Impact Wrench

MPD Team #6

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BOSCH Cordless Impact Driver/Wrench GDX 18V-180

Function

Used to exert high torque

ex) Loosening frozen bolts and nuts

Features

Maximum Torque: 180 Nm

Maximum No-Load Speed: 2800 rpm

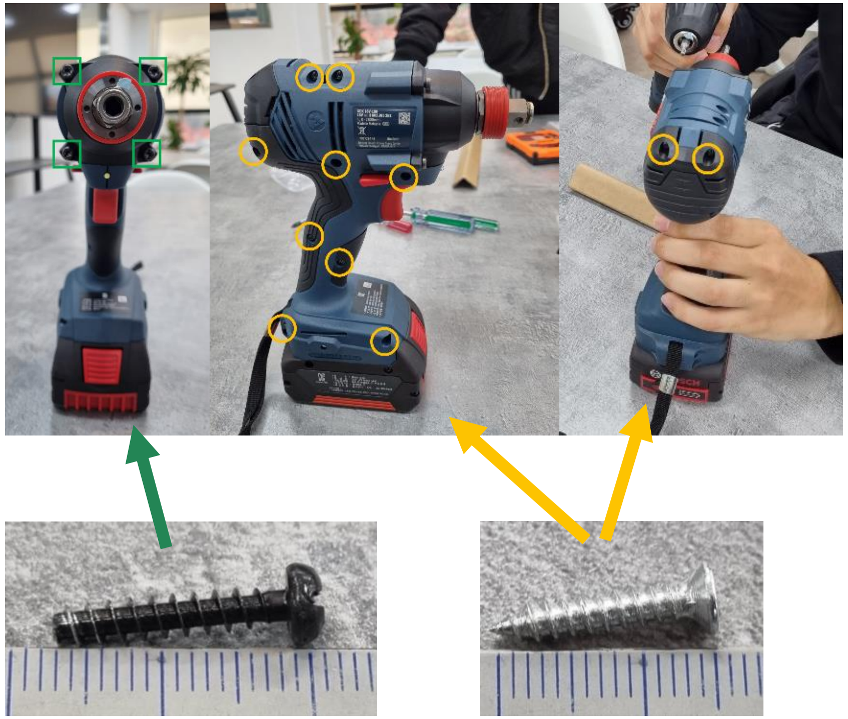
Maximum Impact Rate: 3600 bpm

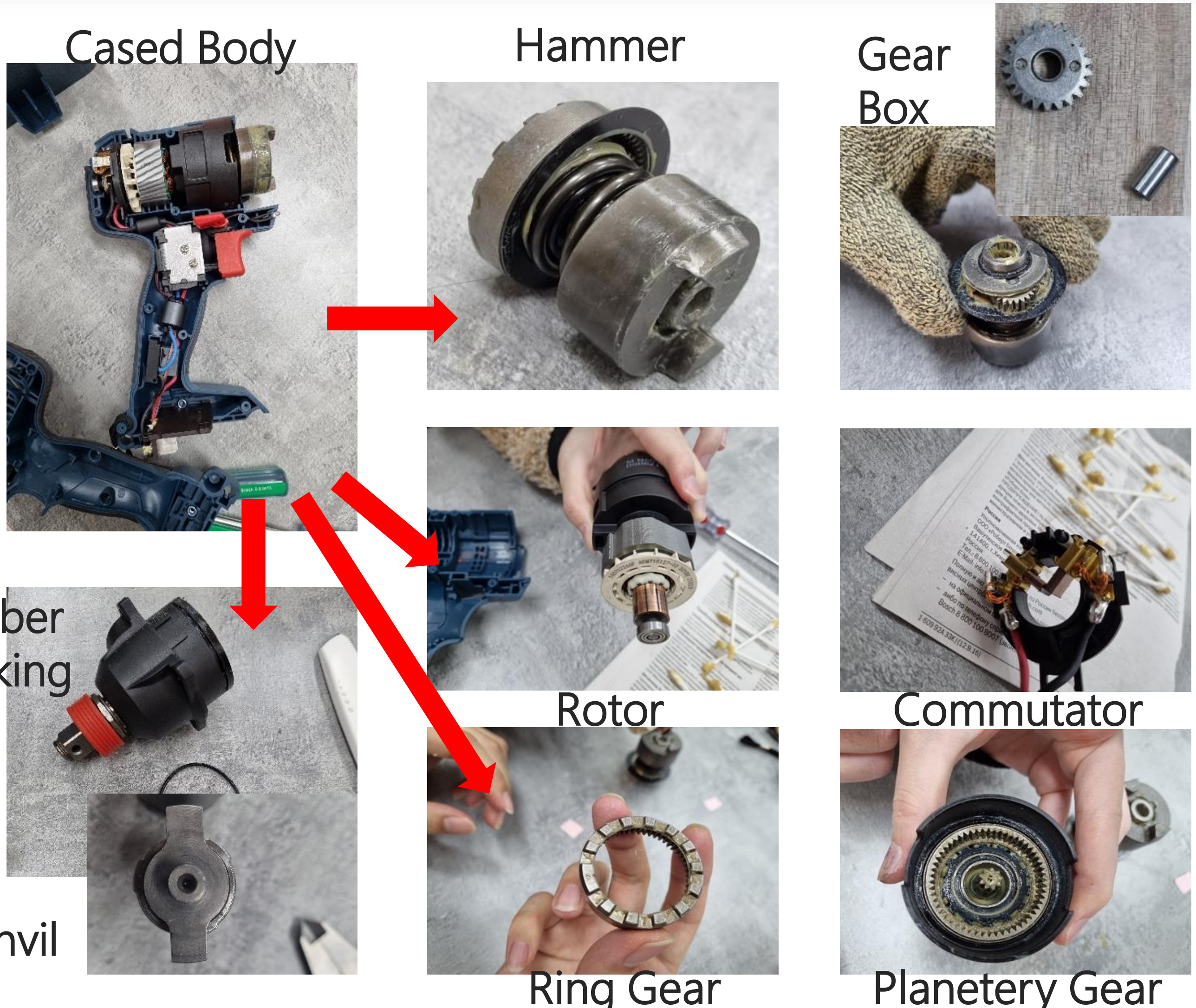
Content

1. Process of disassembly
