

# Retrofitting Engineering

Fracture Control Design  
Chitoshi MIKI

## Retrofitting Works for Fatigue Damaged Structures

- Remove causes of fatigue damage
- Improve fatigue strength  
Improvement techniques are intended to use
  1. increasing fatigue strength of new structures
  2. repair or upgrading of existing structures
- Reduce stress fluctuations
- Identification of fatigue is essential

## Improve Fatigue Strengths

- *IIW Recommendations on Post Weld Improvement of Steel and Aluminum Structures*  
By P.J. Haagenzen and S.J. Maddox  
IIW XIII-1815-00

### Improvement of fatigue strengths—two concepts

1. reduction of the severity of the weld toe stress concentration
2. introduction of beneficial compressive residual stress

## 1.Reduction of Stress Concentration

Remove or reduce the size of the weld toe flaws  
And thus extend the crack initiation part of fatigue life

- Grinding
- Re-melting by TIG dressing

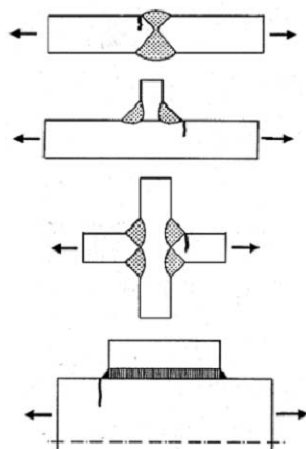
## 2. Introduction of Compressive Residual stresses

Clamping the weld toe in compression

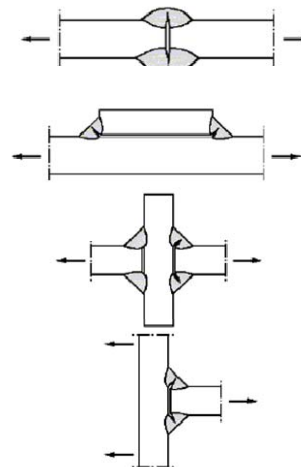
- hammer and needle peening
- UIT (Ultrasonic Impact Treatment)
- LTT (Low temperature transform Electrode)
  - New technologies originated Ukraine and Japan

## Types of Welded Joints

Fatigue failure from weld toe



Fatigue failure from weld root



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# Grinding

## Burr Grinding

Not desk grinding

The primary aim of grinding is to remove or reduce size of weld toe flaws.

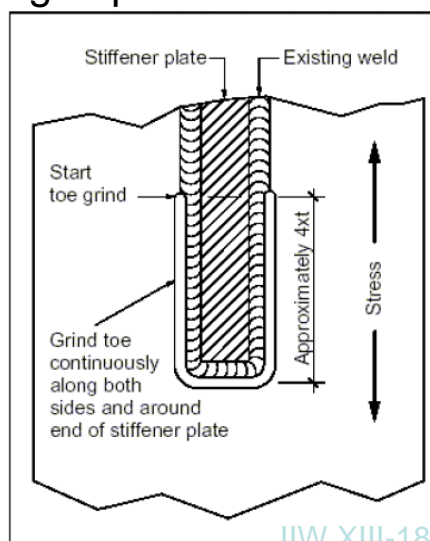
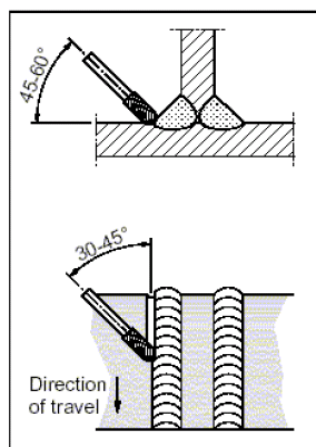
At the same time, it aims to reduce the local stress concentration effect

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## Procedure (1/3)

The quality of grinding depends on the skill of the operator

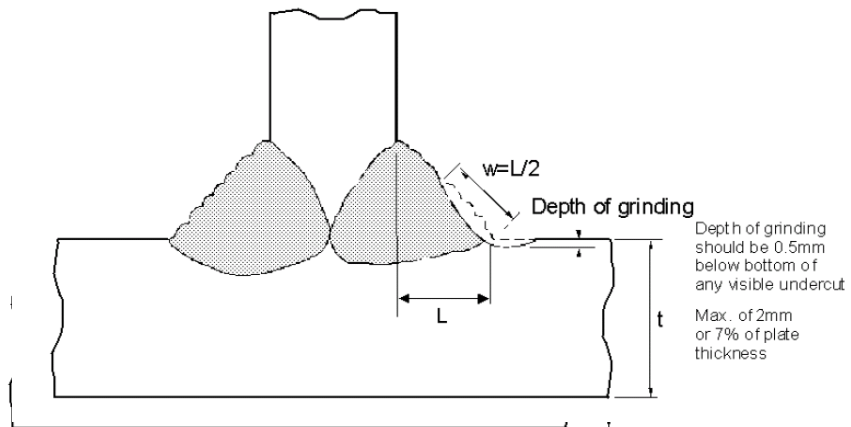


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## Procedure (2/3)

