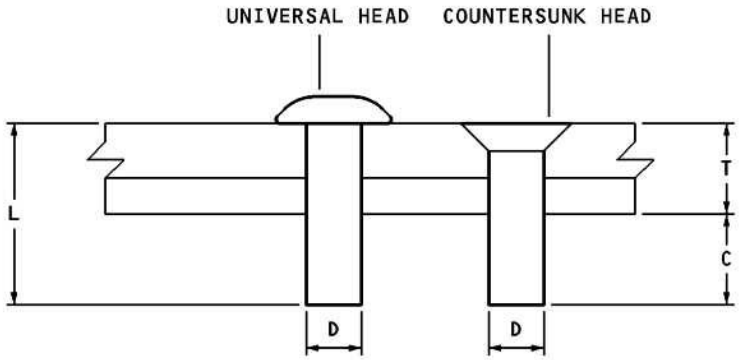
The allowances given in the SRM are recommendations, which have to be possibly adjusted in practice.

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NOTE: TO FIND THE REQUIRED RIVET LENGTH (L),MEASURE THE TOTAL THICKNESS OF THE MATERIALS (T),ADD TO THIS THE REQUIRED PROTRUSION (C)(GIVEN IN THE APPLICABLE TABLE).THIS THEORETICAL LENGTH CAN BE ADJUSTED AS FOLLOWS:

- FOR ALUMINUM ALLOY RIVETS USE THE NEXT SHORTER OR LONGER STANDARD LENGTH RIVET.
- FOR MONEL OR TITANIUM RIVETS USE THE NEXT LONGER STANDARD LENGTH RIVET.

Data to find the necessary Length of Rivets

Rivet Nominal Dia. (D)		Rivet Protrusion (C)	
mm	in.	mm	in.
2.4	3/32	3.6	0.141
3.2	1/8	4.8	0.189
4.0	5/32	6.0	0.236
4.8	3/16	7.2	0.283
5.6	7/32	7.3	0.287
6.4	1/4	8.3	0.327
8.0	5/16	10.4	0.409

Data to find the necessary Length of Rivets

NOTE: The above given table is applicable to 2017A, 2024, 2117, 3.1124 and 3.1324 rivets

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Figure 3 Rivet Length Determination

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Upset Head Limits

The forming of the upset head does extensively influence the fatigue resistance of the rivet joint. So it is important to follow the upset head limits given by the manufacturer in the SRM.

Besides the forming of the upset head also the hitting time is important for the later lifetime of the rivet joint. So it is noticed in the Airbus SRM that the forming of the upset head in 3–4 sec. is optimal, but has to be finished not later than 7 sec.

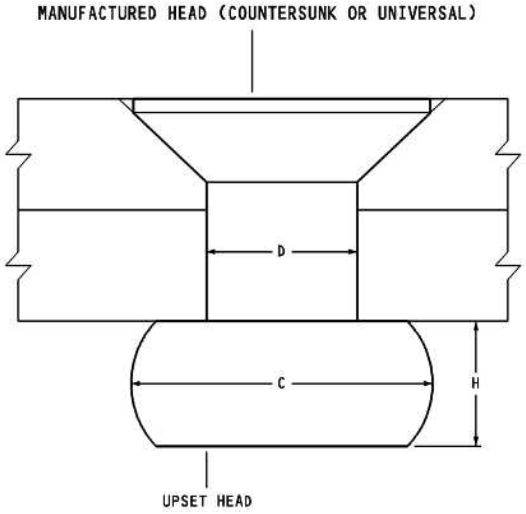
Regardless which riveting method is used (Hand Hammering/Rivet Gun), too light adjusted rivet guns or too light hits during hand riveting can cause cold work hardening, which can result in cracking in the upset head.

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RIVET NOMINAL DIA (D)		RIVET UPSET DIA. (C)		RIVET UPSET HEIGHT (H)			
		MINIMUM		MAXIMUM		MINIMUM	
mm	in.	mm	in.	mm	in.	mm	in.
2.4	3/32 (0.094)	3.8	0.150	1.6	0.063	1.0	0.039
3.2	1/8 (0.126)	5.0	0.197	2.0	0.079	1.3	0.051
4.0	5/32 (0.157)	6.0	0.236	2.4	0.094	1.6	0.063
4.8	3/16 (0.189)	7.3	0.287	2.9	0.114	1.9	0.075
5.6	7/32 (0.219)	8.4	0.331	3.2	0.126	2.2	0.087
6.4	1/4 (0.252)	9.6	0.378	3.8	0.150	2.6	0.102
8.0	5/16 (0.312)	11.8	0.465	4.6	0.181	3.1	0.122

Upset Head Dimensions

NOTE: The above given table is applicable to 2017A, 2024, 2117, 7050, 3.1124 and 3.1324 rivets.

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Figure 4 Upset Head Dimensions

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Riveting Layout

General

The layout in aircraft manufacturing is done in different ways and types. According to the application area the rivets are located parallel or shifted.

Parallel Layout

Preferable the parallel layout is used due to its linear distribution of forces. This type of layout is used in fuselage manufacturing (lap-/butt-joint).

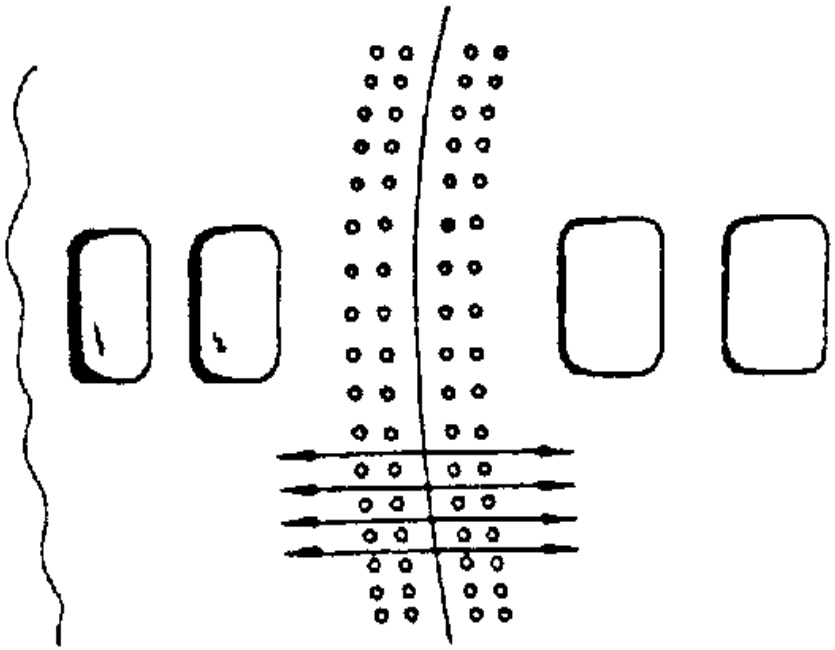
Shifted Layout

In the wing tank area the shifted layout is often used. This is done because of the higher surface pressure (fuel leak tightness) of the shifted layout compared to the parallel layout.

