ALHT SUPPORT PIN DESIGN ANALYSIS

A redesign of the ALHT support pin has been accomplished. The strength of the pin has been effectively increased by approximately 60%, which will preclude failure of the pin in future tests.

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During the design limit test of the ALSEP Subpack II qualification model one of the ALHT support pins (Part No. 2333306) failed. Specifically, the failure occurred during the z-axis sine vibration test, per test procedure TP 233438.

The cause of the pin failure is not readily discernible. The subject pin is part of a structural indeterminate system which does not lend itself to a straight forward analysis. However, since pins of identical design had previously passed a complete vibration test series, during Proto model testing it had to be concluded that even a nominal increase in pin strength would suffice. The material of the pin was changed per CRD 55377 from titaluim with an ultimate yield strength (Ftu) of 160, 00 psi, to 4340 steel with a Ftu of 260, 00psi.

Appendix I presents the detail stress analysis perfirmed on this system. The principal difference between this analysis and the previous analysis performed, is in the assumption of the amount of load carried by the rear diagonal braces. From the actual design of the ALHT it becomes apparent that little load is carried by the diagonal braces, particularly during the initial deflections of the carrier. Consequently, in the current analysis it has been assumed that the total load is carried by the spherical pins. This latter assumption then being the only significant difference in the two analyses.

As shown on page 7 of Appendix I the calculated Margin of Safety (M. S.) for the titanim pin is negative 0. 09. The M. S. for the steel pin is positive 0. 43, as shown on page 8 of the Appendix. The M. S. of the current design is sufficiently large that a qualification test is not warrented. This contention is further supported by the test performed on the titanim pins used on the Prototype and Qualification Models. In the former the tests were successful, in the latter one of the pins failed, which corroborates the marginal condition predicatd analytically in the Appendix.

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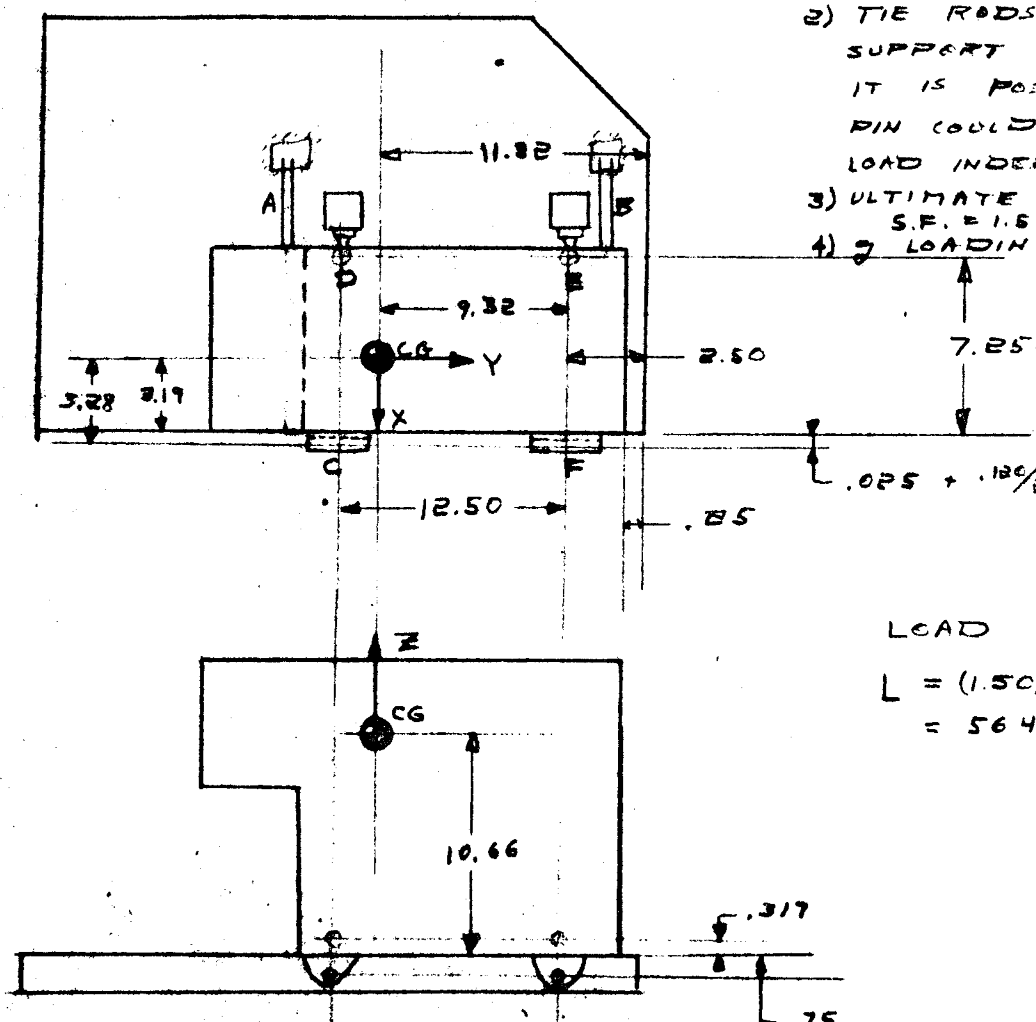
ALHT SPHERICAL PIN ANALYSIS

