The International Institute of Welding

IIW Commission XIII

IIW Recommendations on Post Weld Improvement of Steel and Aluminium Structures

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XIII-1815-00

Revised 18 August 2006

CONTENTS

1. INTRODUCTION

Weld toe improvement methods have been widely investigated and have in most cases been found to give substantial increases in fatigue strength. However, there are large variations in the actual improvements achieved, and the results obtained by various methods are not always ranked in a consistent manner. One explanation for the observed variations is the lack of standardization of the optimum method of application, but variations in the material, type of loading and type of test specimens may also have influenced the results. The effectiveness of the treatment also depends heavily on the skill of the operator. In order to improve the reproducibility of the methods, and to produce guidance for the degree of improvement that could be expected when using the methods in actual practice, an inter-laboratory round-robin test programme was undertaken by IIW in 1995. The participating organizations are listed in Appendix 1. The programme, in which 13 testing laboratories in 10 countries participated, involved the three commonly used improvement methods: burr grinding, TIG dressing and hammer peening. It has contributed to a better understanding of the reasons for the large scatter that is sometimes observed in fatigue tests of improved welds, and has provided a basis for a higher confidence in using the methods.

The recommendations in this document are derived mainly from earlier IIW publications but many publications were consulted, as listed in Appendix 2. They supplement the IIW fatigue design recommendations for as-welded joints [6] and the benefits from the use of the techniques are related to those Recommendations. Those fatigue design Recommendations are based on S-N curves expressed in terms of nominal applied stress range. Further preliminary advice is given on the benefit to be claimed if the fatigue assessment is based on the alternative hot-spot stress approach. In addition to specifications for the practical use of the methods, guidance on their inspection and quality control is also given. Successful implementation of these methods depends on adequate training of operators as well as inspectors. IIW Commission XIII is therefore committed to providing training aids and issuing guidance for educating, training and certifying operators and inspectors.

The improvement techniques described in these recommendations are intended for use under the following circumstances:

a) Increasing the fatigue strength of new structures.

b) Repair or upgrading of existing structures.

It should be noted that the use of the higher S-N curves for improved weilds given in this document depends critically on adherence to the the quality requirements outlined under each improvement technique. Depending on the circumstances, approval from, for example, the purchaser or a certifying authority may be required before an improvement technique is used and an increase in fatigue strength is claimed.

2. SCOPE

2.1 Methods

The weld toe is a primary source of fatigue cracking because of the severity of the stress concentration it produces. Apart from a relatively sharp transition from the plate surface to the weld, dependent on the weld profile, the stress concentration effect is enhanced by the presence of minute crack-like flaws, extending to depths (below any undercut) of a few tenths of a millimeter. Fatigue cracks readily initiate at these flaws.

The weld toe improvement methods described in these Recommendations rely on two main principles:

a) Reduction of the severity of the weld toe stress concentration - Two methods are given, grinding and re-melting by TIG dressing. The primary aim is to remove or reduce the size of the weld toe flaws and thus extend the crack initiation part of the fatigue life. A secondary aim is to reduce the local stress concentration due to the weld profile by achieving a smooth blend at the transition between the plate and the weld face.

b) Introduction of beneficial compressive residual stress – The other main approach to improving in the fatigue lives of welded joints that are most likely to fail from the weld toe is to introduce compressive residual stresses in the weld toe region. These have the effect of ‘clamping’ the weld toe in compression, with the result that an applied tensile stress must first overcome the residual stress before it becomes damaging. Thus, the applied stress range is less damaging. Two techniques described in this specification, hammer and needle peening. In each case, compressive residual stresses are induced by mechanical plastic deformation of the weld toe region. Residual stresses then arise as a result of the constraint imposed by the surrounding elastic material. The same effect can be achieved with other techniques, such as shot peening, ultrasonic impact treatment (UIT) and ultrasonic peening (UP), laser peening, water jet peening, and they will be addressed in a future update of these Recommendations.

An important practical limitation on the use of improvement techniques that rely on the presence of compressive residual stresses is that their fatigue lives are strongly dependent on applied mean stress. In particular, their beneficial effect decreases as the maximum applied stress approaches tensile yield, disappearing altogether at stresses above yield. Thus, in general the techniques are not suitable for structures operating at applied stress ratios of more than 0.5 or maximum applied stresses above around 80% yield. Note that the occasional application of high stresses, in tension or compression, can also be detrimental in terms of relaxing the compressive residual stress.

2.2 Materials.

The Recommendations apply to any arc welded steel or aluminium structure that is subjected to fatigue loading. Due to lack of experimental data for extra high strength steels, the fatigue strength (or S-N) curves apply only to structural steel grades up to a maximum specified yield strength of 900 MPa. However, it is reasonable to expect that, in principle, the methods will also improve the fatigue performance of welded higher strength steels, and indeed stainless steels [7]. In the absence of relevant published data, it is recommended that such benefit should be quantified by special testing. The present Recommendations are also applicable to aluminium alloys commonly used in welded structures, primarily the 5000 and 6000 series alloys.

2.3 Environment and loading.

The application of improvement techniques is limited to structures operating at temperatures below the creep range. Although some of the improvement methods will increase the fatigue lives of to structures operating under freely corroding conditions, no guidance is given on the improvement that can be expected.

The Recommendations for burr grinding and TIG dressing only apply to conditions where the nominal stress range $\Delta\sigma < 2\times\sigma_{YS}$, σ_{YS} being the minimum specified yield stress of the material. For peening techniques, special restrictions are imposed regarding applied peak loads and stress ratios, see Chapters 5 and 6. Consistent with the IIW fatigue design Recommendations for as-welded joints [6], the present Recommendations do not apply to low-cycle fatigue conditions. However, there is evidence that the weld toe dressing methods are still effective under strain cycling.

2.4 Types of welded joints.

The Recommendations apply to the improvement of welded planar joints or welded hollow section connections with plate thickness from 6 to 50 mm for steel, 4 to 50 mm for aluminium, or as specified for each improvement method.
The improvement methods covered in this document are applied to the weld toe. Thus, they are intended to increase the fatigue lives of the weld treated from the viewpoint of potential fatigue failure from the weld toe. Some examples of relevant weld details are show in Fig. 2.1 .

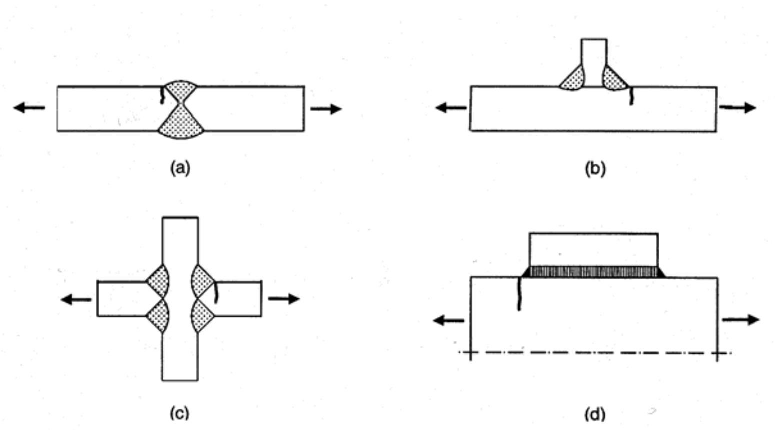


Fig. 2.1 Examples of joints suitable for improvement

Therefore, the possibility of a failure starting at some other location must always be considered. For instance, if the failure origin is merely shifted from the weld toe to the root there may be no significant improvement in fatigue life. It is emphasized that fatigue cracking from the root is governed by different design curves so toe treatment cannot be expected to provide any improvement in the general case. Examples of details in which root cracking might occur are shown in Fig. 2.2.
When weld improvement is planned, full penetration welds should be used where possible and welds at ends of cover plates should have extra large weld throats.

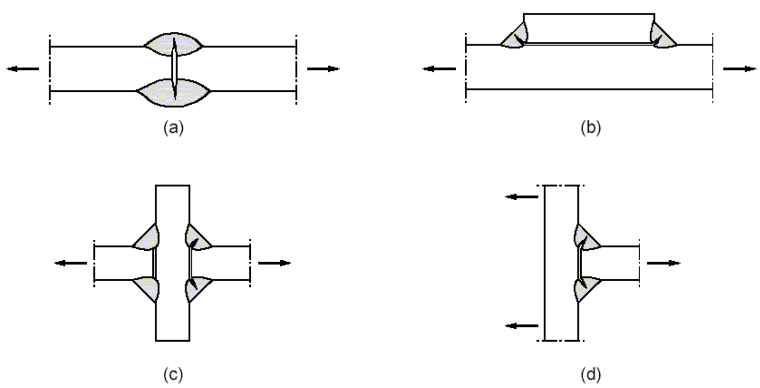


Fig. 2.2 Examples of details for which the improvement in fatigue strength is likely to be limited by the occurrence of root cracking. To ensure that a significant increase in fatigue strength is obtained full penetration welds should be used in case a), c) and d), while an extra large weld throat should be used in case b).

3. BURR GRINDING

3.1 Introduction

The primary aim of the grinding is to remove or reduce size of the weld toe flaws from which fatigue cracks propagate. At the same time, it aims to reduce the local stress concentration effect of the weld profile by smoothly blending the transition between the plate and the weld face.

3.2 Equipment

A high speed pneumatic, hydraulic or electric grinder with rotational speed from 15 000 to 40 000 rpm is required.

A pressure from 5 to 7 bars for air-driven grinders is recommended. The tool bit is normally a tungsten carbide burr (or rotating file) with a hemispherical end (Fig. 3.1).

Fig. 3.1 Pneumatic grinder and burrs

To avoid a notch effect due to small radius grooves, the burr diameter should be scaled to the plate thickness (t) at the weld toe being ground. The diameter should be in the 10 to 25 mm range for application to welded joints with plate thickness from 10 to 50 mm. The resulting root radius of the groove should be no less than 0.25t.

3.3 Safety aspects

The high-speed grinding tool removes material at a high rate and is therefore capable of

Fig. 3.2 Example of protective clothing used during weld toe burr grinding.

inflicting serious injuries to the operator or bystanders. The cutting operation itself produces hot, sharp cuttings and some noise. Therefore, heavy protective clothing together with leather gloves, safety glasses and ear protection are mandatory, see Fig. 3.2.

3.4 Weld preparation

The weld should be de-slagged and cleaned by wire brush before burr grinding.

3.5 Procedure

The quality of grinding depends on the skill of the operator, and each operator should experiment to find a technique that gives the desired result. Therefore, only general advice is given below.

The burr grinding procedure is illustrated in Fig. 3.3. The burr is centered over the weld toe. The axis of the tool should be 45-60° to the main plate, and approximately 45° to the direction of travel. The grinder can be either pushed or pulled along the weld. Usually the former is more successful at establishing a straight groove of even depth. Grinding has to be extended to areas well outside the highest stress region at the ends of attachments, as indicated in Fig. 3.3(b).

In general, grinding must extend to a depth of at least 0.5 mm below any visible undercut, see Fig 3.4. For plates up to 40 mm thick the maximum allowable depth is 7 % of the plate thickness, i.e. the maximum depth for a 20 mm plate is 1.4 mm. For thicker plates the maximum depth of grinding is 3 mm. However, it is clearly preferable to minimize the depth of groove produced and, in general, a maximum of 1mm will be sufficient.

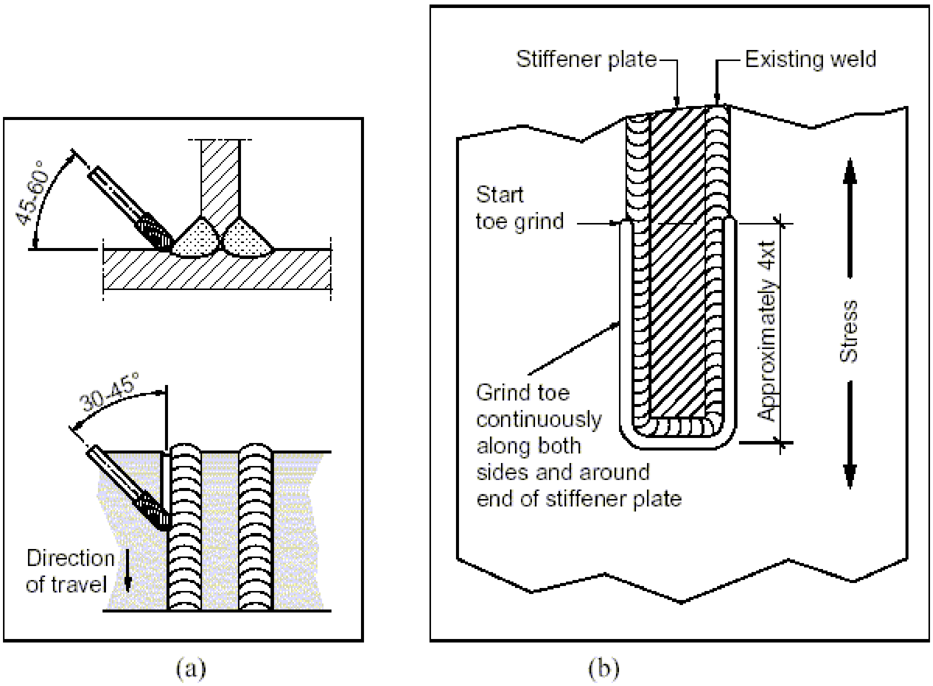


Fig. 3.3 The weld toe burr grinding technique

In large scale planar welded joints with plate thickness of the order of 40 mm and more, the high notch stresses in the toe region extend up on the weld face, and inter-bead toes may become crack initiation sites rather than the weld toe. This applies in particular to welds with low weld face angles. The treatment must therefore be applied to inter-bead toes within a region extending up the weld face by a distance (w) of at least half the leg length L, as illustrated in Fig. 3.4.

