Application of the Latest Technologies to Fatigue Strength Improvement

Kawasaki Heavy Industries, Ltd.,
IHI Marine United Inc.,
Mitsui Engineering & Shipbuilding Co., Ltd

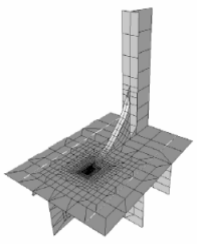
Fatigue design

Fatigue requirement ➡ NA 25-year

Fatigue Design

Fatigue Improvement Measures

Structural design improvement for critical areas



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Weld toe grinding ➡ *UP-Method*

Selection of new material ➡ *FCA-W steel*

FCA-W Steel

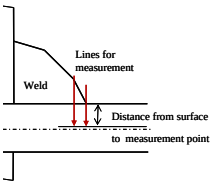
History of FCA-W Steel

- **Sumitomo Metals developed FCA (Fatigue Crack Arrester) Steel on 2001. (The steel is approved material by ABS/DNV/LRS/NK, and applied more than 60 vessels.)**
- **KHI applied FCA-W Steel (2nd generation of FCA) to an LNG carrier by fatigue analysis using tentative proposed S-N curve at JRP with ClassNK/SMI on 2008.**
- **JRP for FCA-W steel application (DNV/LRS/ABS with SMI/KHI/IHI-MU/MES): 2007-2009**

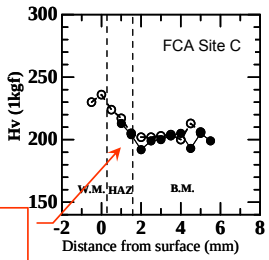
FCA-W Steel

Mechanisms of FCA-W Steel for fatigue improvement

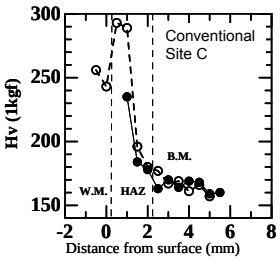
- **Increase fatigue initiation resistance at weld HAZ by suitable micro structure**



FCA-W Steel



Conventional Steel

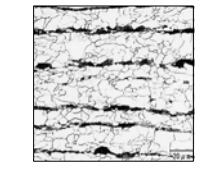


Avoidance of **material notch effect** by homogeneous distribution

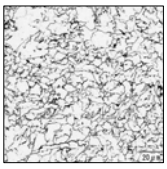
FCA-W Steel

Mechanisms of FCA-W Steel for fatigue improvement

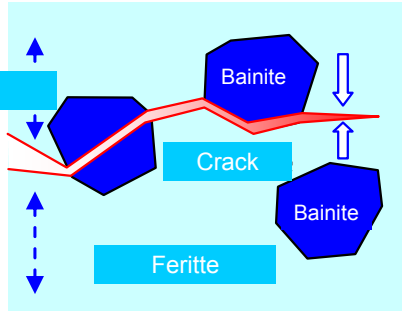
- **Increase fatigue initiation resistance at weld HAZ by suitable micro structure**
- **Decrease crack growth rate in base metal when a fatigue crack passes a grain boundary from a soft phase (feritte) to a hard phase (bainite)**



Conventional Steel



FCA-W Steel



FCA-W Steel

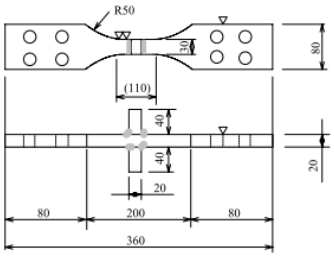
Characteristics of FCA-W Steel

- **Fatigue life improvement**
- **Mechanical properties and corrosion rate equivalent to the conventional steel or more**
- **Welding and fabrication abilities equivalent to the conventional steel → Same welding process and welding material can be applied at fabrication stage.**