MAT'L = AISI 4340
F_{tu} = 260
F_{ty} = 217

$$\frac{260}{1.5} < \frac{217}{1.15}$$

ASSUME:

1) WT. AT C.G. = 18.8 LB
2) TIE RODS A AND B SUPPORT NO LOAD SINCE IT IS POSSIBLE THAT A PIN COULD RECEIVE FULL LOAD INDEPENDENTLY OF RODS
3) ULTIMATE ANALYSIS IS CRITICAL. S.F. = 1.50
4) g LOADING = 20 g



LOAD AT C.G.:

$$L = (1.50)(20)(18.8) = 564.0 \text{ LB}$$

FOR L ACTING IN X-DIRECTION

ASSUME NO AXIAL LOAD CARRIED.

$$M_{DC} = \frac{9.32}{12.50} M_x, \quad M_x = 10.66\,(L_x)$$

$$L_D = \frac{M_{DC}}{5.88 + .09} = \frac{M_{DC}}{5.97} = \frac{9.32}{12.50} \cdot M_x \cdot \frac{1}{5.97}$$

$$= \frac{9.32}{12.50} \cdot \frac{10.66}{5.97} L_x$$

$$L_D = 1.33\, L_x$$

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ALHT SPHERICAL PIN ANALYSIS

FOR L ACTING IN Y-DIRECTION

HORIZONTAL LOAD (Y):

$$L_{DE} = \frac{3.28}{5.97} L_y$$

$$L_{Dy} = L_{DE}/2 = \frac{3.28}{5.97} \cdot \frac{1}{2} L$$

VERTICAL LOAD (Z):

