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STATUS OF FATIGUE ROAD MAP AND
REMAINING UNCERTAINTIES IN FATIGUE LIFE EVALUATION

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ABSTRACT

During the past 30 years many fatigue tests and fatigue analysis improvements have been developed in different countries in order to improve Codified Fatigue Rules.
This paper will present the major technical improvements obtain in the last 5 years to obtain "reasonable evaluation rules" of potential fatigue damage through a road map.
Recently new results confirm possible un-conservative fatigue test results on tubular specimen. In front of these new results different proposals has been issued to explain differences between tubular and bar specimen.
A periodic up-dating of proposed rules in the different Codes are on-going with research of international convergence between Code rules developed in USA, Japan, France and Germany in particular, will be done on a yearly basis.
Many results have been obtained through fatigue tests of stainless steel materials:
- mean and design fatigue curve in air,
- environmental effects on fatigue curves,
- plasticity effects,
- bi-axial load effects,
- mean stress effects,
- transferability from small to large specimen,
- weld versus base metal
- piping stress indices

In parallel, many new developments have been made in non-nuclear pressure equipment industry: like the reference stress of ASME Section VIII or the structural stress of EN 13445 to analyse fatigue of welds.
In front of that situation, the code organization needs to propose reliable rules for new design and for operating plants. Different proposals are under discussion and summarized in the paper.

INTRODUCTION

General

Fatigue evaluation needs a "realistic evaluation method" in order to develop an optimized in-service inspection program in operation. During the design analysis, the pipe rupture locations are also connected to fatigue usage factor evaluation (and anchor points)…
In France, a lot of theoretical and experimental work has been done in different directions in the past 30 years:
- tests and analysis of structures, like butt weld, pipe to valve connections, valve inner surface stress concentration location, thickness variation and socket welds,
- computation of K_e for a set of different thermal loads,
- crack like defect fatigue analysis rules.

Major aspects of the general fatigue procedure are presented Figure 1 and some "boxes" are continuously under review process; some improvements and proposals are presented in this paper, they are part of different unofficial road map defined by different experts in some Code development organization.

Fatigue analysis rules

Two different aspects have to be considered in order to understand uncertainties in the design rules, in particular for piping analysis:

- the strain amplitude evaluation $\Delta\varepsilon/2$ in %
- the fatigue (S,N) curve with associated reduction factors ($S= E\ \Delta\varepsilon/2$ and N allowable number of cycles)

Strain amplitude evaluation and uncertainties

The major assumptions in fatigue piping analysis are on:

- geometry of the component, in particular for pipes, and associated tolerances,
- material properties: thermal and mechanical,
- elastic stress evaluation through codified rules,
- plasticity correction factors, like K_e and K_ν,
- stress tri-axiality consequences to define the strain amplitude for a given cycle of load

Component geometry

For the geometry, in particular for piping the thickness tolerance is 12.5 %, if it is roughly accepted that the thermal stresses are proportional to the square of the thickness, the uncertainty is 1.125^2= 1.265. In some cases, 20% over-estimation on strain amplitude leads to 30 to 60% reduction in the fatigue life evaluation.
For some of the pipe fitting the uncertainty are larger due to the effect of the stress indices B, C and K, that are for some of them different between different nuclear design codes. Figure 4 compares ASME Section III-NB-3600 and RCC-M Section I-B3600. In the last published Edition, the 2 Codes consider very similar values for these stress indices.

Material properties and temperature variation

- First the basic thermal-mechanical properties:
  - what could be the uncertainties on Young Modulus, on thermal expansion, on thermal conductivity and on their variation with temperature?
  - for example for stainless steels, the value of Young modulus can be lower of 10 to 15% than the codified values. If the strain amplitude is well evaluated, the multiplication by the Young modulus before using the S-N curve leads to overestimation of the stress amplitude of 15 to 20%, that reduced the fatigue life of the component.
  - the way Young Modulus is associated to temperature variation in the stress analysis under thermal load is important to assure a valid strain amplitude. The objective is a strain amplitude evaluation from piping code corrected by the elastic Young modulus associated to the fatigue curve used.
- This practice based on strain amplitude evaluation transformed in elastic stress is associated to many uncertainties: on the fatigue curve no consequences the multiplication by Young modulus is artificial, but the idea to use inner surface Tresca stress and transform it in strain amplitude is associated to many assumption, but as result of Finite Element Analyses a possible direct access to strain amplitude is possible, and my suggestion is to work in fatigue analyses mainly with strain amplitude directly from FEA result, like the French RCC-MRx Code.
- Secondly the monotonic stress-strain curve: for stainless steels the yield stress and the maximum strength can be very different for different heats and different materials. Just in RCC-M, with a limited number of materials, the allowable values in yield stresses for codified stainless steels varied from 100 to 200 MPa, and the maximum strength from 380 to 520 MPa, consequently the allowable stress S_m from 90 to 180 MPa, in some cases with conservative values.