FCA-W Steel

Fatigue test for establishment of S-N curves

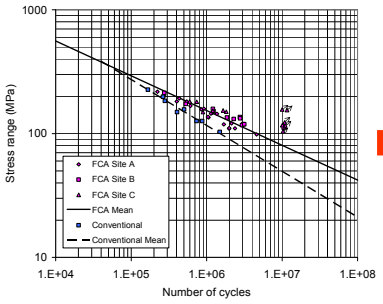
- **Fatigue test pieces were fabricated and welded by three shipbuilders and SMI.**

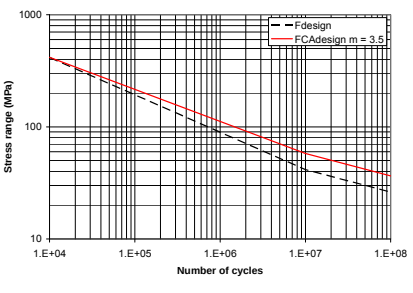


FCA-W Steel

Fatigue test for establishment of S-N curves

- **S-N curves newly established by the Classes in JRP.**

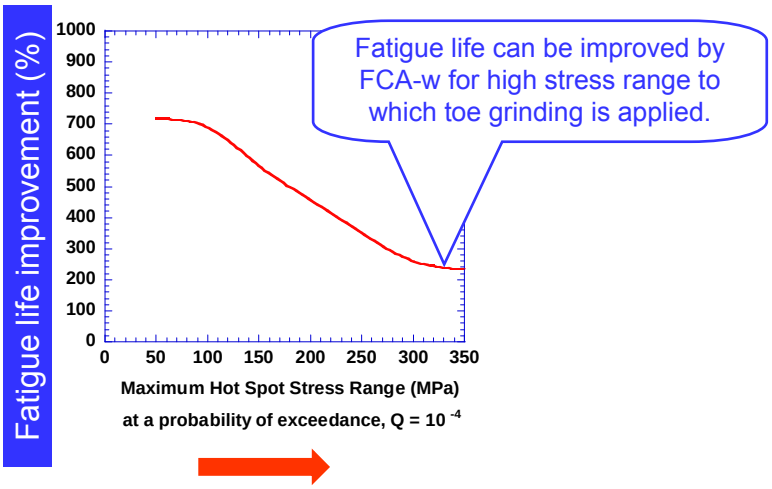




An Example of proposed S-N curve

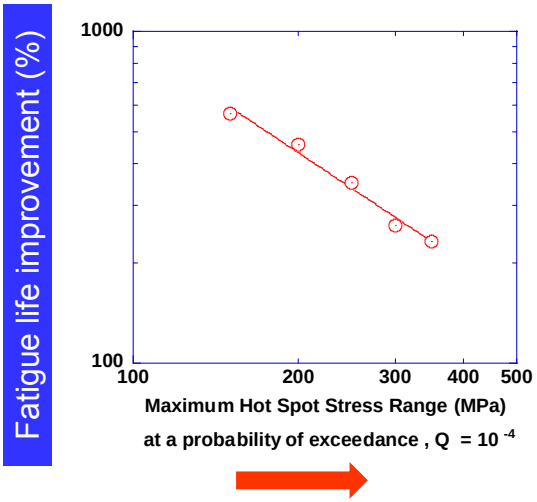
FCA-W Steel

Fatigue life improvement



FCA-W Steel

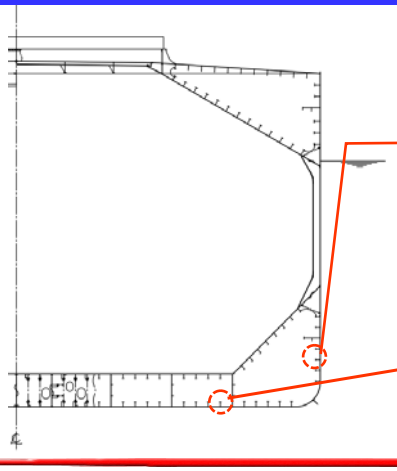
Fatigue life improvement



FCA-W Steel

Proposed application of FCA-W Steel

