

## ON-LINE MONITORING OF STEEL CONSTRUCTION DURABILITY

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**Key words:** rainflow matrix, fatigue, durability

### **Introduction:**

Durability analysis can be used to determine how long a component can survive in a given service environment. In the general case, durability refers to failure according to a number of different mechanisms such as fatigue, overloading, corrosion, wear, creep, etc. In practice, however, the predominant failure mode is fatigue. Between 80-90% of all structural failures occur through a fatigue mechanism.

The critical inputs for steel construction durability are operating loadings which are usually defined by rainflow matrix. This input can be measured or predicted (e.g. by MSS – mechanism system simulation). Other inputs for durability solutions are material properties (S-N or E-N curves), surface treatments, and stress or strain concentrations effects. This paper describes the on-line service environment processing from long-time strain gage measurement. Long-time fatigue monitoring is important for residual durability estimation because construction can be monitored for whole life. Consequently, we have exact information about loading effect.

### **Data processing:**

On-line data processing for long-time measurement is important for some reasons. The primary reason is quantity of measured data which can be radically reduced by rainflow matrix decomposition. In addition by using standard methods we need strain gage equipment and PC for whole operation time.

Example: 240 days (1 year) x 8 hour (1 shift/day) x 60 minutes x 60 seconds x 10 Hz → 69 120 000 stress or strain values → more than 650 MB hard-disc space.

Rainflow matrix can be used as a direct input for many commercial durability softwares or it can be transformed for blocks of load amplitudes. Acquired rainflow matrix is two-parameters one, so it includes mean stress or strain values.

This method was especially designed for overhead crane, but it is usable for all steel constructions. In respect thereof, this method is tested in laboratory overhead crane which is controlled by PLC (Program Logic Control).

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Figure 1 shows the main alternatives for measuring chain. Economically suitable is integration with cranes PLC or independent chip usage. Both concepts need special programs for data processing which are different than Matlab routines described below, but the algorithm is the same.