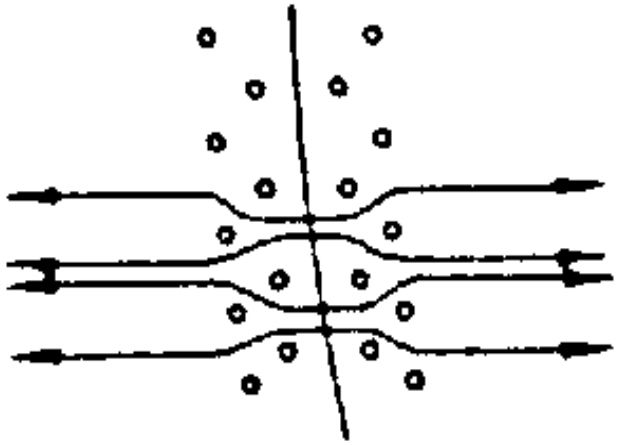
Generally the distribution of stress inside a rivet joint is always critical. Due to these occurring stress peaks around the rivet, it is important to follow the rivet spacing and edge margins defined in the SRM.

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Parallel Layout



Shifted Layout

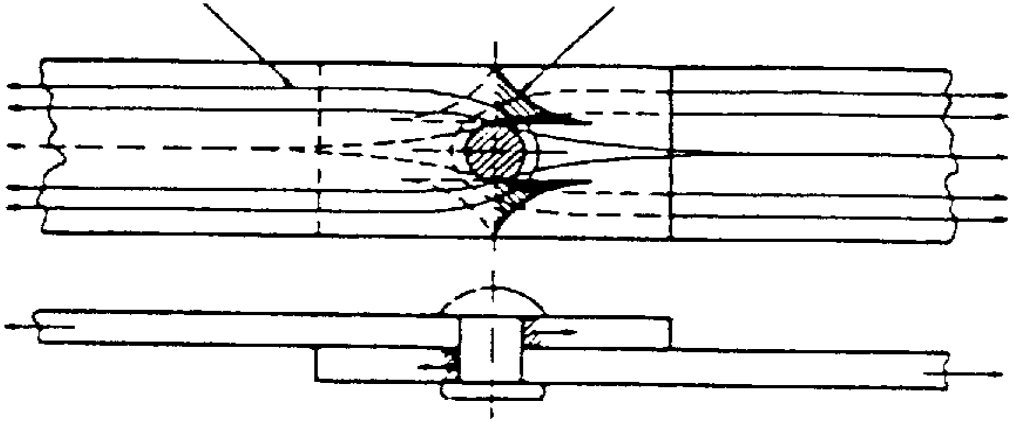


Figure 5 Riveting Layout

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INSPECTION OF RIVETED JOINTS

Installation of a solid Rivet

Drilling of Rivet Hole

To join two structural elements with solid rivets properly, it is necessary to drill holes.

The quality of the hole has a high influence on the lifetime of the rivet joint. It should be perpendicular to the surface and without any scratchings.

The diameter of the hole depends on the diameter of the solid rivet and can generally be found in the SRM (CH 51). As a rule of thumb you can say that the hole should be 0.1 mm larger than the solid rivet diameter.

After marking the positions of the holes on the structural element (only with special lead pen), they are drilled with a suitable driller regarding the above listed points. After that the hole should be deburred on both sides to prevent cracking.

Determination of the Rivet Length

In order to achieve the manufacturer's specifications regarding the upset head diameter and the height, the correct rivet shaft length has to be determined. This consists out of the total material thickness of the structure plus a riveting allowance. This can be found in the SRM (CH 51). Generally it is 1.5 x times the rivet diameter.

Squeezing of the Rivet

After determining the right rivet length, the rivet, if required with sealer, is put into the hole. For forming the rivet normally a rivet gun with a rivet set and a dolly is needed. The selection of the rivet set and also the form and weight of the dolly is done regarding the rivet type and the accessibility of the structural surrounding.

For forming the upset head of the rivet the, concerning the punch, preadjusted rivet gun is put on the die-head of the rivet. The rivet is hold up at the other side with the help of the dolly. It has to be looked for the perpendicularity of the rivet gun and the dolly.

The forming of the upset head is now done according to manufacturer's specifications, that means the punch should be chosen in such a way that the rivet is formed after 3–4 seconds but at last after 7 seconds.

Installation Check

After that the upset head height and diameter are compared with the specifications in the (CH 51) and if necessary corrected. Also the set of the die-head is checked; thereby the specifications in the SRM have to be followed compulsory.

After completion of the work the structural area is checked for foreign objects and all tools are removed. According to SRM now the specified surface protection can be applied.

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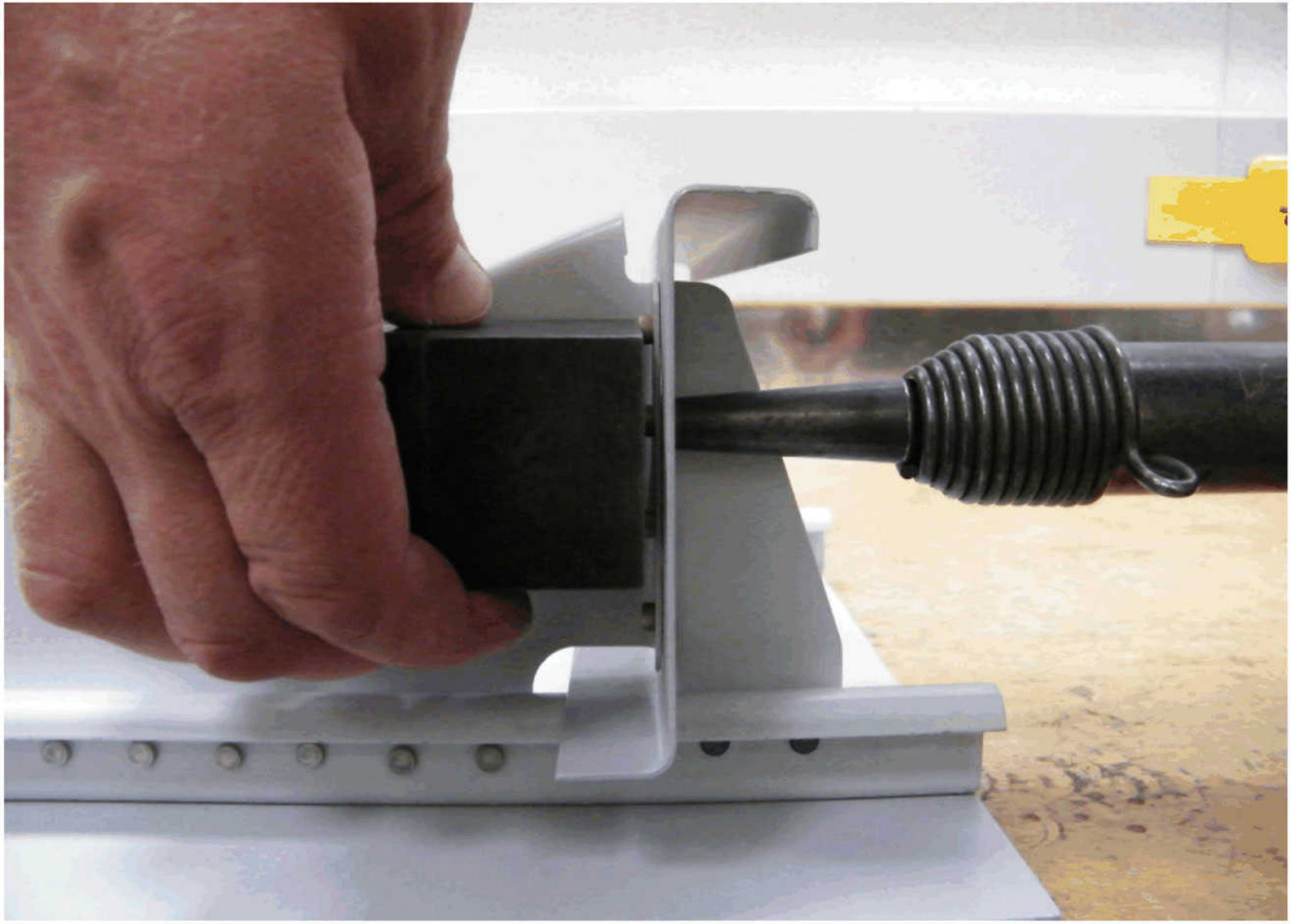


