AMR Rolling Chassis Design

기계요소설계

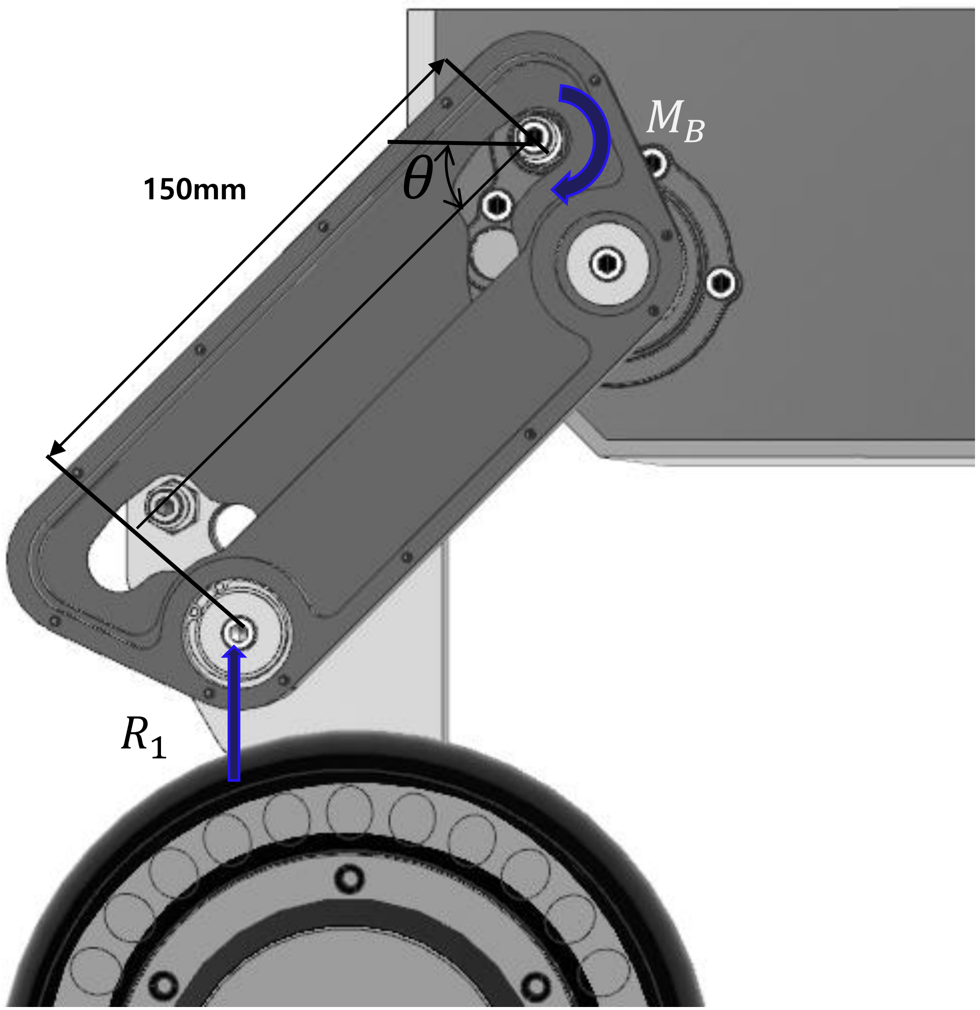
16조
B917074 성현진
B917078 양예준
B917079 양정현

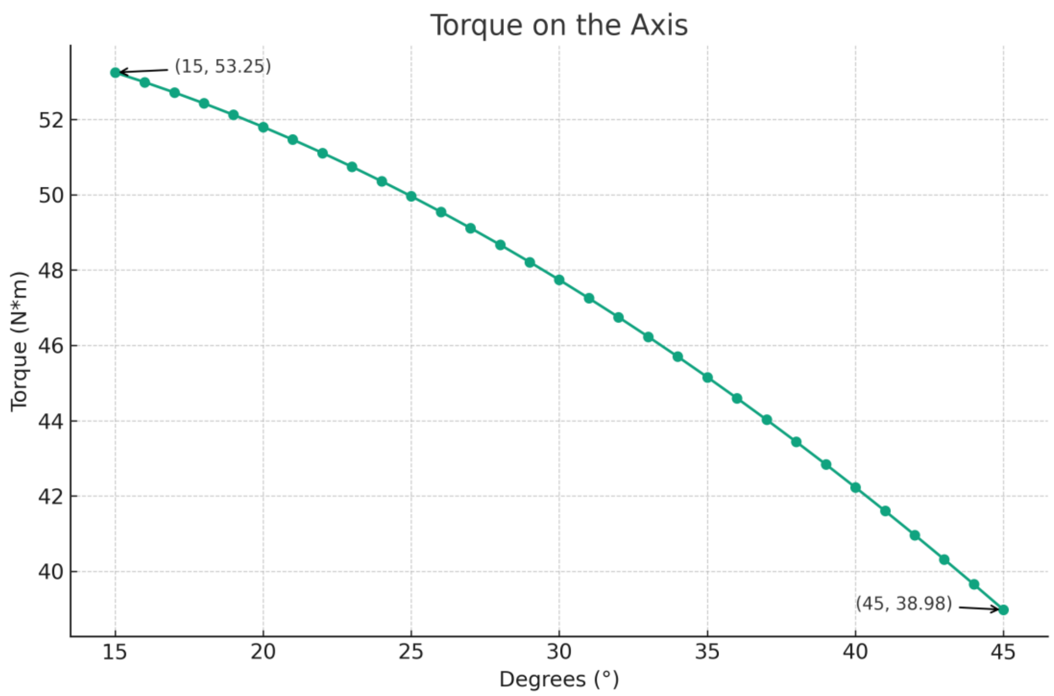
INDEX

1.설계 조건 선정

01.제원 및 하중 분석

자세 제어를 위해 필요한 모멘트 분석



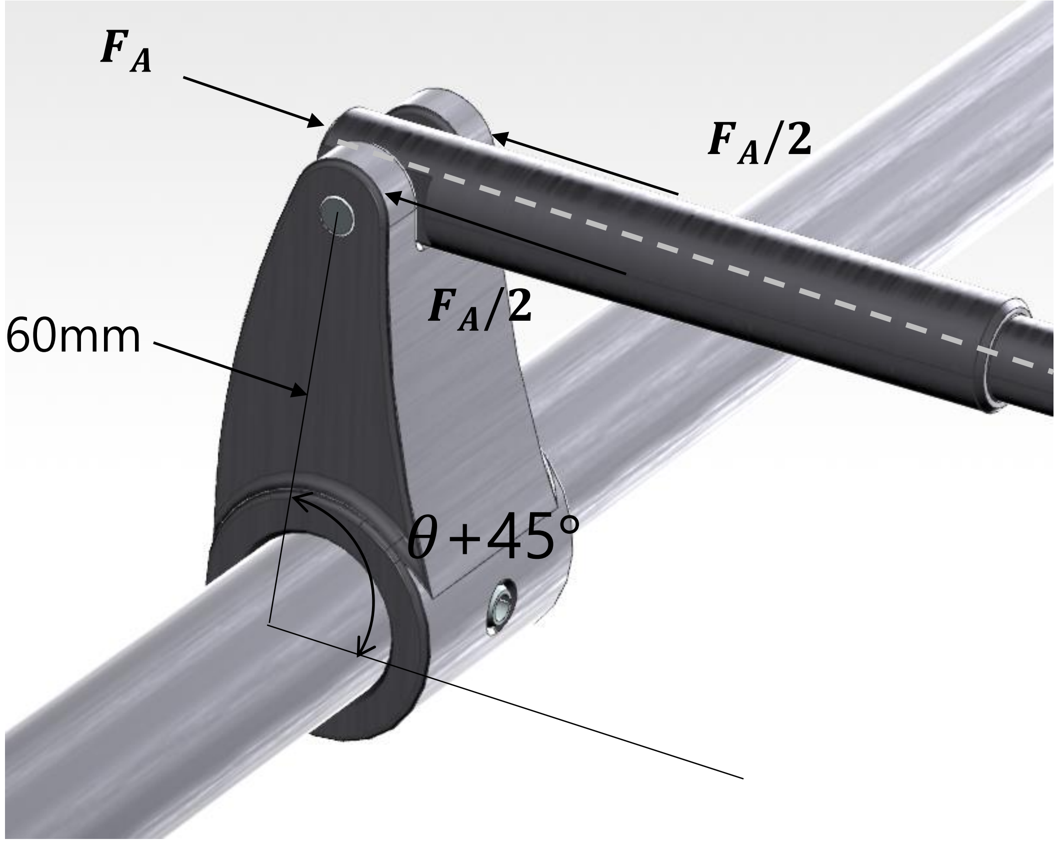


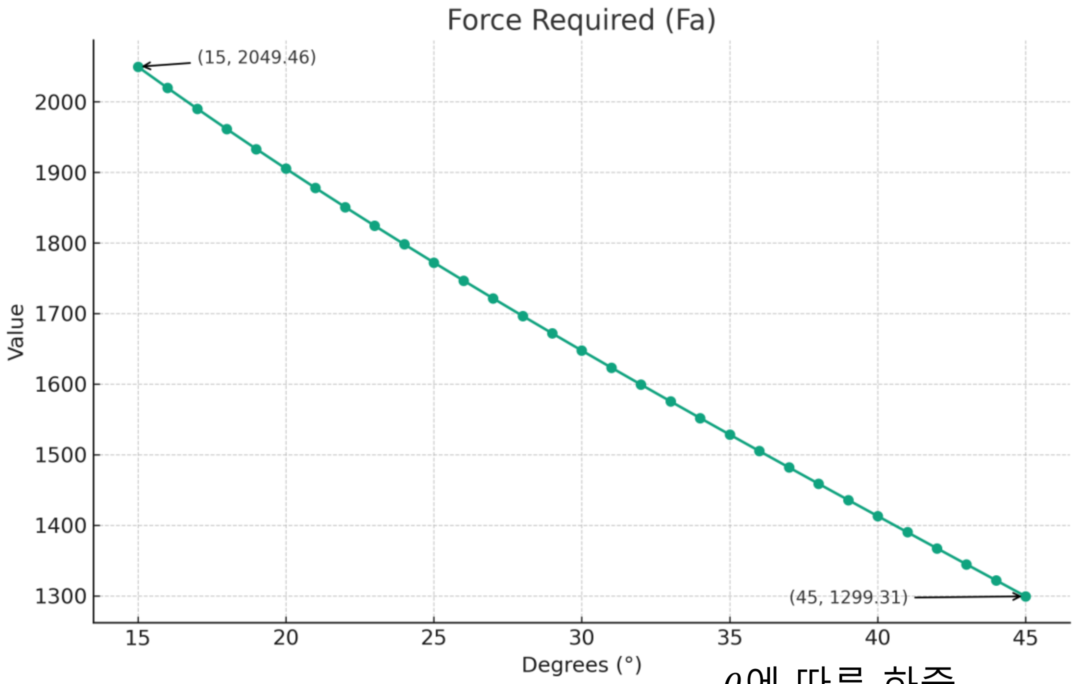