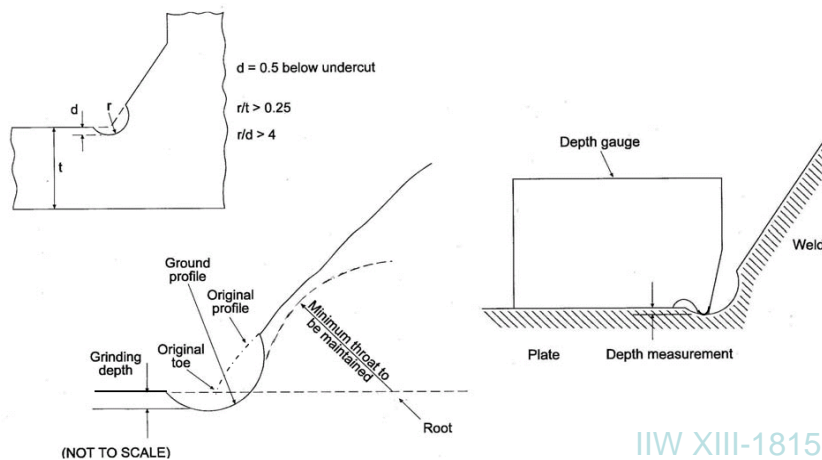
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The quality of grinding depends on the skill of the operator



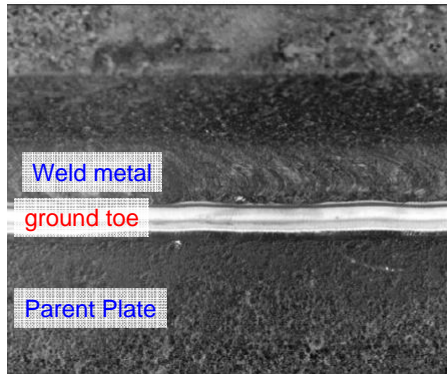
## Procedure (3/3)

The quality of grinding depends on the skill of the operator

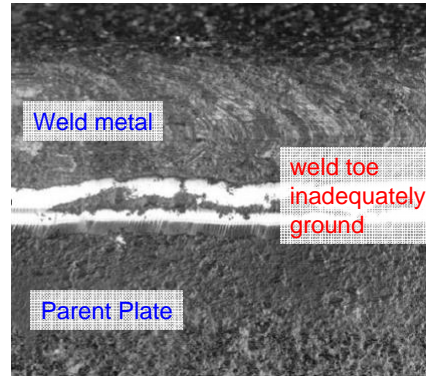


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## Appearance of burr ground weld toe



Correctly ground weld toe



Incorrectly ground weld toe

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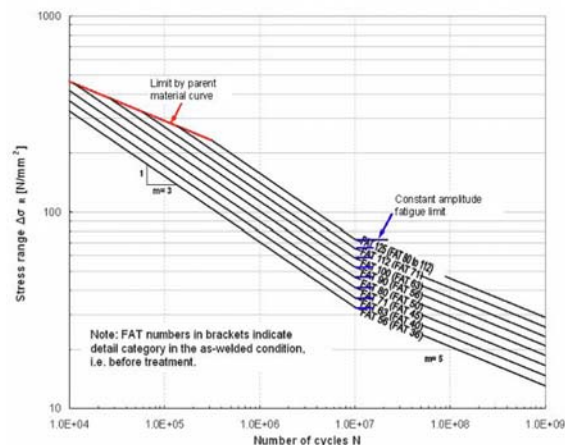
## Fatigue strength of joints improved by grinding

For IIW FAT 90 or lower class: the benefit of burr grinding corresponds to an increase in allowable stress range by factor of 1.5

For example  
FAT63 class  
is toe grinding

$$63 \times 1.5 = 94.5$$

→ FAT90



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## TIG DRESSING

The aim of TIG dressing is to remove the weld toe flaws by re-melting the material at the weld toe, to reduce the local stress concentration effect of the local weld toe profile.