$$M_{DE} = \frac{3.28}{5.97} M_y \quad , \quad M_y = 10.66 \; L_y$$

$$L_{Dz} = M_{DE}/12.50 = \frac{1}{12.50}\left(\frac{3.28}{5.97}\right) M_y$$

$$= \frac{10.66}{12.50}\left(\frac{3.28}{5.97}\right) L$$

$L_{Dy} = .274 \; L$

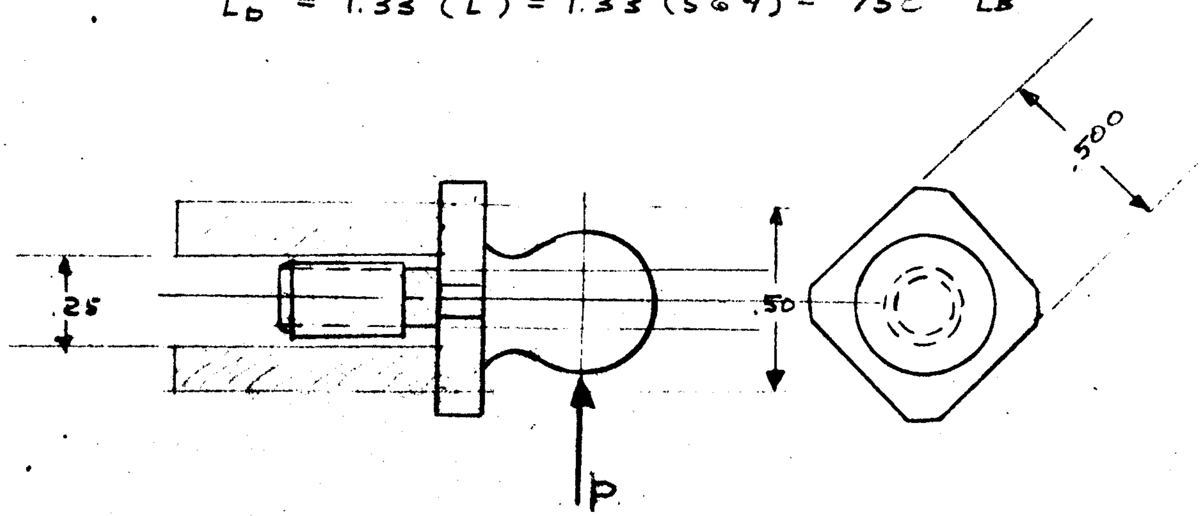
$L_{Dz} = .468 \; L$ $\quad L_{D(TOT)} = L\sqrt{.274^2 + .468^2} < 1.33 \; L$

FOR L ACTING IN Z-DIRECTION:

IT IS OBVIOUS THAT L_D OR L_E WILL NOT BE GREATER THAN L_D FOR L_x OR L_y.

HENCE, L ACTING IN X-DIRECTION IS CRITICAL. AND WORST PIN LOADING IS

$$L_D = 1.33\,(L) = 1.33\,(564) = 750 \quad LB$$



CONSIDERING A 10% POSSIBLE LOCATION ERROR OF C.G., CHANGE 9.32 TO 10% (12.50) + 9.32 = 10.57

THEN,

$$P = \frac{10.57}{9.32}(L_D) = 850 \quad LB.$$

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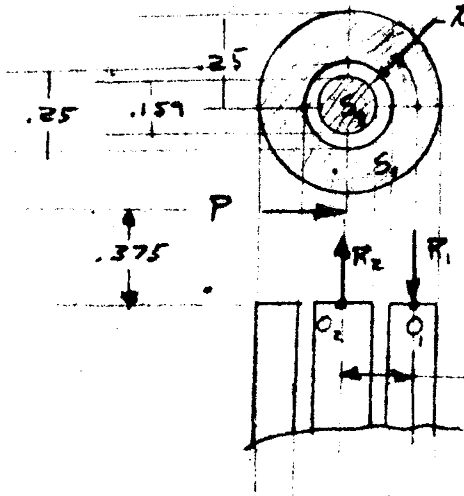
ALHT SPHERICAL PIN ANALYSIS

AREA OVER WHICH MOMENT ACTS:



$r = (.50 - .25)(2/3)(\frac{1}{2}) = .083$

ASSUME THAT PIN TIPS ABOUT POINT O_1. THEN, ASSUMING NO PRELOAD, THE FORCE INDUCED AT O_1 AND O_2 IS

$$R_2 = -R_1 = \frac{.375}{.208}(P)$$
$$= 1.8\,P = 1.80(850)$$
$$= 1530 \text{ LB.}$$

$.083 + .125 = .208$

PRELOADED SYSTEM W/O EXTERNAL LOAD P:

TORQUE = 20 IN-LB

FACTOR FOR TORQUE VARIATION — SAFETY FACTOR

$R_0 = (1.20)(1.50)(560) = \underline{1010 \text{ LB}}$ ASSUMING $k = .20$ FROM "MACH. DESIGN"

IN THE CALCULATION OF THE EFFECTIVENESS OF PRELOAD, CONSIDER

(1) $A_1 = 2/3\, S_1$, $E_1 = 10.3\,(10^6)$

$A_2 = \frac{(\pi)(.159)^2}{4}$ $E_2 = 30.0\,(10^6)$

(2) RESULTANT OF PRESSURE RELIEF AREA ($2/3\, S_1$) ACTS AT O_2.