$R_1 = R_2$ (바퀴하나의 반력)=150 × 9.81÷4 (N)

M_B(축에 걸리는 모멘트)

$M_B = R_1 \times \cos\theta \times 0.15 \quad (15° \leq \theta \leq 45°)$

자세 제어를 위해 핀에 걸리는 힘 분석





θ에 따른 하중

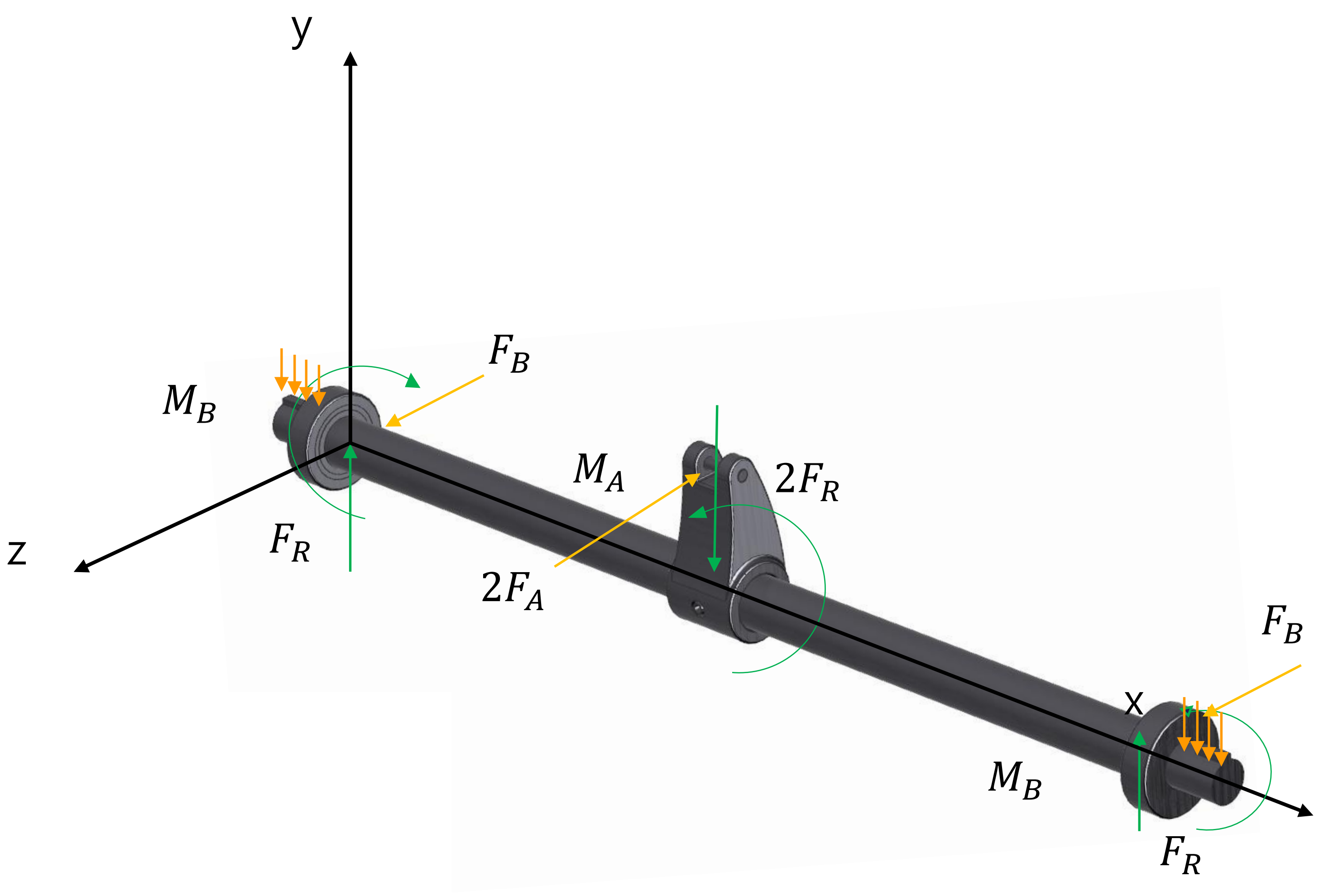
$$F_A = M_A/(0.006 * cos(-\theta + 45°)) \quad (M_A = 2M_B)$$