**Shielding gas:**

Argon or Argon + Helium

**Electrode diameter:**

3-4mm

**Voltage:**

12-17 V

**Current:**

160-250

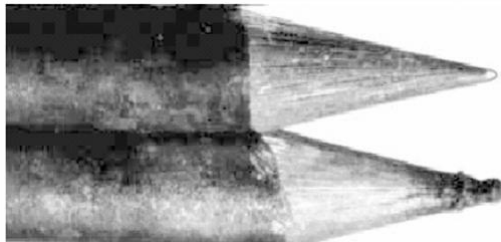
**Dressing speed:**

80-160mm/min



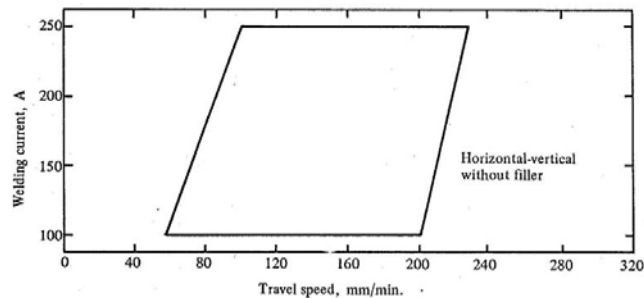
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### Electrodes for TIG torch



Unused tip

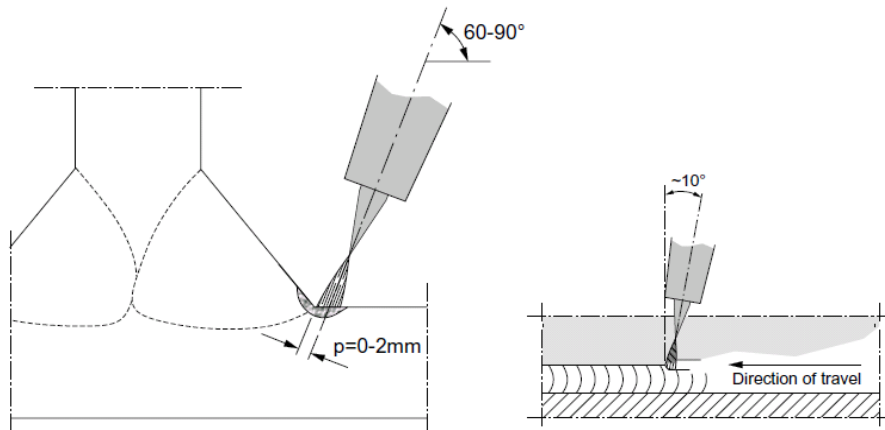
Contaminated electrode  
used on oxidized plate



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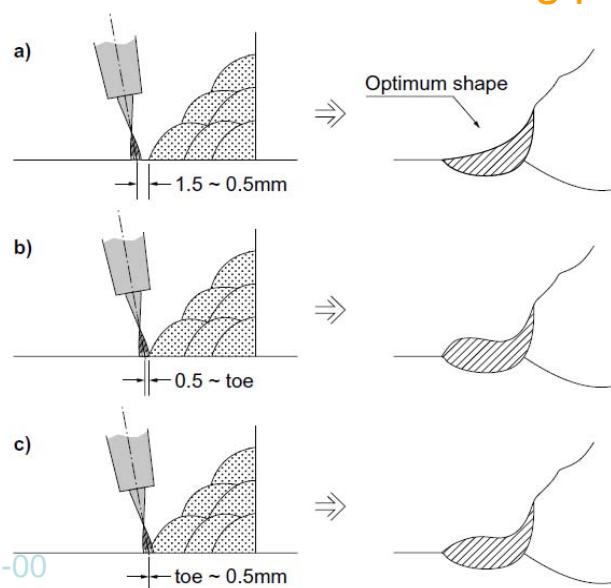
TIG dressing conditions for steel

