EXAMPLE NO. 1

MECHANICAL RELIABILITY

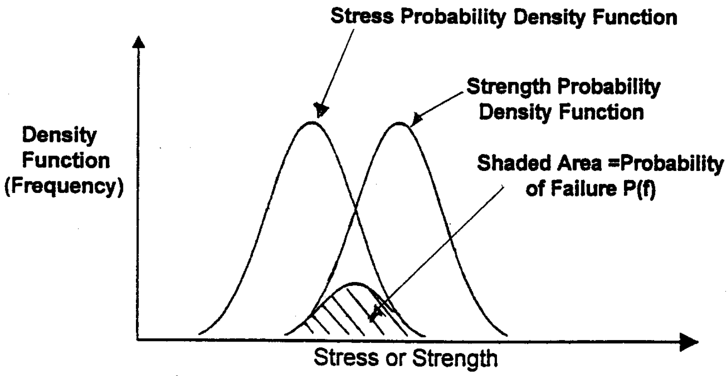
RADC-TR-85-194

October 1985

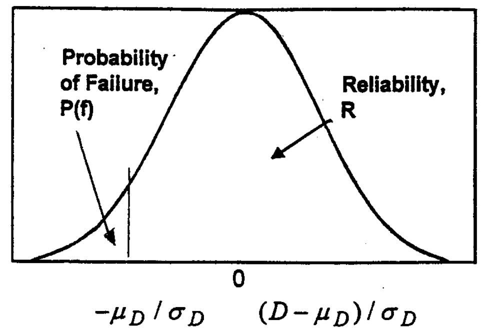
Stress/Strength Interference Method

for the

Monopropellant Tank



Stress/Strength Interference Method



Normalized Density Function of Excess Strength Over Load

Establish a new random variable D, where the difference of strength minus stress (load) is

$D =$ Strength (S) - Stress (L) $= S - L,\ \mu_D = \mu_S - \mu_L,\ \sigma_D = \sqrt{\sigma_S^2 + \sigma_L^2}$ and where

$\mu_D, \mu_S, \mu_L =$ Mean of the difference, strength and stress, respectively, and

$\sigma_D, \sigma_S, \sigma_L =$ Standard Deviation of the difference, strength and stress, respectively.

Then the probability of failure, P(f), is

$$P(f) = P(S - L < 0) = P(D < 0) = P\left\{\frac{D - \mu_D}{\sigma_D} < \frac{-\mu_D}{\sigma_D}\right\} = \frac{1}{\sqrt{2\pi}} \int_{-\infty}^{-\mu_D/\sigma_D} \exp\left(-t^2/2\right) dt$$

for the $P(f) = \frac{1}{\sigma\sqrt{2\pi}} \int_{-\infty}^{+\infty} e^{-\frac{1}{2}\left(\frac{x-\mu}{\sigma}\right)^2} dx$ where the standard normal random variable at

$t = \frac{x-\mu}{\sigma}$ & $-\mu_D / \sigma_D = -9.0766753347$ at $t = \frac{\mu_S - \mu_L}{\sqrt{\sigma_S^2 + \sigma_L^2}}$, the difference probability density

function is normalized to a zero mean and a standard deviation of one.

The reliability prediction, 1 - P(f), for the MTA Propellant Tank, which has a ultimate strength normal distribution mean of $\mu_S = 160{,}000$ psi and a standard deviation of $\sigma_S = 17{,}660$ psi and an in-orbit stress load (MEOP) normal distribution mean of $\mu_L = 250$ psi and a standard deviation of $\sigma_L = 50$ psi, is 0.999999999.

Monopropellant Tank Reliability Mathematical Model and Prediction

EXAMPLE NO. 2

FAILURE RATE ANALYSIS

Carderock Div, NSWC-92/L01,

"Handbook of Reliability Prediction Procedures

for Mechanical Equipment", May 1992

for the

Poppet Valve Assembly

Poppet Valve Assembly

$$\lambda_{PO} = \lambda_{PO,B} \frac{Q_a}{Q_f}$$

Where:

$\lambda_{PO} =$ Failure rate of the poppet assembly, failures/million operations

$\lambda_{PO,B} =$ Base failure rate for poppet assembly, failures/million operations

$Q_a =$ Leakage rate, in^3/min

$Q_f =$ Leakage rate considered to be valve failure, in^3/min

$$Q_a = \frac{2x10^4 \ D_{MS} \ f^3 \ (P_1^2 - P_2^2)}{V_a \ L_W \ (S_S)^{3/2}}$$

Where:

$Q_a =$ Actual fluid leakage, in^3/min

$D_{MS} =$ Mean seat diameter, in

$f =$ Mean surface finish of opposing surfaces, min

$P_1 =$ Upstream pressure, lb/in^2

$P_2 =$ Downstream pressure, lb/in$_2$

$V_a =$ Absolute fluid viscosity, lb-min/in^2

$L_W =$ Radial seat land width, in.