Figure 6 Rivet Installation

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Rivet damages

General

Rivet damages always have an effect on the lifetime of the rivet joint. Only a properly squeezed rivet can meet the high specifications.

Rivet Defects

Besides the upset head dimensions also the correct set of the die-head must be checked.

There can be several rivet damages and some are tolerable (see SRM CH51), others lead to an exchange of the rivet.

Common Defects/Causes

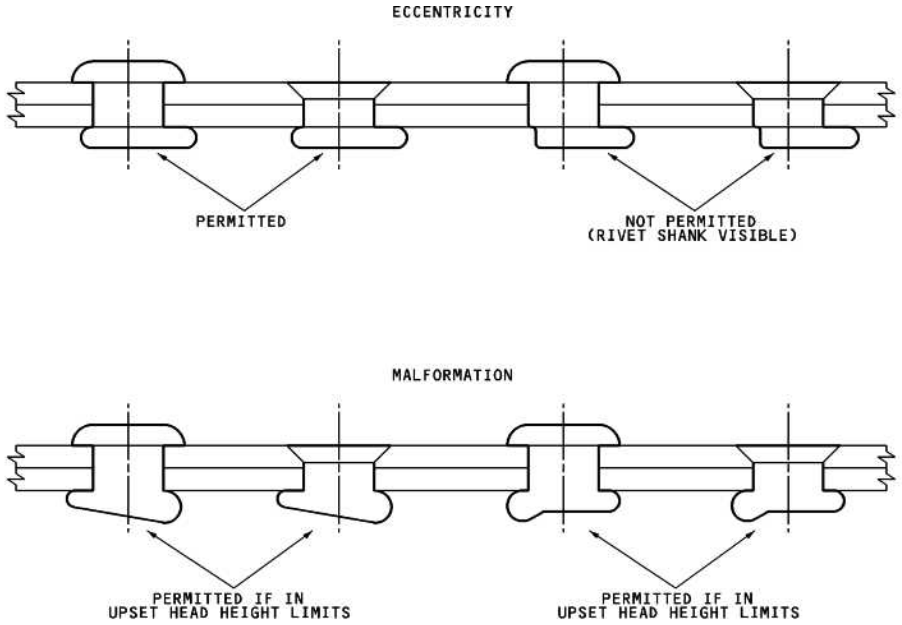
- Too small upset head:
  - too small rivet length;
  - or too large hole for the rivet diameter.
- Too large upset head:
  - too long rivet.
- Die head does no set right:
  - Often a hole or a countersink that is not perpendicular.
- Rivet shaft drops during squeezing:
  - too long rivet;
  - too large hole;
  - dolly contaminated by sealer;
  - or not perpendicular dolly.
- Cracks in upset head:
  - too heavily squeezed rivet;
  - cold work hardening caused by weak punches;
  - missing heat treatment;
  - or false storage of cooled rivets.

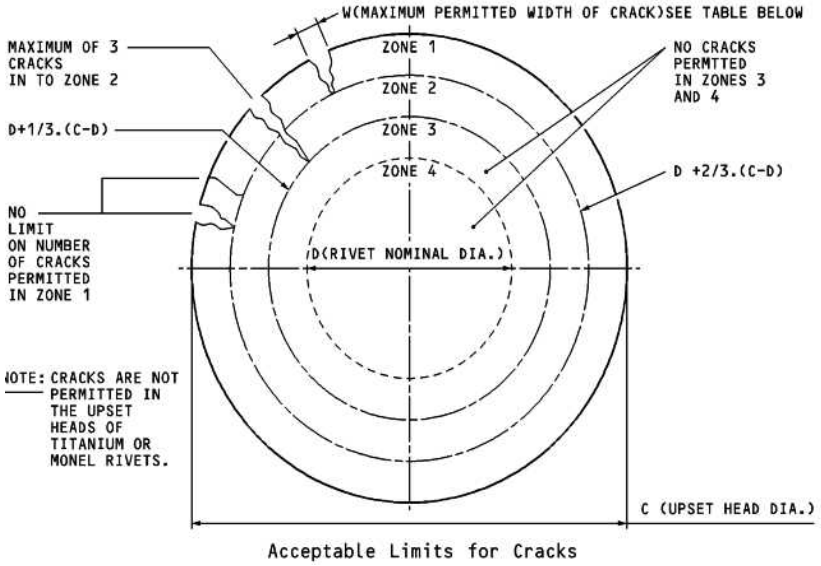
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Acceptable Limits for Cracks

Figure 7 Riveting Defects

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Rivet Removal

General

If defects or failures in rivet joints do occur the particular rivets have to be changed. The drillout of rivets is also necessary if structural parts have to be repaired or changed.

Removal

The removal of rivets is described in SRM chapter 51–40 „Installation and Removal“.

According to the SRM prior of drilling out a universal head rivet a flat surface (Boeing) has to be created at the die-head with a file. Adjacent the head has to be centre punched (Airbus/Boeing) with a punch.