Longitudinals in a cape size bulk carrier



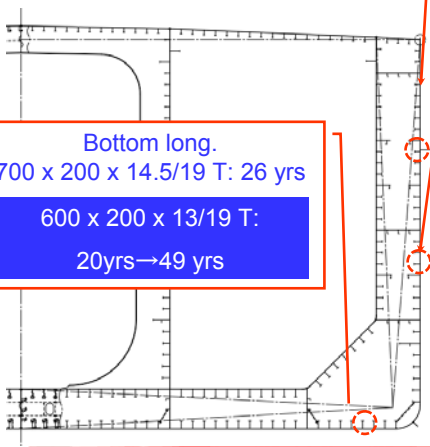
Side long.
350 x 125 x 10/19 T
Fatigue life improvement: 2.39

Bottom long.
350 x 125 x 10/21 T
Fatigue life improvement: 2.31

FCA-W Steel

Proposed application of FCA-W Steel

Longitudinals in a VLCC



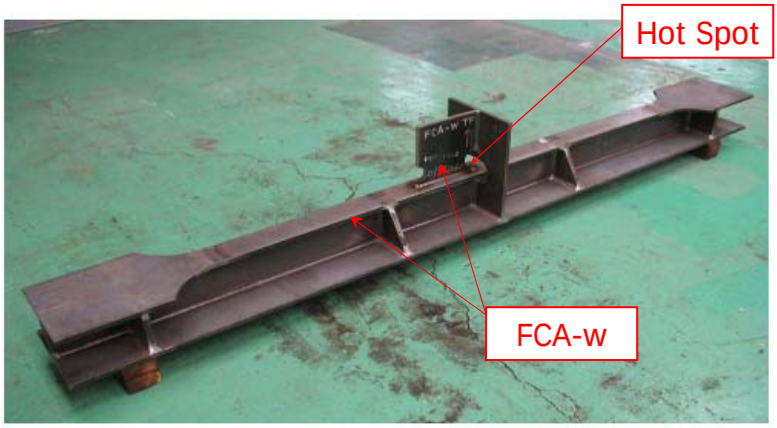
Side long.
450 x 150 x 11/22 T: 27 yrs
450 x 150 x 11/16 T:
17yrs →48 yrs

Bottom long.
700 x 200 x 14.5/19 T: 26 yrs
600 x 200 x 13/19 T:
20yrs→49 yrs

Side long.
600 x 200 x 13/16 T: 29 yrs
500 x 150 x 11/22 T:
12yrs →33 yrs

FCA-W Steel

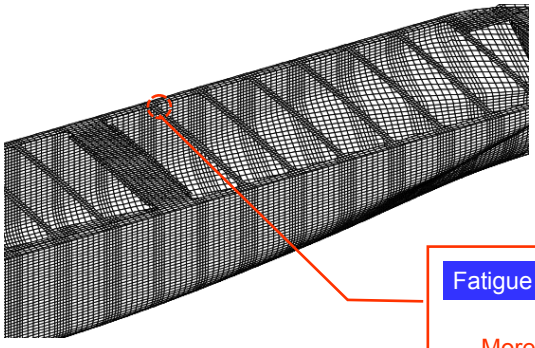
Large scale fatigue test for longitudinals