For fatigue analysis the cyclic stress-strain curve is required for plasticity effects: no nuclear Code make reliable proposals except RCC-MRx for a limited number of stainless steels. Many differences and uncertainties are associated to these cyclic curves.

Elastic-plastic simplified analysis

- K_e is a simplified factor to evaluate the plastic strain amplitude by correction of elastic strain amplitude:
- $K_e = \Delta\varepsilon_{plastic} / \Delta\varepsilon_{elastic}$
- Three different aspects have to be considered to analyse uncertainties:
  - the K_e formulae
  - the material property S_m and it's conservative value effect on K_e
  - the cyclic stress-strain curve

For RCC-M:

$$S_{alt}(i,j) = \frac{1}{2}\left\{(K_{e\,meca})_{pq}\,(S_{p\,meca})_{ij} + (K_{e\,ther})_{pq}\,(S_{p\,ther})_{ij}\right\}$$

$$S'_{alt}(i,j) = \frac{E_c}{E}\,S_{alt}(i,j)$$

	m	n	Max Temp. °C
Low Alloy Steel	2	0.2	370
Martensitic Stainless Steel	2	0.2	370
Carbon Steel	3	0.2	370
Austenitic Stainless Steel	1.7	0.3	450
Nickel-Chromimiu-Iron Steel	1.7	0.3	450

$$K_{e\,ther} = \max\left(1\,;1.86\left\{1 - \frac{1}{1.66 + \frac{S_n}{S_m}}\right\}\right)$$

$K_{e\,mech} = 1.0$	for $S_n \le 3\,S_m$
$K_{e\,mech} = 1.0 + \frac{1-n}{n\,(m-1)}\left(\frac{S_n}{3\,S_m} - 1\right)$	for $3\,S_m < S_n < 3m\,S_m$
$K_{e\,mech} = 1/n$	for $Sn \ge 3m\,S_m$

For ASME Section III:

$$S_{alt} = K_e\,\frac{S_p}{2}$$

$K_{e\,mech} = 1.0$	for $S_n \le 3\,S_m$
$K_{e\,mech} = 1.0 + \frac{1-n}{n\,(m-1)}\left(\frac{S_n}{3\,S_m} - 1\right)$	for $3\,S_m < S_n < 3m\,S_m$
$K_{e\,mech} = 1/n$	for $Sn \ge 3m\,S_m$

Same m and n value for ASME Section III and RCC-M section I for mechanical loads.
The 2 major formulae used for K_e are the ASME Section III NB formulae and the RCC-M Section I B formulae. They are compared on figure 3: "Comparison of ASME III and RCC-M K_e solution". The differences that are significant for stainless steels: between 1.and 3.3 for ASME Code and 1 and 1.8 for RCC-M Code.
In figure 2 "Comparison of different K_e solutions with direct cyclic elastic-plastic evaluation", that compares different K_e formulae, the RCC-M code is close to the direct elastic-plastic finite element evaluation of strain amplitude (the reference value). The ASME Code Section III is too much conservative.
The second aspect is the consequences of the S_m conservatisms. If the S_m of the material is greater than the codified values by 10 or 20% it can have an important effect of 17 to 31 % increase in K_e with the ASME formulae, less effect with the RCC-M formulae.

S_n	$3\ S_m$	$S_n / 3\ S_m$	K_e ASME	K_e RCCM	K_e ASME %	K_e RCCM %
540	360	1.50	2.67	1.56	reference	reference
540	396	1.36	2.20	1.54	17,60	1.38
540	432	1.25	1.83	1.52	31,46	2.69

The consequences on life cycle evaluation are roughly in K_e power 4: between 80% and 300% in allowable number of cycles.

