Road Load Data Acquisition Committee

SAE FD&E
4-5 April, 2000

Minutes

Current Activities:

•Rainflow Standard - closed

•Time History format - closed

•ASCII data for web page - Andrew Whelan

•Statistical Data Analysis

•ATV contributions

Today's Presentation Session:

•Non-Stationary Random Load Modeling

•Discussion on RLDA contributions to ATV project

Modeling of non-stationary variance in vehicle loading histories for fatigue analysis

SAE FD&E Spring 2000
4-5 April, 2000

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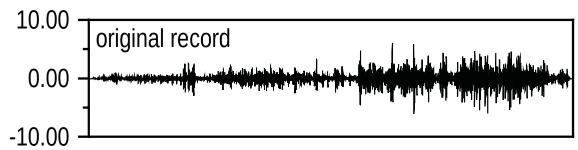
Professor Surot Thangjitham, Virginia Tech

Professor Norman Dowling, Virginia Tech

Concise fatigue load description



$$\mathbf{x}_t = \mathbf{s}_t \quad \mathbf{n}_t$$

Motivation:

- storage reduction
- test machine / FEA compatibility
- monitoring
- concentration on relevant content
- elimination of non damaging events
- manipulation
  superposition
  extrapolation

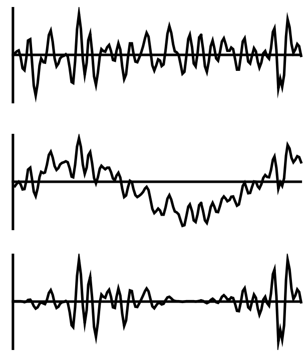
General Random Fatigue Loads

- Stationary
- Nonstationary

    in mean

    and / or

    in variance



Model for Nonstationary Fatigue Loading:

x(t) = s(t) n(t)

s(t) … variance scaling function

$$s_t^{BC} = \frac{1}{2}c_0 + \sum_{k=1}^{M_s}\left[c_k \cos(\omega_0 k t \Delta t) + d_k \sin(\omega_0 k t \Delta t)\right]$$

n(t) … zero mean, stationary noise content

$$n_t - \phi_1 n_{t-1} - \ldots - \phi_p n_{t-p} = e_t - \theta_1 e_{t-1} - \ldots \theta_q e_{t-q}$$

Data Reduction Schemes

full time record	⇔	Counting Methods (Markov - Rainflow)
⇓		
time domain	⇔	frequency domain
⇓		
stochastic	⇔	deterministic
⇓		
stationary	⇔	non-stationary
⇓		
general linear model	⇔	non-linear models
⇓		

ARMA model

$$n_t - \phi_1 n_{t-1} - \ldots - \phi_p n_{t-p} = e_t - \theta_1 e_{t-1} - \ldots \theta_q e_{t-q}$$

Modeled	**Characteristics of ARMA Method**	***Not Modeled***
Dynamics		Rainflow Cycles
Auto-Cross-Correlations		Extremes
Advantages	**Fundamental**	***Disadvantages***
Stochastic Description (Ensemble)		"Involved" Model Building
Consistent Multichannel Extension		Not Same Rainflow Cycles
Continuous Nonstationarity Description		Not Identical Extremes
Concise Description		
Simple, Fast Simulation		

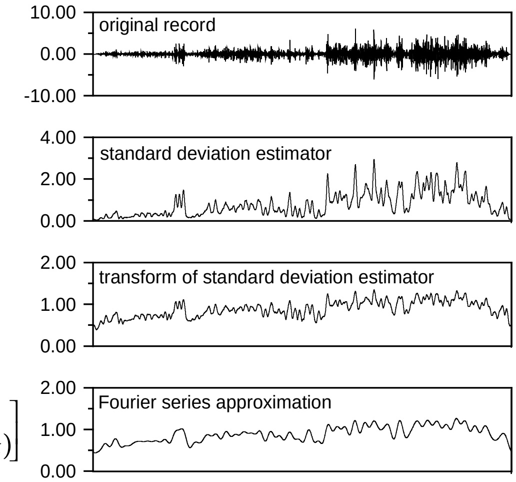
Reconstruction Procedure

$$x_t = s_t \cdot n_t$$

$$\tilde{\sigma}_t^2 = \sum_{j=0}^{n} w_{j-\frac{n}{2}} x_{t+j-\frac{n}{2}}^2$$

$$\tilde{\sigma}_t^{BC} = \begin{cases} \tilde{\sigma}_t^{\lambda} & \text{for} \quad \lambda \neq 0 \\ \log \tilde{\sigma}_t & \text{for} \quad \lambda = 0 \end{cases}$$

$$s_t^{BC} = \frac{1}{2} c_0 + \sum_{k=1}^{M} \begin{bmatrix} c_k \cos(\omega_0 k t \Delta t) \\ + d_k \sin(\omega_0 k t \Delta t) \end{bmatrix}$$