$F_A\,(Max) = 2049.46N$ **(Link와 지면의 각도가 15° 일때)**

2.요소 설계

01.축 설계
02.키 선정
03.PIN 설계
04.베어링 선정
05.키 선정

축 설계 : FBD



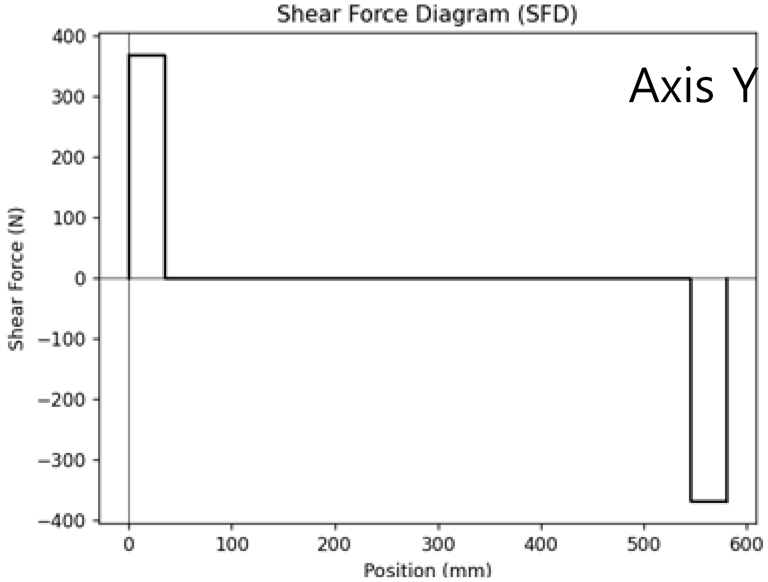
$\boldsymbol{\theta} = 15°$일 때를 기준으로 설계

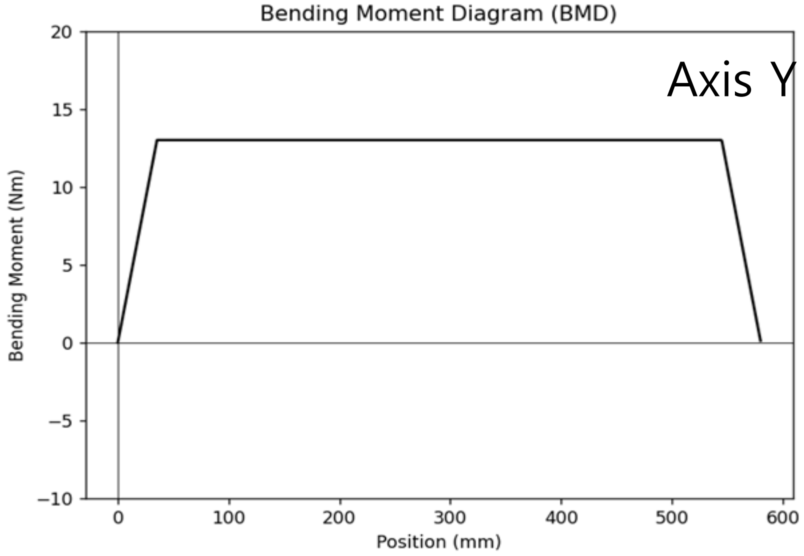
$M_B = 53.25\ N \cdot m, F_R = 367.5\ N$