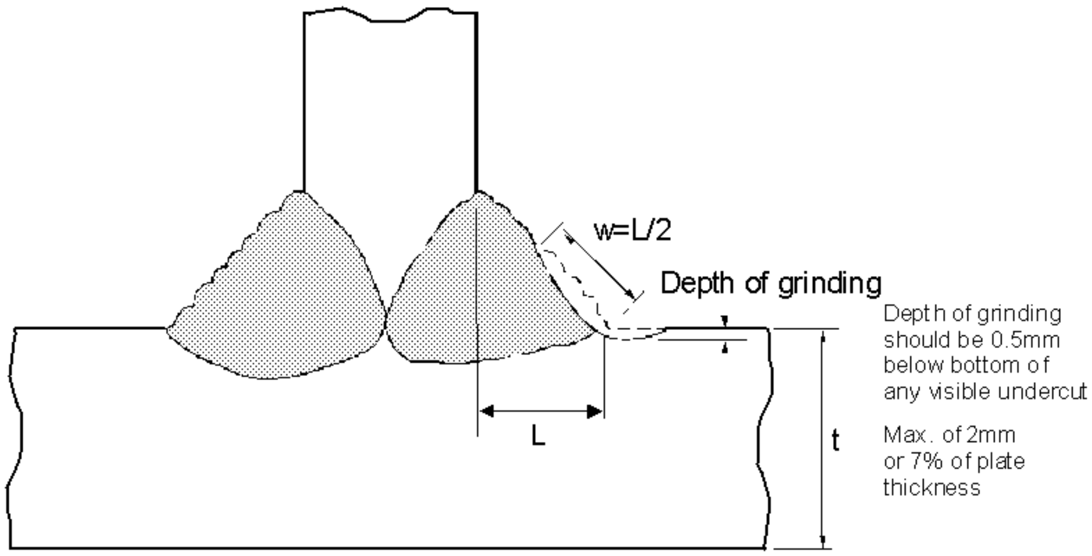


Fig. 3.4 The burr grinding technique, showing depth and width of groove in stressed plate.

A similar situation arises for welds in tubular joints, particularly those with large beta ratios (β = brace diameter/chord diameter), where the maximum stress is likely to be located on the weld face. Thus the whole weld face is highly stressed and must be ground as well as both weld toes. The situation is illustrated in Figure 3.5.

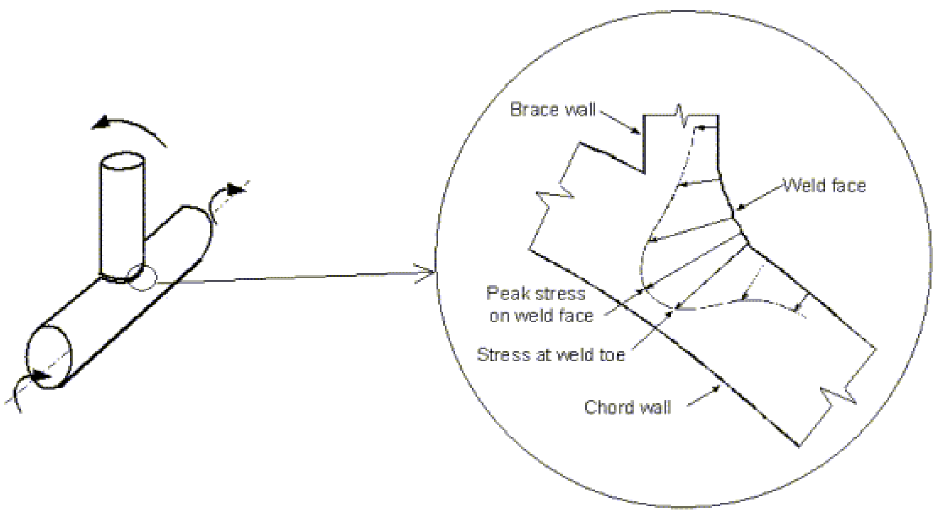


Fig. 3.5 Stress distribution in a tubular joint (schematic), requiring grinding of the entire weld face and the weld toes in the brace and the chord.

The weld toe geometry to be achieved by burr grinding is illustrated in Fig. 3.6. Note that an adequate throat thickness must be maintained and that the burr radius has to be scaled to the plate thickness and to the grinding depth.

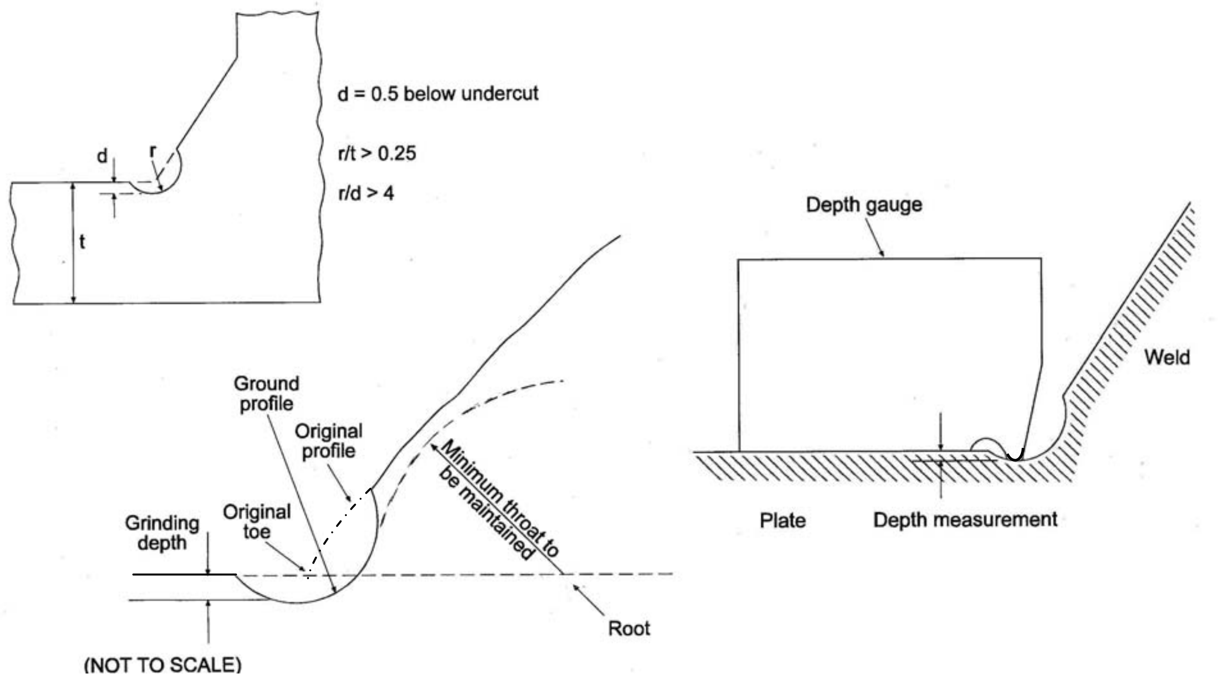


Fig. 3.6 Details of burr ground weld toe geometry.

3.5.1 Two stage grinding.

In case of a steep weld angle fillet or T butt welds in thick plates, for which large diameter burrs are required, it is often found that the burr has a tendency to 'climb' up the weld face, making it difficult to position it on the weld toe line. In such circumstances, it is recommended that grinding should be carried out in two stages. First, a small spherical tool, e.g. 6 mm diameter, is used to establish a groove of the correct depth and position, see Fig. 3.7. The grinding operation is then completed with the larger diameter burr. In this way, it proves to be easier to obtain the required quality of grinding in less time than when using the large diameter tool alone.

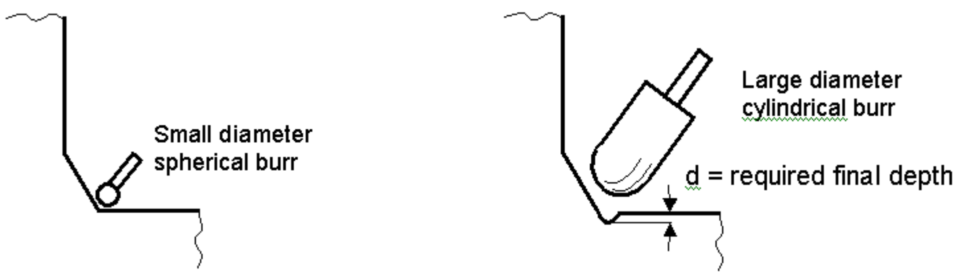
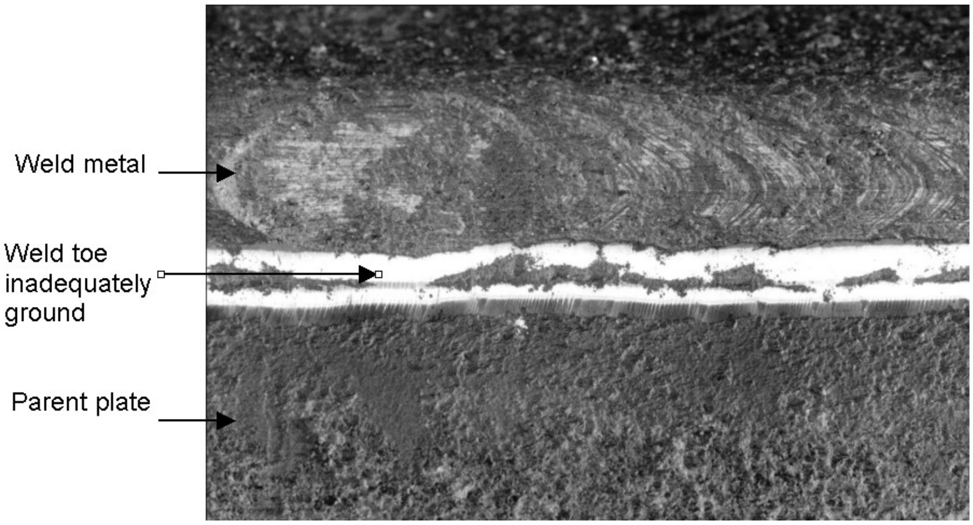


Fig. 3.7 Two stage grinding of large welds with steep weld angles.

The grinding rate depends on the weld geometry and material, but will be typically 50 to 100 mm per minute. The finished ground surface should be as smooth as possible, with no visible evidence of the original weld toe and any grinding marks at right angles to the weld toe line. Examples of the appearance of correctly and incorrectly ground welds are shown in Fig 3.8 (a) and (b), respectively.

(a) Correctly ground weld toe



(b) Incorrectly ground weld toe

Fig. 3.8 Appearance of (a) correctly and (b) incorrectly burr ground fillet weld toes

3.6 Corrosion protection

Corrosion pitting of the ground metal surface virtually eliminates the benefit of burr grinding. Therefore, the ground surface must be adequately protected. The protection may be of a temporary nature, as would be the case for a part of an offshore structure that would eventually be submerged and protected by a cathodic protection system. In other cases permanent protection must be provided by other means, e.g. a paint system.

3.7 Operator and inspector training

Some skill is required to perform burr grinding according to this specification and a training programme should be implemented for inexperienced operators. This should include a demonstration of the appearance of an adequately ground well as well as a demonstration of unacceptable welds and an explanation of the factors that influence the result. Actual grinding of at least 2 meters of weld, combined with periodic inspection and evaluation, is recommended.

3.8 Inspection and quality control

The inspection procedure must include a check on the weld toe radius, the depth of grinding, and confirmation that the weld toe has been removed completely. A depth gauge similar to the one used for measuring weld toe undercut (see Fig.3.9(a)) may be used, although the accuracy is low. Alternatively, a ‘go - no go’ type of gauge such as shown in Fig. 3.9(b) may be more suitable. Visual examination under a bright light should be made to ensure that all traces of the original weld toe have disappeared. The ground surface of the groove should be inspected to make sure there are no deep scratches in the length direction, i.e. all grinding marks should be normal to the weld. A low power (approximately x5) magnifying glass is suitable.

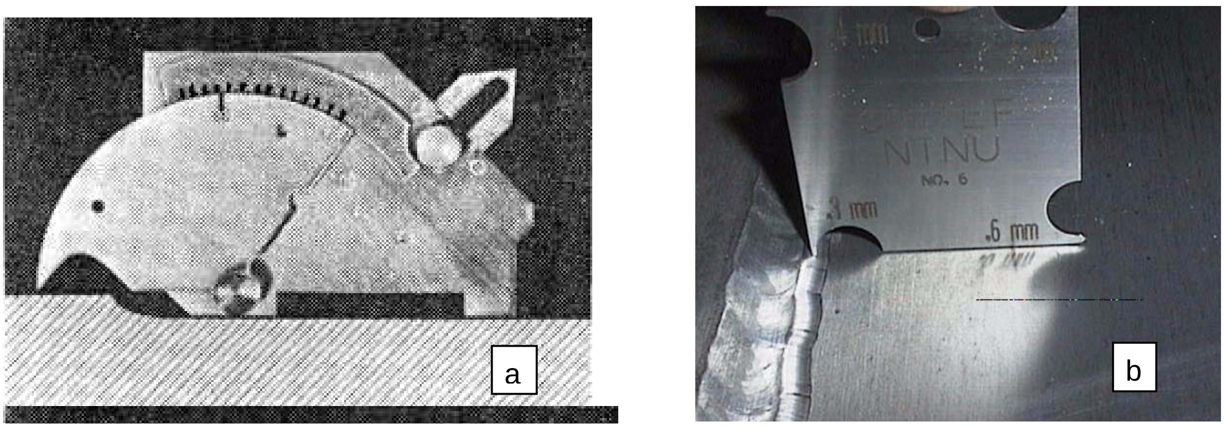


Fig. 3.9 Gauges for checking depth of groove.

3.9 Documentation.

A cast of the weld made using a silicone rubber of the type used by dentists is useful for documentation and for measuring the local geometry at the weld toe.

Data pertaining to the procedure should be recorded for the purpose of quality control and quality assurance. The data are also useful for correlating fatigue performance with burr grinding conditions when fatigue testing is performed. An example of a suitable data sheet, similar to those used for welding procedure specification (WPS), is reproduced in Appendix 3.

3.10 Fatigue strength of joints improved by grinding.

The benefit of weld toe grinding for steel can be claimed only for details in FAT 90 Class or lower in the IIW notation for S-N curves. This limitation is due to the fact that the higher classes include non-welded details, details whose lives are not governed by weld toe failure or welds that have been already been improved, e.g. by grinding the weld flush with the surface.

