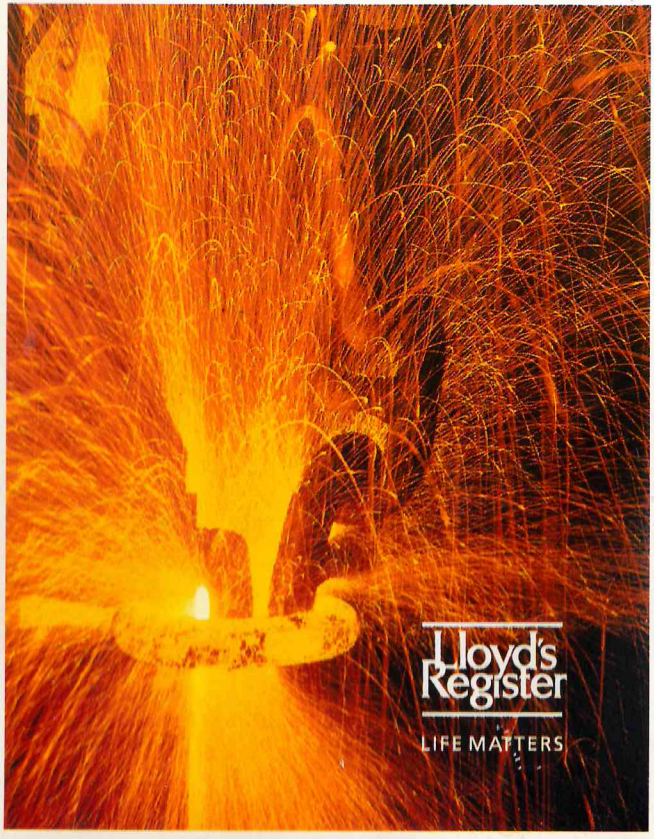
Marine Chain Cable
Pocket Guide



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1. Introduction

The risk associated with chain failure, as well as the costs of replacement mean that it is essential that welded chain cable is properly manufactured, tested and certified.

Stud link chain cable is a relatively high strength steel compared with weldable structural steel. This is particularly true for grade U3 chain materials. In order to achieve the required strength the carbon is increased and the correct heat treatment is therefore critical to achieving the required properties.

The composition of the steel used to manufacture chain cable necessitates care when welding these materials. Most stud link chain is manufactured by an automated flash butt welding process, and where studs are welded this is normally done manually. It is important that both processes are properly conducted according to Rule requirements, since the result of poor welding is a reason for rejection of the chain cable, as some of the examples in this guide show.

This guide has been produced to assist LR Surveyors in the survey of marine chain and fittings according to LR Rules. The intention is to provide guidance on the correct interpretation of the Rules, with regard to the survey of chain during manufacture.

LR has a wealth of knowledge and experience in the survey of chain. Therefore Surveyors are reminded that if there is any doubt over the acceptance of chain according to Rule requirements, they should ask for advice.

The guide does not form part of LR Rules, and where necessary, reference should be made to the Rules. The guide is based on the requirements incorporated into the Rules for Materials dated July 2011, but Surveyors must always make reference to the current version of the Rules.

In addition to the Rules, Surveyors should make reference to the LR Survey Procedures Manual Part B, Chapter 10, Section 2.

As far as possible, the guide uses pictorial examples of imperfections in chain. It should be noted that acceptance or rejection is to be in accordance with the Rules and the images provided are only for guidance purposes.

This guide is restricted to chain cable for ships, and covers stud link chain cable, short link chain cables and the more common fittings which are attached to them. The guide does not specifically relate to mooring chain cables although similar imperfections can potentially arise in them.

The guide concentrates on the flash butt welding process for the manufacture of chain. The manufacture of chain by casting or forging is not covered, and neither are the types of imperfections which may arise in casting and forging processes.

Lloyd's Register appreciates all the invaluable input from organisations while compiling this guide book and would like to specifically mention The Solid Swivel Co Ltd. and Vicinay Cadenas S.A. for their feedback and for providing many of the images contained with in this booklet.

2. How to Use This Guide

The guide is intended to follow the flow of the manufacturing process. At each stage, the manufacturing process is briefly described, followed by a brief reference to Survey requirements and the types of imperfections which may be encountered.

Reference is made in the text to the various imperfections, which are collected together in Appendices at the back of the guide.

3. Chain Types & Fittings

Chain cable for ships may be classified as being one of two general types, stud link or short link chain cable

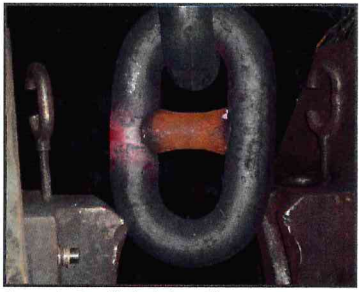


Figure 1 - Stud link chain cable

Stud link chain cable, see *Figure 1* are intended for anchoring or mooring purposes.