## Position of TIG torch and dressing zone



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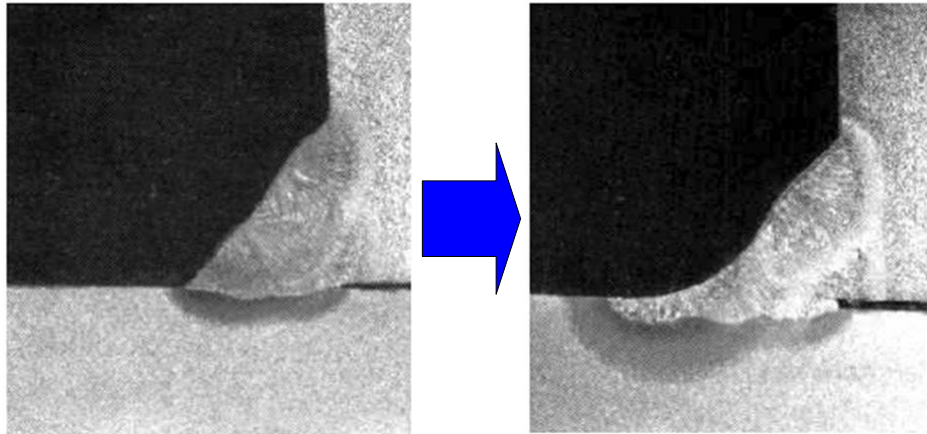
## Position of TIG torch and resulting profile



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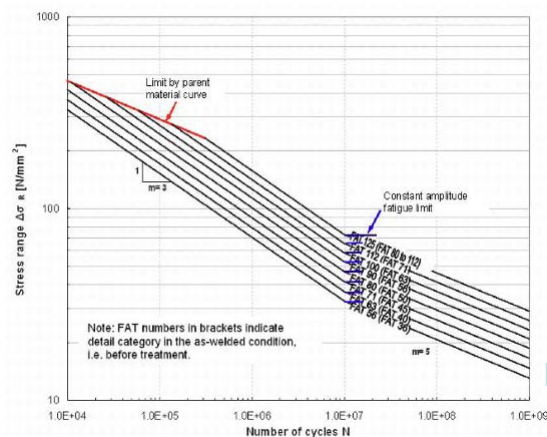
## Fillet weld before and after TIG dressing



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## Fatigue strength of joints improved by TIG dressing

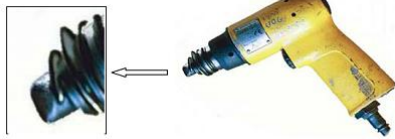
For IIW FAT 90 or lower class details,  
Benefit in allowable stress range by a factor of 1.5



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## PEENING: Hammer or Needle

Compressive residual stresses are introduced by repeatedly hammering the weld toe region



Hammer peening  
pneumatic riveting guns

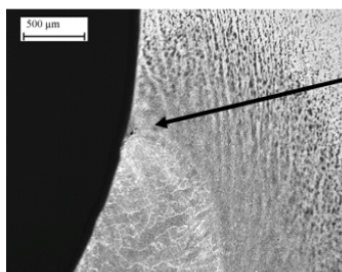
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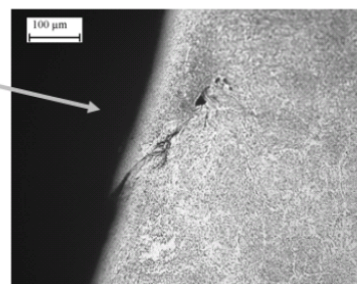
Needle peening  
equipment and operation

## Lap type defect by hammer peening

Hammer peening is carried out manually.  
Some skill is required.

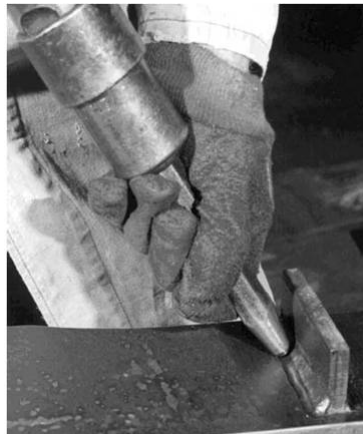
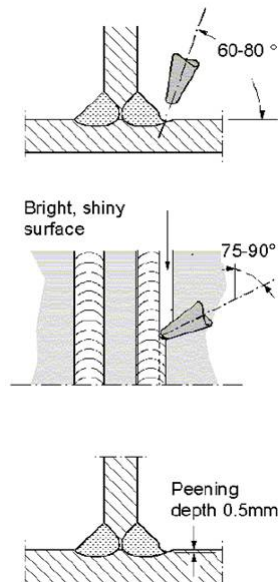


Lap-type feature  
produced by  
hammer peening



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## Operation - Hammer Peening