FCA-W Steel

Proposed application of FCA-W Steel

Hatch corners on the upper deck of container ship

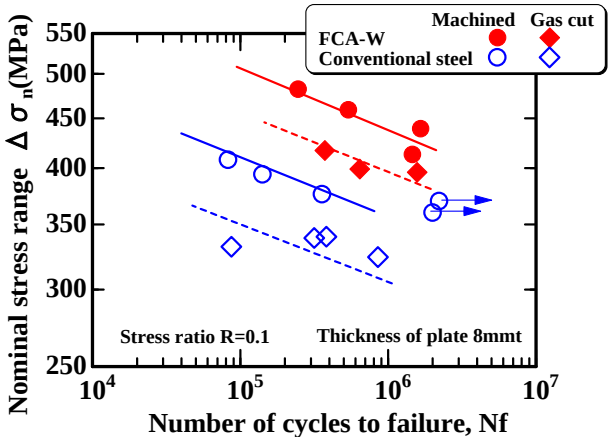


Fatigue life improvement: 1.8 times

More improved in base metal

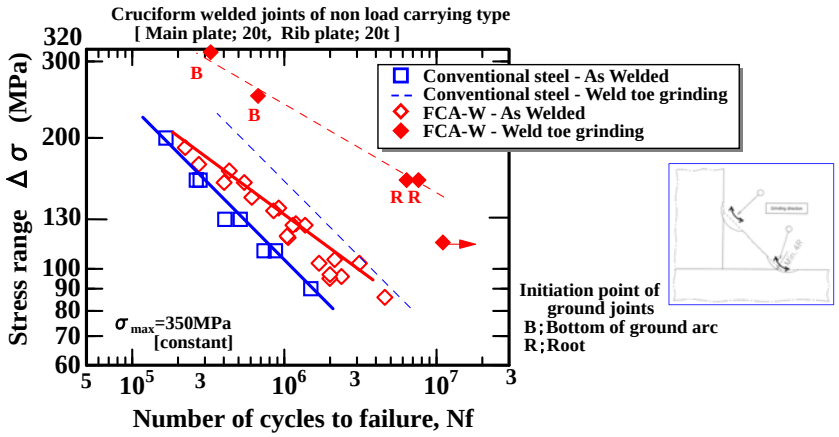
FCA-W Steel

Fatigue test results of FCA-W steel for base metals



FCA-W Steel

Fatigue test results of FCA-W + WTG



FCA-W Steel

Conclusions and future work

- **Fatigue life improvement can be achieved by using FCA-W Steel without any structural reinforcements.**
- **Combined application of FCA-W steel and WTG is also effective on fatigue life improvement.**
- **New S-N curves of FCA-W steel will be confirmed by the Classes for fatigue analysis in the Rules and the Guidelines.**

Experimental S-N curves are defined by their mean fatigue life and standard deviation. (1.4.5.3 in Appendix C of CSR for D/H oil tankers)

"Material" and "Fabrication"

Fatigue Strength Improvement Method

Material	*Fabrication*
・FCA-W steel	*・Toe Grinding* *・TIG Dressing* *・Ultrasonic Peening*

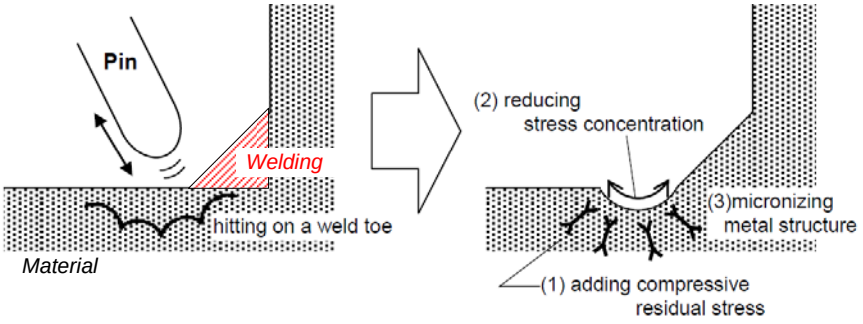
Ultrasonic Peening Method (UP)

The UP method improves fatigue life affected by imparting impulses at the weld toe with radiused pins

The Principle of "UP"

The Principle of Fatigue Strength Improvement

(1) Adding Compressive Residual Stress
(2) Reducing Stress Concentration
(3) Metal Structural Refinement