The stud has two functions; it prevents lateral deformation of the link in service, and also prevents the chain becoming entangled in the chain locker.

The Rules specify three grades U1, U2 and U3. Grade U1 has to meet chemical analysis restrictions, but has no specified mechanical properties, and is now not normally used. Grades U2 and U3 have specified supply conditions, chemical analysis and mechanical properties.

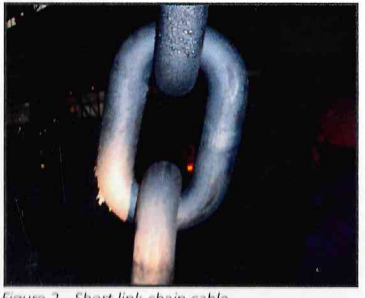


Figure 2 - Short link chain cable

Short link chain cables, *Figure 2*, are manufactured without a stud. The Rules cover marine applications but exclude applications covered by the Code for Lifting Appliances in a Marine Environment. Typical applications include buoy mooring chain, steering chains for

yachts and small anchor chains for pleasure craft. These chains are smaller, and are often galvanized. One grade (M4) is included in the Rules.

Fittings for chain cables are to be of an approved design. The list of type approved fittings is given in CD Live, and includes the approved manufacturing process route. Fittings such as shackles and swivels are to be forged or cast in steel of at least grade U2.

An LR Certificate (Form 1110) may apply to welded chain only, welded chain in combination with specified fittings, or to fittings only. Some examples of the more common fittings for chain cable are shown in *Figures 3 to 7*.

Figure 3 - Dee shackle (lugged joining shackle)

Shackle bolts should be an easy driving fit and be secured in place by small tapered pins passing through the ends of the shackle pins and both sides of the eyes. The securing pins may be either riveted over or kept in place by lead pellets hammered into recesses in the shackle eyes, or alternatively fixed by epoxy-based adhesive. See *Figure 4*.

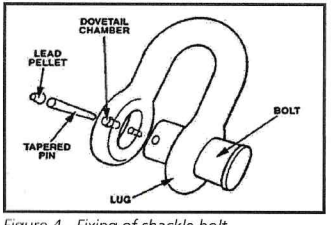


Figure 4 - Fixing of shackle bolt

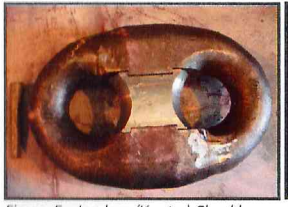


Figure 5 - Lugless (Kenter) Shackle

Figure 6 – Assembly of Kenter Shackle

Figure 7 - Swivel

Figure 8 – Enlarged End Link

4. Stud Link Chain Manufacture

The various stages in the manufacture, testing and inspection of welded chain cable are shown in *Diagram 1*. This applies to both stud link chain cable and short link chain cable.

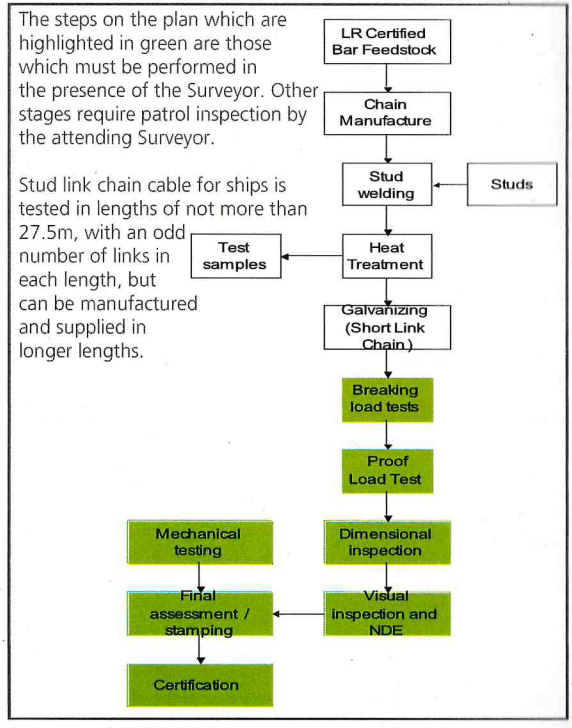


Diagram 1 - Flow diagram showing manufacturing stages

4.1 Bar Material

All bars for welded chain manufacture are to be from an LR Approved works. Acceptable forms of material certificates include:

- An LR certificate
- A manufacturer's certificate produced under the LR Materials Quality Scheme
- A certificate from a Classification Society recognised by LR

Details of a bar manufacturer's scope of approval can be found on the List of Approved Manufacturers on CD Live.

Imperfections which have originated from the bar will be seen during visual inspection by the Surveyor at the Proof Testing stage.

- Surface Lap (shell) on chain link (see BD1)
- Surface Lap (shell) on bar feedstock (see BD2)

Bars are first cut to length, and then heated, before going through the bending process.