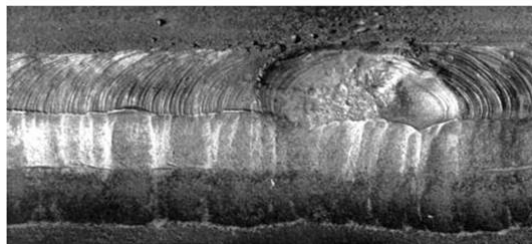


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## Operation Hammer peened weld toe

### Acceptable

Smooth surface



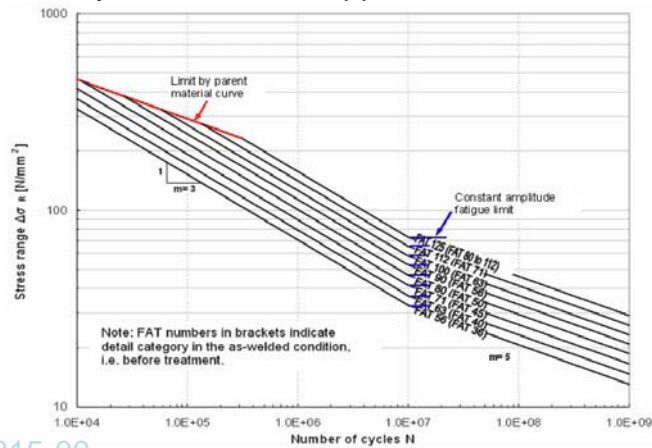
### Unacceptable



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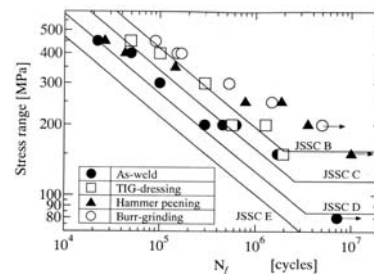
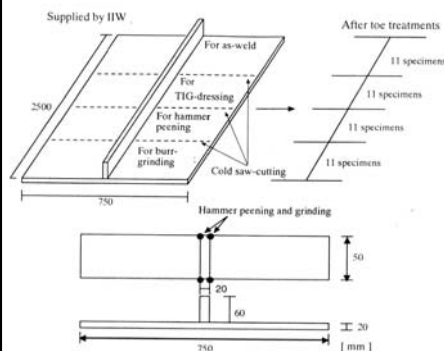
# Fatigue strength of joints improved by hammer peening and needle peening

For FAT90 or lower class details, benefit consist of an upgrade by a factor of 1.6 applied to the stress range



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## Fatigue Strength Improvement -TIG dressing, Hammer peening, Burr Grinding- Joint Specimen

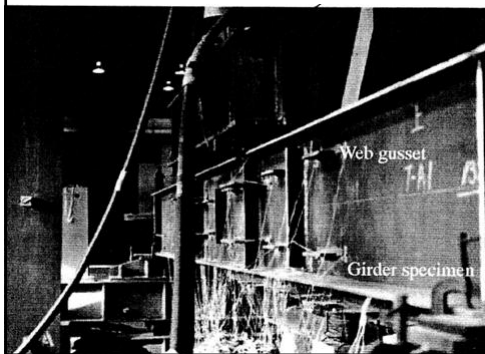
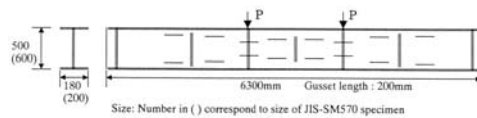