For IIW FAT 90 or lower class details the benefit of burr grinding corresponds to an increase in allowable stress range by a factor of 1.5, corresponding to a factor of 3.4 on life. However, the maximum class which can be claimed is the closest category below the FAT value obtained when the as-welded FAT value is multiplied by 1.5. For example, when a in the FAT 63 class is toe ground the new FAT value is found like this: 63x1.5 = 94.5, which gives a FAT 90 S-N curve. In addition, it can be assumed that for constant amplitude loading the change of slope takes place at N = 2mill cycles, i.e there is no fatigue limit. for the improved weld corresponds to an endurance of 2 x 10^6. For lower grade steels, with specified minimum yield strength below 350 MPa, the improvement factor is 1.3, corresponding to a factor of 2.2 on life. The highest class which can be claimed, is also in this case FAT 100.

In the low cycle region all S-N curves are limited by the IIW parent materiel curve, i.e. the FAT 160 curve with a slope parameter of m = 5 [6].

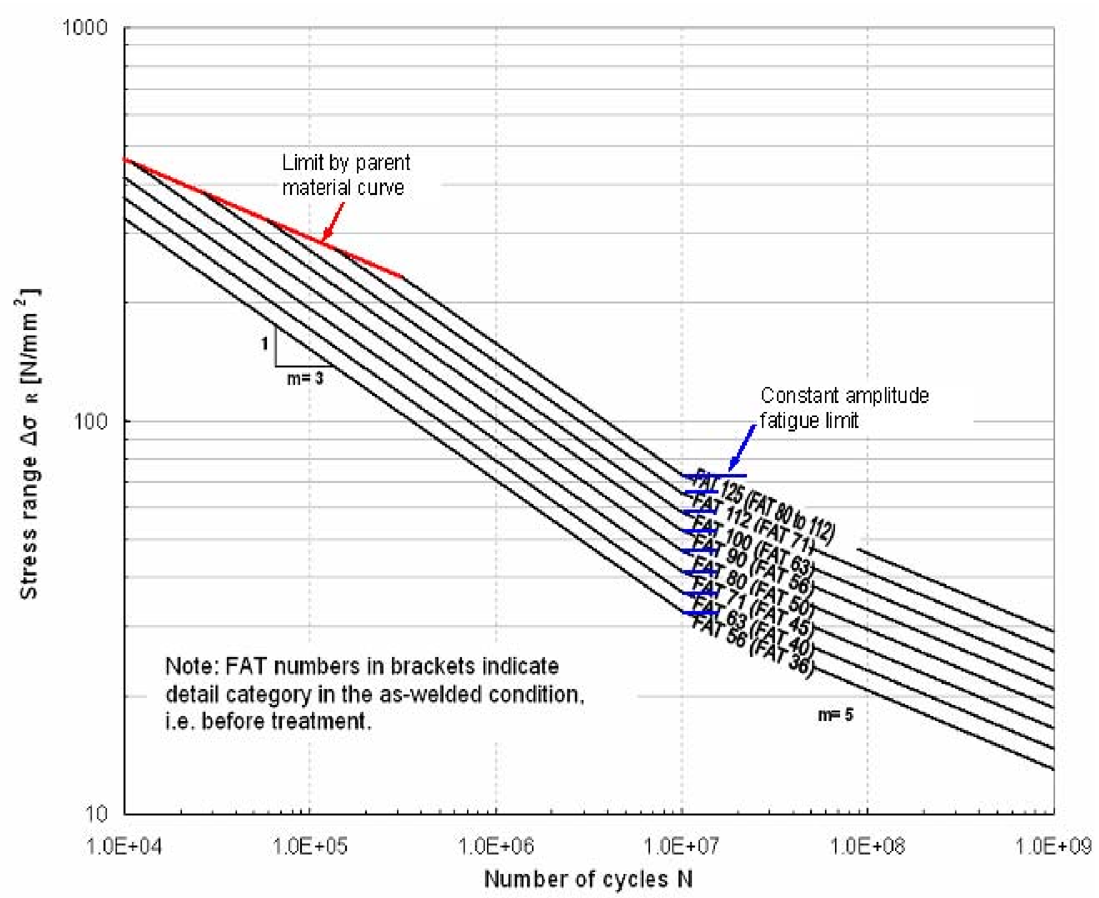


Fig. 3.10 Design S-N curves for weld toe burr ground welds in steel structures

For welds in aluminium alloys, a factor 1.5 on allowable stress range applied to the design S-N curves may be assumed. The highest detail class for which an improvement can claimed is now FAT 40, and the highest S-N curve that can be claimed is FAT 45, as shown in Fig. 3.11. As for steel, all S-N curves in the low cycle region are limited by the IIW parent materiel curve, i.e. the FAT 160 curve with a slope parameter of m = 5.

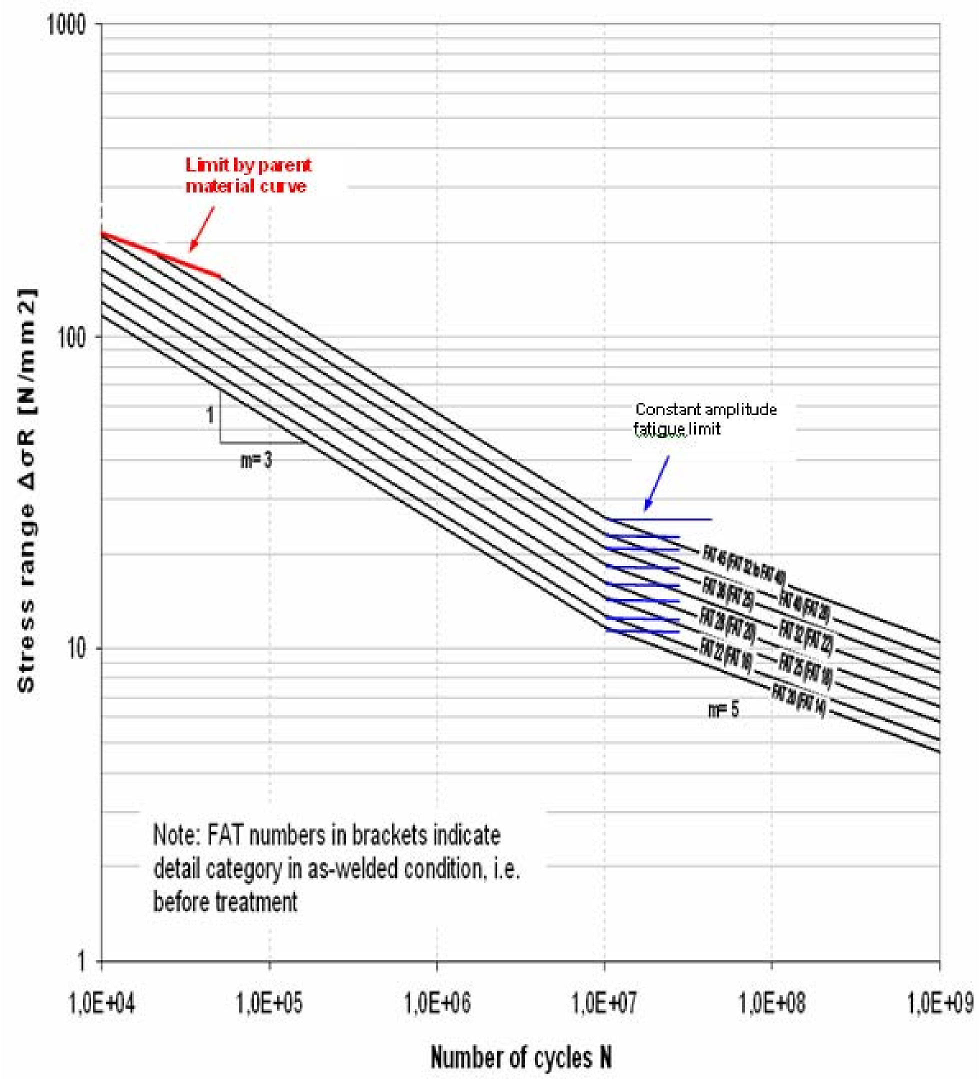


Fig. 3.11 Design S-N curves for weld toe burr ground welds in aluminium structures

3.11 Thickness effect for joints improved by grinding

Weld toe grinding reduces the stress concentration factor, and in accordance with Section 3.5.2 in Ref. 6 the thickness correction factor f(t) for toe ground joints is

$$f(t) = \left(\frac{25}{t_{eff}}\right)^{0.20}$$

where t_{eff} = t for L/t > 2

t_{eff} = 0.5L for L/t ≤ 2, or t_{eff} = t, whichever is greater

L is the sum of the attachment plate thickness and the leg lengths, see Section 3.5.2 in Ref. 6

4. TIG DRESSING

4.1 Introduction

The aim of TIG dressing is to remove the weld toe flaws by re-melting the material at the weld toe. It also aims to reduce the local stress concentration effect of the local weld toe profile by providing a smooth transition between the plate and the weld face.

The present specifications are only applicable to connections with main plate thicknesses of at least 4 mm for aluminium and 6 mm for steel.

4.2 Equipment

A standard TIG welding machine is used. Argon is normally used as shielding gas. The addition of helium is beneficial since this gives a larger pool of melted metal due to a higher heat input. Typical conditions and range of dressing parameters used in reported tests are shown in Table 4.1. Typical manual TIG dressing equipment is shown in Fig. 4.1

Table 6.1 Typical TIG dressing conditions for steel.

Shielding gas	Argon or argon + helium
Gas flow rate	7 - 12 liter/min
Nozzle diameter	10 -14 mm
Preheat[1]	50 - 200 °C
Electrode diameter	3 to 4 mm
Voltage, V	12 - 17 volts
Current, A	160 - 250 amperes
Dressing speed, S	80 - 160 mm/min
Heat input, Q[2]	1.0 - 2.5 kJ/mm

1) Dependent on steel type and plate thickness.

2) Heat input is calculated from $Q = \frac{60 \times V \times A}{1000 \times S}$ (kJ/mm)

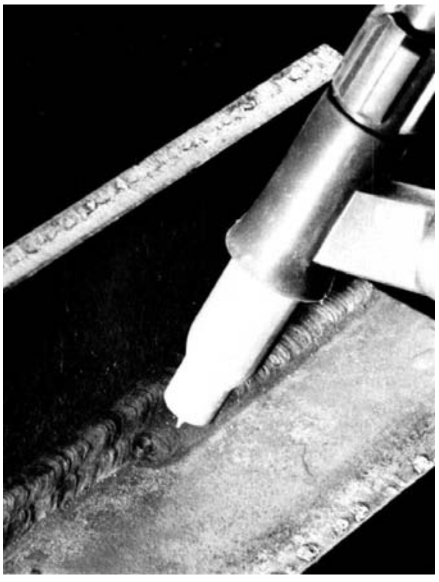


Fig. 4.1 TIG dressing equipment and a partially dressed weld..

4.3 Weld preparation

TIG dressing is sensitive to most types of common weld contaminants such as mill scale, rust, oil and paint. The weld and adjacent plate should be thoroughly de-slagged and wire brushed. If necessary, light grinding should be used to obtain a clean surface. Insufficient cleaning tends to result in the formation of gas pores that can have a strongly detrimental effect on fatigue performance. The problem of porosity is particularly important in TIG dressed aluminium welds.

4.4 Dressing conditions and procedure

4.4. 1 Tungsten electrode

The shape of the arc depends on the shape and condition of the electrode tip. If the tip is contaminated or rounded by wear (oxidation), the arc becomes concentrated with the result that the re-melted zone narrows with and unfavorable effect on the bead shape. It is also difficult to start the arc and to keep it stable. These problems can be avoided by re-grinding the tip or replacing the electrode. Acceptable and unacceptable electrode tips are show in Fig. 4.2 (a) and (b) respectively.

4.4.2 Shielding gas

If the gas flow rate is low or strong draughts disturb the gas shield the arc becomes unstable and defects such as surface pores are formed, or the electrode and bead oxidize. An adequate gas supply rate depends on many factors, including gas cup size, welding conditions and welding location (presence of draughts). An optimum flow rate should therefore be determined by trial dressing. For TIG dressing of duplex stainless steels it is advisable to add 1 to 2% Nitrogen to the shielding gas to avoid unfavourable changes to the austenite-ferrite balance.

(a) (b)

Fig. 4.2 Electrodes for TIG torch; (a) unused tip, (b) contaminated electrode used on oxidized plate. After Millington [4].

4.4.3 Preheat (steel only)

The heat input during TIG dressing is normally less that that used for welding the joint. Therefore, as a general rule the minimum preheat temperature to be used should be equal to that specified in the welding procedure. The exception to this is welds produced by the flux-cored arc welding (FCAW) process due to a high hydrogen content. If TIG dressing is carried out just after welding, a preheat of approximately 150 ° C for minimum 20 minutes must then be chosen to avoid cracking of the weld metal. However, some time after welding is completed the hydrogen content is less and the risk for weld metal cracking is reduced, with the result that the preheat temperature can be reduced. In this case, therefore, the preheat temperature for TIG dressing of FCAW joints may be chosen on the basis of the preheat temperature that would be used for MMA welding. For steels with a carbon content in excess of 0.12 % weight, the possible formation of hard zones in the heat-affected zone (HAZ) should be considered. In such cases a second tempering TIG pass on the weld metal should be considered (8).

4.4.4 Dressing parameters

The objective of TIG dressing is to obtain a smooth transition from the plate to the weld bead. Dressing conditions may vary with the welding position, but as a general rule a high heat input should be used since this normally gives a low hardness in the HAZ. Additionally, a high heat input also allows higher dressing speeds. An excessive heat input caused by a combination of high current and a low travel speed usually produces undercut or a poor bead profile. Suitable dressing conditions for the horizontal-vertical position are shown in Fig. 4.3

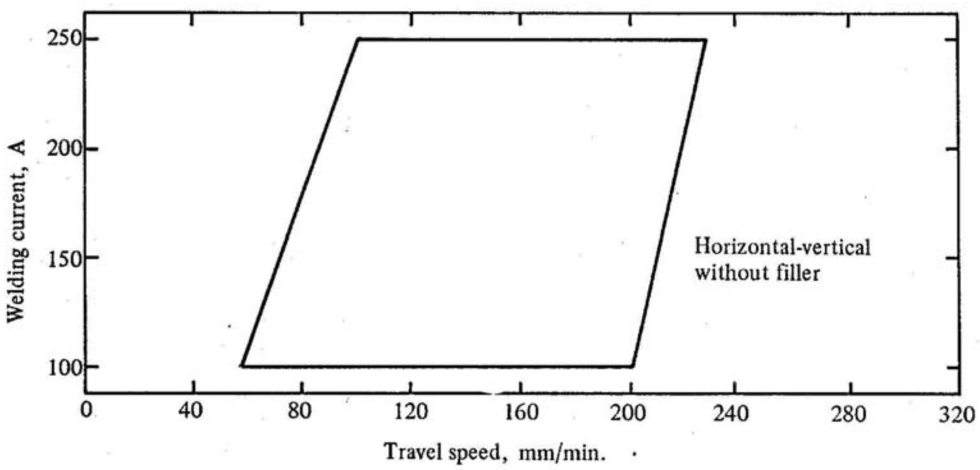


Fig. 4.3 TIG dressing conditions for steel (Millington [4]).