Bars are usually supplied in the as rolled condition but can also be forged. Bars that have been turned to size by machining may also be accepted in isolated cases. For guidance, machining should not exceed 10% of the bar diameter.

- Machined bar (see CD1)

4.2 Chain Link Manufacture

Automation of the manufacturing process has led most manufacturers to use a carousel process which involves the five stages of, heating, bending, flash butt welding, trimming and stud pressing.

The mechanics of the carousel means that four separate lengths of chains are made concurrently. The four stages are carried out at work stations placed at the 12, 3, 6 and 9 o'clock positions on the carousel. After each stage has been completed the carousel moves around so that the next operation can be completed.

Because four chain lengths are generally made concurrently, any imperfections introduced by the manufacturing process are likely to be present in all four chain lengths produced at the same time.

4.2.1 Bending

Figure 9 - Forming by bending

Once cut to length and heated, the bar is pre-bent and inserted into the last completed link. Bending is completed around formers of the appropriate diameter.

It is important that these are of the correct design and dimensions to give a smooth radius, to produce a bend without depressions or distortions in accordance with the Rules.

For end links and enlarged links a different former will be needed to bend the links. Rollers may be in two parts, and if incorrectly adjusted can produce a ridge in the crown of the link.

Bending must be performed within the approved temperature range. If the bending temperature is too low, insufficient ductility in the material may result in cracking.

Imperfections which can arise in the bending process include:

- Cracking (see CD2)
- Scoring due to inaccurate set-up (see CD3)

4.2.2 Flash Butt Welding

The second stage of the operation takes the bent bar and positions the ends into the copper clamps. The end faces are forced together under forging pressure and electric resistance welded together. This process is known as flash butt welding, see *Figure 10*. During this process, the material in contact on the end faces are heated and softened, until the applied pressure is sufficient to force the oxide contaminated material from the interface giving a sound weld.

Figure 10 - Flash Butt Welding

If properly carried out, all of the interface will be removed into the flash. If incorrectly carried out, the weld interface may contain imperfections (oxides and lack of fusion) producing a weld prone to failure.

Figure 11 – Good condition of flash butt welding copper jaws

It should be noted that the welding parameters used for end links and enlarged links will be different to the parameters used to weld the main chain links.

Figure 12 – Correct position of chain link in copper jaws

Imperfections which can arise in the flash butt welding process include:

- Lack of fusion (see CD4)
- Compression marks (see CD5)
- 'Copper' cracks (seeCD6)
- Misaligned flash butt welding (see CD7)

Figure 13 – Poorly maintained and worn copper jaws

'Copper' crack is cracking that appears on the chain link in the region of the copper clamp

electrical connection. These can occur when the copper shoe is not fully clamped to the chain link or excessive wear of the copper clamp has occurred resulting in arcing between the copper clamp and chain link.

Cracking may not be apparent until the proof load is applied during testing.

4.2.3 Trimming

During welding excess material (flash) is forced out of the weld. This is removed during the trimming stage.

This may be done by an automatic machine, see *Figure 14*, or by using a pneumatic chisel, see *Figure 15*. It is important that the area is cleaned properly so that no flash remains, as this may act as a stress raiser in service. Excessive removal may result in significant loss of section.

Figure 14 – Machine removal of the extruded flash

Imperfections which can arise in the trimming process include:

- Excess flash removal (see CD8)
- Insufficient flash removal (see CD9)

Figure 15 - Manual removal of flash

4.2.4 Stud Pressing

The final operation is the insertion of the stud.

Studs for chain cable for ships are preferably to be made of steel similar to that of the chain material but may be of mild steel. The use of other materials such as cast iron is not permitted. The chemical composition of the stud material is to be checked, and should have a C content of 0.23% maximum if the studs are to be welded.

The stud will normally be cold. It is placed into the hot link, and the link is pressed together. The ends of the stud make an impression or 'footprints' on the sides of the link, which help to keep it in place during service.

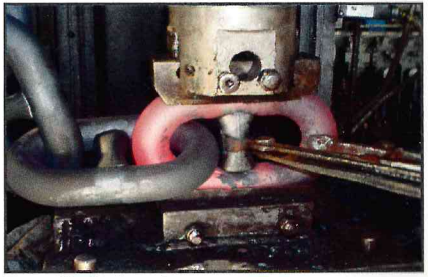


Figure 16 - Stud pressing

It is important that the stud is placed centrally and is perpendicular to the link legs.

Imperfections which can arise from the stud pressing process include:

- Misaligned studs (see CD10)
- Off-centre studs (see CD11)
- Damage from stud pressing (see CD12)
- Deformation from stud pressing (see CD13)
- Loose studs
- Studs inserted onto spatter or irregular surface

4.3 Stud Welding

Where welding of studs is required, this is to be carried out to Rule requirements, using an approved welding procedure and suitably qualified welders. The stud weld should be placed on the end away from the flash butt weld.

Welding of studs is normally carried out manually, and the quality of workmanship is critical to achieving a good quality weld. The Rules require that MPI testing is conducted on stud welds after proof loading.