THEN, THE RESULTANT LOAD ACTING ON S_2 BECOMES

$$F = \frac{k_2 R_2}{k_1 + k_2} + R_0$$

(FROM M.E. DESIGN, SHIGLEY, p. 243)

WHERE,

$$k_1 = \frac{A_1 E_1}{L} = \frac{10^6}{L}\left(\frac{2}{3}\right)\left[\frac{\pi(.50)^2}{4} - \frac{\pi(.25)^2}{4}\right](10.3)$$
$$= 1.01\,(10^6/L)$$

$$k_2 = \frac{A_2 E_2}{L} = \frac{10^6}{L}\left(\frac{\pi}{4}(.159)^2(30.0)\right)$$
$$= .594\,(10^6/L)$$

ASSUMING THAT BOLT HEAD IS RIGID.

THEN,

$$F = \frac{(.594)(1530)}{1.604} + 1010$$
$$= 567 + 1010$$
$$= 1577 \text{ LB.}$$

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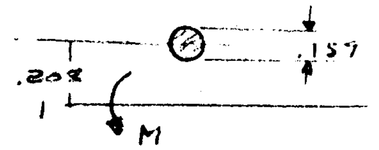
ALHT SPHERICAL PIN ANALYSIS

HENCE, THE WORST LOADING CONDITION PROVIDES A TENSION LOAD OF 1577 LB. IN THE PIN SHANK. EXCLUDING STRESS CONCENTRATION, THE MAX. STRESS IS FOUND BY,

$$M = 567(.208) = 118 \quad \text{IN-LB.}$$

$$I_{1-1} = I_o + \frac{\pi(.159)^2}{4}(.208)^2$$



$$= \frac{\pi}{4}\left[\left(\frac{.159}{2}\right)^4 + (.159)^2(.208)^2\right]$$

$$= \frac{\pi}{4}(10^{-4})(11.35)$$

$$= 8.92(10^{-4})$$

$$c = .208 + \frac{.159}{2} = .288$$

$$\sigma_t = \frac{Mc}{I} + \frac{P}{A} = \frac{(118)(.288)}{8.92}(10^4) + \frac{1010(4)}{\pi(.159)^2}$$

$$= 38,100 + 50,800 = \underline{\underline{88,900 \text{ PSI}}}$$

CHECKING FOR SHEAR STRESS:

$$N = F = \frac{567}{1.50} + \frac{1010}{(1.8)(1.50)} = 378 + 562 = 940$$

FROM M.E. H/B. $f_c = .61$ FOR ALUMINUM ON MILD STEEL,

THE $F_{FRIC.} = (.61)(940)$

$= 573$ LB.

850
573
277

SHEAR FORCE $F_s = P = 850$

$$\text{AVERAGE } \tau_s = \frac{(850 - 573)4}{\pi(.159)^2} = \frac{(4)(277)(10^4)}{(\pi)(15.9)^2} = 1.40(10^4)$$

$= 14,000$ PSI.

SINCE, FATIGUE IS CRITICAL IN THIS PROBLEM, SINCE τ_s IS ZERO ON SURFACE WHERE FATIGUE IS CRITICAL, AND SINCE THE BOLT IS STRONG ENOUGH IN STATIC SHEAR, SHEAR STRESS WILL HENCEFORTH BE NEGLECTED.

ALHT SPHERICAL PIN ANALYSIS

FATIGUE ANALYSIS

$$S_e = k_a\, k_b\, k_c\, k_d\, k_e\, k_f\, S_e'$$

S_e = CORRECTED ENDURANCE LIMIT (PSI)
S_e' = ENDURANCE LIMIT (PSI)
k_a = SURFACE FACTOR
k_b = SIZE "
k_c = RELIABILITY "
k_d = TEMP " ($0 \le T \le 120°$)
k_e = MOD FACTOR FOR STRESS CONCENTRATION
k_f = MISC. - EFFECTS FACTOR

LOADING REMOVING THE SAFETY FACTOR OF 1.50 AND ASSUMING A DYNAMIC LOADING DUE TO 6 g THE FLUCTUATING STRESS BECOMES (SEE σ_T pg. 4),

$$0 \text{ TO } \left[\frac{6.0}{20}(38.1) + 50.8\right]\frac{1}{1.50} \quad \text{OR} \quad 0 \text{ TO } 41{,}500 \text{ PSI}$$