During center punching the rivet has to be supported from the backside with a dolly. Center punching should prevent a movement of the driller.

This procedure is not used in practical work since the movement of the driller can be prevented by the use of a driller which cutting edges have been reduced. If the driller is centred the die-head can firstly be spot bored and then drilled out with a speed that is suitable for the rivet material.

The selected driller diameter is the same as the nominal diameter of the rivet. The drilling depth depends on the die-head height.

After drilling away the die-head it is broken off with a cotter pin driver and the remaining rivet shaft is punched out. The structural element has to be supported with the dolly from the backside.

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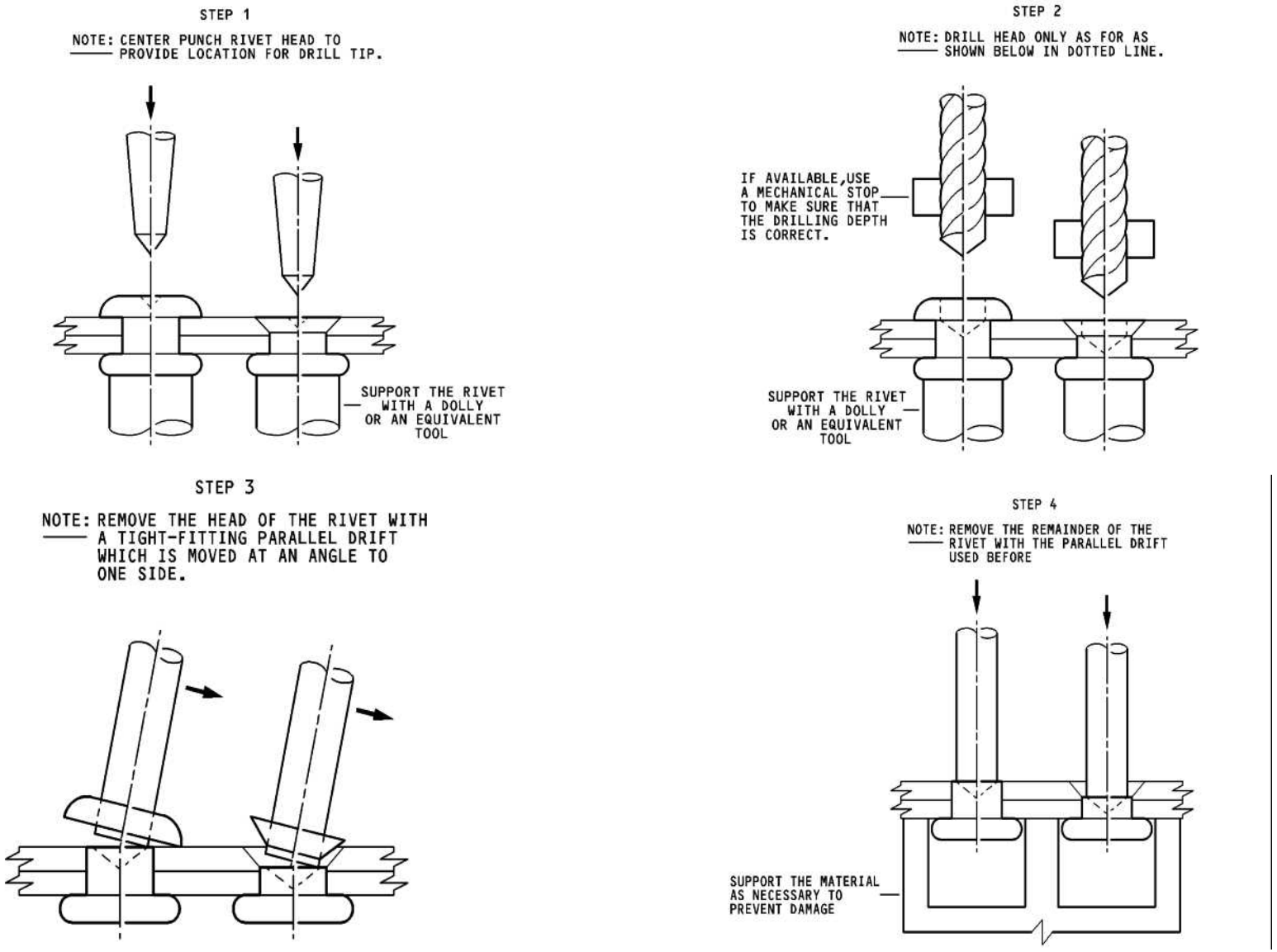


Figure 8 Rivet Removal

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Creation of countersinks

Installation of Flush Head Fastener

Flush head rivets are normally used to create a aerodynamically clean and smooth surface.

During installation into the planking the so called „Aerodynamic Critical Areas“ have to be considered. These are described in subchapter „AERODYNAMICAL SMOOTHNESS“ in CH51 of the SRM and specify the countersink depths for all flush head joints with regard to the application area.

The production of the countersink is done with a three-cutting-edge countersink tool or with a microstop.

Normally a 100 degree countersink is used, but there can be exceptions depending on the fastener.

Countersink Depth

The countersink depth has to be adjusted according to the SRM.

Solid flush head rivets are generally installed with a small positive protrusion of the head, NEVER with a negative protrusion of the head.

A negative protrusion would cause a bad set of the flush head and would decrease the lifetime of the joint heavily.

Knife Edges

Besides the countersink depth also the relation between the flush head height and the material thickness has to be kept in mind.

So called „Knife Edges“ have to be avoided categorically. These can occur if the flush head height is larger than the material thickness of the part.

The countersinking through the whole structural element does weaken the part in the area of the countersink and can lead to cracking. That is why a cylindrical remaining hole (Airbus min. 0,2mm) has always to stay.