Studs welded into the links is to be completed before the chain cable is heat treated.

Stud welding should be completed in the downhand position. To achieve this, it is best completed in an arc of up to 60° either side of centre line of the stud.

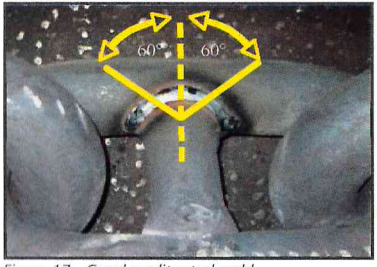


Figure 17 - Good quality stud weld

This makes it easier to control the weld quality, reduce the skill level required by the welder and reduces the complexity of the start and stop position. *Figure 17* shows a well made weld.

4.4 Heat Treatment

Heat treatment is to be carried out prior to proof loading and breaking tests and must be carried out in accordance with the LR Rules. The required heat treatment depends on the grade and chemistry of the chain cable.

Grade	Manufacturing method	Condition of supply
U1 cable	Flash butt welded	As welded
		Normalised
U2 cable	Flash butt welded	As welded
		Normalised
U3 cable	Flash butt welded	Normalised
		Normalised and Tempered
		Quenched and Tempered

Important parameters the manufacturer must control:

- Heating rates
- Soak time
- Maintain correctly calibrated equipment
- Quench medium temperature and circulation
- Keep records for every batch- You should review the record for each batch.

The furnace must be regularly checked to ensure that these parameters are maintained and a qualified system is in place to ensure the correct heat treatment.

The heat treatment may be carried out using either:

- Batch heat treatment furnace
- Continuous furnace heat treatment

Imperfections which can arise as a result of heat treatment include:

- Cracking (see CD20)

Figure 18 – An example of chain correctly fixtured for batch heat treatment

5. Testing: Finished Chain Cables

Proof and break load tests are to be witnessed by the surveyor. All chain must be tested at a proving establishment officially recognised by, and on a machine approved by LR. The machine must be properly calibrated under survey at least once per year.

5.1 Proof Load Test

Each length of stud link chain cable is to be subjected to a proof loading test in an approved testing machine and is to withstand the load given in the Rules for the appropriate grade and size of cable. The chain must be held in a way so that no damage is done to any of the links and all links are tested.

In addition to passing the loading requirements, the samples should be inspected after testing for imperfections such as:

- Loose studs
- Cracking (see CD19, 21)
- Gross deformation

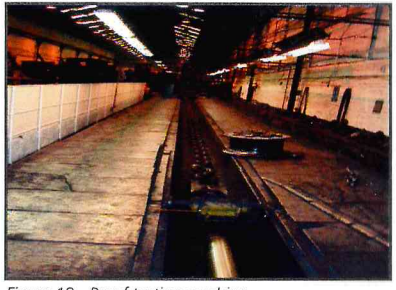


Figure 19 - Proof testing machine

The cable must be clean, and free from coating or other anti-corrosive coatings.

On completion of the test, each link is to be visually examined by the manufacturer, and is to be free from significant defects. Special attention is to be given to welds.

Dimensional measurements are made on the chain under partial load, after proof testing- see section on dimensional inspection.

Welding of chain (other than stud welding) is not permitted, and any chain links found to contain welds should be rejected.

Typical imperfections observed after proof testing are shown in Appendix 1 and can be considered as a cause for rejection.

5.2 Dimensional Inspection

The dimensional inspection of chain should be conducted after proof load testing, whilst the chain is still maintaining approximately 10% of the proof load.

5.2.1 Five Link Length

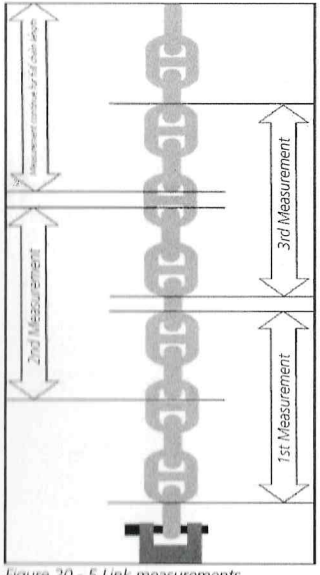


Figure 20 - 5 Link measurements

After proof testing:

a) The manufacturer is to check the entire chain for tolerance on length (+2.5%, -0%). This is achieved by measuring the tolerances across five link lengths. An overlap of two links is to be made between each five link length as shown in *Figure 20*.

This arrangement of measuring tolerances on overlapping five link lengths is to continue until the entire length of chain is covered. These measurements are to be recorded and verified by the Surveyor. The links held in the end blocks may be excluded from these measurements.

This measurement is essential to prevent in-service problems with the chain running through the capstan etc.

If the length over five links is less than the nominal, the chain may be stretched (with the Surveyor's agreement) by loading up to 10% above the specified proof test load.

b) The surveyor is to randomly select at least one five link length from each 27.5 m length of chain and measure the length under 10% of the proof load, see *Figure 21*. The tolerance on length is (+2.5%, -0%).