Temperature effect on material properties

The nuclear ideas is to express the strain in a pseudo-elastic stress by multiplication of strain amplitude by E_c for the fatigue curve use E for the elastic stress evaluation (like finite element analysis).
Why to transform the basic Finite Element parameter: the strain in pseudo elastic strain and move to TRESCA stress range? Why to transform the strain control fatigue test in an (S-N) curve?
My proposals are close to RCC-MRx Code:

- output of component finite element analyses: ε_{min} and ε_{max} using Von Mises plasticity criteria
- develop the corresponding fatigue curves: $\Delta\varepsilon_{VM} = 3/4(1+\nu)\ \Delta\varepsilon_{test}$

First conclusions on strain amplitude evaluation

All the material strength properties are less conservative than the codified values, and affect the fatigue life evaluation. For example, 50% overestimation in the strain amplitude can lead to a reduction factor of 8 in the fatigue life evaluation for stainless steels, for strain amplitude between 0.54 and 0,26 % (respectively 5000 and 40000 cycles on the mean stainless steel fatigue curve).
All these uncertainties on material properties and piping analysis methods, supplemented by over like the summation in piping analysis of pressure stress amplitude, bending stress amplitude and thermal stress amplitude without transient time consideration, will affect the strain amplitude evaluation and corresponding fatigue life assumption. Direct finite element calculation of strain amplitude for temperature variations can be an important improvement, but needs recommendation for geometry and material properties to use in these elastic or elastic-plastic analyses.

Fatigue curve and reduction factors

General introduction

From NUREG 6909, the mean fitting equation of the fatigue S-N curve for stainless steels are:
Air mean curve:

$$\ln(N) = 6.891 - 1.920\ \ln(\varepsilon_a - 0.112)$$

Air Design is obtained by reduction factors on strain amplitude ε_a and number of cycles N: proposed NUREG values 2 and 12
This proposed mean curve for stainless steels is now accepted in many countries, including France. But the differences are in the criteria and the corresponding reduction factors.
Criteria for the limited usage factor of 1 are diverse:

- no leak equivalent to no through wall cracks,
- no crack greater than 2 mm
- 95% probability of crack initiation with 95% confidence…

The definition can affect the different reduction factors: heat to heat scatter, size effect, surface finish-atmosphere that have the value, up to recently in existing nuclear codes, respectively: 2.5, 2.0 and 4, for a total of 20 on the number of cycles, associated to a reduction factor of 2 on strain amplitude generally associated to uncertainties in the high cycle fatigue range. The corresponding criteria was no through wall crack for a usage factor of 1.
The fatigue rules have been developed and used in 2 steps: up to 2009 on the basis of ASME Code Section III, and after 2009 when some laboratories found environmental effects to be added in fatigue S-N curves

on the basis of large program on standard tests on small laboratory specimens. All the international Codes organisations have to consider these results in order to review their own fatigue design rules.

Different proposals have been done by different experts and remains under review before final code modification. A proposal done in 2007 by Argonne National Laboratory defines a F_{en} factor to be applied to the air design curve to include environmental effects. $F_{en} = N_{air} / N_{water}$. The F_{en} factor value is associated to: material, strain rate, temperature, oxygen content.

In France different proposals are under review, using long investment in fatigue analysis, test programs and Code rules development.

Concerning air design curve, the proposal is to reduce the air mean curve by 10 on cycles and 1.4 on strain amplitude for RCC-M codified stainless steels. The reason for that lower reduction than NUREG 6909 proposal is the reduce number of RCC-M stainless steels and the use of reference tests under strain control for high cycle fatigue done only on these materials (fig. 5,6)

For the factor attached to environment effect, the proposal in Tables 2-3 is to add reduction factors to mean air curve and check interactions with the other reduction factors: synergy or independency.

Fatigue curve reduction factors

The French proposal is to apply a set of reduction factors to the air mean curves with particular values in front of environmental effects.