$S_S =$ Apparent seat stress, lb/in2

$$\lambda_{PO} = \lambda_{PO,B} \cdot C_P \cdot C_Q \cdot C_F \cdot C_V \cdot C_N \cdot C_S \cdot C_{DT} \cdot C_{SW} \cdot C_W$$

Where:

$\lambda_{PO} =$ Failure rate of poppet assembly in failures/million operations; 1.26

$\lambda_{PO,B} =$ Base failure rate of poppet assembly, 1.40 failures/million operations

$C_P =$ Multiplying factor which considers the effect of fluid pressure on the base failure rate, 1.0

$C_Q =$ Multiplying factor which considers the effect of allowable leakage on the base failure rate, 1.0

$C_F =$ Multiplying factor which considers the effect of surface finish on the base failure rate, 1.0

$C_V =$ Multiplying factor which considers the effect of fluid fiscosity/temperature on the base failure rate, 1.0

$C_N =$ Multiplying factor which considers the effect of contaminants on the base failure rate, 1.0625

$C_S =$ Multiplying factor which considers the effect of the apparent seat stress on the base failure rate, 0.621119

$C_{DT} =$ Multiplying factor which considers the effect of the seat diameter on the base failure rate, 1.09

$C_{SW} =$ Multiplying factor which considers the effect of the seat land width on the base failure rate, 1.001182

$C_W =$ Multiplying factor which considers the effect of flow rate on the base failure rate, 1.25

Where:

$$C_P = \left(\frac{P_1 - P_2}{3000}\right)^2$$

$$C_Q = 0.055 / Q_f \text{ For leakage (Per GPM}_\text{R}) > 0.03,$$

$$C_Q = 4.1 - (79Q_{f)} \text{ For leakage (Per GPM}_\text{R}) < 0.03,$$

$$C_F = \left(\frac{V_O}{V}\right)$$

Where: $V_o = 2\ x\ 10^{-8}\ \text{lb min / in}^2$

$$C_N \left(\frac{C_0}{C_{10}}\right)^3 N_{10}\ GPM_R$$

Where:

$GPM_R =$ Rated Flow in gallons/min, 5.0

$C_{10} =$ Standard System Filter Size = 10 micron

$C_0 =$ System Filter Size in microns = 5 micron

$N_{10} =$ 1.7 Particles under 10 microns/Hour/GPM

$$C_S = \frac{1}{S_R^{3/2}} = 0.621119$$

Where:

$$S_R = \frac{12\pi D_M L_W}{D_S^2} = 0.758$$

$$S_S = \frac{P_S D_S^2}{4 D_M L_W} = 1.2$$

$$S_S = \frac{\text{Force on Seat}}{\text{Seat Land Area}} = \frac{F_S}{A_{SL}}$$

$$F_S = \frac{\pi P_S D_S^2}{4}$$

$$\text{Stress Ratio} = \mathrm{S_C} / S_S = S_R$$

Therefore, leakage varies with the seat stress as:

$$\left(\frac{1}{S}\right)^{3/2}$$

Minimum Contact Pressure $= S_C = 3P_S$ approximately three times the fluid pressure.

$$A_{SL} = \pi D_M \cdot L_W$$

Where:

$A_{SL} =$ Seat land area, in^2

$L_W =$ Land area width, in

$D_M =$ Mean land width diameter, in

$$A_{ST} = \frac{\pi (D_s)^2}{4}$$

Where:

$A_{ST} =$ Seat Area, in$_2$

$D_S =$ Diameter of seat exposed to fluid pressure, P_S, 0.70 in

$$C_{DT} = 1.1\, D_S + 0.32$$

$$C_{SW} = 3.55 - 24.52\, L_W + 72.99\, L_W^2 - 85.75\, L_W^3 \text{ for } L_W < 6$$

$$C_W = 1 + \left[\frac{F_L}{100}\right]^2$$

Where:

$F_L =$ Ratio of actual flow rate to manufacturer's rating