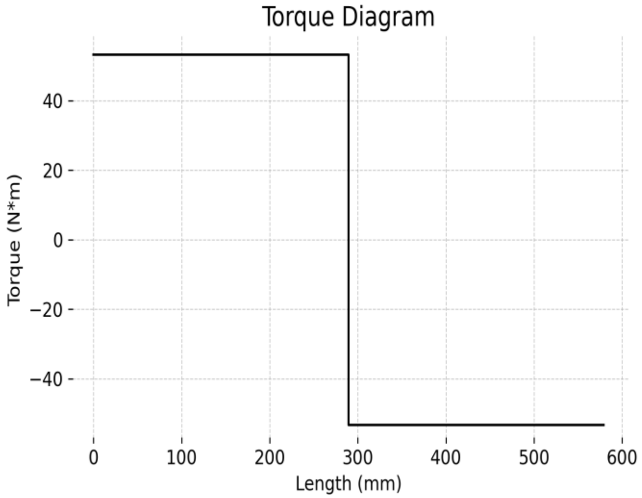
$M_A = 2M_B,\ F_A = 2F_B$

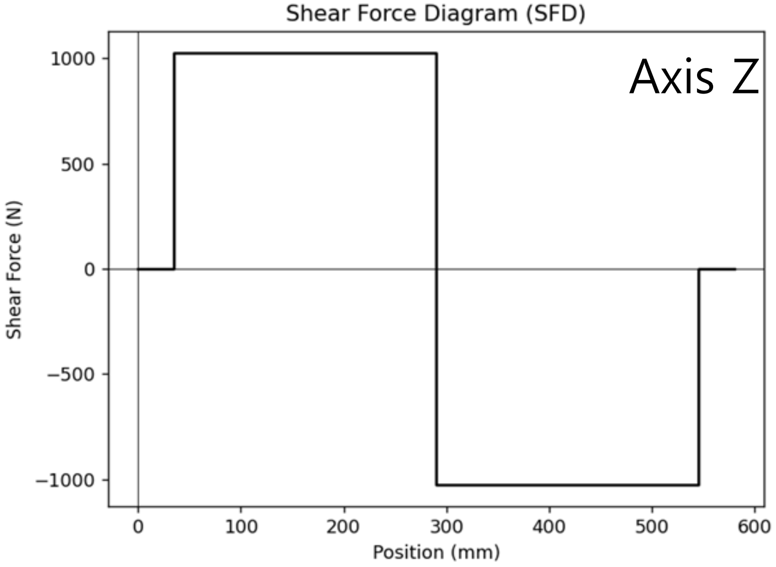
자세 제어시 축에 가해지는 SFD, BMD

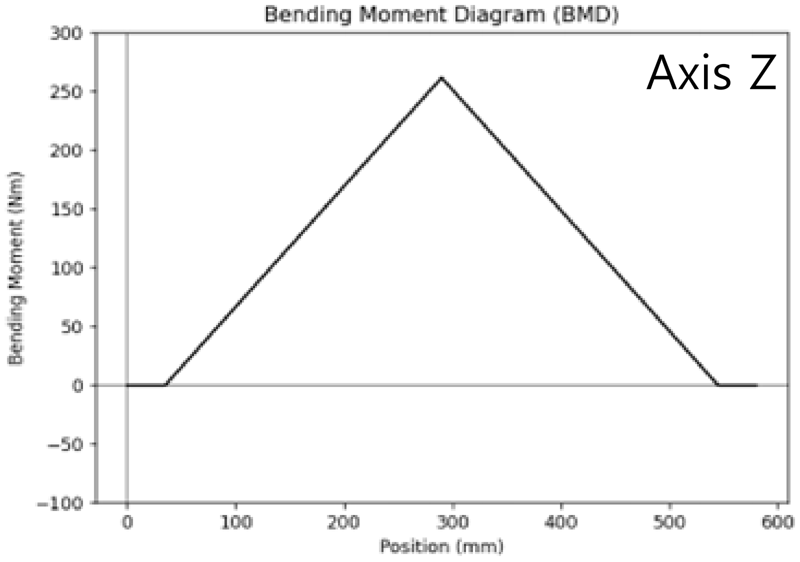
$\theta = 15°$
일때 축의 하중선도



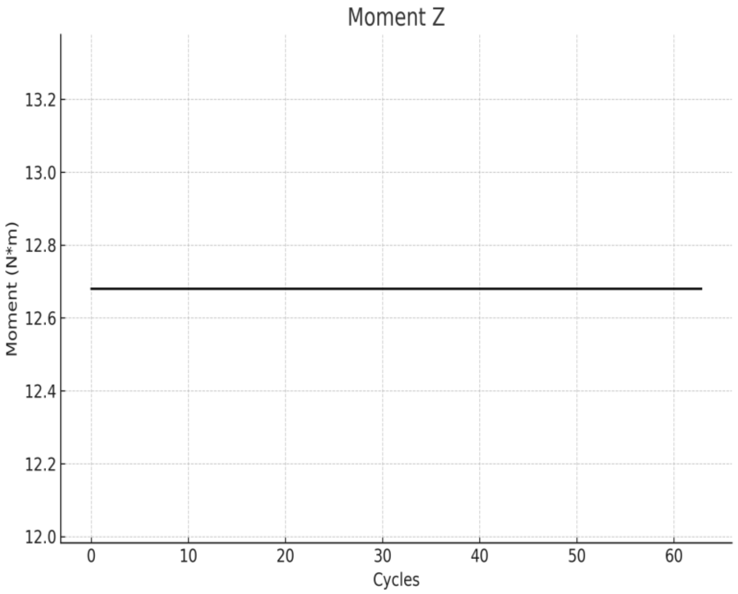


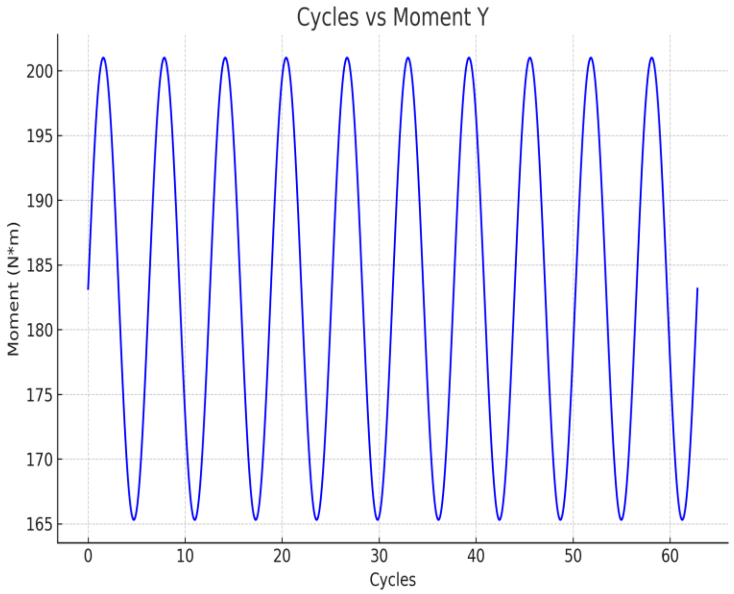


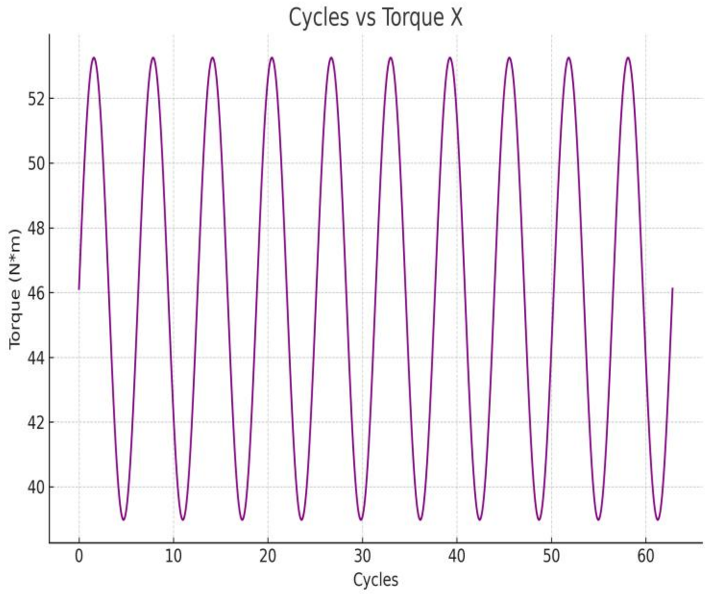




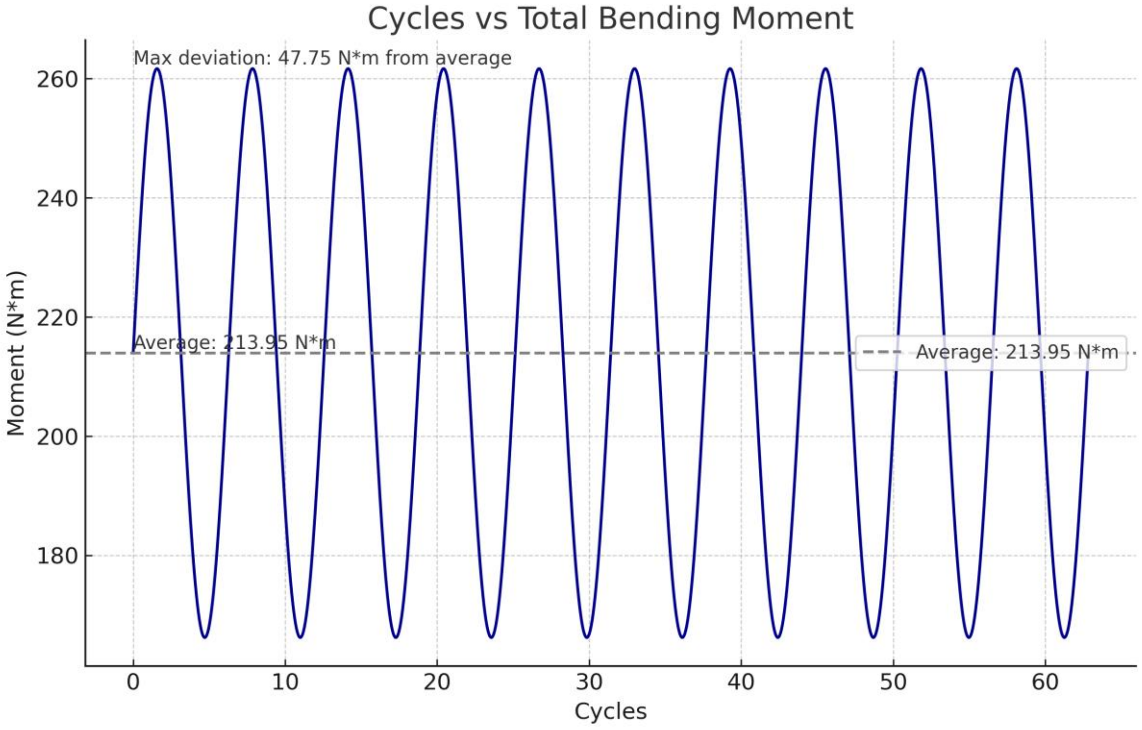
$15° \le \theta \le 45°$ 반복하중에서의 모멘트,토크 선도