The list of major factors considered are:

- RF_{sct} scatter on Nc
- RF_{scl} scale on Nc
- RF_{temp} temperature on Nc
- RF_{cwo} cold work on Nc
- RF_{biax} biaxiality on Nc
- RF_{ht} hold time on Nc
- RF_{sha} transient shape on Nc
- RF_{rou} roughness on Nc
- RF_{en} environment on Nc
- RF_{mst} mean stress on Nc
- RF_{inter} interaction on Nc

- RF_{wld}* weld on $\Delta\varepsilon$
- RF_{hcy}** high cycle on $\Delta\varepsilon$

 * Use of tabulated stress indices for welds: 1.7

 ** Use max factor on strain for High Cycle Fatigue: 1.4

and their proposed values based on existing available knowledge are attached in Tables 2 and 3 with some proposed update.

Some of these reduction factors are on cycles, some on strain due to historical background, in particular in piping Code for weld stress concentration factor or fatigue strength reduction factor. This difficult point has to be re-discussed in the final step of reviewing conservatism and uncertainty.

Experimental programs continue to be developed in many countries to support value of these different factors.

Uncertainties and conservatism

The first idea to multiply all the maximum reduction factors is too much conservative and is not in agreement with field experience and laboratory tests on specimens or structures.

All of them are under review to prepare French RCC-M update. As mention before, in air, the total reduction factor proposed by NUREG Report are 2 strain amplitude and 12 on cycles. The factor on cycles of 12 is associated to 2.5 data and heat scatter, 1.6 scale effect, 2 roughness, 1.5 atmosphere The recently proposed RCCM Code Case proposed 10 on cycle and 1.4 on strain amplitude for RCCM Materials (Table 2).

The RF_{sct} (scatter) and RF_{scl} (scale) can probably be reduced, in particular for 304-316 stainless steels, if the criteria selected will be "no crack greater than 3mm for usage factor of 1": the scale effect could be strongly reduced from 1.6 to 1.2 and the scatter reduction factor from 2.5 to 2 due to limited types of stainless steels in class 1 components; consequently the factor of 12 could be reduced to 8 (Table 3).
If a Code has a too large number of different stainless steels, they have to use higher scatter reduction factor or to group the steels by families.
Concerning environmental effects, the shape of the transient is an important factor and extremely limited number of tests are available with realistic load history; it's the reason why the "integrated method" proposed in NUREG 6909 is not accepted to-day in France and a particular shape factor is proposed for thermal shocks or triangular transient shape to evaluate the F_{en}
Some French tests performed by AREVA confirm that NUREG 6909 is too much conservative and a proposed interaction factor between environmental effects and surface roughness is proposed (less than 1).

Fatigue criteria and flaw crack growth

Different criteria are used at international level:
- through the wall leaking crack in ASME
- no crack initiation in RCC-M / RCC-MRx

This differences can have consequences on the transferability factors:
- no size effect if you are just concerned by crack initiation
- an appropriate transferability factor for through wall cracks

Consequently, to-day:
- the ASME BPVPC2015 with large number of materials proposes to use transferability factors of 2 on strain and 12 on cycles
- the RCC-M , with a limited number of different materials proposes to use transferability factors of 1.4 on strain and 10 on cycles in 2016 Code Case

My personal proposal is to use 8 and 1.4 for RCC-M 304 and 316 stainless steels, mainly due to the criteria based on crack initiation less than 2 mm.

ROAD MAP APPROACHES

After different Road Maps for Faigue Design Rules developed by EPRI, SDO Board, Bill O'Donnell and ASME BPVC Design Working Groups, a new one will be proposed very soon by ASME to assure a set of Tasks in order to arrive at the Code modification level.

CONCLUSION ON FATIGUE CURVES

Many parameters play a role on fatigue curve. They can be handle through set of reduction factors, development of each of them one by one, analysis of synergies or independencies, but never direct multiplication of each of them "maximum value". In any case, these reduction factors are applied to the air mean curves. The proposed value associated to "3mm crack initiation" could be 8 on cycles and 1.4 on strain amplitude for RCC-M stainless steels air design curve. A set of reduction factors are proposed under environment with a specific factor associated to "transient shape" (not the integrated method). An interaction factor less than 1 for environmental effects and surface roughness can be proposed with a "surface roughness effect" formulae associated to number of cycles and surface state effect, like cold work...

GENERAL CONCLUSIONS AND RECOMMENDATIONS

Concerning fatigue analyses of nuclear pressure equipment, in particular for piping systems using simplified conservative analysis (ASME III NB-3600, RCC-M B 3600) are different on many aspects: K_e, time consideration for pressure + bending + thermal strain amplitude, possible coupling between "beam element" and "brick or shell element" for finite element analysis in RCC-M Appendix ZE.