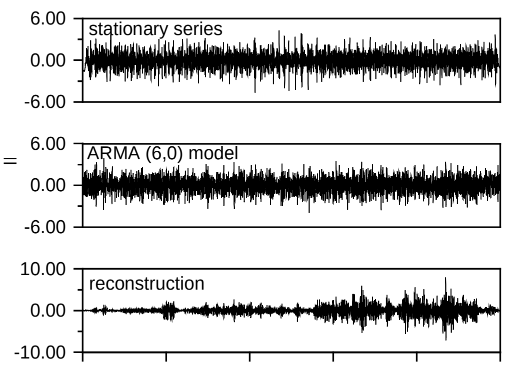
Reconstruction

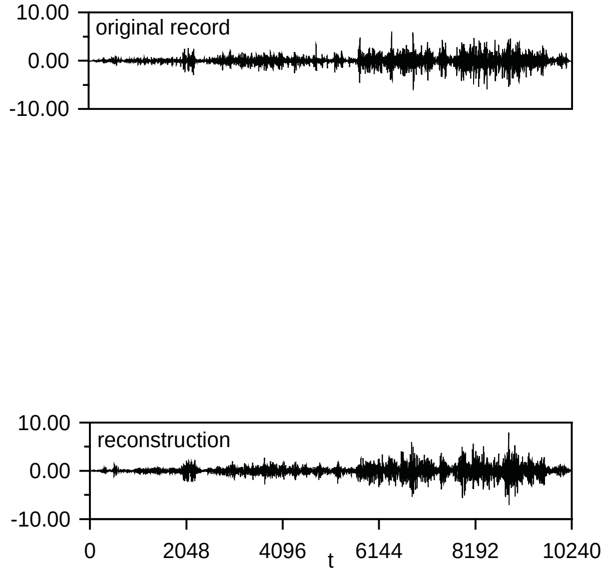
Procedure

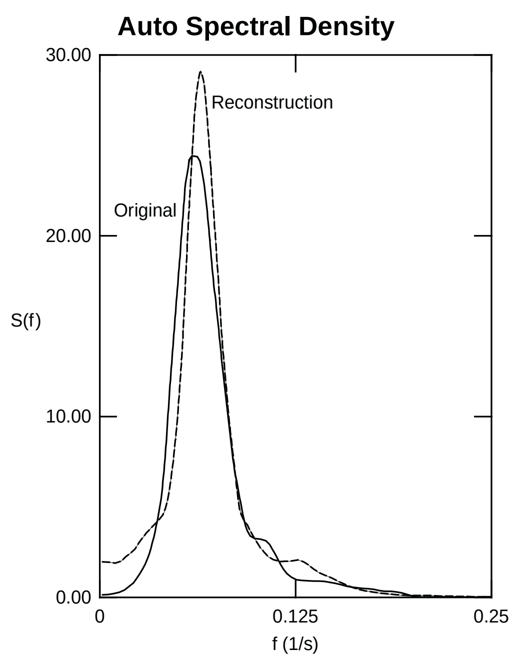
$$x_t / \sigma_t = n_t$$

$$n_t - \phi_1 n_{t-1} - \phi_2 n_{t-2} - \ldots - \phi_p n_{t-p} = a_t - \theta_1 a_{t-1} - \theta_2 a_{t-2} - \ldots - \theta_q a_{t-q}$$

$$x_t = s_t \cdot n_t$$



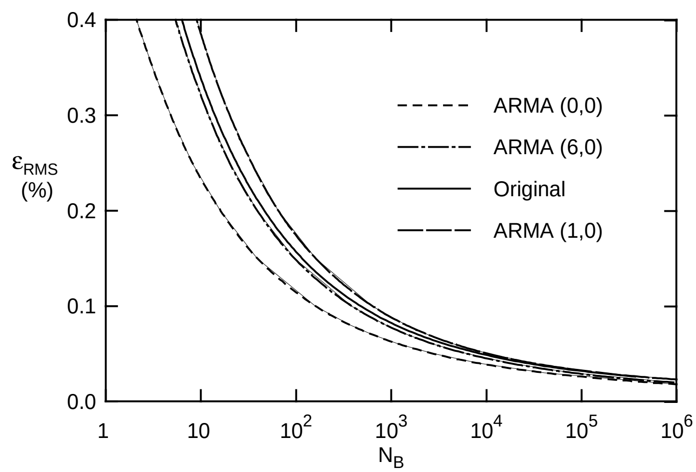

10.00
original record
0.00
-10.00
10.00
reconstruction
0.00
-10.00
0
2048
4096
t
6144
8192
10240


Auto Spectral Density
30.00
Reconstruction
Original
20.00
S(f)
10.00
0.00
0
0.125
0.25
f (1/s)

Fatigue Life Calculation

- RMS scaling factors
- Rainflow Count
- Local Strain Approach
- Palmgren Miner Rule

Fatigue Life



Ensemble Generation

$$s_t^{N_Z} = \frac{1}{2}c_0 + \sum_{k=1}^{M}\left[\begin{array}{l} c_k \cos(\omega_0 k t \Delta t - \gamma_k) \\ + d_k \sin(\omega_0 k t \Delta t - \delta_k) \end{array}\right]$$

$$\gamma_k, \delta_k = \begin{cases} U & \text{for} \quad k \in (N_Z + 1, M) \\ 0 & \text{for} \quad k \in (0, N_Z) \end{cases}$$