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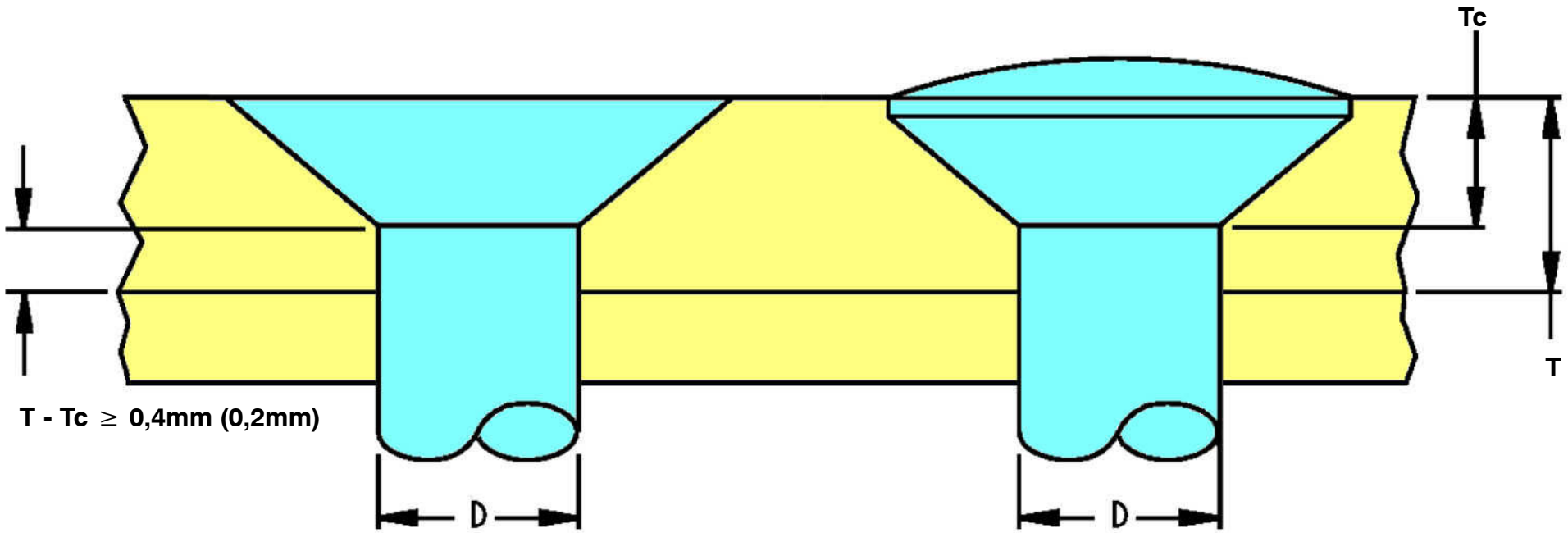


Figure 9 Countersunk Depth

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TOOLS USED FOR RIVETING AND DIMPLING

Tools used for Riveting

Riveting Methods

There are different methods for the installation of rivets. The most common method is the pneumatic rivet gun.

But when you look at the squeezing process, a rivet squeezer has to be preferred since no cold work hardening does occur during forming the upset head.

The usage of a hammer (hand) is a typical basic procedure of riveting. It is not applied in aircraft manufacturing except for a few usages.

Hand Hammering

The riveting by hand with a hammer is a barely used method in aircraft production except for a few applications.

The upset head is formed by direct hits on the rivet shaft end (see riveting methods/direct riveting).

It is important that the hammer hits the rivet shaft parallel to the element's surface.

The forming of the upset head should be done with preferably few but relatively hard hits, to prevent cold work hardening and therefore possible cracking.

This method of riveting is for example used to install rivet nuts on small structural elements with the help of a punch and a directing plate.

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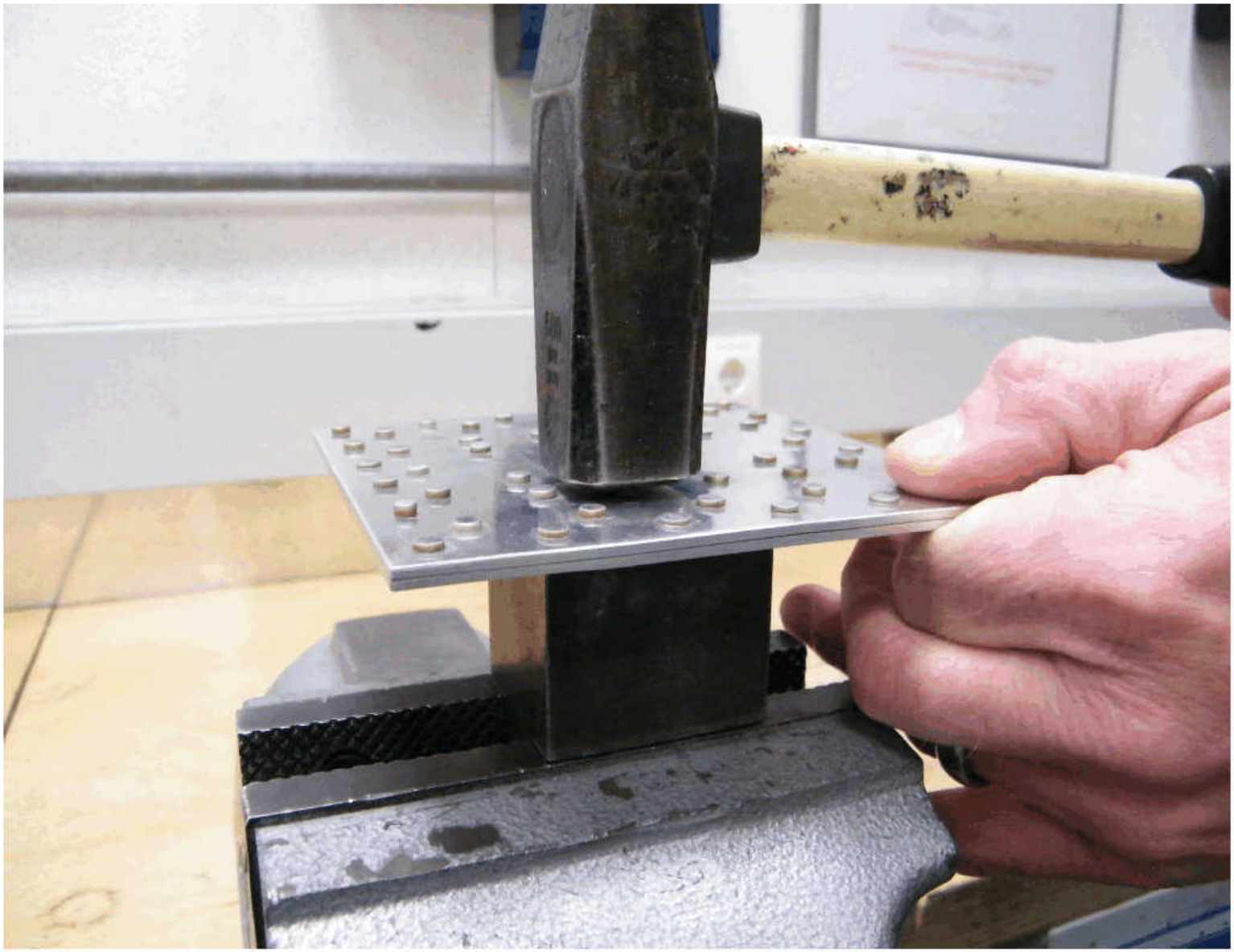


Figure 10 Riveting by Hand

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Gun Riveting (pneumatic)

The rivet gun is operated with compressed air and is available in different sizes and with different punches.

The punch of the power can be adjusted by a controller.

For every rivet diameter and every rivet head type special rivet sets (forming or flat head) are available, which are put into the rivet gun and are clamped with a locking spring.