4.4.5 Position of TIG torch and dressing zone

For an optimum result the re-melted zone has to be positioned carefully with respect to the original weld toe. Normally the best result is obtained when the arc centre is located a small distance away from the weld toe, as indicated in Fig. 4.4(a). Also shown in Fig. 4.4(a) is a slight sideways tilt of the torch from the perpendicular position to obtain a favorable bead profile. In addition, the small backward tilt shown in Fig. 4.4(b) may help to maintain an adequate gas shield.

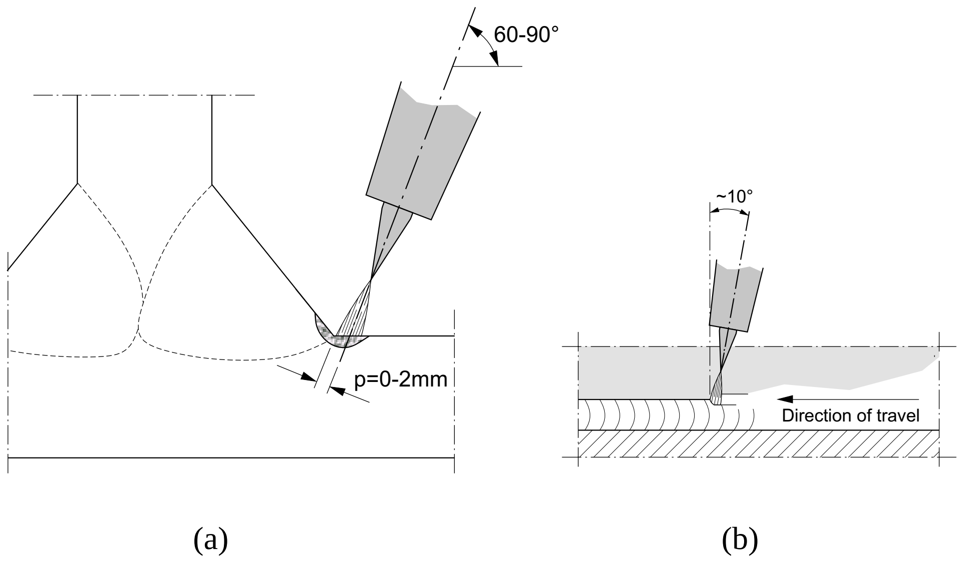


Fig. 4.4 Typical position of torch and dressing zone.

If the arc is positioned too close to the weld bead it may result in the formation of a new toe as shown in Fig. 4.5(b) and (c). In general the electrode should be directed more towards the parent plate for steeper weld profiles, whereas for flatter beads the electrode should be positioned closer to the weld toe. If bead shapes similar to those shown in Figs. 4.5(b) and (c) are obtained, remedial treatment should be considered, see Sect. 4.6. A re-melted weld toe as shown in Fig. 4.5(a) represents an optimum shape with respect to fatigue. An example of a satisfactory treated weld profile is shown in Fig. 4.6. Care is also needed to ensure that the original weld toe is, in fact, re-melted. Experience indicates that the fatigue life of a region where TIG dressing has missed the toe is the same as that of the as-welded joint.

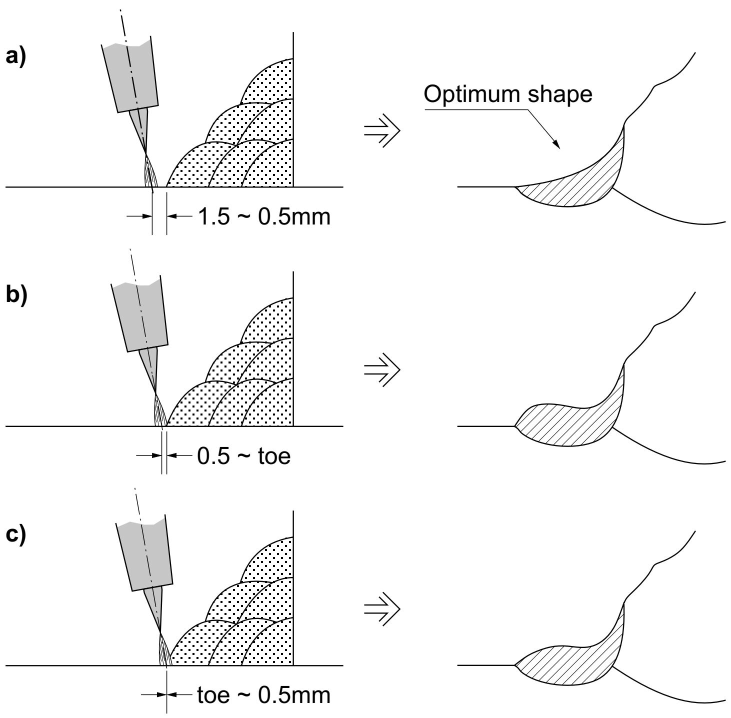


Fig. 4.5 Position of torch and resulting profiles from Kado et al [5])

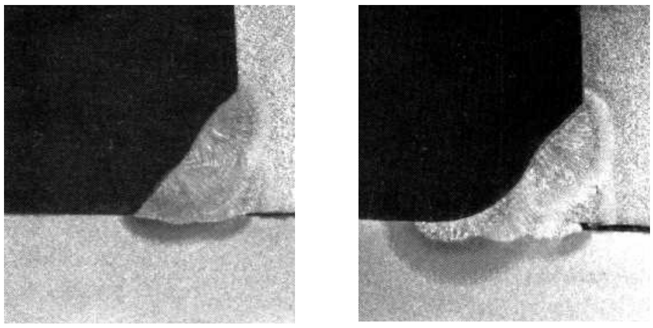


Fig. 4.6 Fillet weld before and after TIG dressing (x2 magnification).

4.4.6 Arc stopping and restarting

Arc starting and stopping may create craters or unfavorable bead profiles. This can be avoided by starting the arc about 6 mm behind the stop position, as indicated in Fig. 4.7(a). Alternatively, the arc may be started on the bead and moved to the toe, Fig. 4.7(b). The stop can also be made on the bead, Fig. 4.7(c). The methods illustrated in Fig. 4.7(a) and (c) may be combined, as shown in Fig 4.7(d). Craters may also be avoided by changing the direction of welding, see Fig 4.7(e). The welder should try various stop/restart techniques and choose one that gives a favourable bead shape.

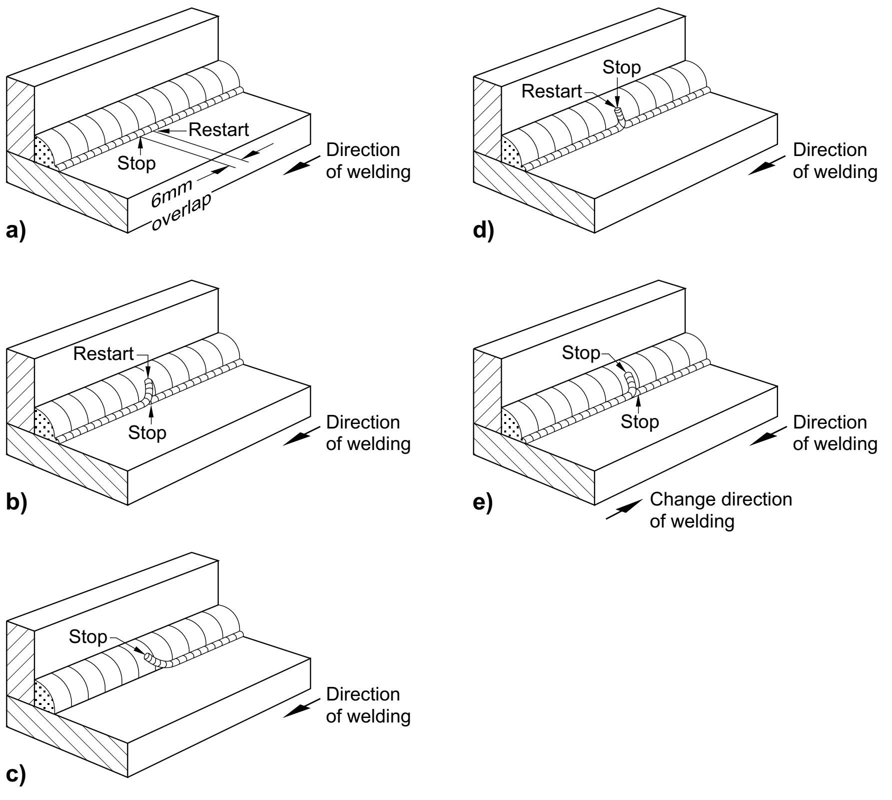


Fig. 4.7 TIG dressing stop and restart techniques (After Millington [4])

4.5 Operator and inspector training

The quality of TIG dressing depends on an optimum combination of dressing parameters and the manual skills of the operator. The optimum dressing conditions are related to the individual characteristics of the welding equipment. The optimum shape of the dressed profile also depends to some extent on the shape of the initial bead profile. For this reason it is recommended that a trial programme is set up to familiarize the welder with the technique and develop optimum dressing conditions. The trials should include dressing with different heat inputs and torch positions. Arc starting and stopping techniques should also be practiced, see Section 4.6. After completing the training, the operator should treat at least 1m of similar weld before starting production treatment.

4.6 Remedial dressing

If the TIG-dressed weld does not satisfy the inspection criterion with respect to weld shape (see 4.8), a new dressing run may be performed. If necessary a weaving technique may be tried or filler material could be used. The ease of repeating TIG dressing is one of the advantages of this method.

4.7 Corrosion protection

The benefit of TIG dressing is reduced if the surface is degraded by corrosion. Therefore, for maximum benefit, the TIG dressed surface must be adequately protected against possible corrosion. The protection may be of a temporary nature, as would be the case for a part of an offshore structure that would eventually be submerged and protected by a cathodic protection system. In other cases permanent protection must be provided by other means, e.g. a paint system.

4.8 Inspection

The dressed weld should have a smooth transition from the plate to the weld face, with a minimum toe radius of 3 mm, in accordance with Figs. 4.5 and 4.6. However, recent data for stainless steels indicate that the radius may need to be 6mm. The weld should be checked for complete treatment along the entire length of the part treated. If any part of the weld toe is found to have been missed by the TIG dressing it should be treated again.

4.9 Documentation.

Data pertaining to the procedure should be recorded for the purpose of quality control and quality assurance. The data are also useful for correlating fatigue performance with TIG dressing conditions when fatigue testing is performed. An example of a data sheet for TIG dressing, similar to that used for welding procedure specification (WPS), is reproduced in Appendix 3.

4.10 Fatigue strength of joints improved by TIG dressing.

For IIW FAT 90 or lower class details the benefit of burr grinding corresponds to an increase in allowable stress range by a factor of 1.5, corresponding to a factor of 3.4 on life. However, the maximum class which can be claimed is the closest category below the FAT value obtained when as-welded FAT value is multiplied by 1.5. For example, when a in the FAT 63 class is toe ground the new FAT value is found like this: 63x1.5 = 94.5, which gives a FAT

90 S_N curve. The highest class, which can be claimed is FAT 125. In addition, it can be assumed that for constant amplitude loading the change of slope takes place at N = 2mill cycles. For lower grade steels, with specified minimum yield strength below 350 MPa, the improvement factor is 1.3, corresponding to a factor of 2.2 on life. The highest class, which can be claimed, is in this case FAT 100.

In the low cycle region all S-N curves are limited by the IIW parent materiel curve, i.e. the FAT 160 curve with a slope parameter of m = 5 [6].