The Composition of UP Tool

Total Weight abt. 5 kg

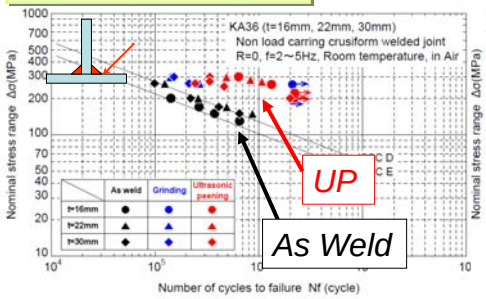
Pins Module

The Picture of UP Process

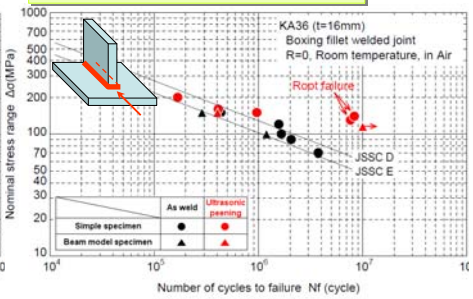
Easy Working!

Fatigue Strength Improvement Effect of "UP"

<Fillet Weld Joints>



<Boxing Weld Joints>



Examples of the Experiments

Joint Type	Stress Range [MPa]	Fatigue Life [Cycles]		Improvement rate
		As Weld	UP	
Fillet Weld Joints	200 MPa	219,374	over 2,000,000	**over 910%**
Boxing Weld Joints	150 MPa	434,762	963,830	**220%**

TSCF 2010 Shipbuilder's Meeting

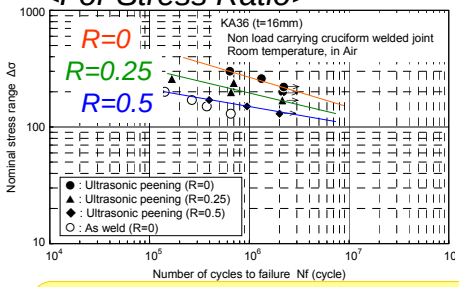
Application of "UP" for the Ship Structure

How about for Load History?

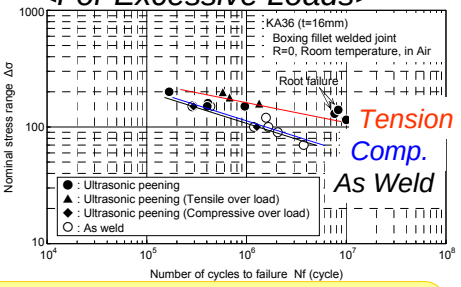
Compressive Residual Stress

Change due to the fluctuating loads?

<For Stress Ratio>



<For Excessive Loads>



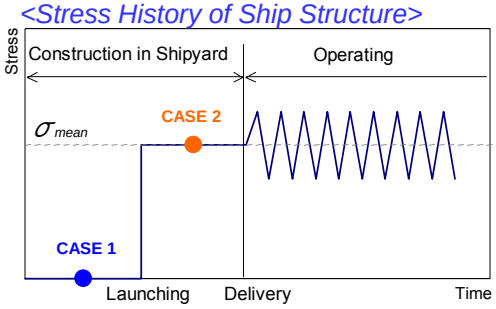
✓*The UP effect is changed due to the stress ratio.*
✓*The UP effect may be reduced, once the excessive compressive loads were worked.*

TSCF 2010 Shipbuilder's Meeting

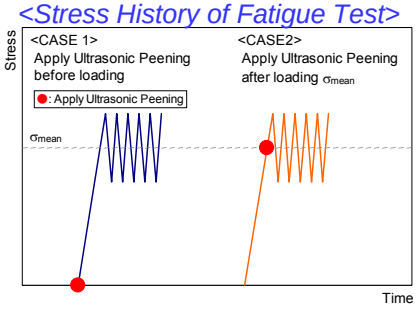
Application of "UP" for the Ship Structure