During riveting it has to be paid attention to apply the riveting gun perpendicular to the part's surface on the upset head and to hold a dolly at the backside of the rivet.

The size and the punch of the rivet gun and the mass of the dolly depend on the rivet diameter, the rivet material and the accessibility of the structure.

Furthermore it has to be assured that the rivet set and the dolly are without any damages since these would be transferred on the upset head during riveting.

Adjustment of the Punch

For adjusting the punch, proceed as follows:

1. set in the rivet set with the safety spring into the rivet gun and lock the feather.
2. Connect the rivet gun to the air source and put it perpendicular on a wooden plate.
3. Slowly pull the trigger entirely and at the same time adjust the punch to the desired level with the controller.

WARNING: FOR SAFETY REASONS DO NEVER USE THE RIVET GUN WITH A RIVET SET WITHOUT A SAFETY SPRING!

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Figure 11 Rivet Gun

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Rivet Set

For different rivet guns different rivet sets in a lot of variations are available.

They have to be selected depending on the diameter of the rivet gun's receptacle. Furthermore the selection depends on the structural surrounding area and the rivet type, e.g. a flat head rivet set for flush head rivets or a forming head rivet set for universal rivets.

A universal head rivet set is available for every rivet diameter in different lengths and forms. They are provided in a slightly angular, crumped or straight form.

Also here it is valid: Only use faultless rivet sets and only with a safety spring!

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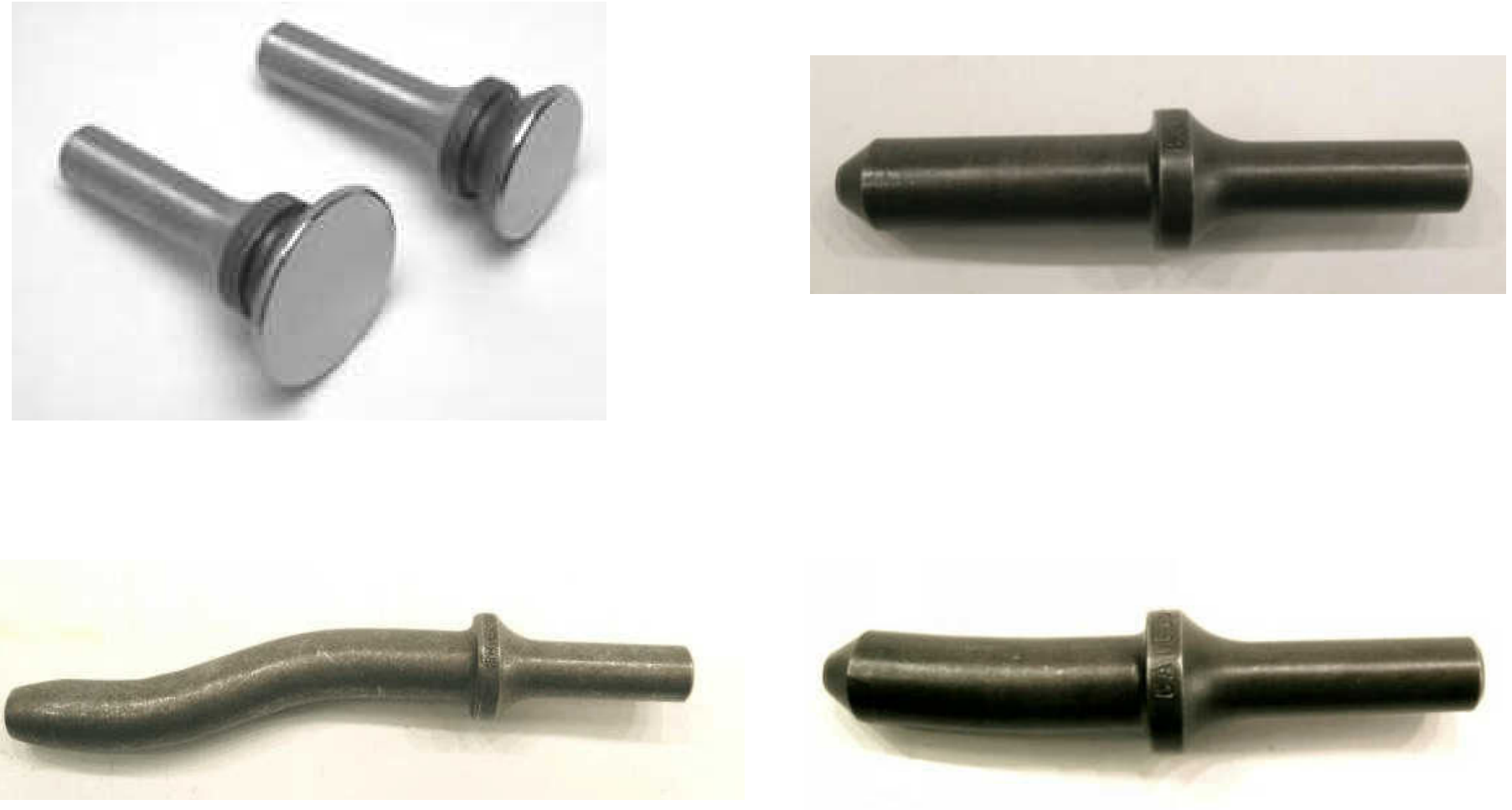


Figure 12 Rivet Set

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Back-Up Dolly

To form the upset head of a solid rivet correctly a back-up dolly is needed.

The mass of the dolly depends on the rivet diameter and the rivet material.

The selection of the dolly form is done according to the structural surrounding. Hereby also the mass of the dolly is influenced.

The rivet surfaces should be polished since every surface damage is transferred on the closing head. Dirty rivet surfaces, e.g. by sealer, have to be cleaned before riveting. If this is not done a tilting of the rivet shaft is possible.

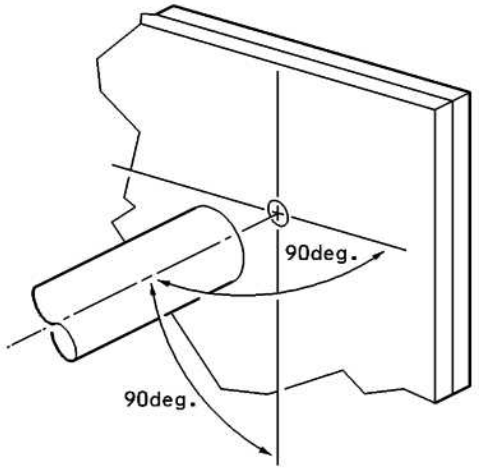
The edges of the dolly should be rounded to prevent sharp edged structural damages.

For areas which only allow very small dollies, it is reasonable (if available) to use dollies out of wolfram since they have despite their small size a high mass due to the high density.

