통계적기법을 이용한 기계부품 피로수명 예측

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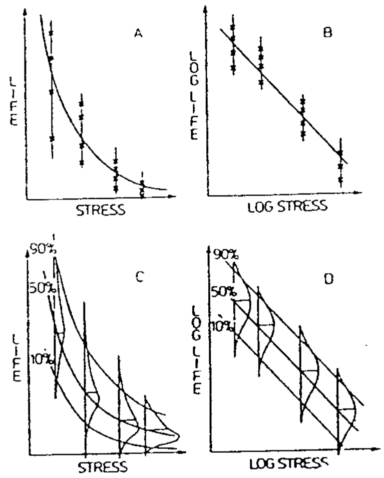
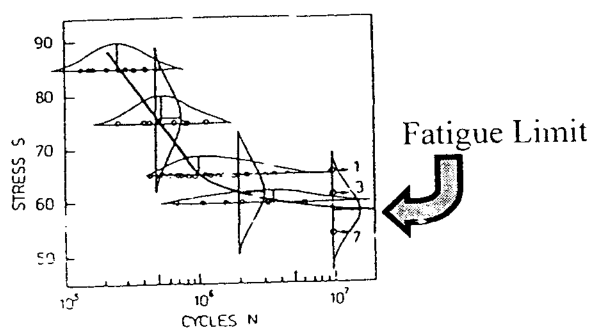
목차

일반적인 수명-스트레스 관계



S-N Curve

- 상당수 주요 기계부품의 경우 무한수명을 요구
- 피로한(Fatigue Limit, Endurance Limit)이 중요

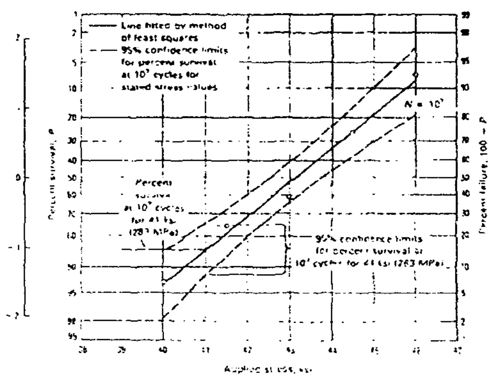


피로한 추정을 위한 통계적 기법

- Probit Method
- Staircase Method
- Two-Point Strategy

Fewer Specimens

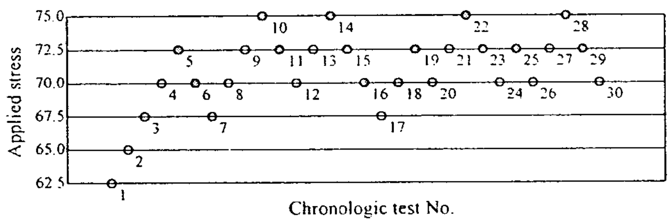
Probit Method



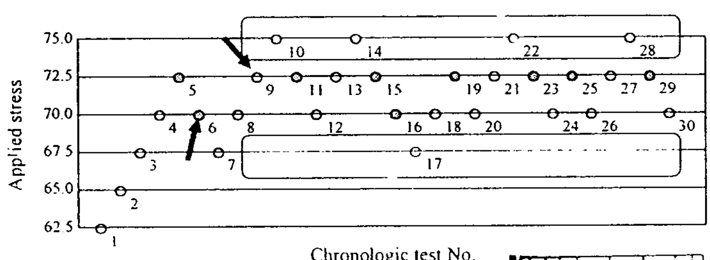
Applied stress,ksi	No. of Specimens tested	No. of specimens surviving 10^7 cycles	Survival ,%
40.0	15	14	93.33
41.5	8	6	75.00
43	5	3	60.00
44.5	8	2	25.00
46.0	15	1	6.67

Staircase(Up-and-down) Method

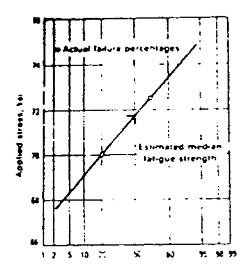
- 시편수가 제한된 경우 적용
- Probit method보다 단시간에 피로한 추정
- 피로한 상하의 스트레스수준에서의 생존율에 관련된 정보 제공 불가능