The ASME code section III is too much conservative on many aspects. RCC-M has optimized fatigue rules in the past 20 years in accordance with a large experimental program.
They are a lot of conservatisms in the strain amplitude evaluation:
- geometry of the component,
- thermal and mechanical properties, and their dependency with temperature, in particular Young modulus and S_m,
- elastic evaluation of strain in piping Code, in particular under thermal loads,
  the use of K_e through ASME Code Section III NB 3600,
- the use of no-time history pressure, bending and thermal stresses remains.

Important short term improvements of ASME Code could be considered, as it is proposed in the RCC-M Code. For more sensitive location to fatigue, a detailed analysis can be proposed:
- using B 3200 rules, coupled with beam element (like RCC-M Appendix ZE)
- using time history approaches for pressure, bending and thermal loads
- using Code case N779 for K_e
- using non-linear analysis for cyclic strain evaluation.

A short term improvement for RCC-M is connected to stress index table B 3680, in order to harmonize them with ASME NB 3600 (Table 1).
Much conservatism is also in fatigue design curves. Many improvements are possible in air and under PWR environment. Concerning the fatigue reduction factors, the analysis of two of them leads to proposed reduction for heat to heat based on material family from 2.5 to 2 and strong reduction of scale factor from 2 to 1.2, in order to propose a design air curve through reduction factors of 8 on cycles and 1.4 on strain. All these last proposals need additional confirmation and validation.
The systematic review of all the fatigue codified design rule assumption is a continuous process that is necessary to understand the gap between prediction rules and field experience. Two of them are not discussed in this paper:
- the cycle combination of all the cycles for the all life of the component,
- the case of varying principal stress direction (NB3216-2 or B 3232-6), more for discontinuity in vessels

For new design, more precise information can be collected for precise (in the design specification for example) in order to reduce conservatism of some of these reduction factors, like surface finish in fatigue sensitive areas for example.
A set of statistical analysis and probabilistic analysis can offer highlights on the conservatism of different parts of the fatigue analysis rules and the contribution of the different hypotheses to the final damage analysis.
All the different boxes of the fatigue analysis (Fig. 1) have to be considered in the future road map under development. All these improvement are necessary to assure an optimum in-service inspection program and a long term operation justification of nuclear power plants.
Another key proposal is to use Von Mises equivalent strain instead of S_{alt} by direct evaluation on the finite element analysis and a dedicated coefficient on the ($\Delta\varepsilon$, N) standard fatigue tests on $\Delta\varepsilon$ of 3/4(1+ν).

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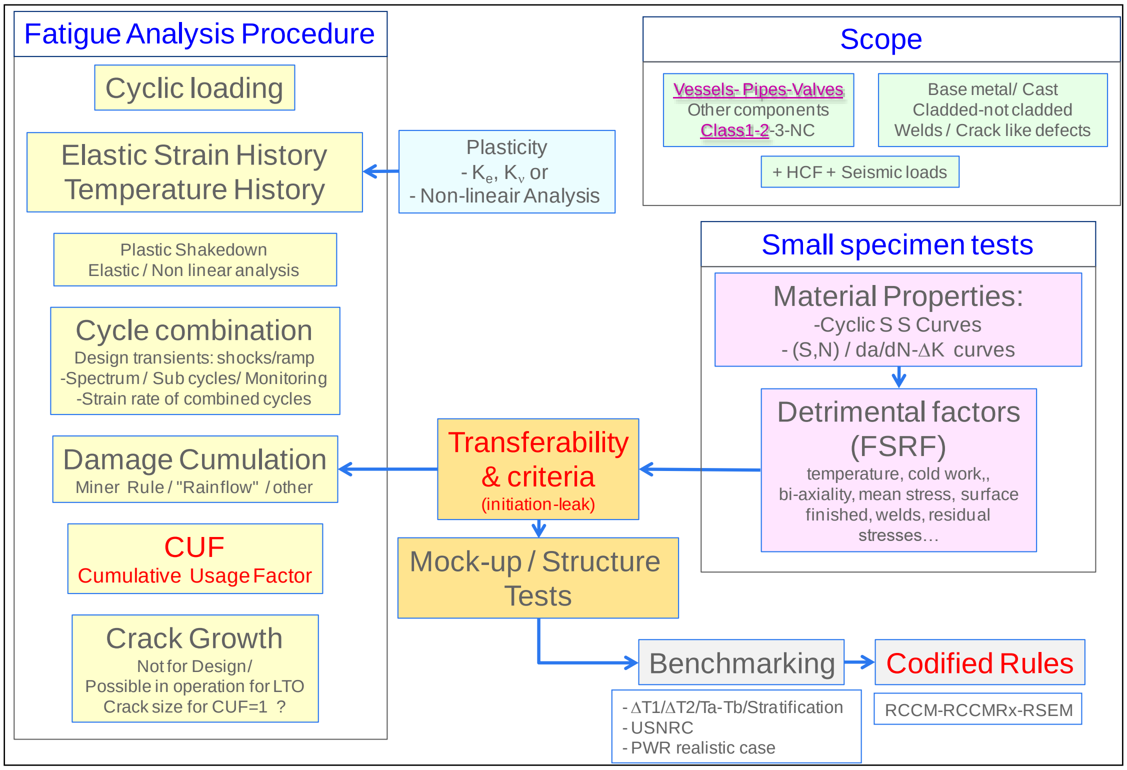