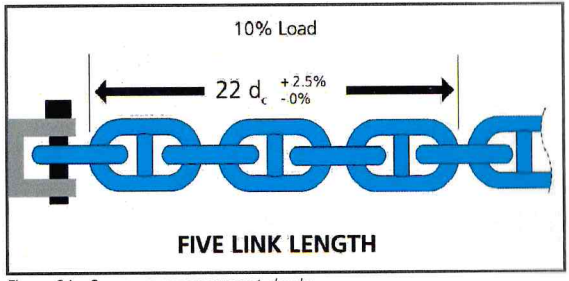


Figure 21 - Surveyors measurement checks

5.2.2 Link Dimensions

Checks of all other dimensions are to be made on three links, selected by the Surveyor, from every four 27.5 m lengths, when the proof load is removed.

Dimensional imperfections may include:

- Length or width outside specified tolerances
- Diameters in the crown outside specified tolerances
- Stud misaligned (see CD10)
- Stud off-centre (see CD11)

5.3 Break Tests

Breaking load tests are to be carried out on three link samples selected by the surveyor from the completed chain in accordance with the Rules.

5.4 Mechanical Tests

The location and frequency for tensile testing and impact testing are given in the Rules.

Mechanical tests are not to be taken from the same length as a break test unless all lengths are subject to a break test.

6. Certification and stamping of identity

Before certification, each length of chain cable must be closely visually inspected by the LR Surveyor. For visual inspection the chain cable must be laid out and be clean and free from paint.

Both sides of the chain is to be inspected to ensure 100% visual inspection is completed.

Examination is to confirm the chain is free from significant defects. Some defect examples are illustrated in Appendix 1 of this guide but this should not be considered as an exhaustive list.

Subject to agreement by the Surveyor, surface defects may be removed by grinding provided the dimensions still meet LR Rule requirements.

Where surface defects have been removed by grinding or other mechanical means and where this results in the link being outside the dimension tolerances, the link should be rejected.

Restoration of the dimensions by welding is not allowed and any link showing such welds should be immediately rejected.

Following satisfactory inspection, all lengths of chain cable are to be identified at both ends by hard stamping in accordance with *Figure 22* and the Rules.

The Surveyor's personal stamp is also to be included adjacent to the Lloyd's Register society stamp.

For future reference rubbings or photographs of the stampings should be retained on record.

An example of incorrect hard stamping on a chain is shown in *Figure 23*.

Certificates are wherever possible to be issued one per 27.5 m length. This solves the problem of dividing certificates at a later date. Form 1110 is to be used.

A- The abbreviated name of the LR office issuing the certificate followed by the certificate number.

B- Proof load in kN and the grade of chain

C- The letters LR and the surveyors personal stamp. The interlaced brand stamp markings should not cross the flash butt.

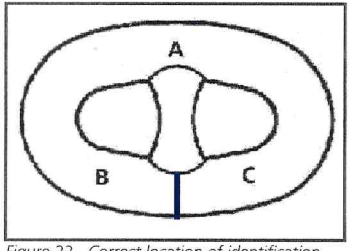


Figure 22 - Correct location of identification markings.

NOTE: Markings should not cross the flash butt weld

Figure 23 – Example of incorrect LR stamp and incorrect stamp location.

APPENDIX 1 – Defect Catalogue

Chain Link Defects

CD1 Machined Bar

Machining marks are evident on the chain link surface, this indicates that it has been produced from a machined bar. The use of machined bar is acceptable for the manufacture of chain cable provided the certification is current and reflects this. In this instance only one link showed evidence of machining, the rest of the chain had a surface condition indicative of manufacture from hot rolled bar. The presence of only one link in the length of chain could be indicative of problems with traceability.

Remedial Action: The origin and processing history of the bar should be checked. This link should be rejected, unless traceability can confirm compliance with the Rules.

CD2 Cracking on Bending /dʌk'tiliti/

This bar has insufficient ductility at the temperature at which the chain link has been formed. This could be due to a low bending temperature, or could be due to compositional issues with the steel chemistry. This will be a batch issue and therefore all chain links made at the same time should be examined for signs of cracking.

Remedial Action: It is unlikely that any remedial action will recover this situation the cracked links should be rejected. Any links showing such cracking may be dressed by grinding, provided dimensional tolerances are maintained. Ground chain should be checked by MPI in the presence of the LR surveyor to ensure all imperfections have been removed.

CD3 Marking Due to Inaccurate Roll Set Up

Inaccurate set-up of the bending rolls has produced a gouge in the surface of the link.

Remedial Action: This link could be dressed by grinding provided dimensional tolerances are maintained. Otherwise the link should be rejected and replaced. Weld repair is not acceptable.