AND A STEADY STATE STRESS OF

$$\frac{P}{A} = \frac{\frac{1010}{1.50}(4)}{\pi d^2} = \frac{858}{d^2} = \frac{(8.58)(10^{-2})}{(1.59)^2(10^{-4})} = 3.395\,(10^4)$$

$$= 34{,}000 \text{ PSI.}$$

HENCE,

$$\sigma_s = 34{,}000$$

$$\sigma_r = 41{,}500$$

$$\sigma_a = \frac{\sigma_r}{2} = \frac{41{,}500}{2} = 20{,}250$$

$$\sigma_m = 34{,}000 + 20{,}250$$

$$= 54{,}250$$

$$\frac{\sigma_a}{\sigma_m} = \frac{20.5}{54.3} = .378$$

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ALHT SPHERICAL PIN ANALYSIS
FOR 4340 STEEL, $S_{tu} = 260$ KSI

$S_e' = 97,000$ PSI FOR 4340 $S_{tu} = 260$ KSI

$k_a = 1.00$ FOR PLATING (NO SCRATCHES)

$k_b = 1.0$ FOR AXIAL LOADS

$k_c = 1 - .08\,D$, FOR A SURVIVAL RATE OF 99%
$D = 2.3$
$= 1 - .18$
$= .82$

$k_d = 1.00$ (ASSUMED)

$k_e = \frac{1}{k_f}$ $\quad k_f = 1 + q\,(k_t - 1)$

q = NOTCH SENSITIVITY
$r = .01$

$q = .90$

k_t (PETERSON p. 68), $D = .375$, $d = .157$

$k_t = 2.20$ $\quad D/d = 2.36$

$k_f = 1 + .90\,(2.20 - 1.)$ $\quad \frac{r}{d} = \frac{.01}{.159} = .063$
$= 1 + 1.08$
$= 2.08$

$1/k_f = .481$

$k_e = .481$

$k_f = .65$ (PLATING)

$S_e = (97)(1.0)(1.0)(.82)(.481)(.65) = \overset{k}{.256}\,(97)$
$= 24,850$ PSI

FOR Ti 6AL-4V (160 KSI = S_{ut})

$S_e = k\,S_e' = (.256)(80,000)$
$= 20,500$ PSI

$S_e' = (.50)(S_{ut}) = \frac{1}{2}(160)$
$= 80$ KSI

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ALHT SPHERICAL PIN ANALYSIS

FATIGUE ANALYSIS USING:

1) 6 g DYNAMIC LOAD AT 2×10^4 CYCLES
2) SCATTER & SAFETY FACTOR OF 2.00
3) TI 6AL-4V (160 KSI. = S_{ut})
4) 20 IN-LB TORQUE FOR PRELOAD