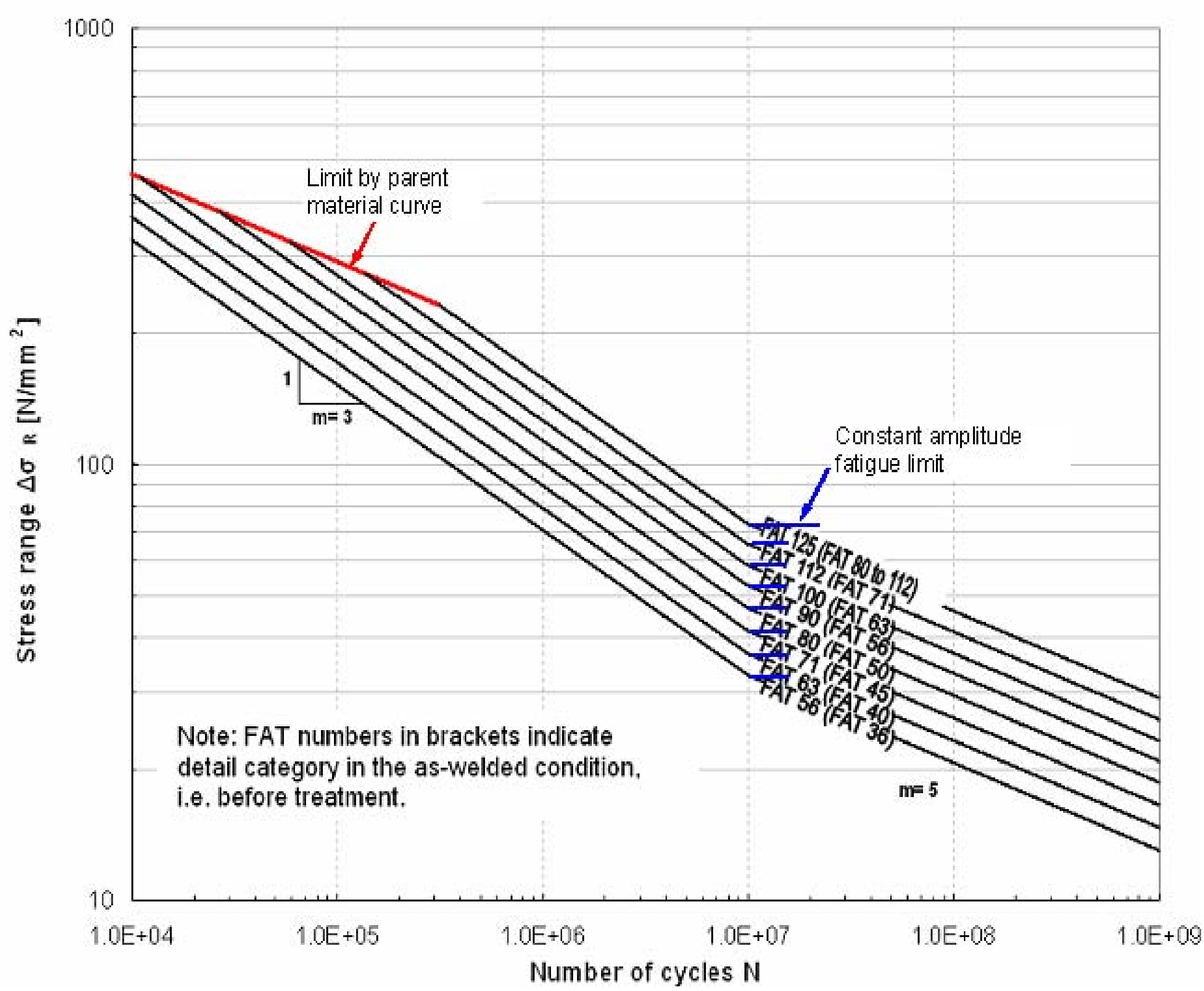


Fig. 4 .8 Design S-N curves for TIG dressed welds in steel structures

For welds in aluminium alloys, a factor 1.5 on allowable stress range applied to the design S-N curves may be assumed. The highest detail class for which an improvement can claimed is now FAT 40, and the highest S-N curve that can be claimed is FAT 45, as shown in Fig. 4.9. As for steel, all S-N curves in the low cycle region are limited by the IIW parent materiel curve, i.e. the FAT 160 curve with a slope parameter of m = 5.

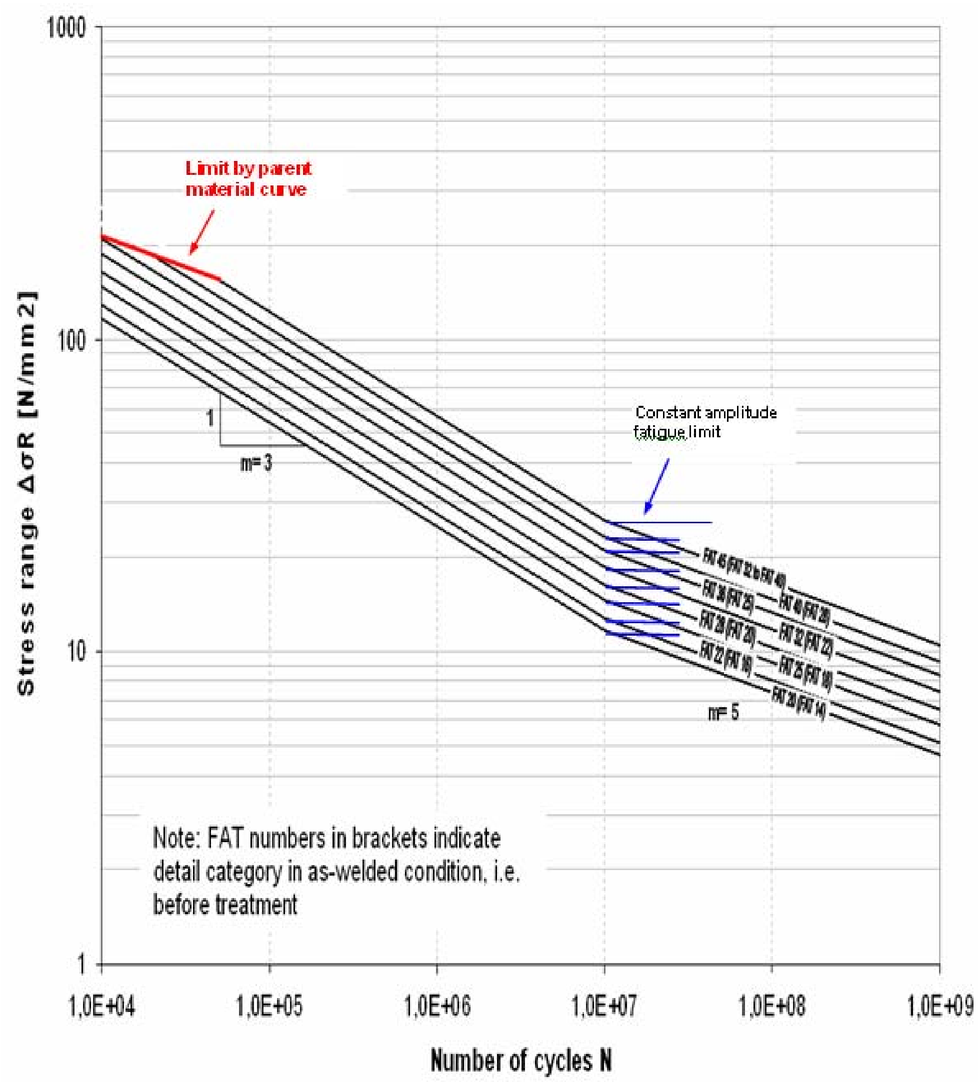


Fig. 4.9 Design S-N curves for TIG dressed welds in aluminium structures

4.10 Thickness effects of joints improved by TIG dressing

TIG dressing reduces the stress concentration factor, and in accordance with Section 3.5.2 in Ref. 6 the thickness correction factor f(t) for TIG dressed joints is

$$f(t) = \left(\frac{25}{t_{eff}} \right)^{0.20}$$

where t_{eff} = t for L/t > 2

t_{eff} = 0.5L for L/t ≤ 2, or t_{eff} = t, whichever is greater

L is the sum of the attachment plate thickness and the leg lengths, see Section 3.5.2 in Ref. 6.

5. HAMMER PEENING

5.1 Introduction

In hammer peening, compressive residual stresses are induced by repeatedly hammering the weld toe region with a blunt-nosed chisel. The following specification is only applicable to connections with main plate thickness of at least 4 mm for steel and 8 mm for aluminium.

The magnitude of the residual stresses introduced by peening methods depends to a large extent on whether the weld to be peened is under tensile or compressive loading during the peening operation. A better result can be expected if the peened component can be loaded in such a way as to give **tensile** stress in the region to be peened. Conversely, a **compressive** loading will reduce the effectiveness of the peening.treatment.

5.2 Equipment

A pneumatic or hydraulic hammer is commonly used. A suitable pneumatic hammer gun has a 15 to 30 mm diameter piston, operates at an air pressure of 5 to 7 bars and delivers 25 to 100 blows per second. Impact energy is typically in the range 5 to 15 Joules. The weight of the gun is from about 1 to 3.5 kg. Most research investigations of hammer peening have made use of the above types of hammer gun, both of which are primarily intended for use as chipping hammers. However, riveting guns have recently been found to be even better suited for peening because they are lighter and have better vibration dampening. These features will increase operator comfort and ease of use, which in turn should improve control over the peening operation and hence consistency and reliability of the resulting treatment. A riveting gun used successfully for hammer peening is shown in Fig. 5.1.

Hardened steel tool bits with approximately hemispherical tips, diameters between 6 and 18 mm, and length typically 100 to 200 mm are used. Such tools are not generally available as standard equipment, but they can be produced relatively simply by grinding the tips of standard chisels.

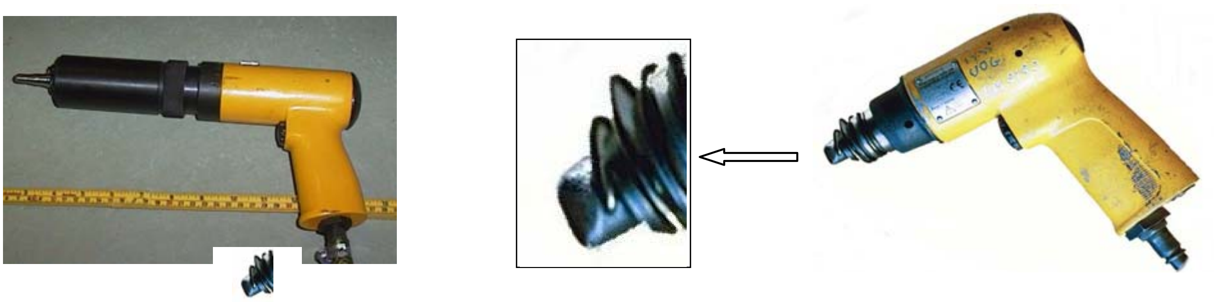


Fig. 5.1. Pneumatic riveting guns used for hammer peening.

5.3 Operator and inspector training

Hammer peening is carried out manually. Some skill is required, and therefore the operator should receive appropriate training, including a demonstration of successfully treated welds as well as unacceptable treatment. Some trial treatments, over at least 1m of weld, should be carried out before attempting to treat the actual component. An elongated tip (Fig. 5.1) rather than a hemispherical one is often an advantage since it makes it easier to make the tool follow the weld toe.

5.4 Weld preparation

The weld cap and adjacent parent material shall be fully de-slagged and wire brushed or ground to remove all traces of oxide, scale, spatter and other foreign material. Peening of the toe of a peaky or severely convex weld profile can cause the plastically-deformed metal to fold over the original weld toe and leave a crack-like lap feature that resembles a cold lap, as illustrated in Fig. 5.2. The resulting fatigue performance of the welded joint may actually be less than that of the original as-welded joint. Therefore, it is advisable to grind the weld lightly to improve its shape by producing a more convex profile. The same flaw has been observed in welds with adequate profiles but in which the material was relatively soft, such that the required depth of peening could be achieved in just one or two passes. However, again light grinding to improve the weld profile should eliminate the problem. Using the elongated “boat shaped” tip shown in Fig. 5.1 usually helps prevent the formation of the folds in Fig. 2.

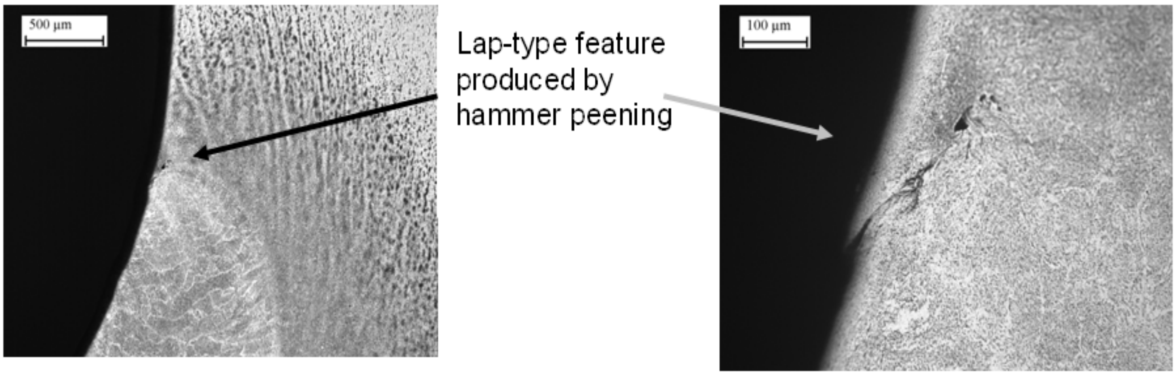


Fig. 5.2. Lap type defect in hammer peened weld.

5.5 Safety aspects

Hammer peening, even using modern silenced hammers, is a noisy operation and it is essential that the operator and others working in the vicinity should use ear protection. Normal protective clothing for working in a fabrication shop is adequate, but it should include a face-mask or goggles. Vibration from peening equipment may cause physical discomfort or harm, and the operator should not perform the operation for extended periods of time. Vibration damping gloves may help to mitigate this problem.

5.6 Procedure

The aim in hammer peening is to plastically deform the material at the weld toe to introduce beneficial compressive residual stresses.

Effective treatment requires reasonably accurate positioning of the tip of the tool over the weld toe so that metal on each side (both weld metal and parent plate) is deformed. This will normally be achieved by supporting the hammer firmly and keeping the peening tool tip in close contact with the weld toe as it is moved along the weld. The hammer should be held at about 45º to the plate surface and approximately perpendicular to the direction of travel, as shown in Fig. 5.3, although in practice there will be a tendency to slope slightly as the tip of the tool tries to run ahead of the operator.