IIW round robin test  
Tokyo Tech's data

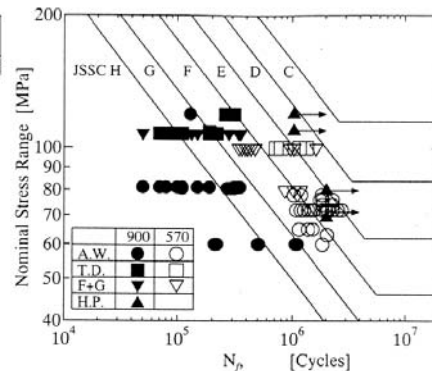
# Fatigue Strength Improvement

-TIG dressing, Hammer peening, Burr Grinding-

## Girder Specimen



## fatigue test results

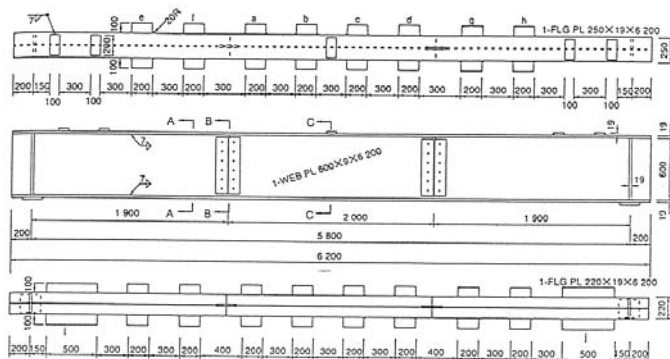


A.W.: as welded	H.P.: Hammer peening
T.D: TIG dressing	F+G: fillet + grinding

# Fatigue Strength Improvement

-Grinding-

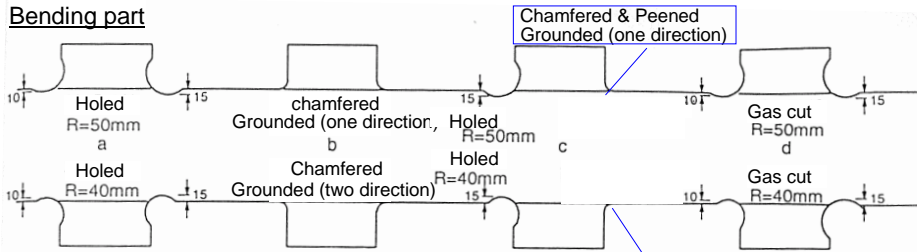
### Flange Gusset Specimen



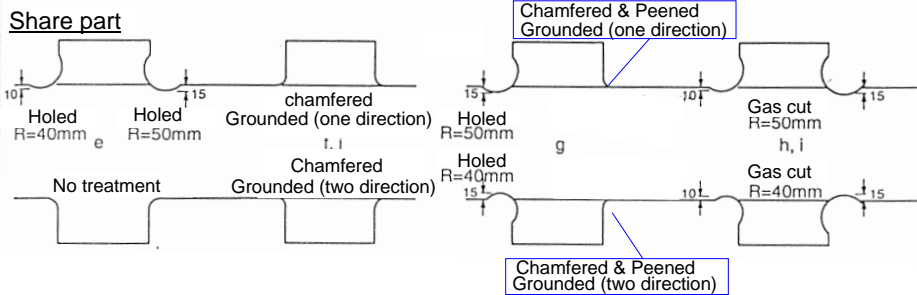