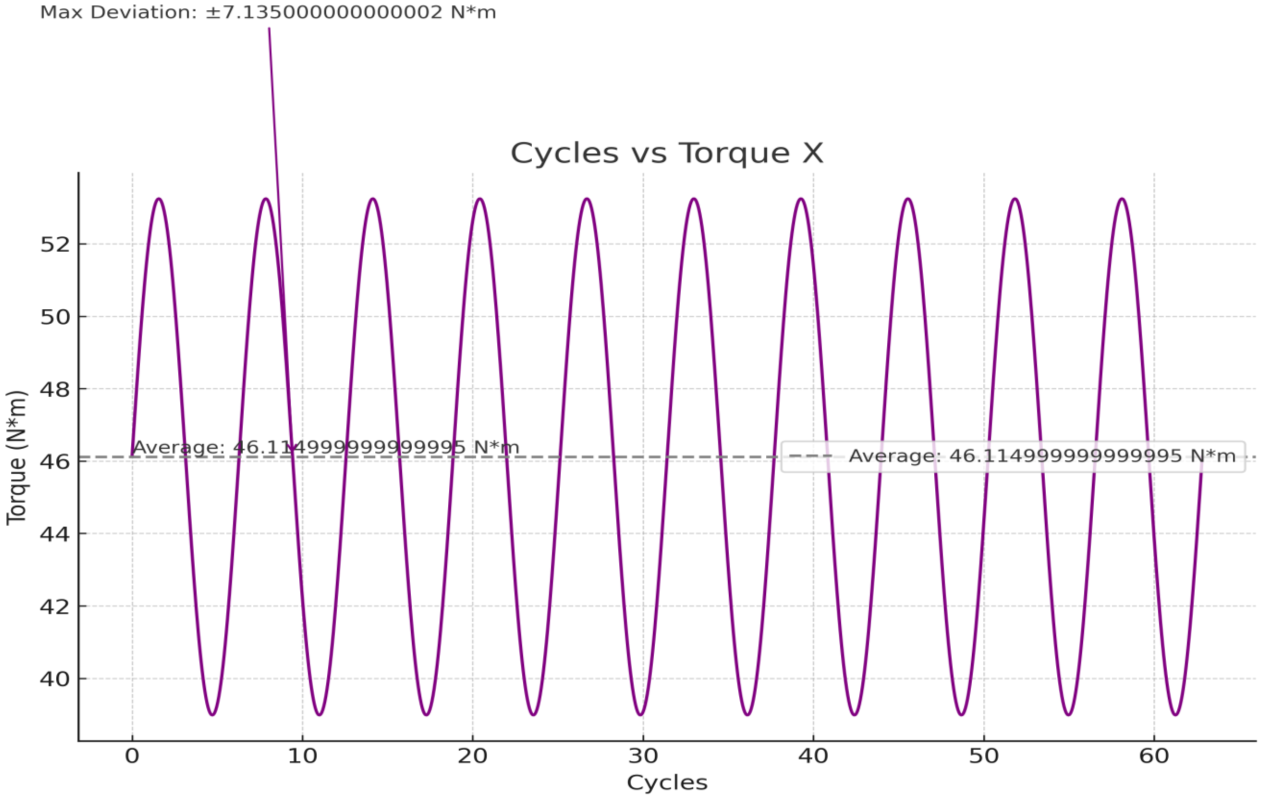






최종 평균 및 교번 토크,모멘트 산출





$M_{max} = \sqrt{12.68^2 + 261.4^2} = 261.7\ N \cdot m$, $M_{min} = \sqrt{12.68^2 + 165.75^2} = 166.2\ N \cdot m$,

$T_{max} = 53.25 N \cdot m$, $T_{min} = 38.98 N \cdot m$ 로 구해진다.

축 피로 설계(hole)

재료 선정 - AISI 4130, $Nomalized,\ S_{ut} = 670\ MPa, S_y = 436\ MPa$

$$D = 25\,mm \quad d = 6\,mm \qquad K_{ts} = 2.97,\ \ K_t = 1.97 \quad (q_s = q = 1)$$

$$Marin\ Factor\ [k_a = 4.51 \cdot (S_{ut})^{-0.265} = 0.8040,\ k_b = 1.24 \cdot D^{-0.107} = 0.902,$$

$$k_c = 1, k_d = 1\ , k_e = 0.814(\text{99\% Reliability})] \qquad \therefore S_e = 197.76\ MPa$$

$$T_m = \frac{\max(T) + \min(T)}{2} = 46.11\ N.m\ ,\ \ T_a = \frac{\max(T) - \min(T)}{2} = 7.14\ N.m\ ,$$

$$M_m = \frac{\max(M) + \min(M)}{2} = 265.72\ N \cdot m\ , \qquad M_a = \frac{\max(M) - \min(M)}{2} = 49.52\ N \cdot m$$

$$A = \sqrt{4\left(K_f M_a\right)^2 + 3\left(K_{fs} T_a\right)^2} = 191.88\ \ N \cdot m\ , B = \sqrt{4\left(K_f M_m\right)^2 + 3\left(K_{fs} T_m\right)^2} = 875.51\ N \cdot m$$

$$n = \frac{\pi d^3}{16}\left(\frac{A}{S_e} + \frac{B}{S_{ut}}\right)^{-1} = 1.34$$

굽힘모멘트에 의한 축의 항복

$$\sigma = K_t \frac{M \cdot c}{I} = \frac{261.7 \times 32}{\pi D^3} \quad (D = 25\, mm)$$

$$\sigma_{max} = 290.02\, MPa < S_y$$

비틀림모멘트에 의한 축의 전단항복

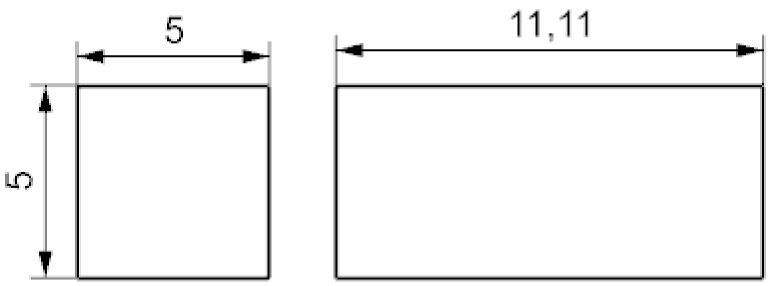
$$\tau = K_{ts} \frac{T \cdot c}{J} = \frac{106.4 \times 16}{\pi D^3} \quad (D = 25\, mm)$$

$$\tau_{max} = 43.35\, MPa < S_{sy}$$

Key 설계

$d = 20mm \longrightarrow w = 5mm, h = 5mm$

$T = 53.25\ N \cdot m \longrightarrow F = \frac{T}{\frac{d}{2}} = 5.325\ kN$

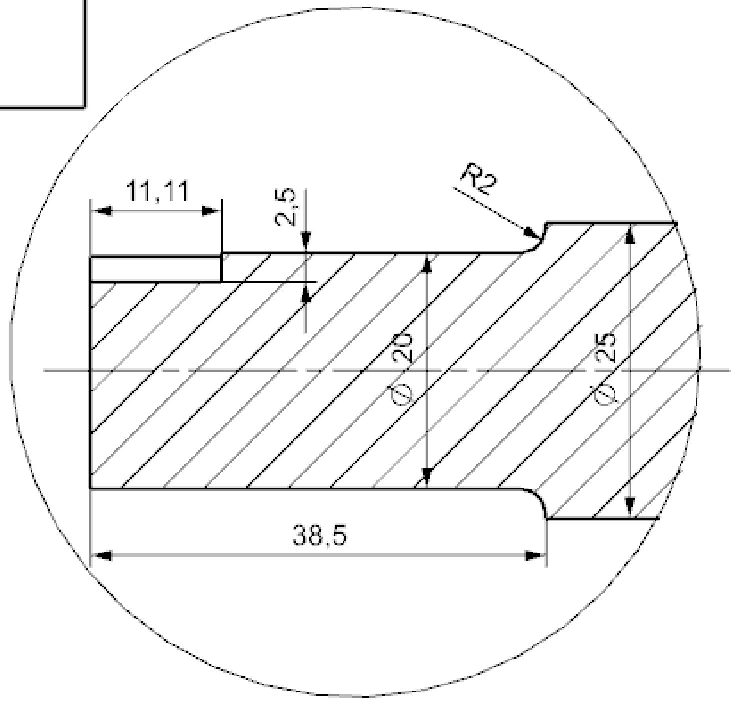


재료선정 AISI 1018 HR $\longrightarrow S_{ut} = 400\ MPa,\ \ S_y = 220\ MPa$

$S_{sy} = 0.577 S_y = 126.94\ MPa$
(**축의 항복강도 낮은 항복강도를 갖고 정밀가공이 유리한 재료로 선정**)