CD 4 Lack of Fusion

Lack of fusion can be caused by inadequate heating, or inadequate pressure. If the oxide on the bar surfaces is not fully expelled into the flash, the resulting flash butt weld interface may have low ductility from contamination with oxide inclusions, making the interface susceptible to cracking during proof load.

Remedial Action: Any chain links showing such cracking must be rejected. The welding conditions should be examined by the manufacturer, and the root cause of the problems identified to the satisfaction of LR. and replaced. Weld repair is not acceptable.

CD5 Compression Marks

These are flat compression marks either side of the flash butt weld, caused by the clamping action of the copper grips which produce the pressure and power for the welding operation.

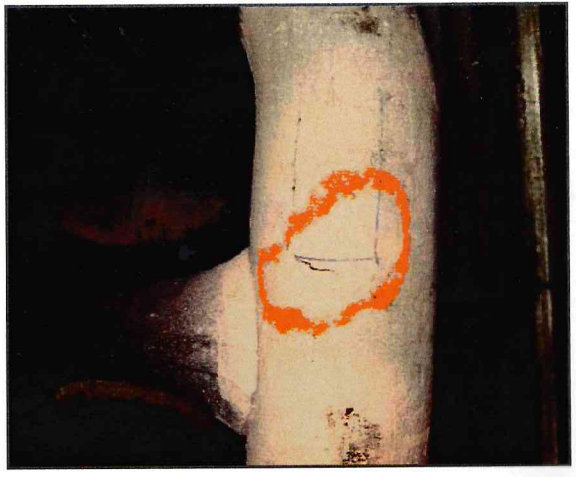
Remedial Action: If found, these should be removed by grinding, and MPI conducted to ensure there is no cracking associated with the compression marks. After grinding the link must still meet dimensional tolerances. Otherwise, the link should be rejected and replaced.

CD6 'Copper' Cracks

They may be related to overheating / arcing in the area of contact with the copper clamps, producing a brittle microstructure.

Note that these cracks may develop some hours after welding. These are cracks which may be associated with the compression marks.

Remedial Action: Minor cracking can be removed by grinding. MPI should be conducted to ensure that the crack has been fully removed. The ground surface should be checked to ensure that the dimensional requirements are still met. Repair by welding is not permitted. Major cracking in a chain link is a cause for rejection.



CD7 Misaligned Flash Butt Welding

During the flash butt welding process the ends of the bar must welded with the correct alignment to ensure the weld properties are correct and avoid forming stress raised features.

Misalignment could be due to incorrect bar length or poor fixturing during welding.

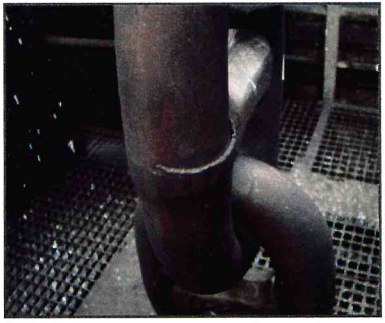
Remedial Action: If present such imperfections may be removed by grinding, provided the dimensions remain in Rule tolerances. Otherwise, such bars or any chain manufactured from them should be rejected and replaced.

CD8 Excessive Flash Removal

In this photograph, material has been removed from the section of the chain link during trimming, in addition to the removal of flash. This is likely to produce an under-tolerance dimension.

Remedial Action:
If outside the dimensional tolerances, the link should be rejected and replaced.

CD9 Insufficient Flash Removal



Unacceptable excess weld flash (burr) remains on this link. The burr acts as a stress raiser in the area of the weld.

The flash can be hidden under the stud resulting in crack initiation from below the stud.

Remedial Action: Burr is to be removed to provide the necessary form of the link. If this cannot be done to the Surveyor's satisfaction, then the link must be replaced.

CD10 Misaligned Stud

This photograph shows a misaligned stud with the misalignment at 7°. The Rules allow a maximum of 4° misalignment.

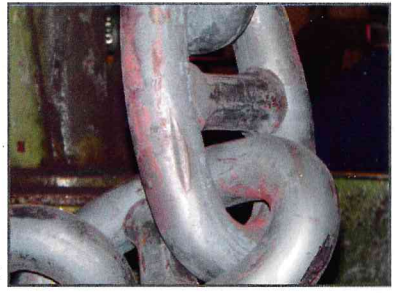
Remedial Action: If such misalignment is outside Rule requirements, the link should be removed and replaced.

CD11 Off-Centre Stud

This photograph shows a number of imperfections, including an off-centre stud. The stud is also too large for the diameter of the chain.

Remedial Action:
If off centre, the link should be removed and replaced.

CD12 Damage From Stud Pressing



This shows marking of the surface from the stud pressing operation. This would act as a significant stress raiser.

Remedial Action: If found this should be dressed, if this can be done so that the link remains in dimensional tolerance. Otherwise the link should be replaced.

CD13 Misalignment From Stud Pressing

This shows chain link deformation caused during stud insertion. The force during stud pressing may have been too high or the stud length may be too long. If the deformation is excessive it can cause the dimensions to be under tolerance. It can form a sharp step which acts as a stress raiser leading to early failure.