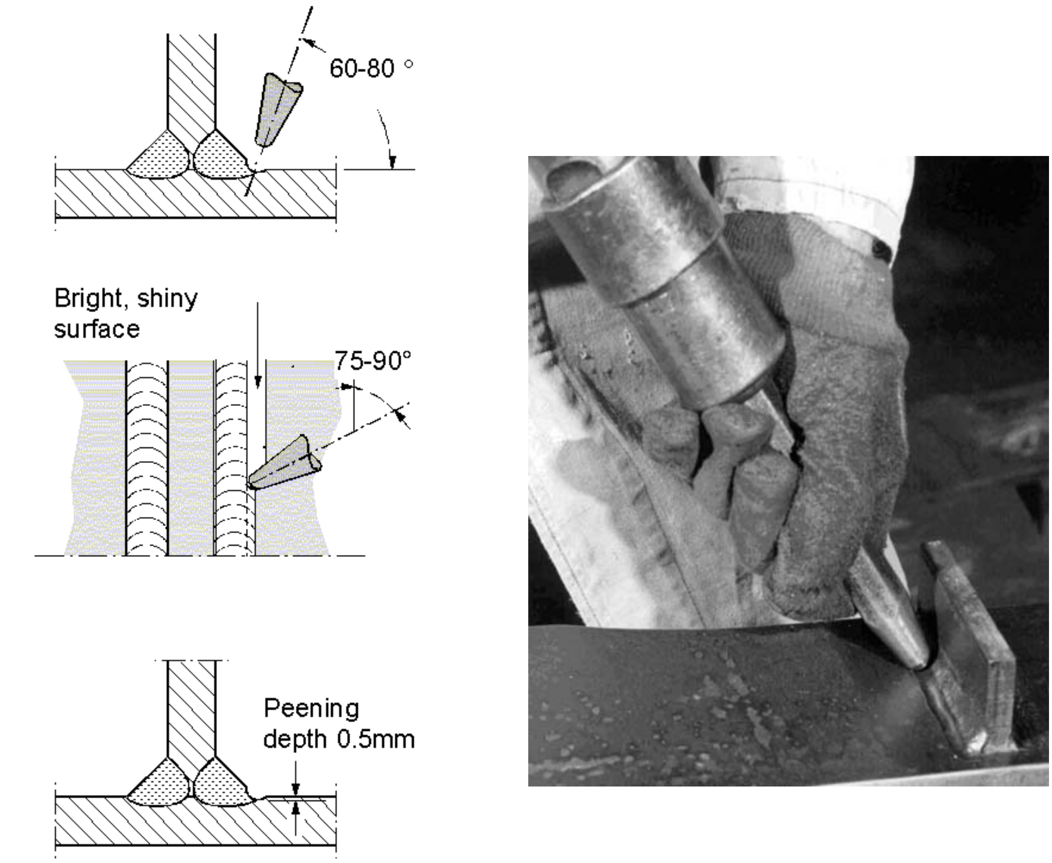
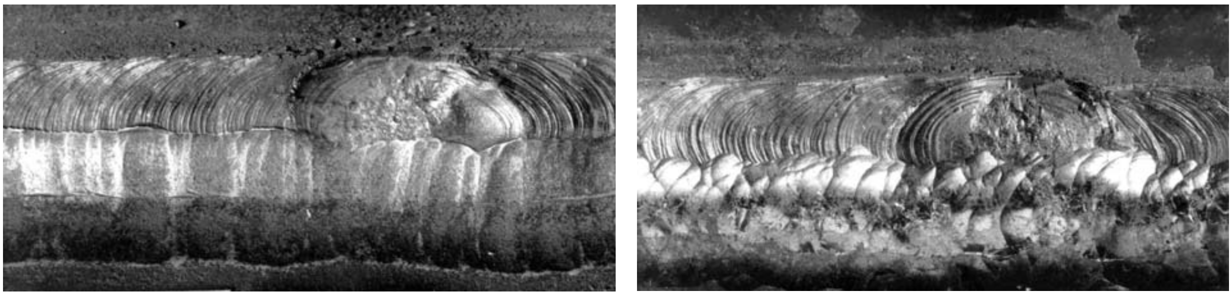


Fig. 5.3 Hammer peening operation

The resulting groove must be smooth and free from obvious individual indentations, as illustrated in Fig. 5.4 a). The depth of the groove should be a minimum of 0.3 mm. The travel speed will depend to some extent on access and hammer peening position, but also on the equipment used. A hammer gun that is heavy and vibrates will cause the tool to jump along the weld, missing some areas. Repeated peening, usually four passes, is then needed to achieve full coverage and a smooth surface. Lighter, vibration-damped hammer guns facilitate slower travel speeds, and hence more thorough treatment per pass. A travel speed of 50 to 100 mm/min per pass, similar to typical welding speeds, is normally sufficient to achieve the required depth is in one pass, although a lower speed might be necessary for higher strength steels.

The diameter of the tool tip influences the resulting appearance of the hammer peened surface. In general, the smaller the diameter, the greater the likelihood that the actual weld toe itself will be peened and eventually disappear. Peening with a large diameter tool (greater than 12 mm) does not usually reach the weld toe but instead deforms material either side of it. Although in general the desired effect will be achieved with fewer passes using a large diameter tool, the presence of the original weld toe is a disadvantage from the viewpoint of inspection.

In particular, it is not obvious that the toe has been correctly treated (i.e. left in a state of compressive residual stress) and remnant traces of weld toe confuse in-service inspection, since it is difficult to distinguish between them and fatigue cracks. Thus, the use of a small diameter tool, or a combination of small and larger diameter tools, with the aim of deforming the actual weld toe offers the best compromise. Inspection would then ensure that all traces of the original weld toe had disappeared.



(a) (b)

Fig. 5.4 Examples of hammer peened weld toes in steel : (a) acceptable, with sufficient coverage to leave a smooth surface; (b) unacceptable, with individual indentations visible due to insufficient coverage

In circumstances in which the treated weld will be subjected to a high-tensile mean stress in service, hammer peening will offer little or no benefit. When practicable, this problem can be overcome by performing the peening operation while the weld is under tensile load. For maximum benefit, this should be at least as high as the minimum stress to be experienced in service.

5.7 Inspection and quality control

In general, it is not possible to verify that hammer peening has been performed correctly by visual inspection alone. Important features like coverage and surface finish can only be described qualitatively, while the extent of plastic deformation, which reflects the level of compressive residual stress induced, is too small for reliable measurement in most practical circumstances. An important step is therefore to establish an acceptable hammer peening procedure and then to ensure that it is followed.The hammer peening procedure should be established by performing trials on the material to be treated, preferably containing a representative weld, in the same position as the welded joint to be treated. The toe should be peened and examined after each pass. The treatment can be assumed to be complete when there is a uniform indentation along the weld toe with a smooth surface finish, and all traces of the original weld toe have disappeared. As a guide, but not a requirement, the indentation depth below the original plate surface is likely to be of the order of 0.5 mm. The minimum depth is 0.3 mm. The indentation depth will not normally exceed l mm. If it is suspected that lap-type flaws of the kind shown in Fig. 5.5 have been produced, the treated area should be inspected carefully. Visual inspection will require a bright light and magnifying glass. Some success at detecting the flaws in ferritic steel has been achieved using magnetic particle inspection (Fig. 5.5).Treatment of the actual weld detail should be verified by visual inspection. This will check hammer peening position, coverage and general uniformity by comparing the hammer peened area with a reference sample or photograph.

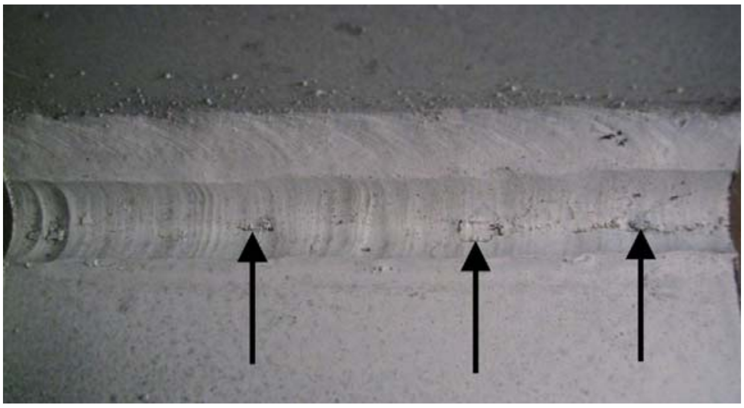


Fig. 5.5 Weld toe lap-type flaws produced by hammer peeing revealed by magnetic particle inspection (arrowed).

5.8 Documentation.

Data pertaining to the procedure should be recorded for the purpose of quality control and quality assurance. The data are also useful for correlating fatigue performance with hammer peening conditions when fatigue testing is performed. An example of production data sheet, similar to those used for welding procedure specification (WPS), is reproduced in Appendix 3. Test pieces used in trials should be retained for later review.

5.9 Fatigue strength of joints improved by hammer peening.

Benefit from hammer peening of steel components can only be claimed for details in design Class FAT 90 or lower in the IIW notation for S-N curves, as shown in Fig. 5.4. This limitation is due to the fact that the higher classes include non-welded details, details whose lives are not governed by weld toe failure or the welds that have been already been improved, e.g. by grinding the weld flush with the surface.
For steels with specified yield stress higher than 350 MPa the benefit consists of an upgrade by a factor of 1.6 applied to the stress range, with a change in slope to $m = 5$ at 2×10^6 cycles, as shown in Fig. 5.4. The highest class that can be claimed is FAT 125.
Additionally, in the low endurance regime the S-N curve is limited by the IIW parent material curve, i.e. the FAT 160 curve with a slope parameter of $m = 5$ [6].

For lower grade steels, with specified minimum yield strength below 350 MPa, the improvement factor is 1.3, corresponding to a factor of 2.2 on life. The highest class that can be claimed is in this case FAT 112.

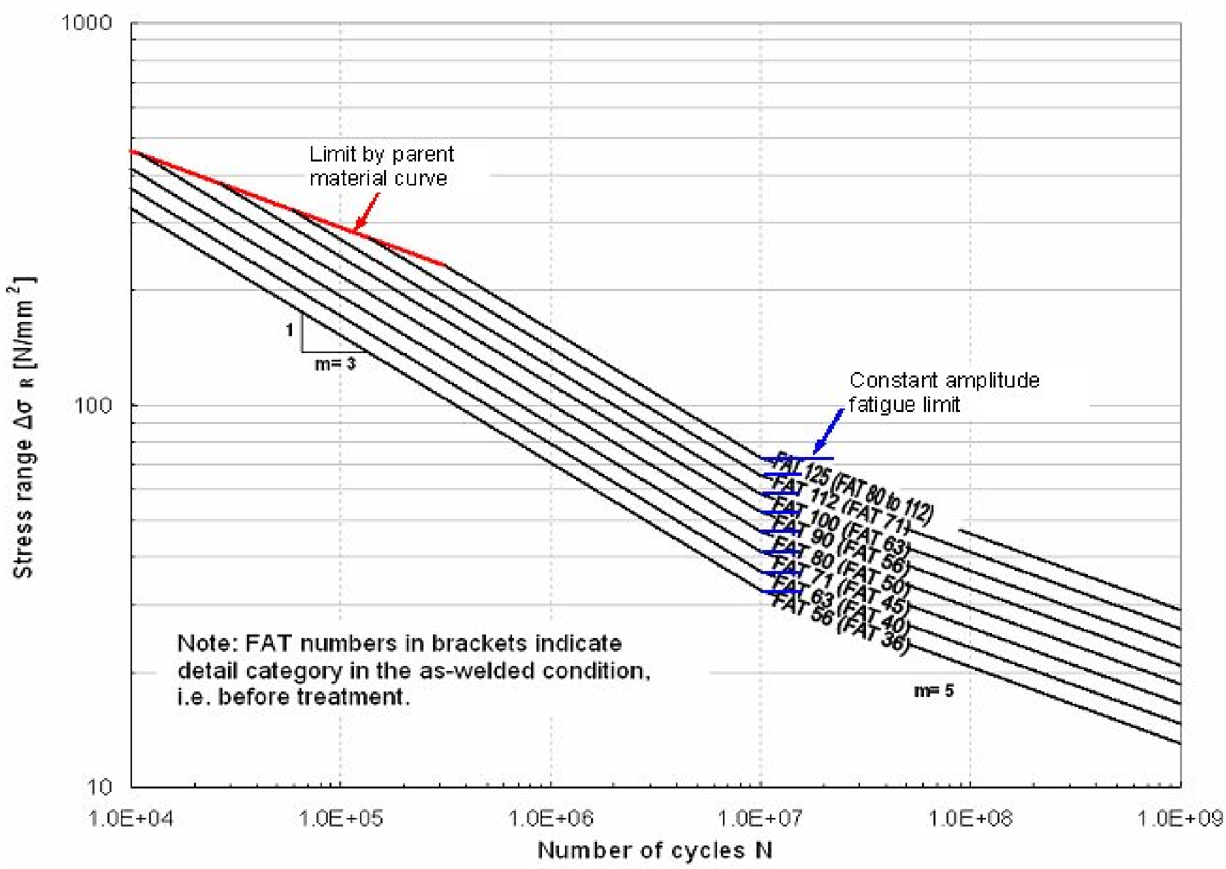


Fig. 5.4 Design S-N curves for hammer peened welds in steel structures.

For aluminium welded components improved by hammer peening, an improvement factor of 1.6 applies to joints corresponding to FAT 40 and lower, see Fig. 5.5. The highest class which can be claimed is FAT 56.

Fatigue tests on large-scale structures indicate lower benefit from hammer peening than for small–scale specimens. However, the main basis for the above recommendations is data obtained from small-scale welded specimens. Therefore, it is recommended that for structures with plate thickness larger than 20 mm the benefit for hammer peening is assumed to be the same as for grinding and TIG dressing. i.e. a factor of 1.5 on allowable stress range, limited to an increase to FAT 100 for steel, and FAT 45 for aluminium weldments.

5.10 Effect of thickness for joints improved by hammer peening.

The increase in fatigue strength for hammer peened joints is mainly due to the effect of the compressive stresses and the higher fatigue strength doe to improved geometry is of less importance. The thickness penalty for peened joints is therefore the same as for as-welded joints.