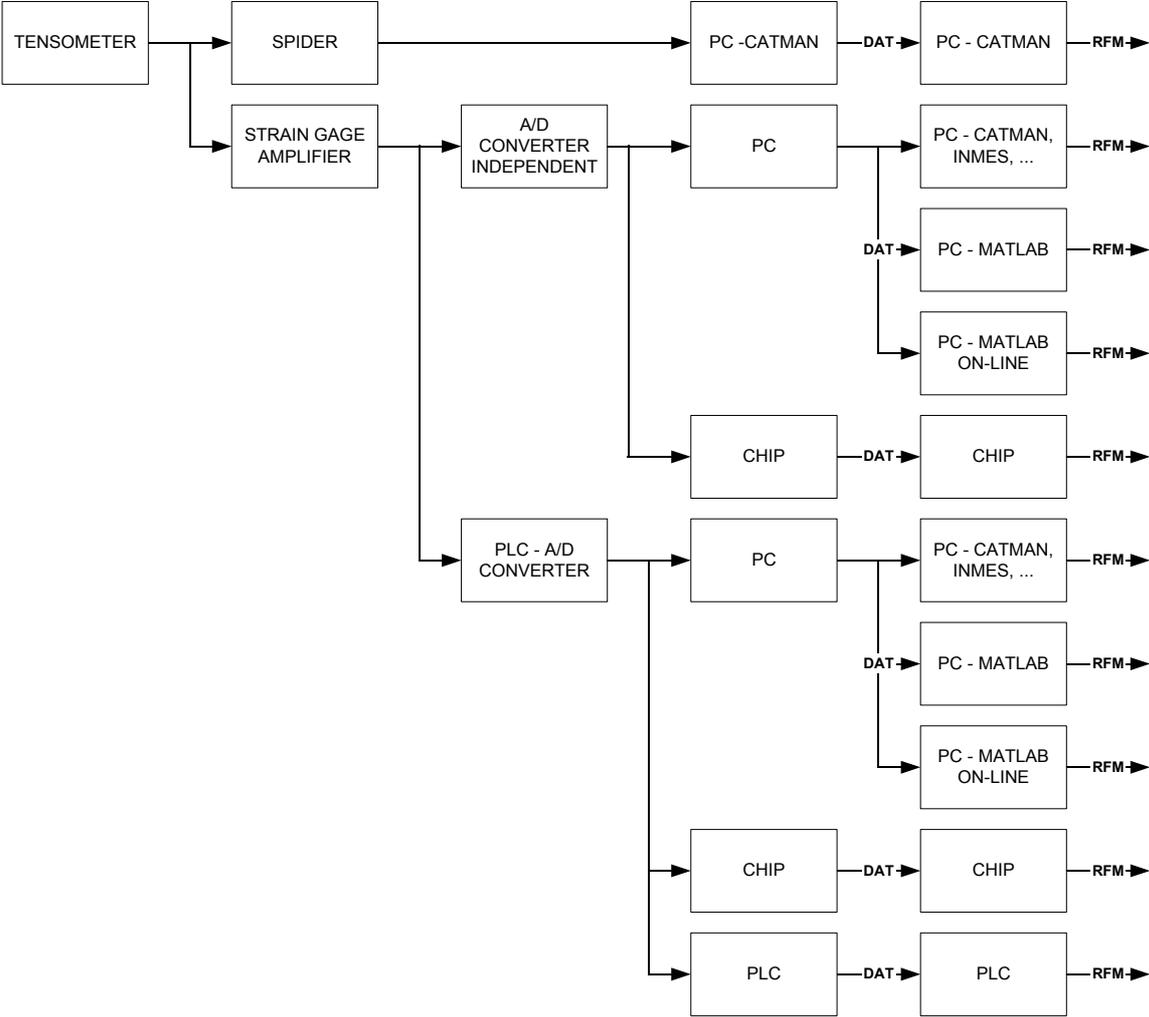


Figure 1. – measuring chain

- SPIDER - strain gage equipment
- CATMAN - SPIDER control software
- PLC - Program Logic Control
- CHIP - independent chip with memory

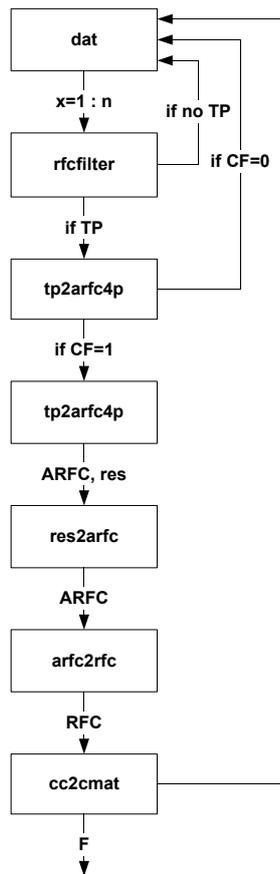


Figure 2. – on-line computational procedure

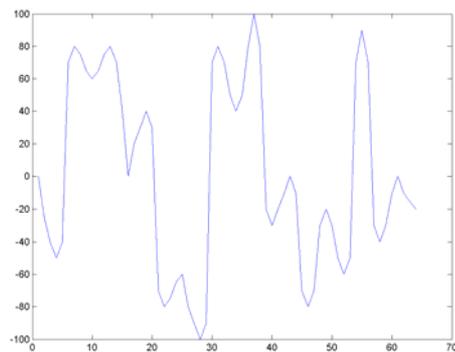


Figure 3. – dat

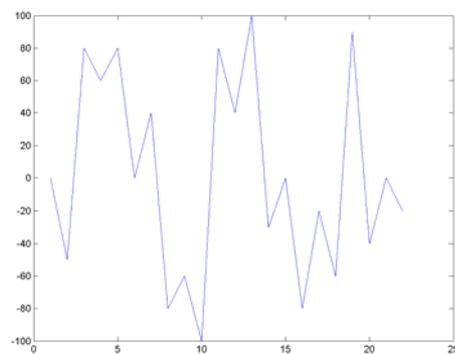


Figure 4. – TP

dat - input signal (strain gage measurement)  
 TP - turning points  
 CF - cycle found  
 RFC - rainflow cycles  
 ARFC - asymmetric RFC (without residual or with residual included)  
 res - residual  
 F (cmat) - cycle count matrix (min-max format)  
 Frm (rmcmat) - cycle count matrix (Range-Mean format)

rfcfilter - rainflow filter of signal  
 tp2arfc4p - calculates asymmetric rainflow cycles from turning points (4-point) and residual  
 res2arfc - calculates asymmetric rainflow cycles for a residual  
 arfc2rfc - converts asymmetric rainflow cycles to symmetric rainflow cycles  
 cc2cmat - calculates the cycle count matrix from a cycle count  
 cmat2rmcmat - converts a cycle matrix from min-max format to Range-Mean format (independent program)

The input for algorithm is analog signal from strain gage amplifier which is discretized in A/D converter (variable x).

The rfcfilter is designed for filtering the signal. It comes to this, that input signal x is converted to TP (rainflow filtered signal y). The important component of rfcfilter is threshold for rainflow filter which ignores amplitudes below set value h. Example: If  $h=5 \rightarrow$  routine removes all rainflow cycles with range less than 5.

If TP is founded then tp2arfc4p is activated and when it finds cycle (CF) then ARFC and res matrices are formed. New cycles are added to old cycle matrix.

Then res2arfc transfer res matrix to ARFC matrix. This matrix is added to previous ARFC matrix from tp2arfc4p.

In additional step ARFC are transferred to symmetric RFC where all data under diagonal are equal to 0.

Finally RFC is discretized by cc2cmat routines and min-max cycle count matrix (cmat) is formed. This matrix may be transferred to Range-Mean cycle count matrix using cmat2rmcmat routines.