Remedial Action: The manufacturer needs to review the set up and maintenance of their machines. They may need to improve quality control of the stud length e.g. more frequent dimensional checks.

If found this could be dressed if the link remains in dimensional tolerance. Otherwise the link should be replaced.

CD14 Welded Both Ends

LR Rules specify that studs are to be welded at one side only, i.e. opposite the flash butt weld joint.

Remedial Action: This link should be rejected and replaced. Other chain from this batch should be examined.

CD15 Poorly Fitting Stud

This picture shows that a stud has been used which was too small for the size of the link. The gap between the stud and the link has been filled with multiple welding passes.

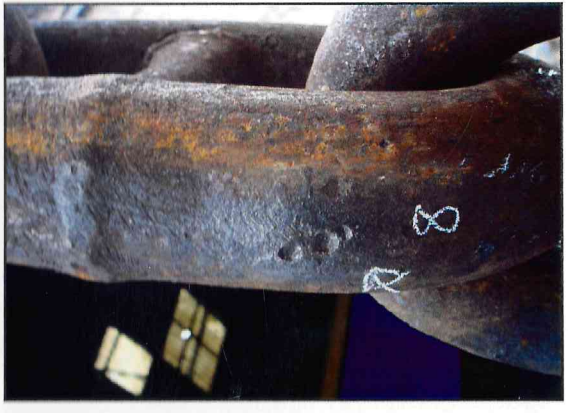
Remedial Action: This link should be rejected and replaced. Other chain from this batch should be examined.

CD16 Arc Strikes

This photograph indicates several arc strikes on the surface of the link, which have probably arisen from electrical contact during the flash butt welding process indicating poor maintenance and house keeping.

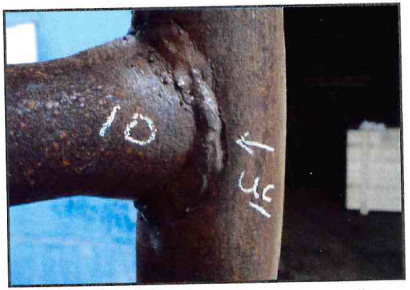
These areas will be subject to rapid heating/cooling cycles and will produce locally hardened structures, with the risk of crack initiation and in-service fracture.

Remedial Action: Such imperfections can be removed by grinding, but sufficient material must be removed to ensure that any heat affected steel is removed. MPI should be conducted after grinding to ensure that no cracking remains. After grinding the link must still meet dimensional requirements, otherwise it should be rejected and replaced.



CD17 Undercut

This photograph shows poor quality welding with several imperfections, including undercut at the toe of the weld. There is also a considerable amount of weld spatter.



Remedial Action: The undercut should be removed by grinding, subject to dimensions remaining within tolerance. Spatter should also be removed by grinding and the appropriate NDE applied.

CD18 Poor Weld Start/Stop

This weld shows a number of different welding imperfections, in particular a poor start/stop. Stud welds are prone to all the types of poor weld profile typical of manual welding.

Remedial Action: The weld should be dressed by grinding, subject to dimensions remaining within tolerance.

CD19 Cracking

Welding of incorrectly fitting studs will cause a susceptibility to cracking from contraction stresses. This photograph shows cracking through the weld bead.

Remedial Action: The link should be rejected and replaced and adjacent links checked.

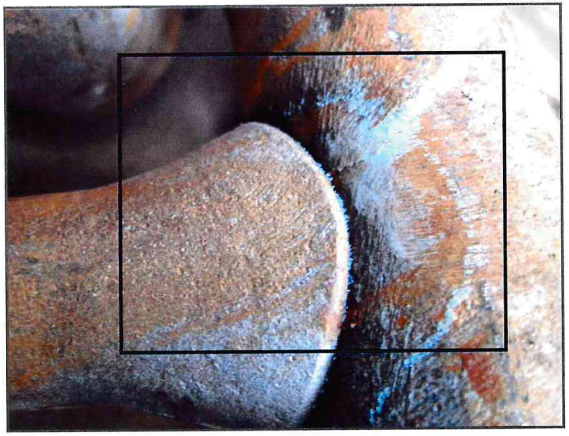
CD20 Cracking

This U3 link was welded satisfactorily but at final inspection the crack was found to be present. This crack is likely to have formed due to contraction stresses in the link which 'clinked' (cracked) most probably from charging into a hot furnace.

The crack will have initiated from the stud weld and it has grown to extend all the way around the chain link.

Remedial Action: No action, the link should be rejected and replaced.

CD21 Cracking



Lack of fusion cracking caused by incorrect flash butt welding parameters.

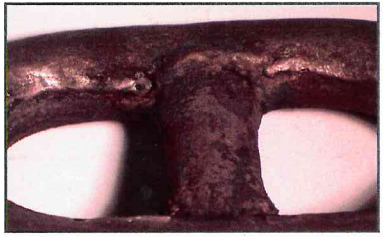
This could be caused by the manufacturer changing parameters or could be caused by a lack of control of the welding parameters e.g. too much variation in the welding parameters.