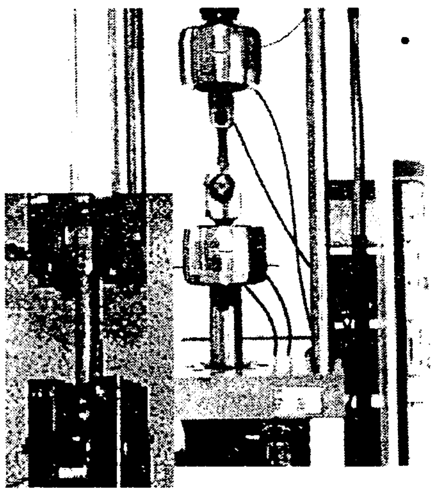
Two-Point Strategy



- 0<Failure percentage<1
- 각 수준에서 최소 6회 반복



Connecting Rod 사례-시험조건

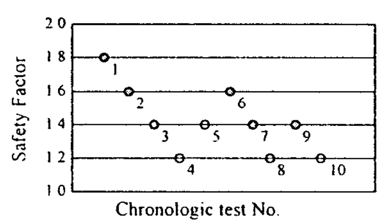


- 피로시험조건(Staircase Method)
  - 2× 10^6 Cycles
  - 10 Hz
  - 시험하중(단위 kgf)

Safety Factor	Min.	Max.
1.0	-7,500	+1,130
1.2	-9,000	+1,356
1.4	-10,500	+1,582
1.6	-12,000	+1,808
1.8	-13,500	+2,034
2.0	-15,000	+2,260

Connecting Rod 사례-시험결과

- 피로시험 결과



안전율	i	N_i	$i(N_i)$	$i^2(N_i)$
1.8	3	0	0	0
1.6	2	0	0	0
1.4	1	1	1	1
1.2	0	3	0	0
Sum		N=4	A=1	B=1

- i : Stress level
- Ni : Number of less frequent event (Fail or Runout)

Connecting Rod 사례-결과분석1

- 평균 피로한

$$\hat{S}_m = S_o + d\left[\frac{A}{N} \pm \frac{1}{2}\right]$$

+ : Less Freq. Event ⇐ Runout
- : Less Freq. Event ⇐ Fail

$$\hat{S}_m = 1.2 + 0.2\left[\frac{1}{4} + \frac{1}{2}\right] = 1.35$$

- 표준편차

$$\hat{\sigma} = 1.62d\left[\frac{NB - A^2}{N^2} + 0.029\right] \quad \text{if} \quad \frac{NB - A^2}{N^2} \geq 0.3$$

$$\hat{\sigma} = 0.53d \quad \text{if} \quad \frac{NB - A^2}{N^2} < 0.3$$

↳ Statistical Estimate of Standard Deviation

$$\sigma_m = \frac{G}{\sqrt{N}}\sigma$$

$$\frac{NB - A^2}{N^2} = \frac{4 \times 1 - 1^2}{4^2} = 0.1875 < 0.3$$

$$\hat{\sigma} = 0.53d = 0.53 \times 0.2 = 0.106$$

$$\sigma_m = \frac{G}{\sqrt{N}}\sigma = \frac{1.15}{\sqrt{4}}0.106 = 0.061$$

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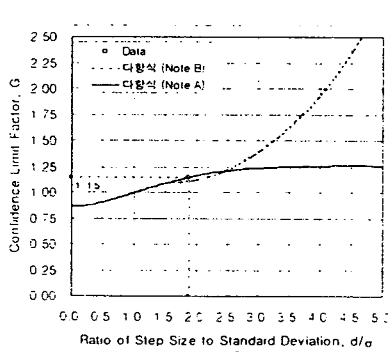
Connecting Rod 사례-결과분석2

- Confidence Limit Factor, G



- Confidence Limit

$$C\left\{\hat{S}_m - y_o\sigma_m \leq \mu \leq \hat{S}_m + y_o\sigma_m\right\} = 100(1 - \alpha)$$

C : Confidence in Percent
μ : True Mean Fatigue Strength
α : Significance Level of Test
y_o : Rejection Region

안전율 신뢰구간 (신뢰수준 90%)

$1.25 \leq \mu \leq 1.45$

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Connecting Rod 사례-결론

- 피로시험결과 Con-rod의 안전율은 평균 1.35로, FEM 결과와 동일. (일반적으로 Con-rod 안전율은 1.6 이상)
- 안전율 미달 원인 : I-Beam부에 양각된 품번이 Notch로 작용, 응력집중에 의한 피로강도 저하.
- 개선사항 : 양각의 간격 ↑, 높이 ↓