Figure 1: **General fatigue analysis procedure**

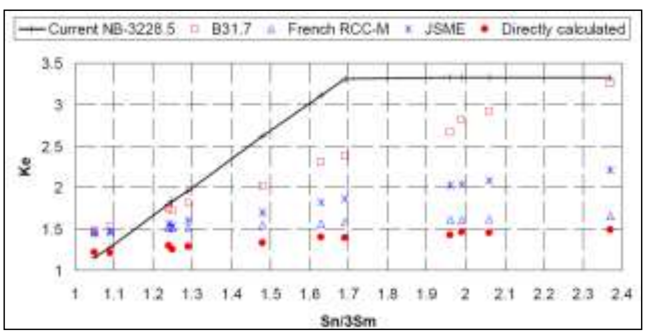

Figure 2: **Comparison of different Ke solutions with direct cyclic elastic-plastic evaluation**

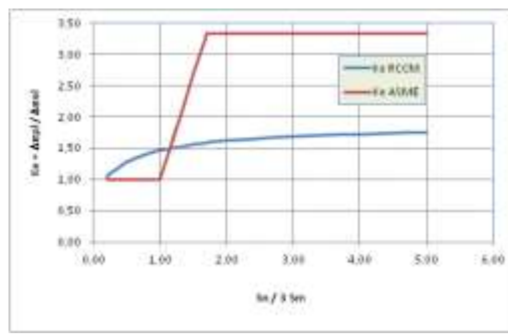

Figure 3: **Comparison of ASME III and RCC-M K_e solution**

Parameters	Scatter	Scale	Temperature*	Cold work*	Biaxiality*	Hold time	Transient shape*	Roughness*	Fen max	Max factor on N (LCF)	Max factor on S (HCF)
Fatigue Reduction Factor Industrial atmosphere	2,5	1,6	1	1	1	1	1	2	1,5	12,0	1.4

Table 1: Previous fatigue reduction factor on SS air mean curve

Design AIR curve reduction factors to mean curve	Scatter	Scale max	Tempe rature*	Cold work*	Biaxiality*	Hold time	Transient shape*	Roughness* max	Industr. Atmosph.	Environment Roughness interaction	Max factor on N (LCF)	Reduction factor on S (HCF)
Fatigue Reduction Factor Industrial atmosphere	2	1,2	1,1	1	1	1	1	2	1,5	1	7,9	1.4

Table 2: Table 1-b: New proposed fatigue reduction factor on SS air mean curve

ASME 2015 - RCCM 2015

RCCM-ASME different — not in one of the Codes (associated to dedicated formulae)