$n = 1.15$ **(축보다 낮은 설계계수 적용)**

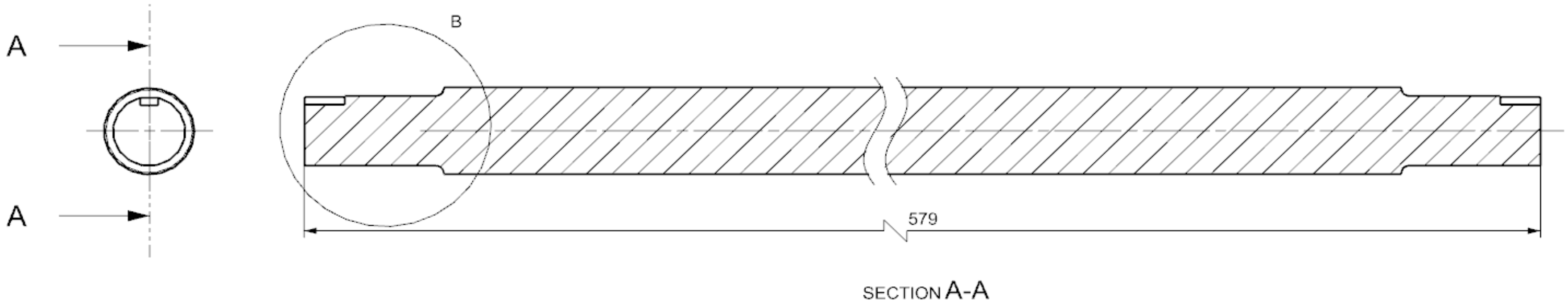
$\frac{S_{sy}}{n} = \frac{F}{w \cdot l_1}$ $\quad l_1 = 9.65\ mm$, $\frac{S_y}{n} = \frac{F}{h \cdot l_2 / 2}$ $\quad l_2 = 11.1mm \longrightarrow \therefore l = 11.1\ mm$

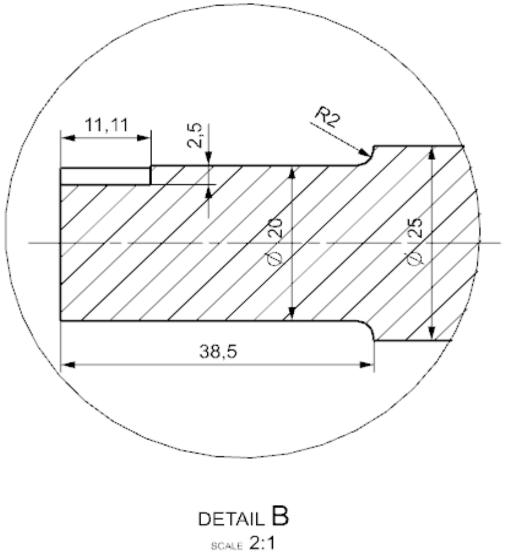


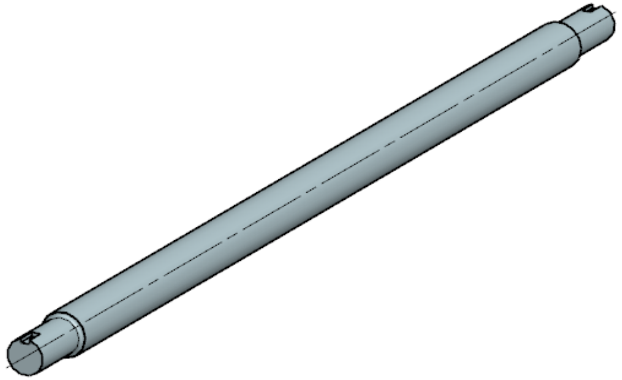
DETAIL B
SCALE 2:1

축 설계 최종안

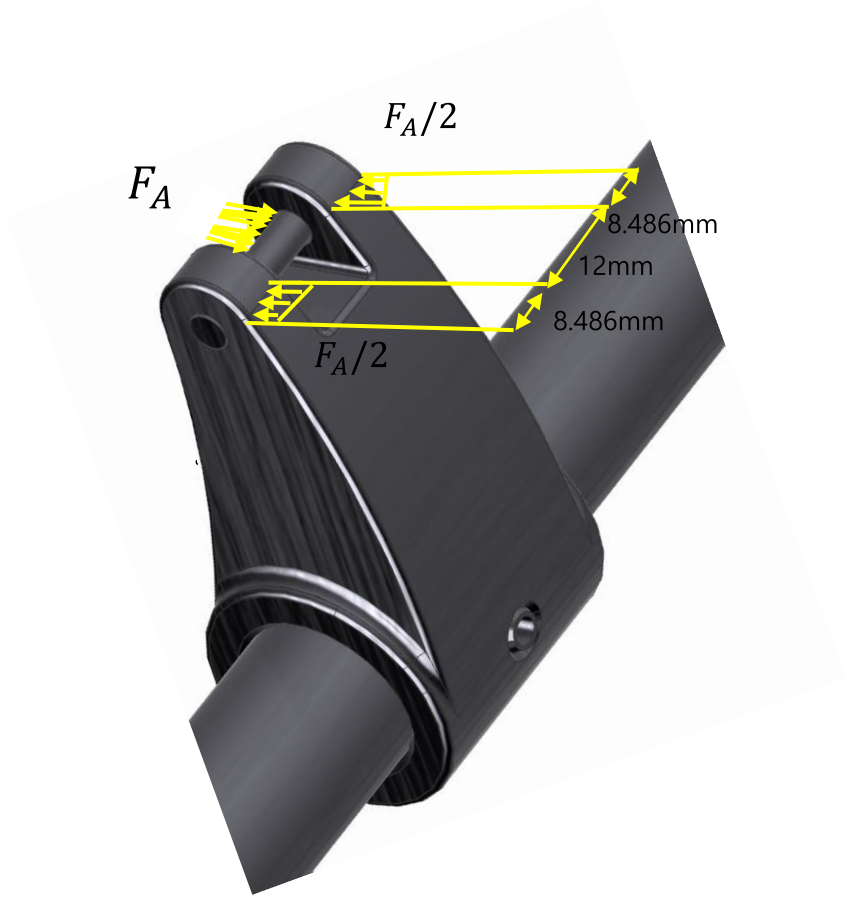
25mm,20mm로 축의 단면적을 적용하였을때 hole에서의 안전계수 = 1.3, 노치에서는 굽힘모멘트가 매우 작아 hole에서보다 안전하다. 따라서 hole에서의 피로파손이 지배적 설계요소이며, 항복보다 피로파괴가 지배적인 설계요소 이다.







Parellel Pin 설계



1. 재료 선정 - $SM45C\ Steel, 220HV, 209Hb, S_{ut} = 686\ MPa, S_y = 490\ MPa$

$S_{sy} = 0.577S_y$=282.73MPa

$F_A = M_A/(0.006 * cos(-\theta + 45°))$ $\quad (M_A = 2M_B)$

$F_{A(max)} = 2050\ N$ (at $\boldsymbol{\theta} = \mathbf{15}°$)

2. 핀의 순수전단응력 관점(n=1.2) / arm이 강체일때

$$\tau_{(max)} = \frac{F_{A(max)}}{2A} = \frac{2050\ N}{2\times\frac{\pi}{4}d^2}$$

$$\tau_{(max)} = \frac{S_{sy}}{n} = \frac{282.73MPa}{1.2} = \frac{2050\ N}{2\times\frac{\pi}{4}d^2} \qquad \therefore d \geq 2.35mm$$

3. 핀의 굽힘응력 관점(n=1.2로 설정)