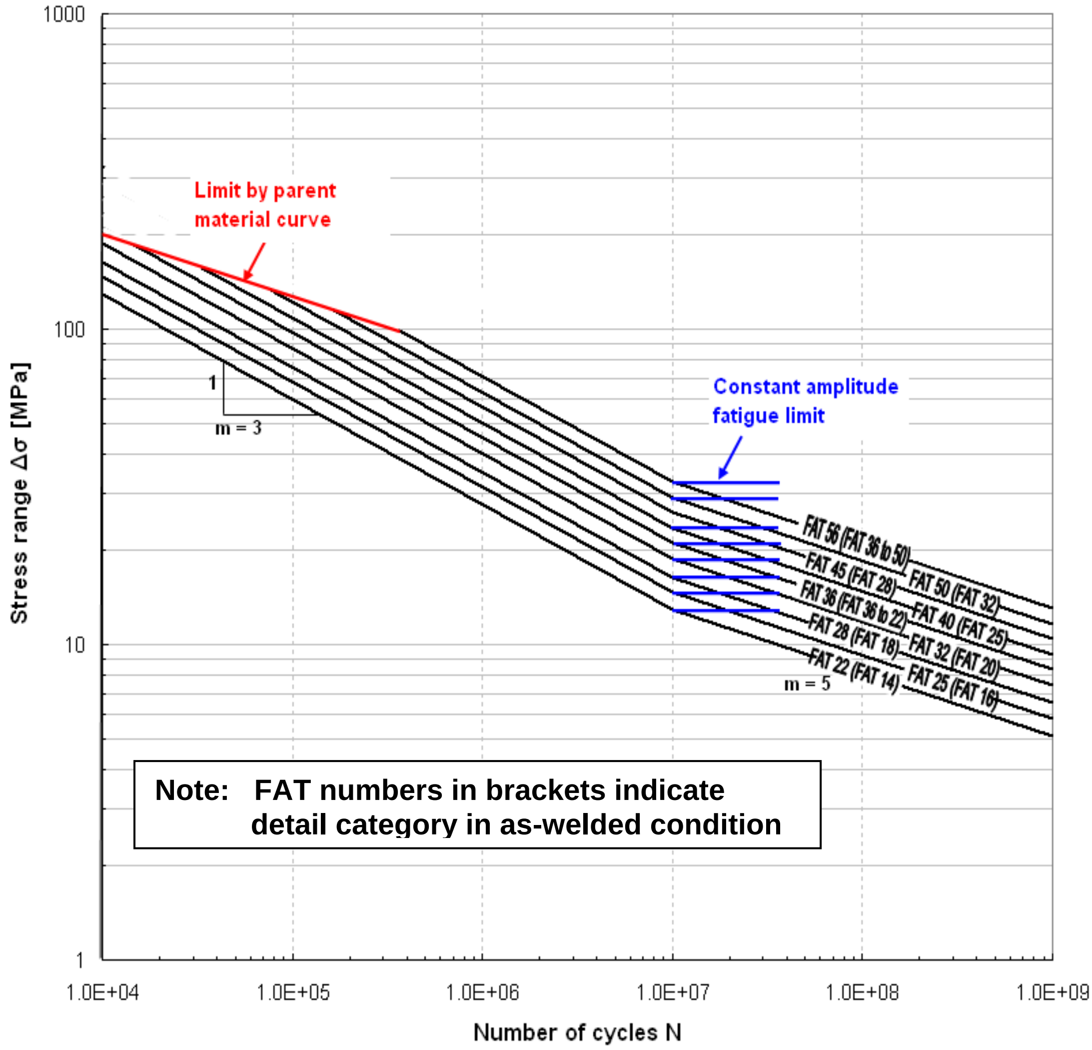


Fig. 5.5 Design S-N curves for hammer peened welds in aluminium structures.

Due to the sensitivity of hammer peened welded joints to applied mean stress, the higher S-N curves can only be used under the following circumstances:

- The maximum nominal compressive stress in the load spectrum is lower than $0.25\times\sigma_Y$.
- When the applied stress ratio $R < 0$, the S-N curve is used in conjunction with full stress range
- When the applied stress ratio $R \geq 0$ (all stresses in tension) the S-N curve is used in conjunction with the maximum stress instead of the full stress range.

The limitations are illustrated in Fig. 5.6

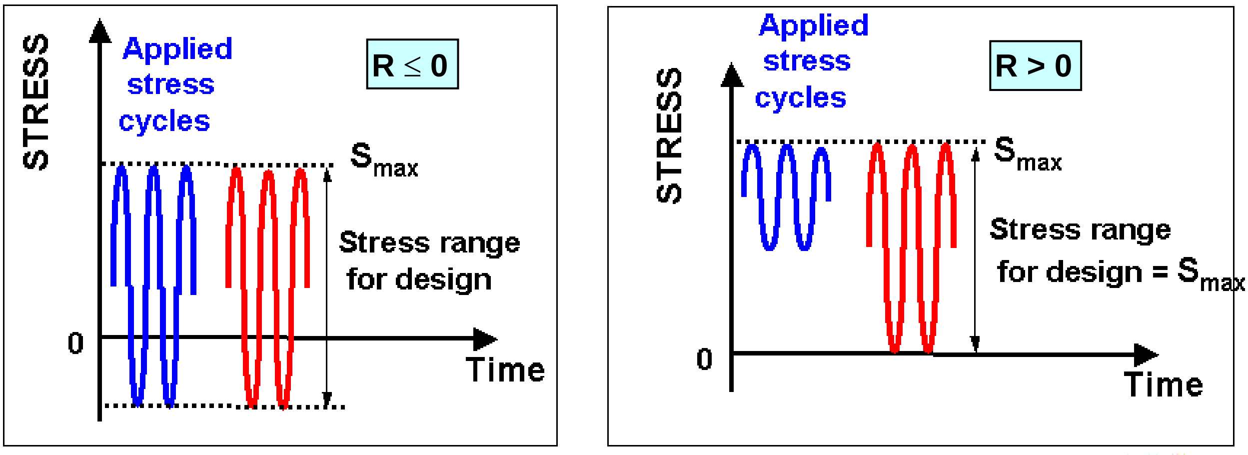


Fig. 5.6 Limitations in allowable stress ranges for hammer peened welds in steel and aluminium alloys

6. NEEDLE PEENING

6.1 Introduction

In needle peening, compressive residual stresses are induced by repeatedly hammering the weld toe region with a bundle of round-tipped rods. Compared with hammer peening, it is generally more suitable when large areas need to be treated. e.g. welds in tubular joints. As in the case of hammer peening, the following specification is restricted to plate thicknesses of at least 4mm for steel and 8mm for aluminium.

The magnitude of the residual stresses introduced by peening methods depends to a large extent on whether the weld to be peened is under tensile or compressive loading during the peening operation. A better result can be expected if the peened component can be loaded in such a way as to give **tensile** stress in the region to be peened. Conversely, a **compressive** loading will reduce the effectiveness of the peening.treatment.

6.2 Equipment

A standard needle gun of the type used for removing slag and scale is suitable for needle peening, Fig. 6.1(a). However, where necessary it is useful to modify the chuck, as shown in Fig. 6.1(b), to align the steel rods in a rectangular pattern rather than a circular one; this will facilitate the treatment of weld toes. Additionally the ends of the rods should be rounded, see Fig 6.1(b).

Fig. 6.1 Needle peening equipment and operation.

6.3 Procedure

The aim in needle peening is to deform the material plastically at the weld toe to induce beneficial compressive residual stresses. Effective treatment requires reasonably accurate positioning of the needles over the weld toe so that metal on each side (weld metal and parent plate) is deformed. Needle peening can be performed immediately after welding, while the weld is still hot, if required. The toe should be needle peened four times to achieve optimum benefit and adequate coverage. The resulting surface should be bright in appearance and contain a uniform distribution of small indentations.

The operation is carried out with the tool held at approximately 45^o to the plate surface with the ends of the needles in contact with the weld toe, as illustrated in Fig.6.1(c). Sufficient force should be applied to the tool to prevent unsteady movement and to ensure even treatment. It is not necessary for the operator to exert undue force in this operation, particularly when using a lightweight gun, and therefore operation in the overhead position can be carried out with relative ease. The rate of treatment is approximately 800mm per minute.

It is important to achieve full coverage of the weld region to be treated. To this end, peening should be continued until the area is free for untreated spots. The time to do this should be noted. It is recommended that 100 % coverage of needle marks is checked visually, using a 5-10 X power magnifying glass. Then the area is treated again for the same length of time, to achieve what is termed 200% coverage.

The location of the needle peened area, extent of coverage and general uniformity of appearance should be checked visually with the aid of a 5X to 10 power magnifying glass A useful contrast between the needle peened surface and the surrounding untreated surfaces can be achieved if the surfaces are first stained with toolmakers blue, the dye being removed by the needle peening operation. Light grinding the weld toe region before needle peening, to obtain a dull surface finish, will also facilitate visual examination of peened areas.

6.4 Operator and inspector training

Some skill is required to perform needle peening and a training programme should be implemented for inexperienced operators. This should include a demonstration of the appearance of an adequately treated weld as well as a demonstration of unacceptable welds and an explanation of the factors that influence the result. If available, reference samples that have been needle peened correctly should be used for comparison. The training programme should include actual peening of at least 1 meter of weld, combined with periodic inspection and evaluation. Inspectors should be similarly trained to understand the requirements for correctly treated welds.

6.5 Safety aspects

Needle peening, even using modern silenced hammers, is a noisy operation and it is essential that the operator and others working in the vicinity should use ear protection. Normal protective clothing for working in a fabrication shop is adequate, but it should include a face-mask or goggles. Vibration from peening equipment may cause physical discomfort or harm, and the operator should not perform peening for extended periods of time. Vibration damping gloves may help alleviate this problem.

6.6 Quality control and documentation

Photographs taken at intervals along the peened area, which should include appropriate identification markers, provide a suitable record of the needle peening treatment. Care is needed to arrange the lighting source in such a way that the photographs show any areas that inadvertently may have been untreated. After prolonged use, the tips of the needles will revert back from the rounded shape introduced by grinding to being flat ended. At this time, the tips should be reground to produce a rounded shape.

6.7 Fatigue strength of joints improved by needle peening.

Benefit from needle peening of steel components can only be claimed for details in design Class FAT 90 or lower in the IIW notation for S-N curves, as shown in Fig. 6.2. This limitation is due to the fact that the higher classes include non-welded details, details whose lives are not governed by weld toe failure or the welds that have been already been improved, e.g. by grinding the weld flush with the surface.
For steels with specified yield stress higher than 350 MPa the benefit consists of an upgrade by a factor of 1.6 applied to the stress range, with a constant amplitude fatigue limit at 2×10^6 cycles, as shown in Fig. 6.2. Additionally, in the low cycle region the S-N curve is limited by the IIW parent material curve, i.e. the FAT 160 curve with a slope parameter of m = 5 [6].
For lower grade steels, with specified minimum yield strength below 350 MPa, the improvement factor is 1.3, corresponding to a factor of 2.2 on life.
The highest class, which can be claimed, is also in this case FAT 125.

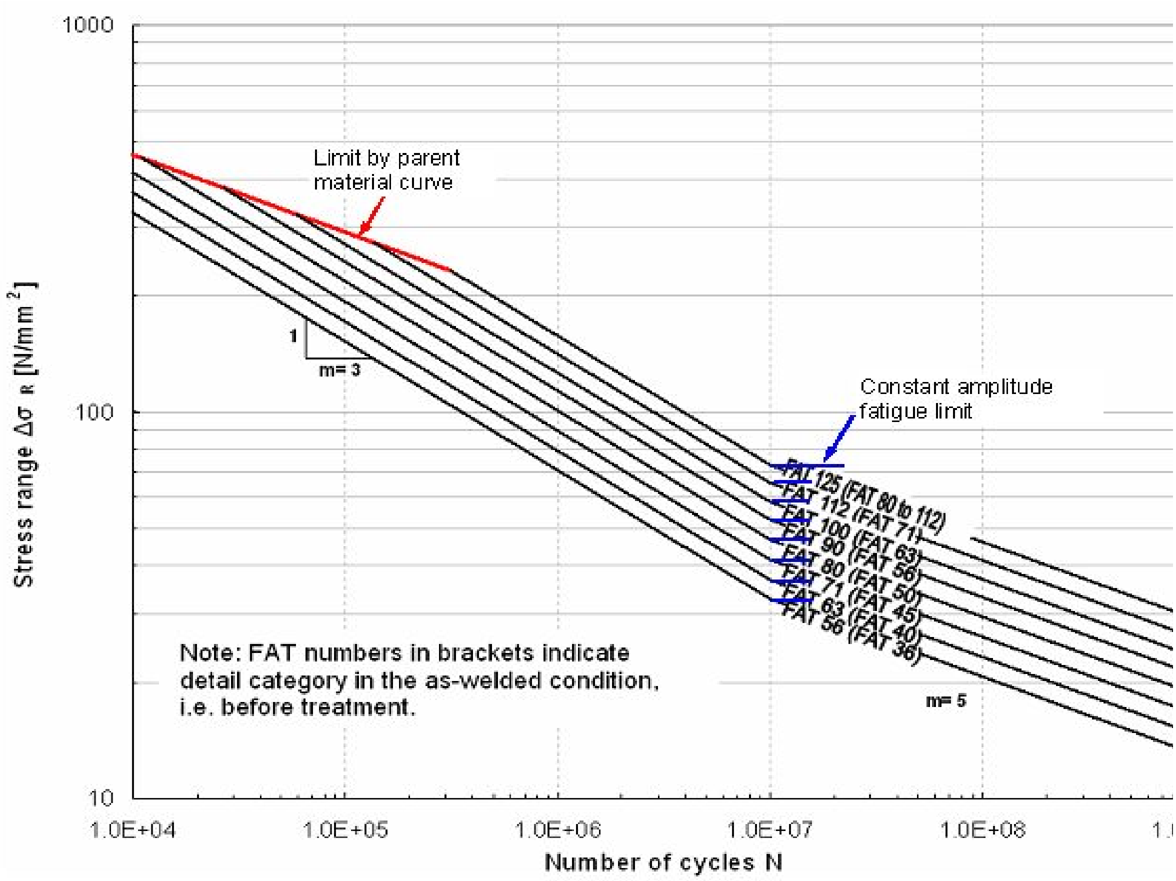


Fig. 6.2 Design S-N curves for needle peened welds in steel structures.

For aluminium welded components improved by needle peening, an improvement factor of 1.6 applies to joints corresponding to FAT 40 and lower, see Fig. 6.3. The highest class that can be claimed is FAT 56.
Fatigue tests on large-scale structures indicate lower benefit from needle peening than for small–scale specimens. However, the main basis for the above recommendations is data obtained from small-scale welded specimens. Therefore, it is recommended that for structures with plate thickness larger than 20 mm the benefit for needle peening is assumed to be the same as for grinding and TIG dressing. i.e. a factor of 1.5 on allowable stress range, limited to an increase to FAT 100 for steel, and FAT 45 for aluminium weldments.

6.8 Effect of thickness for joints improved by needle peening.

The increase in fatigue strength for hammer peened joints is mainly due to the effect of compressive stresses and the higher fatigue strength doe to improved geometry is of less importance. The thickness penalty for peened joints is therefore the same as for as-welded joints.