Piping Products and Joints	B1	C1	K1	B2	C2	K2	C3	C'3	K3	Code
Straight piping havingremote from welds or other discontinuities neither weld nor discontinuity	0.5	1.0	1.0	1.0	1.0	1.0	0.5	0.5	1.0	**RCCM**
	0.5	1.0	1.0	1.0	1.0	1.0	0.6	0.5	1.0	**ASME**
Longitudinal butt welds in straight pipe										
(a) flush	0.5	1.0	1.1	1.0	1.0	1.1	0.5	0.5	1.1	**RCCM**
	0.5	1.0	1.1	1.0	1.0	1.1	1.0	…	1.1	**ASME**
(b) as-welded $t > 6$ mm and $\delta/t \le 0.1$	0.5	1.0	1.1	1.0	1.0	1.1	0.5	0.5	1.7	**RCCM**
	0.5	1.1	1.2	1.0	1.2	1.3	1.0	…	1.2	**ASME**
(c) as-welded $t \le 6$ mm or $\delta/t > 0.1$	0.5	1.8	1.8	1.0	1.0	1.4	1.0	0.5	1.7	**RCCM**
	0.5	1.4	2.5	1.0	1.2	1.3	1.0	…	1.2	**ASME**
Circumferential butt weld between straigth piping or betwee pipe and butt welding and the same nominal thickness component:										
(a) flush	0.5	1.0	1.1	1.0	1.0	1.1	0.60	0.50	1.1	**RCCM**
	0.5	1.0	1.1	1.0	1.0	1.1	0.60	0.50	1.1	**ASME**
(b) as-welded $t > 6$ mm and $\delta/t \le 0.1$	0.5	1.0	1.2	1.0	1.0	1.8	0.60	0.50	1.7	**RCCM**
	0.5	1.0	1.2	1.0	…	1.8	0.60	0.50	1.7	**ASME**
(c) as-welded $t \le 6$ mm or $\delta/t > 0.1$	0.5	1.0	1.2	1.0	2.1	1.8	0.60	0.50	1.7	**RCCM**
	0.5	1.0	1.2	1.0	…	1.8	0.60	0.50	1.7	**ASME**
circumferential fillet weld to fitting	0.75	1.8	3.0	1.5	2.1	2.0	2.0	1.0	3.0	**RCCM**
	…	…	3.0	…	…	2.0	2.0	1.0	3.0	**ASME**
Thickness transitions according to figure B 3683.5:										
(a) flush weld or no circumferential weld closer than $(rt)^{0.5}$ of the analyzed section	0.5	1.8	1.1	1.0	1.7	1.1	2.0	1.0	1.1	**RCCM**
	0.5	…	1.1	1.0	…	1.1	…	1.0	1.1	**ASME**
(b) as-welded	0.5	1.8	1.2	1.0	2.1	1.8	2.0	1.0	1.7	**RCCM**
	0.5	…	1.2	1.0	…	1.8	…	1.0	1.7	**ASME**
Thickness transitions within a 1:3 slope:										
(a) flush weld or no circumferential weld closer than $(rt)^{0.5}$ of the analyzed section	0.5	1.0	1.1	1.0	1.7	1.1	2.0	0.60	1.1	**RCCM**
	0.5	…	1.2	1.0	…	1.1	…	0.60	1.1	**ASME**
(b) as-welded	0.5	1.8	1.2	1.0	2.1	1.8	2.0	0.60	1.7	**RCCM**
	0.5	…	1.2	1.0	…	1.8	…	0.60	1.7	**ASME**
Butt welded concentric reducers according to standards listed in Table B 3611.4										
a) angle $\alpha \le 30°$	0.5			1.0			0.6	0.5	1.0	**RCCM**
	…	…	…	1.0	…	…	1.0	0.5	1.0	**ASME**
b) $30° < \alpha \le 60°$	1.0			1.0			1.0	0.5	1.0	**RCCM**
	…	…	…	1.0	…	…	1.0	0.5	1.0	**ASME**
Curved pipes or butt welded elbows according to standards listed in table B 3611.4	0.5		1.0			1.0	0.5	0.5	1.0	**RCCM**
	…	…	1.0	…	…	1.0	1.0	0.5	1.0	**ASME**
Branch connections covered in B 3643	0.5		2.0				1.8	1.0		**RCCM**
	0.5	…	2.0	…	…	…	1.8	1.0	1.7	**ASME**
Butt welding tees according to standards listed in table B 3611.4	0.5	1.5	4.0			1.0	1.0	0.5	1.0	**RCCM**
	0.5	1.5	4.0	…	…	…	1.0	0.5	1.0	**ASME**