# Fatigue Strength Improvement

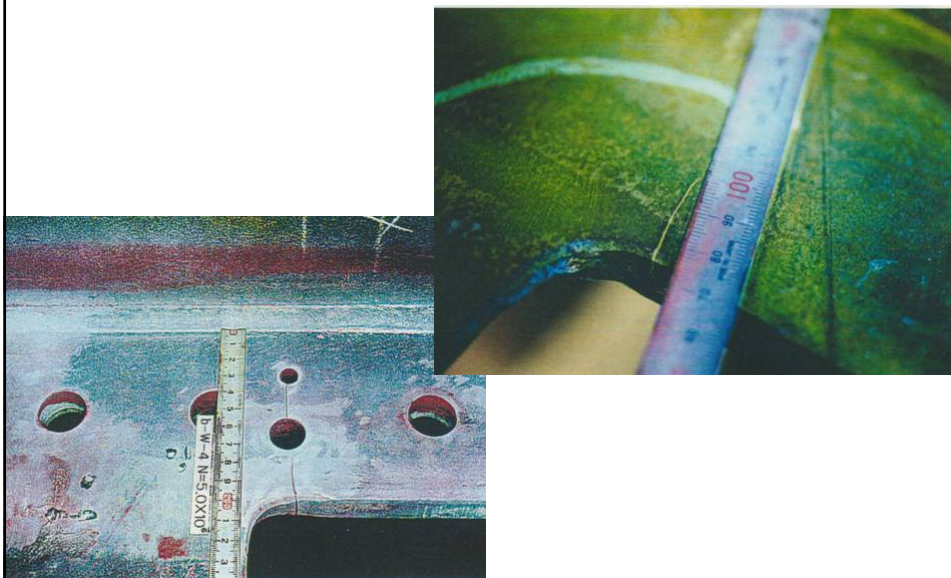
## Bending part



## Share part

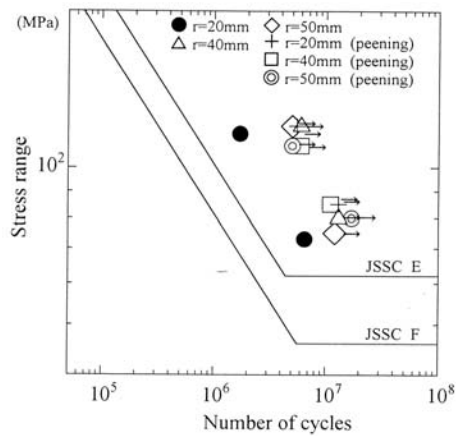


# Fatigue crack

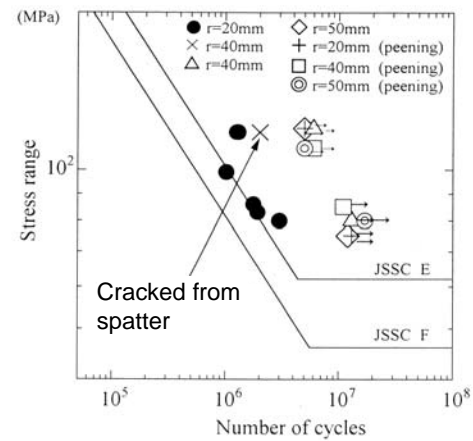


## Fatigue Test Result

### Upper Flange



### Lower Flange

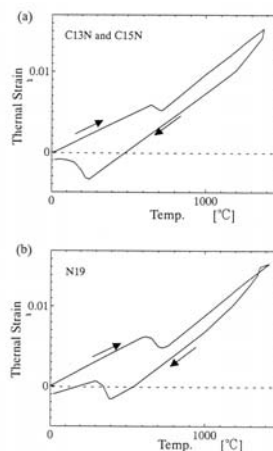
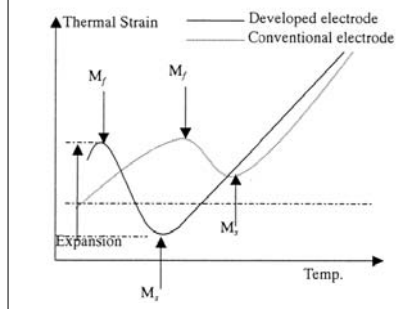


## Low Temperature Transform (LTT) Electrode

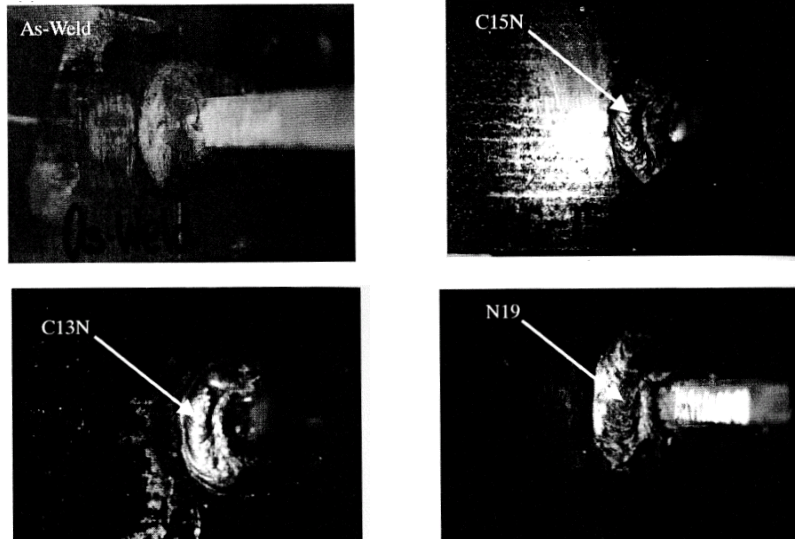
Introduce compressive  
residual stresses