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BACK - UP DOLLY ALIGNMENT

RIVET NOMINAL DIAMETER		RECOMMENDED BACK-UP DOLLY WEIGHT	
mm.	in.	kilograms	pounds
1.6	1/16 (0.062)	0.75 to 1.25	1.5 to 2.0
2.4	3/32 (0.094)	1.0 to 1.5	2.0 to 3.0
3.2	1/8 (0.125)	1.5 to 2.0	3.0 to 4.0
3.6	9/64 (0.140)	1.5 to 2.0	3.0 to 4.0
4.0	5/32 (0.156)	1.5 to 2.0	3.0 to 4.5
4.8	3/16 (0.187)	2.0 to 2.5	4.0 to 5.0
5.6	7/32 (0.219)	2.0 to 2.5	4.5 to 5.5
6.4	1/4 (0.250)	2.25 to 3.0	5.0 to 6.5
8.0	5/16 (0.312)	2.75 to 3.5	6.0 to 8.0

General Details for Back-up Dollies

Figure 13 Back Up Dollies

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Rivet Squeezer

The rivet squeezer, manually or pneumatic, is a further method to produce a rivet joint.

The rivet squeezer has a big advantage compared with the rivet gun. Once correctly adjusted it squeezes the rivet in a single continuous action without any cold work hardening.

Its applicability is restricted due to its large size and weight in comparison to the rivet gun.

Small manual rivet squeeze tongs are very suitable for the installation of e.g. rivet nuts. The large pneumatic squeezer is suitable for frame connections or for the fastening of brackets at the frame.

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Figure 14 Pneumatic Rivet Squeezer

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Riveting Procedures

Direct Riveting

During direct riveting the hammer/rivet set punches directly the rivet's shaft end and though is forming the upset head.

The manufacturer- or die-head of the rivet is hold up by a dolly with the form of the rivet head.

Direct riveting is applied if a large material thickness and therefore a large rivet length is present or if titanium rivets (high strength = hard to squeeze) have to be installed.

Indirect Riveting

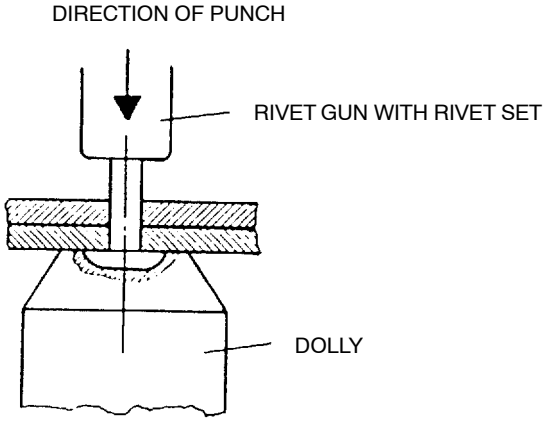
During indirect riveting the punch of the tool is applied to the die-head of the rivet.

The dolly is put on the rivet shaft end.

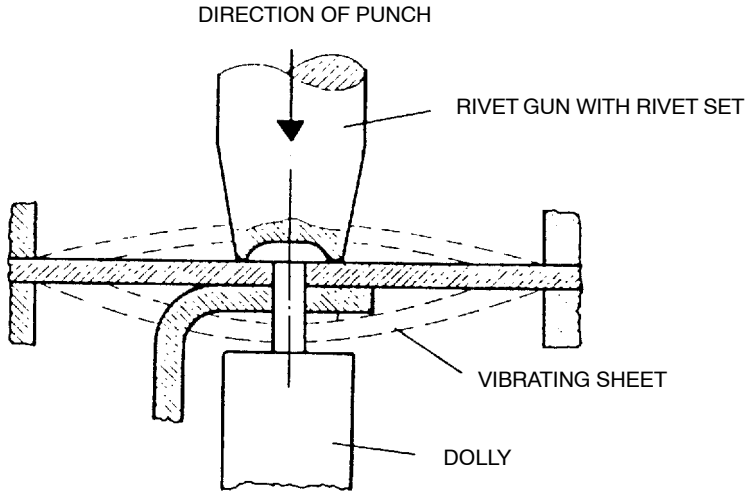
The punch is transmitted to the dolly through the structure, which is vibrating due to the rivet gun, and so the upset head of the rivet is formed.

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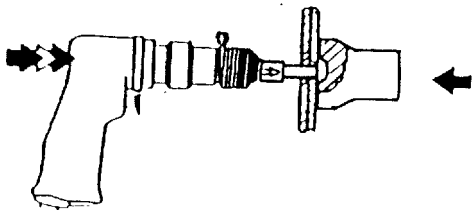
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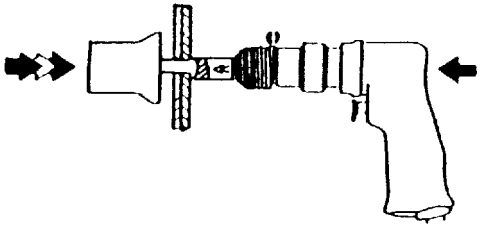
D i r e c t Riveting



I n d i r e c t Riveting



Installation through d i r e c t riveting



Installation through i n d i r e c t riveting

Figure 15 Riveting Techniques

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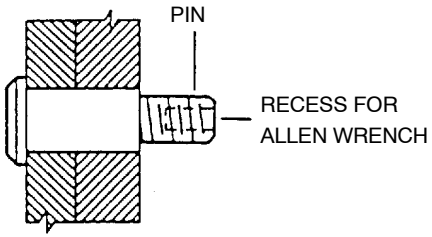
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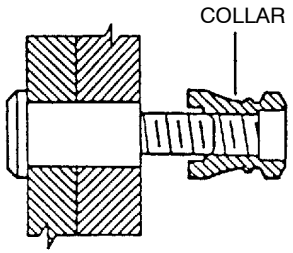
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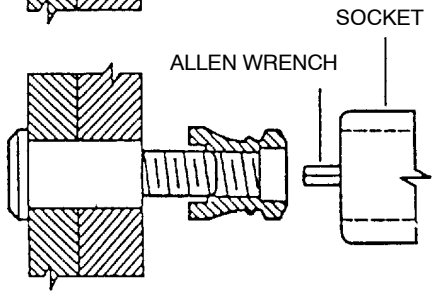
1. INSTALL HIGH–LOCK WITH CORRECT GRIP–LENGTH



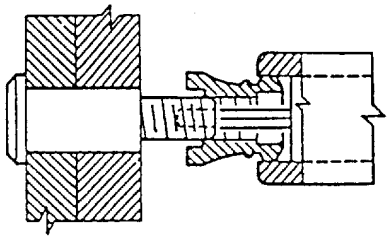
2. INSTALL COLLAR ON THE PIN BY HAND, USE AT LEAST 2 THREADS TO MAKE CORRECT THREAD ALIGNMENT.