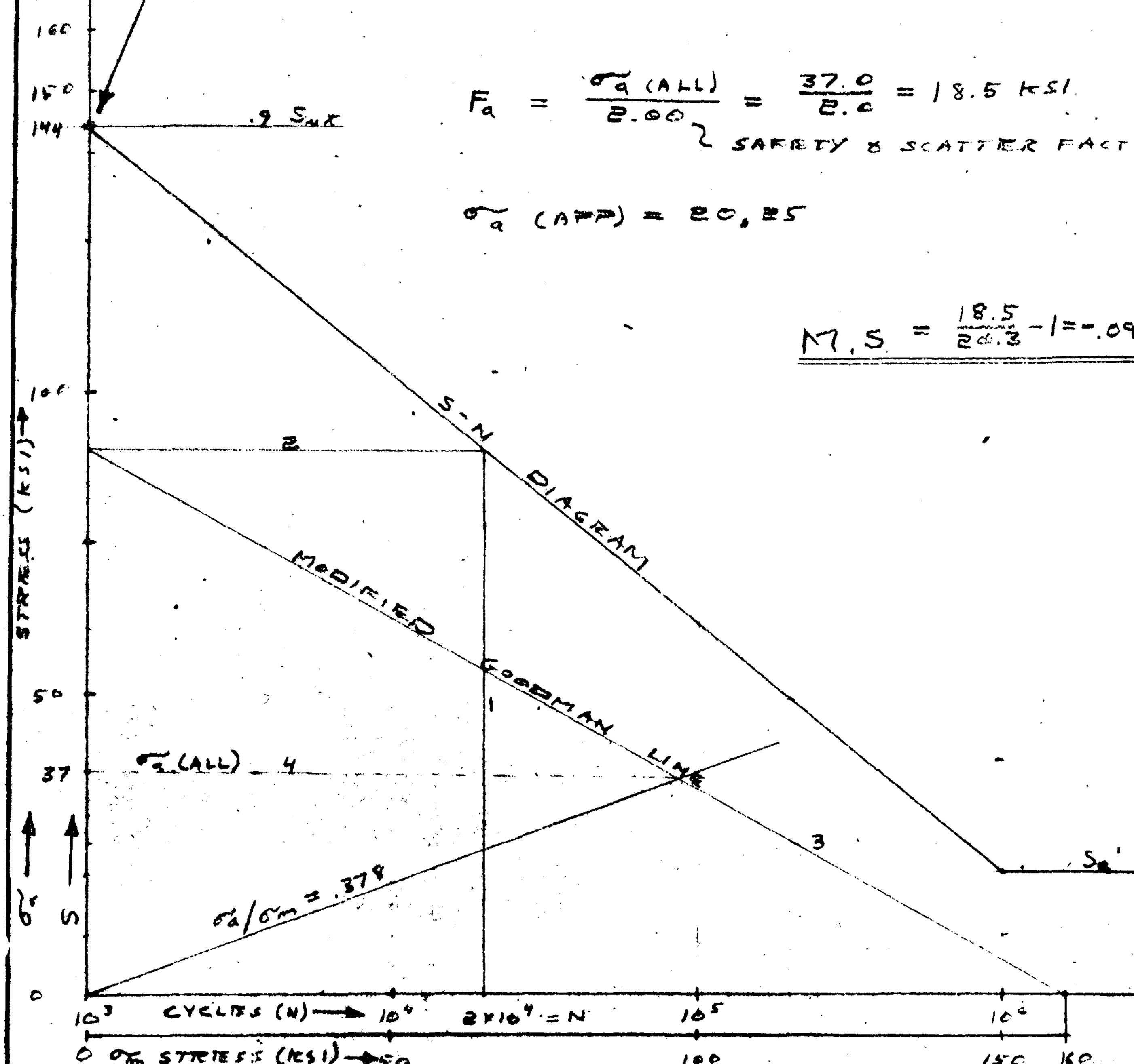
$.9\ S_{ut} = (.9)(160{,}000) = 144$ KSI

$$F_a = \frac{\sigma_a\,(ALL)}{2.00} = \frac{37.0}{2.0} = 18.5 \text{ KSI}$$

2.00 ← SAFETY & SCATTER FACT

σ_a (APP) = 20.25

$$M.S = \frac{18.5}{20.3} - 1 = -.09$$



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ALHT SPHERICAL PIN ANALYSIS

FATIGUE ANALYSIS USING:

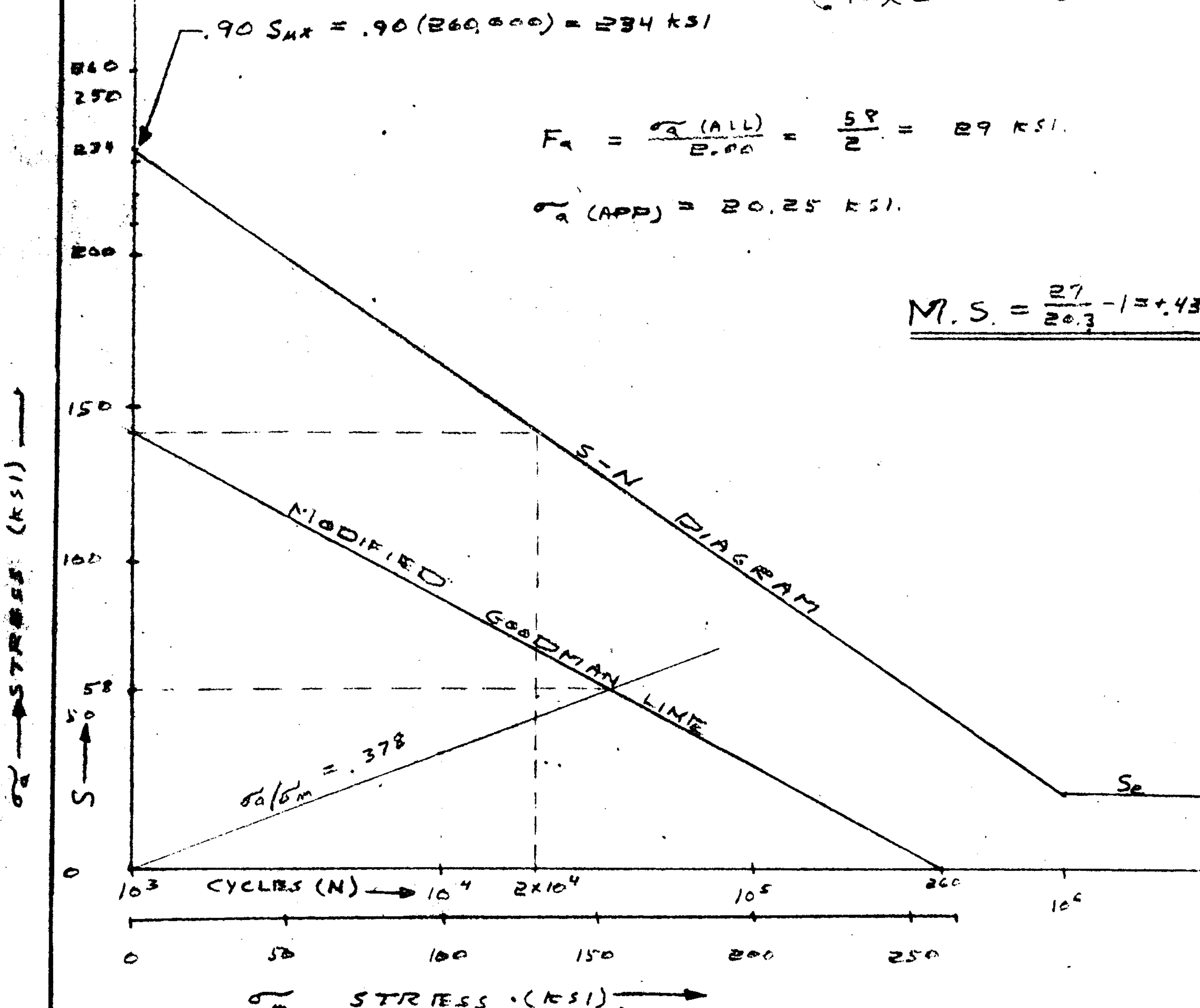
1) 6 g DYNAMIC LOAD AT 2×10^4 CYCLES
2) 20 IN-LB TORQUE FOR PRELOAD
3) SAFETY & SCATTER FACTOR OF 2.00
4) 4340 STEEL (260 KSI = S_{ux})

$(.90)(260) = 234.0$

$$F_a = \frac{\sigma_a\,(ALL)}{2.00} = \frac{58}{2} = 29 \text{ KSI.}$$

$$\sigma_a\,(APP) = 20.25 \text{ KSI.}$$

$$M.S. = \frac{27}{20.3} - 1 = +.43$$



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ALHT SPHERICAL PIN ANALYSIS

CONCLUSIONS

IT IS THE OPINION OF THE AUTHOR THAT THE TITANIUM PIN IS INADEQUATE AND SHOULD BE USED ONLY IN THE CASE OF FAIL-SAFE VERIFICATION BY TESTING. THE STEEL PIN, ON THE OTHERHAND, WILL BE ADEQUATE PROVIDED ALL OF THE PREVIOUS ASSUMPTIONS ARE MET BY THE MANUFACTURER. TESTING IS RECOMMENDED IF REASONABLY CONVENIENT BUT IS NOT CONSIDERED TO BE OF ABSOLUTE NECESSITY FOR THE FAIL-SAFE VERIFICATION OF THE STEEL PIN.