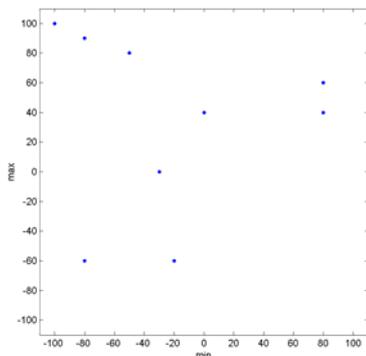


Figure 5. – ARFC (residual included)

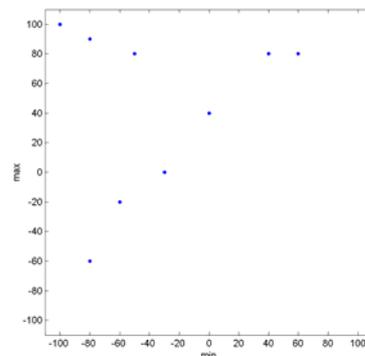


Figure 6. – RFC (residual included)

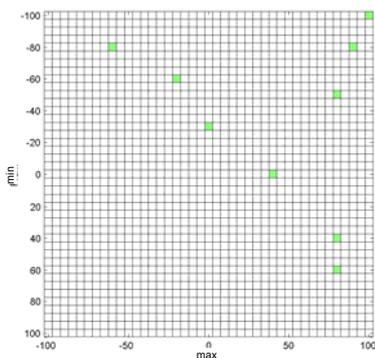


Figure 7. – cmat

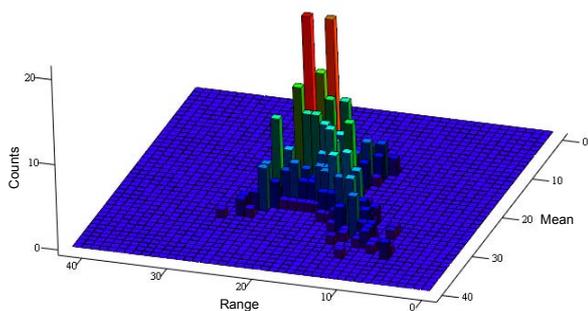


Figure 8. – rmcmat from long-run signal

Figure 9 shows the alternatives for durability calculations. The best way providing this calculation is to accumulate damage which gives whole life rainflow matrix. On the other hand, second method gives only partial rainflow matrix between two inspections. Residual life can be estimated by commercial or special designed fatigue prediction programs.

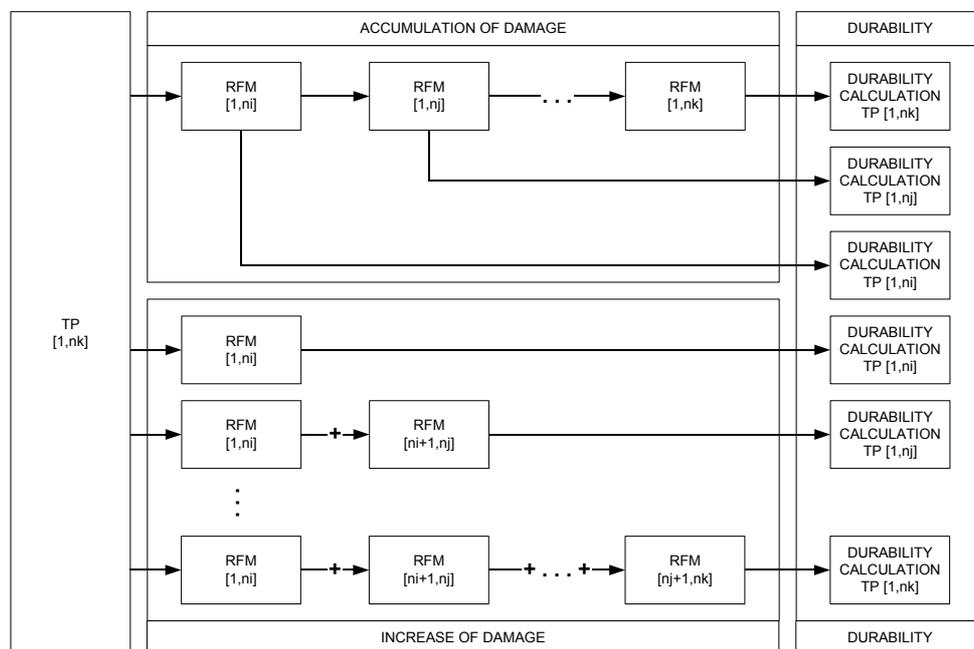


Figure 9. – Damage approach

### Conclusion:

The most optimal concept especially for customers is on-line durability prediction with integrated equipment which contains all parts described above. It could be designed as independent system which direct displayed residual fatigue life value. It is more easy to design variant without last step. In this case we obtain only rainflow matrix and fatigue evaluation must be executed by independent software.

### References:

- [1] Bigoš, P., Pidany, J.: Prevádzková spoľahlivosť. ALFA, Bratislava 1987
- [2] MSC.Patran 2004 and MSC.Fatigue 2004 On-line documentation. MSC.Software, 2004
- [3] nSoft User Manual, nCode International, 2003
- [4] Trebuňa, F., Bigoš, P.: Intenzifikácia technickej spôsobilosti ťažkých ocelových konštrukcií. Vienala, Košice 1998
- [5] WAFO – A matlab toolbox for analysis of random waves and loads, Lund University, 2000