Table 3: Comparison of ASME III and RCC-M stress indices

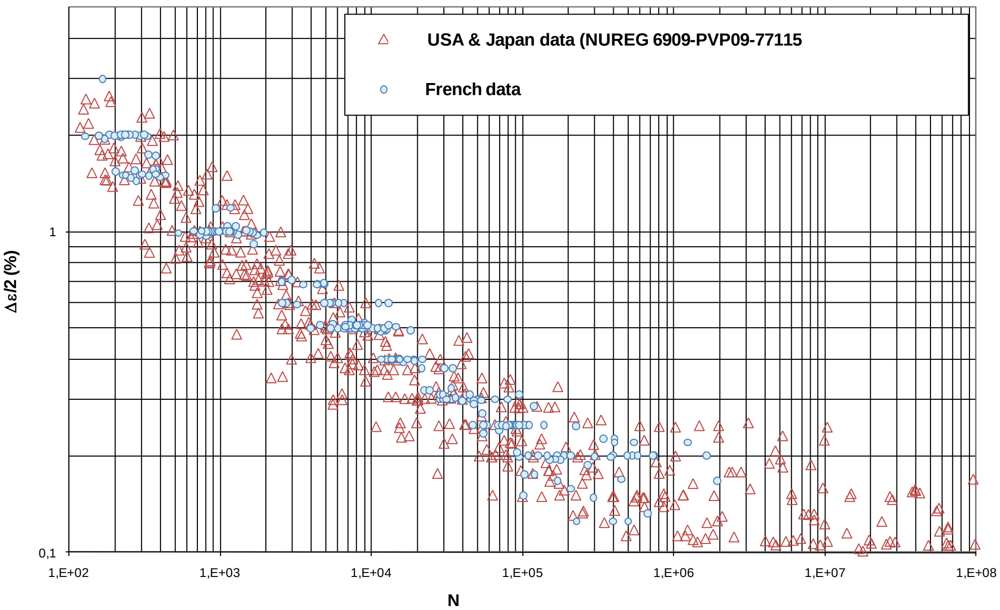

Figure 4: **Stainless steel fatigue test data points fom USA + Japan materials versus RCC-M material**

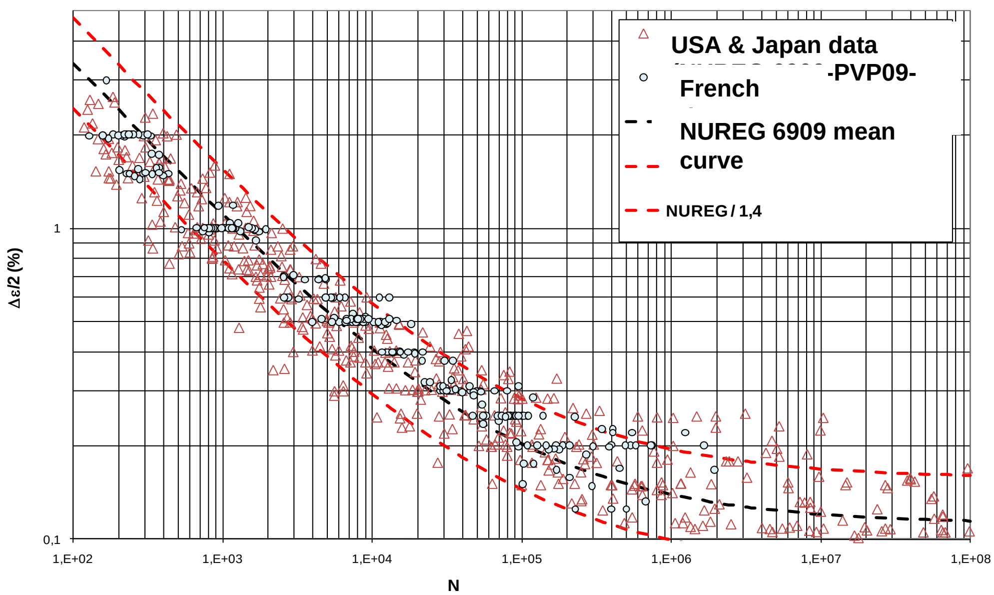

Figure 5: **Effect of 1.4 reduction factor on all the figure 4 data points**