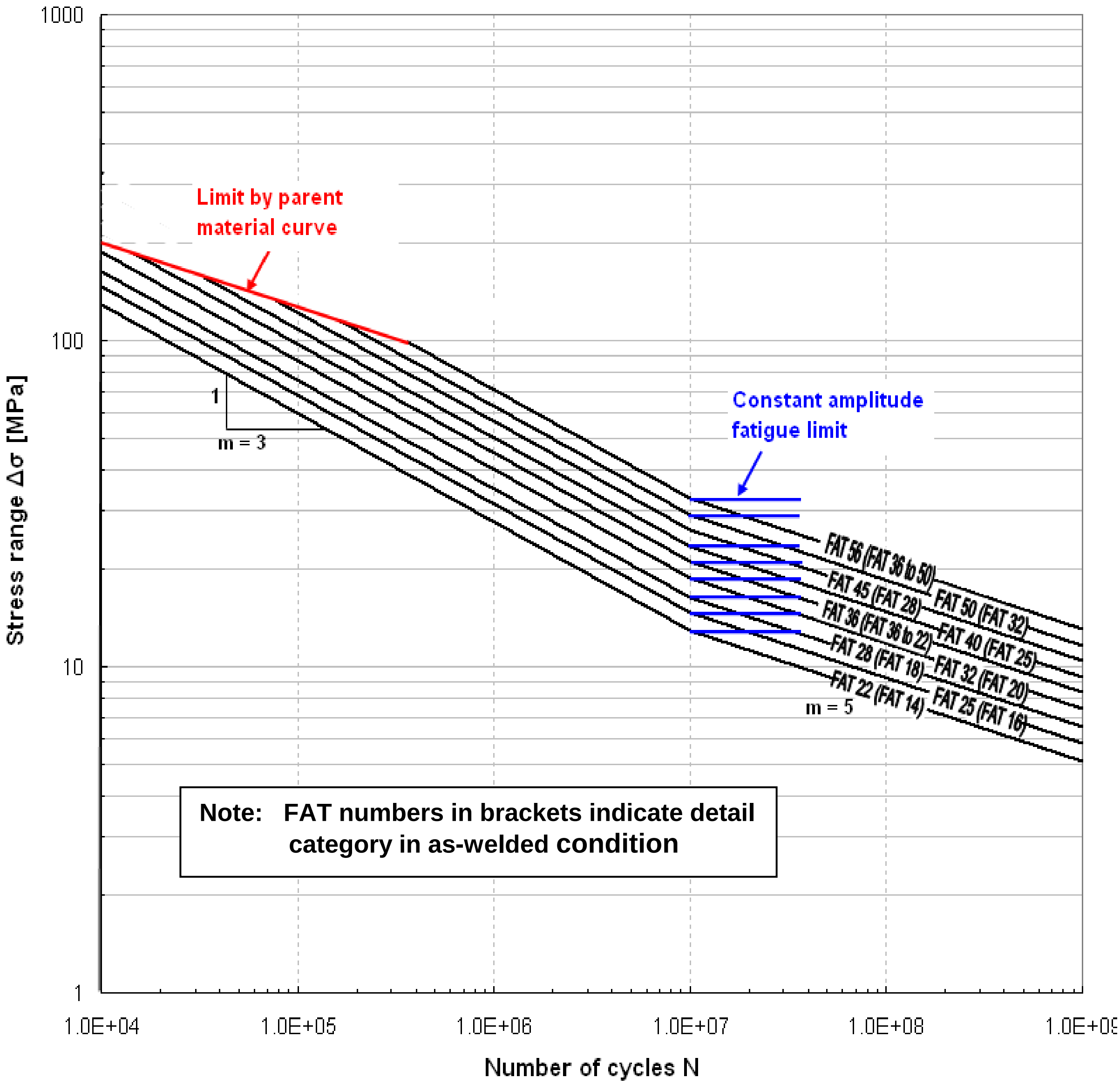


Fig. 6.3 Design S-N curves for needle peened welds in aluminium alloys

Due to the sensitivity of needle peened welded joints to applied mean stress, the higher S-N curves can only be used under the following circumstances:

- The maximum nominal compressive stress in the load spectrum is lower than $0.25 \times \sigma_Y$.
- When the applied stress ratio $R < 0$, the S-N curve is used in conjunction with full stress range
- When the applied stress ratio $R \geq 0$ (all stresses in tension) the S-N curve is used in conjunction with the maximum stress instead of the full stress range.

The limitations are illustrated in Fig. 6.4

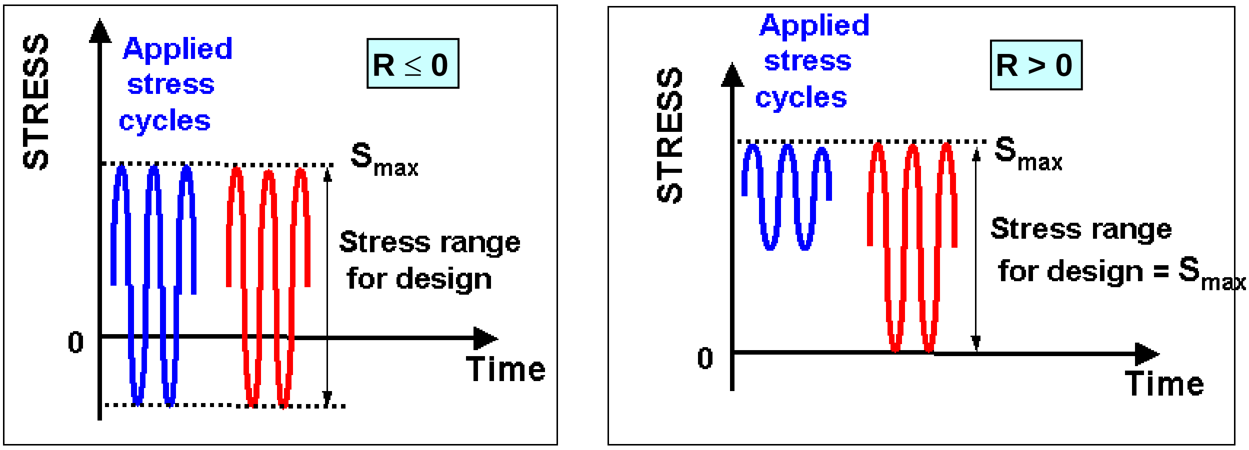


Fig. 6.4 Limitations in allowable stress ranges for hammer peened or needle welds in steel and aluminium alloys

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7. RECOMMENDATIONS RELATED TO STRUCTURAL HOT-SPOT STRESS

All the benefits due to the use of an improvement technique discussed so far have referred to S-N curves expressed in terms of nominal applied stress range. This is the most commonly used fatigue design approach for assessing welded structures and is the basic method in the IIW Recommendations [6]. However, in the context of potential fatigue failure from a weld toe or end, there is growing interest in an approach based on the structural hot-spot. Thus, there will also be an interest in expressing the fatigue performance of improved welds in the same terms. Little direct research has addressed this issue, apart from the case of tubular joints. In this case, notably in the context of offshore structures [9], fatigue design rules already use the hot-spot stress and indeed include design data for toe ground welds. The approach is the same as that recommended in Section 3.10 of the present document, namely the use of an enhancement factor to be applied to the design curve for the as-welded joint. In the absence of relevant data, the same approach is recommended for all the improvement techniques covered by the present document. In view of the lack of experimental data, for safety an added condition is that the constant amplitude fatigue limit should be assumed to correspond to the same endurance as that for the untreated weld, currently $N = 5 \times 10^6$ cycles in the IIW Recommendations [6].

Preliminary fatigue design recommendations based on the use of the hot-spot stress are under preparation by the IIW [10]. These include tentative proposals for design S-N curves expressed in terms of the hot-spot stress range. At this stage, it is recommended that the enhancement factors are applied to those curves.

In the case of welded steel, two design curves are proposed for as-welded fillet welds, namely FAT 90 for load-carrying or FAT 100 for non-load-carrying welds, where fatigue cracking might initiate from the weld root if the toe has been improved. Less data are available for aluminium alloys and at this stage a single curve, FAT 40, is proposed for as-welded joints. Noting the warning about the application of improvement techniques to load-carrying welds, the corresponding S-N curves for welds improved using any of the methods are given in Tables 7.1 and 7.2 below:

Table 7.1 Structural Hot-Spot classes for joints improved by grinding or TIG dressing.

Material	**Load-carrying fillet welds**	**Non-load carrying fillet welds**
Mild steel, YS* < 350 MPa	FAT 112	FAT 125
Higher strength steels, YS*> 350 MPa	FAT 125	FAT 140
Aluminium alloys	FAT 45	FAT 50

Table 7.2 Structural Hot-Spot classes for joint improved by hammer or needle peening, thickness up to 20 mm (steel) and 15 for aluminium.

Material	**Load-carrying fillet welds**	**Non-load carrying fillet welds**
Mild steel YS* < 350 MPa	FAT 112	FAT 125
Higher strength steels YS* > 350MPa	FAT 125	FAT160
Aluminium alloys	FAT 56	FAT 63

** YS = minimum specified yield strength*

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Appendix 1

IIW Round Robin Testing Programme

Participating laboratories

Lab. ID	Organisation		Country
	Short name	Full name	
Lab 1	CETIM/ IRSID	Centre Technique des Industries Mecaniques/ Institut de Recherche de la Siderurgie (two labs shared testing)	France
Lab 2	SSAB	Swedish Steel AB	Sweden
Lab 3	NTNU	The Norwegian University of Science and Technology	Norway
Lab 4	TIT	Tokyo Institute of Technology	Japan
Lab 5	TWI	TWI (formerly The Welding Institute)	UK
Lab 6	CEMUL	Instituto Superior Technico, Lisbon	Portugal
Lab 7	LUT	Lappeenranta University of Technology	Finland
Lab 8	BAM	Bundesanstalt für Materialforschung und -prüfung	Germany
Lab 9	TUD	University of Delft	The Netherlands
Lab 10	TUB	Technical University of Braunschweig	Germany
Lab 11	PWI	Paton Welding Institute	Ukraine
Lab 12	IS	Institut de Soudure	France

APPENDIX 2

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Appendix 3

Production data sheets for

- Burr grinding,
- TIG dressing
- Hammer peening.

PRODUCTION DATA SHEET
for WELD TOE IMPROVEMENT by
BURR GRINDING

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Commision XIII

WELDING SPECIFICATION

Base material: ______________________

Filler material: ______________________

Welding procedure No: __________________

COMPONENT

Type: ______________________________

Identification: __________________________

EQUIPMENT

Make and model: ______________________

Power: ______________________________

Tip diameter: ________________________

Weight (with tool tip): ___________________

Rotation speed: ______________________

SKETCH OF COMPONENT

TREATMENT DATA

Position: __________________________

Work angle, sideways: __________________

Work angle, weld direction:______________

Travel speed: _______________________

Number of passes: ____________________

Length of treatment: __________________

Time of treatment:_____________________

INSPECTION

☐ Visual ☐ Photo ☐ Geometry measurements

Equipmen____________________________

____

____

REMARKS

TOE GEOMETRY MEASUREMENTS

Spacing of measurement points (mm): ______

	Max.	**Min.**	**Mean**
Toe radius (mm):	_____	______	______
Groove depth (mm):	_____	______	______

Measurements report: ___________________

OPERATOR

Experience: 1. Hours: ________ 2. Length of weld treated: __________

Operator’s name: ____

Date: __________________

PRODUCTION DATA SHEET
for WELD TOE IMPROVEMENT by
TIG DRESSING

International Institute of Welding
Commision XIII

WELDING SPECIFICATION

Base material: ______________________________

Filler material: ______________________________

Welding procedure No: ______________________

COMPONENT

Type: ______________________________

Identification: ______________________

EQUIPMENT

Make and model: ____________________________

Power capacity: ______________________________

Electrode diameter: _________________________

Gas cup diameter ___________________________

Shielding gas: ___________________________

SKETCH OF COMPONENT

TREATMENT DATA

Dressing position (flat etc): __________________

Work angle, sideways: ______________________

Work angle, weld direction: __________________

Preheat temperature: _________________________

Distance between electrode tip and weld: ____mm

Gas flow rate: _________________________l/mm

Voltage (U):: _________________________Volts

Current (I): ___________________Amperes

Heat input: $H = \frac{60 \times U \times I}{1000 \times V}$ = ___________ kJ/mm

INSPECTION

☐ Visual & photo ☐ Measurements

Equipment: _______________________________

____

REMARKS

RESULTS OF INSPECTION

Spacing of measurement points (mm): _______

	Max.	Min.	Mean
Toe radius (mm):	_____	_____	_____
Weld angle (deg):	_____	_____	_____
Groove depth (mm):	____________________		
Macroscopic report:	____________________		

OPERATOR

Experience: 1. Hours: _________ 2. Length of weld treated: __________

Operator's name: ____

Date: ________________

PRODUCTION DATA SHEET
for WELD TOE IMPROVEMENT by
HAMMER PEENING

International Institute of Welding
Commision XIII

WELDING SPECIFICATION

Base material: ______________________

Filler material: ______________________

Welding procedure No: ________________

COMPONENT

Type: ______________________________

Identification: ________________________

EQUIPMENT

Make and model: ____________________

Power: ___________________________

Tip diameter: _______________________

Weight (with tool tip): ________________

Impact frequency: ___________________

SKETCH OF OMPONENT

TREATMENT DATA

Position: _________________________

Work angle, sideways: ________________

Work angle, weld direction: ____________

Travel speed: _______________________

Number of passes: ___________________

Length of treatment: __________________

Time of treatment: ___________________

Change of tool: _____________________

Cause: ____________________________

INSPECTION

☐ Visual & photo ☐ Measurements

Equipment: _________________________

____

REMARKS

RESULTS

Spacing of measurement points (mm): ______

	Max.	Min.	Mean
Toe radius (mm):	____	____	____
Weld angle (deg):	____	____	____

Groove depth (mm): ________________

Macrosections, report No: _____________

OPERATOR

Experience: 1. Hours: ________ 2. Length of weld treated: ________

Operator's name: ________________________________

Date: ______________