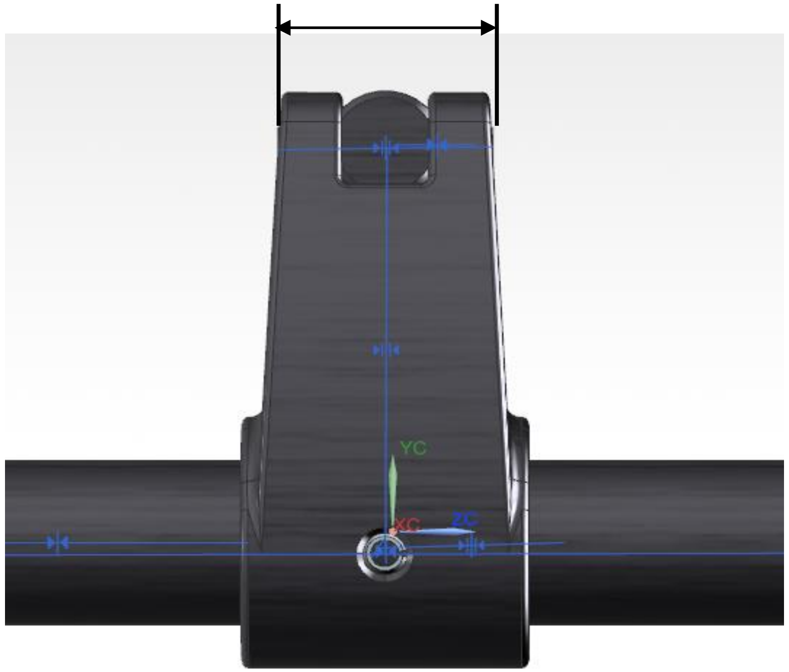
$$\sigma_{(max)} = \frac{M*C}{I} = \frac{\frac{F_A}{2}*\frac{L2}{2}*\frac{d}{2}}{\frac{\pi d^4}{64}} = \frac{6.15*32}{\pi d^3}$$

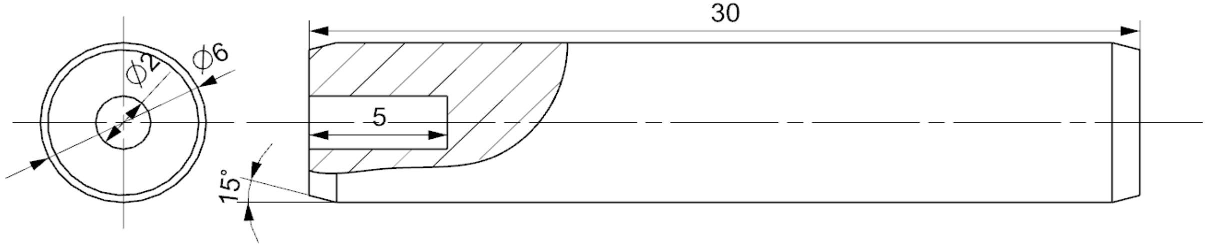
$$\sigma_{(max)} = \frac{S_y}{n} = \frac{490MPa}{1.2} = \frac{6.15*32}{\pi d^3} \qquad \therefore d \geq 5.35mm(control)$$

Parellel Pin 최종 설계

KS B ISO2338 Pin 규격(평행핀) 적용

L=30mm





단위 : mm

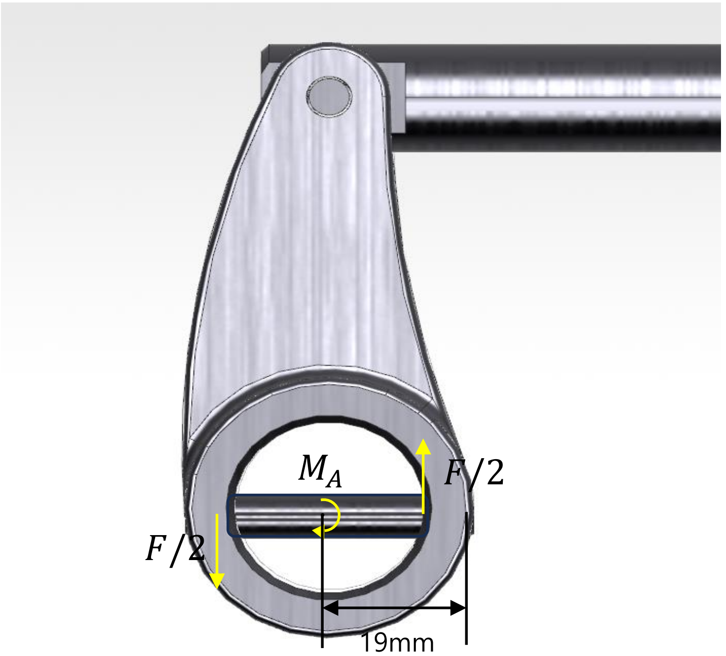
d m6/h8 [a]	0.6	0.8	1	1.2	1.5	2	2.5	3	4	5	6	8	10	12	16	20	25	30	40	50
c ≈	0.12	0.16	0.2	0.25	0.3	0.35	0.4	0.5	0.63	0.8	1.2	1.6	2	2.5	3	3.5	4	5	6.3	8

l [b] 호칭	최소	최대
2	1.75	2.25
3	2.75	3.25
4	3.75	4.25
5	4.75	5.25
6	5.75	6.25
8	7.75	8.25
10	9.75	10.25
12	11.5	12.5
14	13.5	14.5
16	15.5	16.5
18	17.5	18.5
20	19.5	20.5
22	21.5	22.5
24	23.5	24.5
26	25.5	26.5
28	27.5	28.5
30	29.5	30.5
32	31.5	32.5
35	34.5	35.5
40	39.5	40.5
45	44.5	45.5
50	49.5	50.5
55	54.25	55.75
60	59.25	60.75

상용 길이의 범위

H8/g6 또는 H9/f7 끼워맞춤 적용:일반적인 기계적 용도에 적합하며, 조립과 분해가 비교적 쉽다.