3. ENGAGE THE ALLEN WRENCH INTO THE RECESS IN THE PIN



4. PLACE THE INSTALLATION TOOL TIGHTLY OVER THE COLLAR AND TURN UNTIL COLLAR DRIVE END SHEARS OFF



5. DISENGAGE THE INSTALLATION TOOL FROM PIN

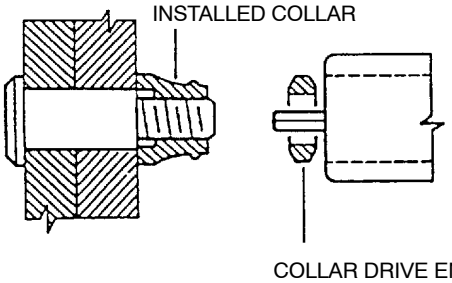


Figure 16 Sequence of Installation: Hi-Loks

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Dimpling

General

To prevent knife edges, elements that are going to be connected with flush head rivets have to have a minimum material thickness (flush head height + min. 0.2mm).

For thin sheets which do not meet these restrictions, these countersinks can be produced without cutting. The non-cutting countersinking of sheets is called dimpling. It is differed between coin and radius dimpling.

Radius Dimpling

Radius dimpling is normally done with the help of simple tools (e.g. manual tongs). Radius dimples have relatively large transient radii on both sheet surfaces. These radii emerge since the sheet is pulled into the die during the dimpling process. They are more inaccurate in forming due to higher spring-back.

Coin Dimpling

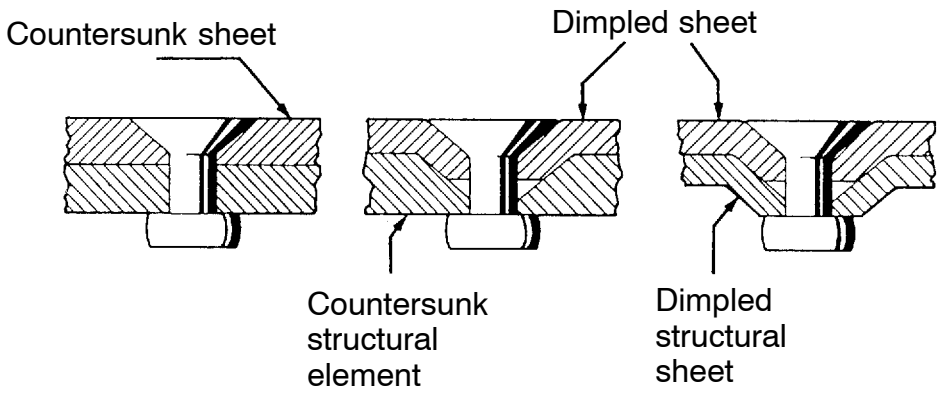
Coin dimpling is normally done with the help of special dimpling machines. With these machines dimples can be produced in a cold or hot state. A possible embrittlement especially when working with hard and therefore brittle material can be reduced by heating the upper and lower dies.

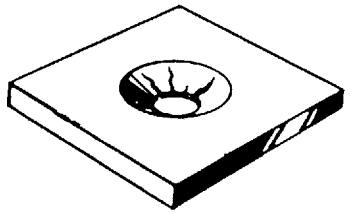
The advantage of coined dimples is the high degree of forming of the countersink and therefore the small transient radii. This is achieved by clamping the sheet prior to the coin dimpling process.

ATTENTION: The dimpling of sheets is only allowed for very thin sheets due to the danger of cracking. Therefore this process is not applied very often anymore. The procedure „Dimpling“ is not described in the actual Airbus SRM anymore!

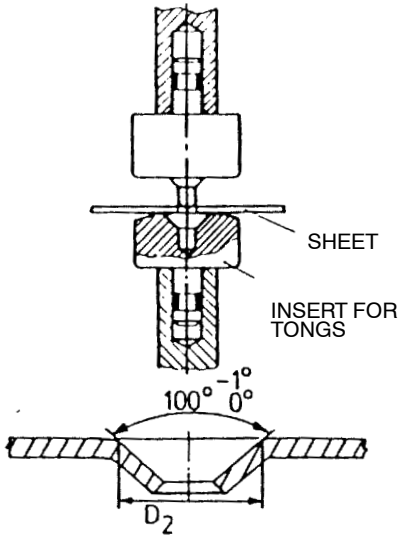
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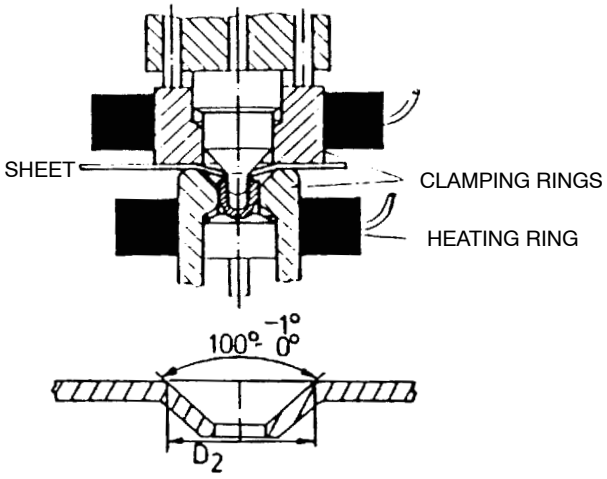




Cracking due to manufacturing failures



Radius Dimpling



Coin Dimpling

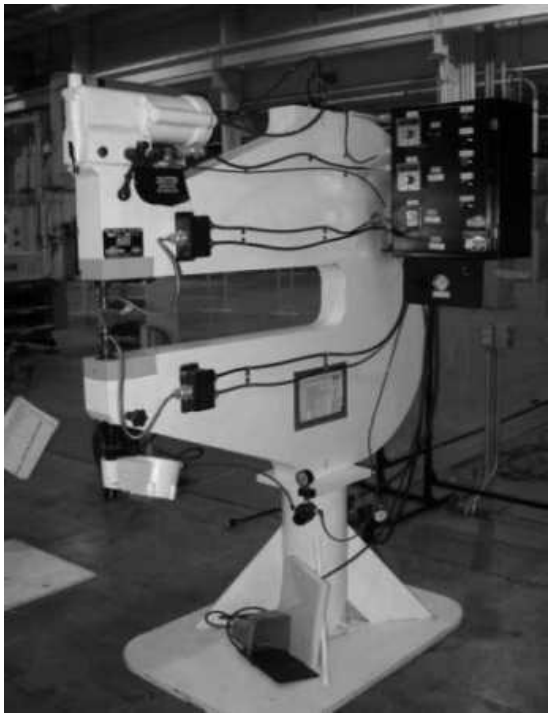


Figure 17 Dimpling Process

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