Real Ship Simulated Tests - From Shipyard to Operating -

<Stress History of Ship Structure>



<Stress History of Fatigue Test>



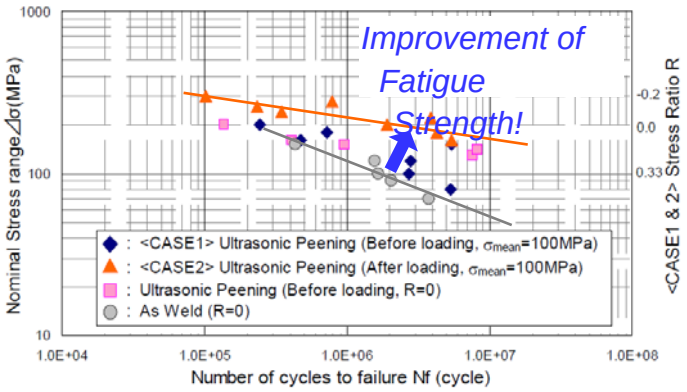
✓ *Mean Stress by the Still Water Bending Moment*

✓ *UP Applied Points*

-CASE 1 Before Launching -CASE 2 After Launching

Application of "UP" for the Ship Structure

Real Ships Simulated Tests - From Shipyard to Operating -



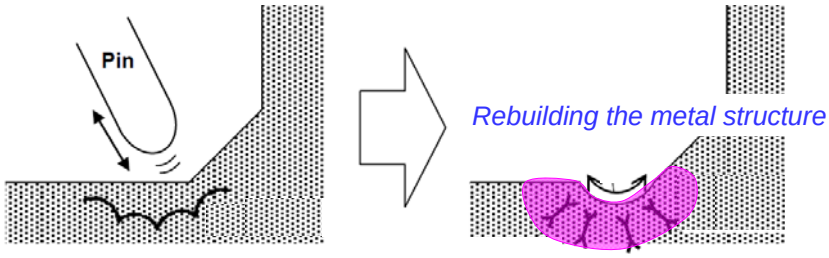
CASE 2, UP applied after Launching, is the most effective!

Rehabilitation Effect of "UP"

For In Service Vessels

Cumulative damage factor is cleared by "UP"
due to rebuilding the metal structure.

<Rehabilitation Effect>



"UP" can extend the fatigue life of in service vessels.

Conclusion of "UP"

✓ *The application of UP to weld toes is as effective as that to weld toe grinding on fatigue life improvement of the weld joints at fabrication stage.*

✓*The stage and scope of UP application must be considered at design stage to take full advantage of its effective use.*

✓*The designers suggest applying UP especially to the weld joints in the tension field constantly,for example, in way of upper deck at the hogging conditions, as an effective application.*

✓ *In service Vessels, the fatigue strength can be extended by UP.*

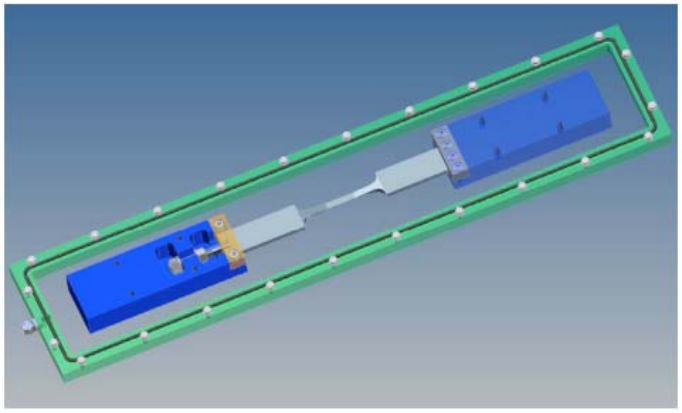
Conclusions

How to apply these new technologies?

- **Reliability and safety ship structure will be strengthen by newly stipulated Rules, CSR, HSR, GBS….**
- **These latest technologies will be incorporated with Rules for their applications through JRPs in the industry.**
- **Fatigue life improvement by these technologies will give positive solutions on GHG emission and recycling.**

Thank you for attention !!

One of the monitoring equipment onboard



First practical application by Kawasaki