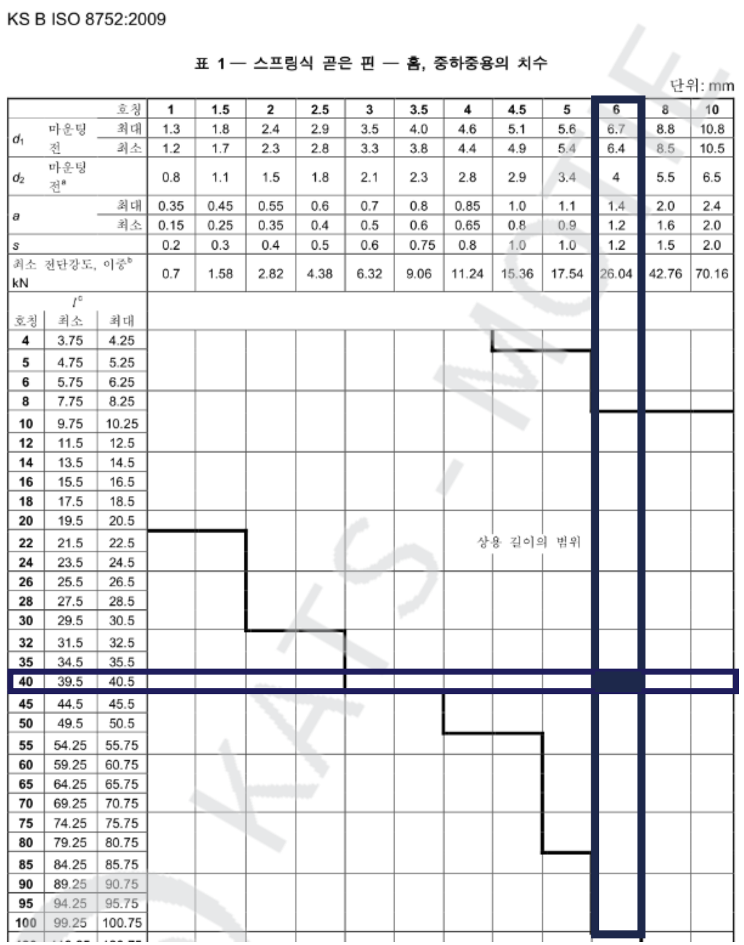
스프링핀 설계



$$M_{A(max)} = 53.25\ N \cdot m\ ,\frac{l}{2} = 19\ mm$$

$$F = \frac{M_A}{l/4} = 28.03\ kN$$

KS B ISO8752 Spring Pin 규격 참고

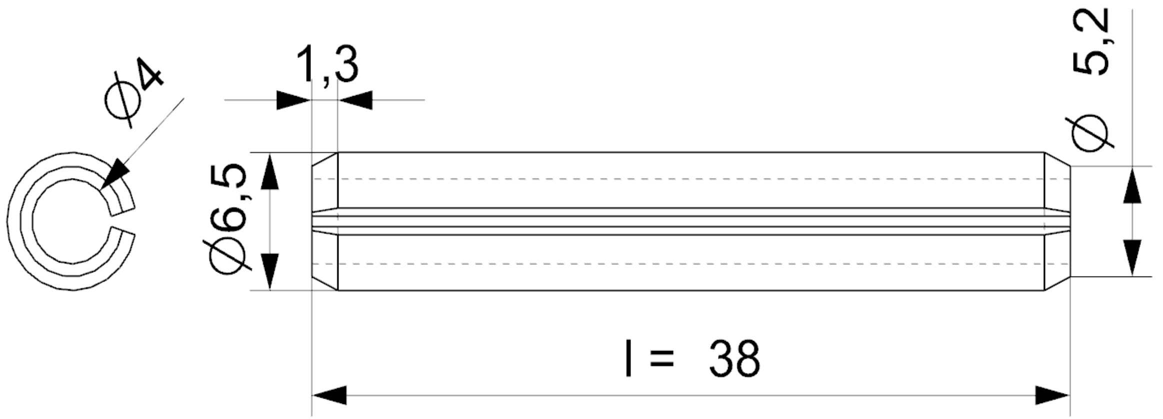


KS B ISO 8752:2009

표 1 — 스프링식 곧은 핀 — 홈, 중하중용의 치수

단위: mm

		호칭	1	1.5	2	2.5	3	3.5	4	4.5	5	6	8	10
d_1	마운팅 전	최대	1.3	1.8	2.4	2.9	3.5	4.0	4.6	5.1	5.6	6.7	8.8	10.8
		최소	1.2	1.7	2.3	2.8	3.3	3.8	4.4	4.9	5.4	6.4	8.5	10.5
d_2	마운팅 전[a]		0.8	1.1	1.5	1.8	2.1	2.3	2.8	2.9	3.4	4	5.5	6.5
a		최대	0.35	0.45	0.55	0.6	0.7	0.8	0.85	1.0	1.1	1.4	2.0	2.4
		최소	0.15	0.25	0.35	0.4	0.5	0.6	0.65	0.8	0.9	1.2	1.6	2.0
s			0.2	0.3	0.4	0.5	0.6	0.75	0.8	1.0	1.0	1.2	1.5	2.0
최소 전단강도, 이중[b] kN			0.7	1.58	2.82	4.38	6.32	9.06	11.24	15.36	17.54	26.04	42.76	70.16
l[c]														
호칭	최소	최대												
4	3.75	4.25												
5	4.75	5.25												
6	5.75	6.25												
8	7.75	8.25												
10	9.75	10.25												
12	11.5	12.5												
14	13.5	14.5												
16	15.5	16.5												
18	17.5	18.5												
20	19.5	20.5												
22	21.5	22.5								상용 길이의 범위				
24	23.5	24.5												
26	25.5	26.5												
28	27.5	28.5												
30	29.5	30.5												
32	31.5	32.5												
35	34.5	35.5												
40	39.5	40.5												
45	44.5	45.5												
50	49.5	50.5												
55	54.25	55.75												
60	59.25	60.75												
65	64.25	65.75												
70	69.25	70.75												
75	74.25	75.75												
80	79.25	80.75												
85	84.25	85.75												
90	89.25	90.75												
95	94.25	95.75												
100	99.25	100.75												



베어링 설계

베어링에 가해지는 하중 ⟶ $F_R = \sqrt{{F_r}^2 + {F_B}^2} = 1088$ N

베어링 설계 조건 ⟶ 최소수명 $L_d = 10000\ hours,$ 속도 $n_d = 5\ rev/min$

베어링에 필요한 정격하중

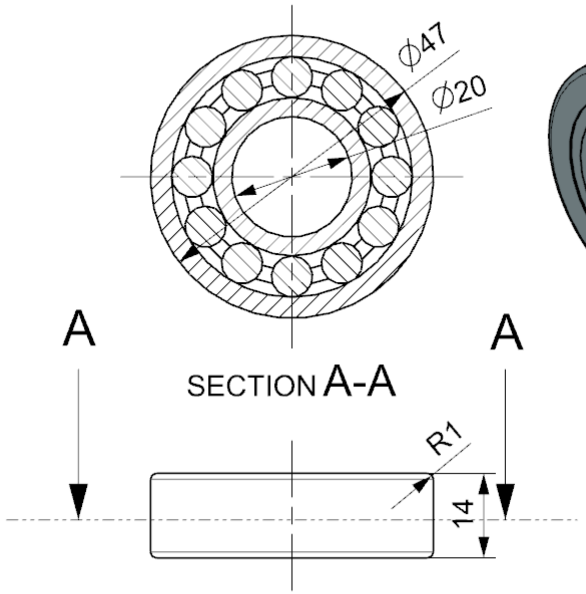
$\sqrt[4]{R} = 0.9\,, R = 0.974$ (신뢰도 97.4%)

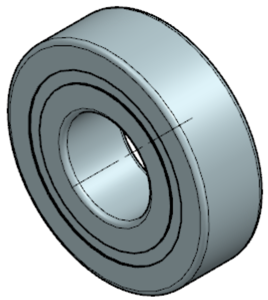
⟶

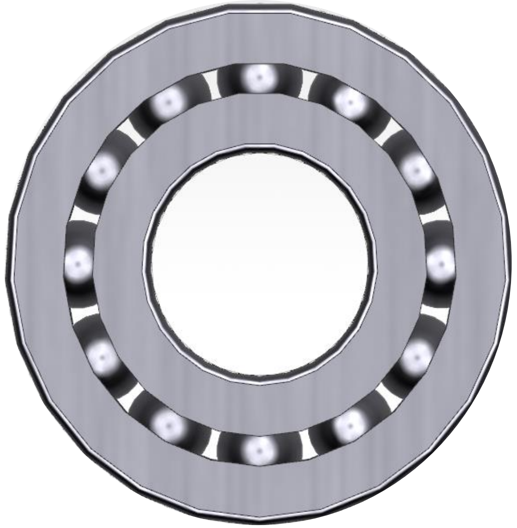
$$C_{10} = a_f * F_r * \left(\frac{X_D}{x_0 + (\theta - x_0)(1 - R_D)^{\frac{1}{1.483}}}\right)^{\frac{1}{3}} = 12.7\ kN$$

(02-20mm 베어링 사용, a_f = 1.2)

실제 수명은 $L \geq 10^6$ (infinte life)







운송용 나사에 필요한 토크

사용된 나사 M12 $\longrightarrow$ $d = 12mm, p = 1.75mm$ $\longrightarrow$ $d_m = 11.125mm$

$l = p = 1.75mm$ (한 줄 나사), $f = 0.2$, $\mathrm{F} = 2050\ N$

$T_R = \frac{Fd_m}{2}\left(\frac{l+\pi f d_m}{\pi d_m - fl}\right),\ T_L = \frac{Fd_m}{2}\left(\frac{\pi f d_m - l}{\pi d_m + fl}\right)$ $T_R = 3.107\ N \cdot m,\ T_L = 1.825\ N \cdot m$

$T_L > 0$ 이므로 자립조건 만족

플랫폼 높이를 제어하기 위한 토크는 나사를 조일때 필요한 토크의 2배이므로

$\therefore T_P = T_R \times 2 = 6.214\ N \cdot m$ Timing Pully가 전달해야하는 최대 토크는 $6.214\ N \cdot m$ 이다.

조립 및 이탈방지