The composition of that batch of bar material may be incorrect.

Remedial Action: No action, the link should be rejected and replaced.

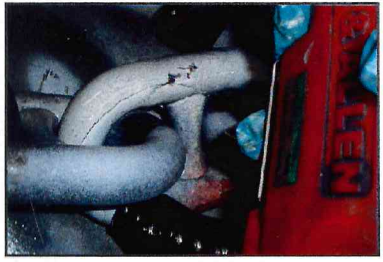
CD22 Repair Weld

The images shown below demonstrates a poor weld repair on a bar containing a lap or seam of rolling mill origin. Such welding of the link is not allowed in the Rules.

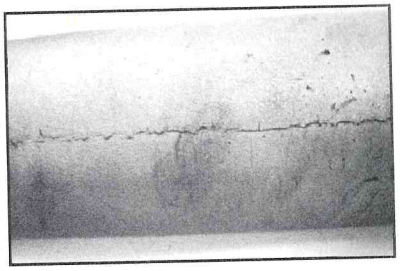


The following macro taken across the section of the weld repair shows the ineffective nature of the repair and the danger from in-service failure.

Remedial Action: This link should be removed and replaced, and other chains from this batch examined thoroughly.



This imperfection is probably a seam, which originated in the bar rolling process, has opened up on proof testing, and has been detected by MPI.



Such imperfections should be picked up by visual inspection or NDE in the rolling mill.

Remedial Action: Such an imperfection may be removed by grinding, followed by MPI to ensure that all of the imperfection is removed. After grinding, link dimensions must still be within Rule dimensional requirements. If repair by grinding is not possible, the link should be rejected and replaced and other chains from this batch examined thoroughly.

CD23 Repair Weld

This shows a weld repair on a link.

Remedial Action: As above this link should be removed and replaced, and other chains from this batch examined for suspect weld repairs.

CD24 Mechanical Damage During Handling

Mechanical damage can occur on the surface of the link from many different sources in the rolling mill, handling, transport, or during the chain manufacturing operations.

Remedial Action: If present such imperfections may be removed by grinding, provided the dimensions remain in Rule tolerances. Otherwise, such bars or any chain manufactured from them should be rejected and replaced.

Imperfections Related to Bar Feedstock

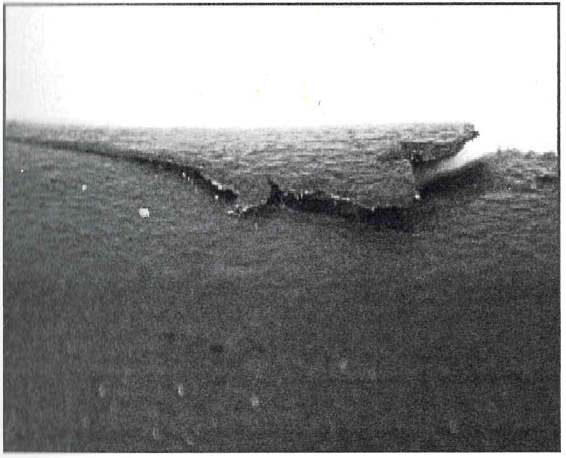
BD1 Surface Lap (Shell) on Chain Link

Bars must be free from cracks, laps, seams or any other imperfections which would affect the performance of the finished chain.

This surface lap (sometimes called shell) is one example of surface imperfections which are not acceptable. This type of feature originates in the steel casting, and upon rolling produces a lap, where one end is detached from the bar surface.

Remedial Action: Such imperfections may be removed by grinding, provided the links remain within specified dimensional tolerances. All bar from this batch should be subject to close visual inspection prior to use, and any chain manufactured from this batch should also be closely examined.

BD2 Surface Lap (Shell) on Bar Feedstock



Bar feedstock must be free from cracks, laps, seams or any other imperfections which would affect the performance of the finished chain.

Remedial Action: Such imperfections may be removed by grinding, provided the links remain within specified dimensional tolerances. All bar from this batch should be subject to close visual inspection prior to use, and any chain manufactured from this batch should also be closely examined.

Lloyd's Register EMEA
T: +44 (0)20 7709 9166
F: +44 (0)20 7423 2057
E : emea@lr.org

71 Fenchurch Street
London EC3M 4BS, UK

Lloyd's Register Asia
T: +852 2287 9333
F: +852 2526 2921
E: asia@lr.org

Suite 3501 China
Merchants Tower
Shun Tak Centre
168–200 Connaught
Road Central
Hong Kong, SAR of PRC

Lloyd's Register Americas, Inc.
T: +1 (1)281 675 3100
F: +1 (1)281 675 3139
E: americas@lr.org

1401 Enclave Parkway,
Suite 200
Houston,
Texas, 77077, USA

www.lr.org

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