Relationship between temperature  
and volume change due to welding

Volume change of weld metal  
during cooling press of welding

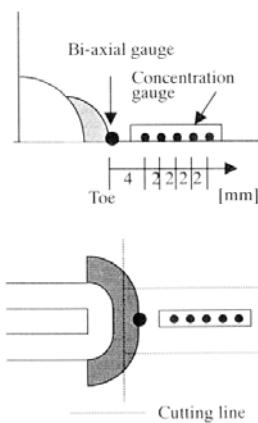


## Surface of boxer welded bead

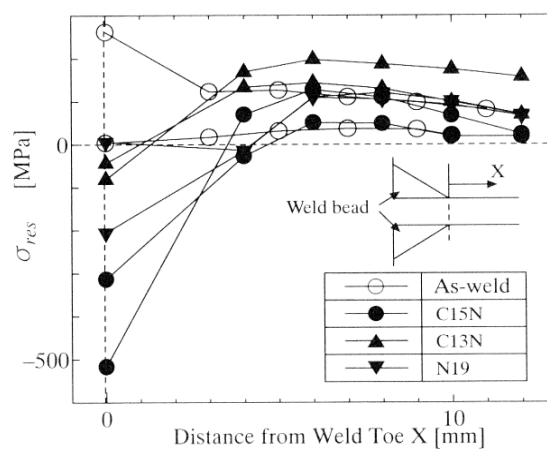


## Example

### Distribution of residual stress

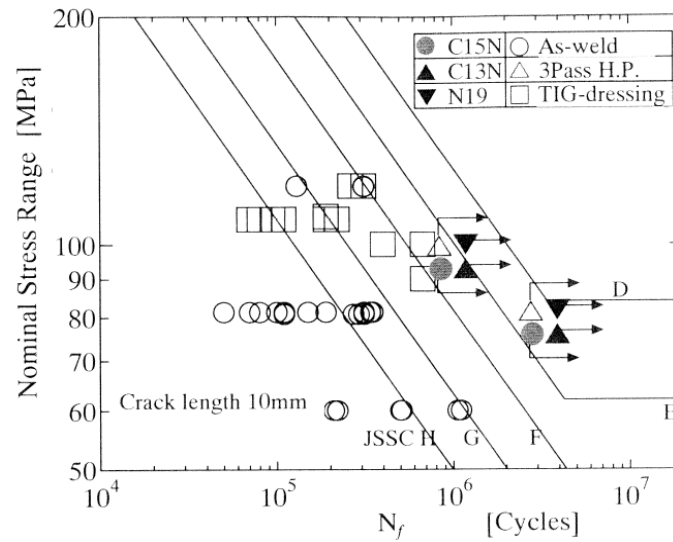


Gauge setup





## Improvement of fatigue strength



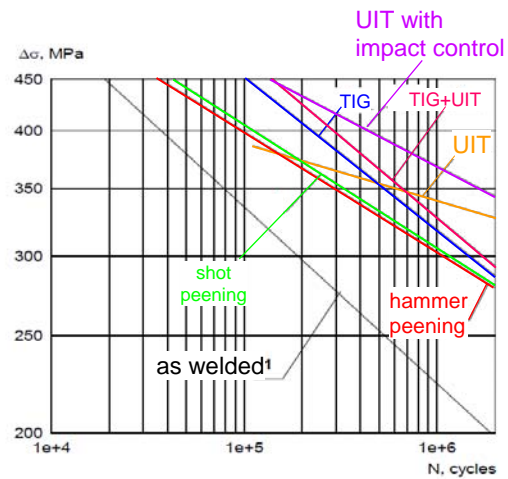
## Ultrasonic Impact Treatment (UIT) Equipment for UIT



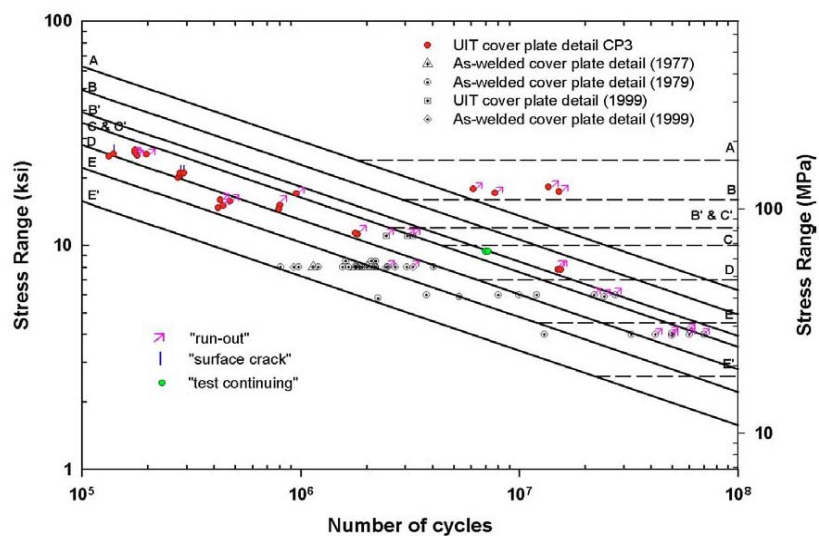
Developed by PATON Lab. In Ukraine

Create compressive  
residual stress  
Reduction of  
stress concentration

IIW-XIII-2049-05



## S-N curve for welded cover plates



## S-N curves for welded transverse stiffeners