2. Rotational speed
3. Gear ratio
4. CAD Modeling – mechanism verification
5. Motor shaft fatigue analysis
6. Screwing experiment
7. Hammer fatigue analysis
8. Further discussion

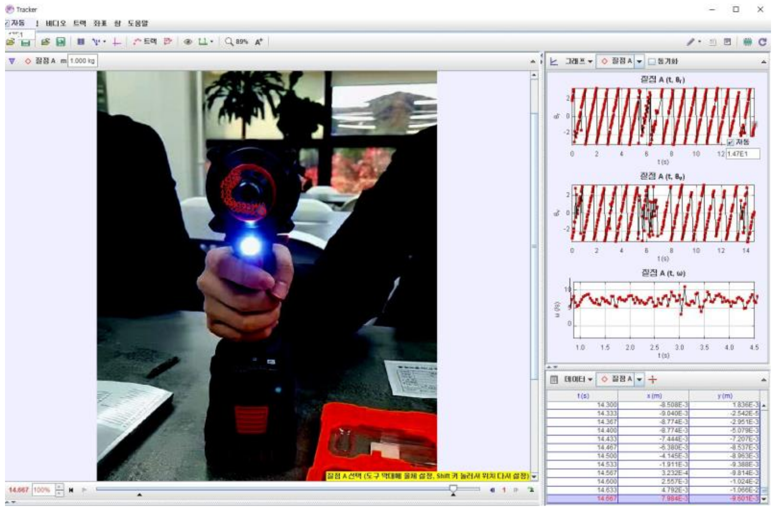
Disassembling Process

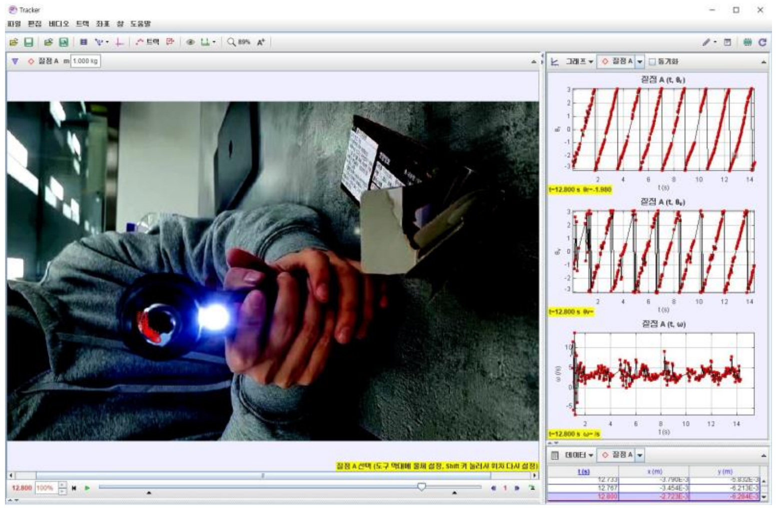
2 Types of Bolts Disassembled

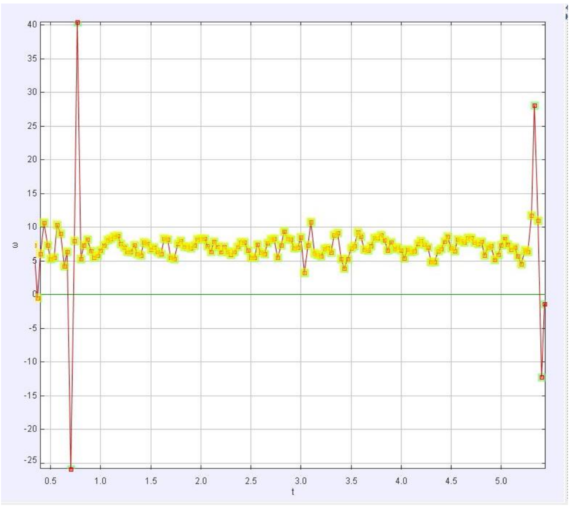




Analysis – Rotating Speed







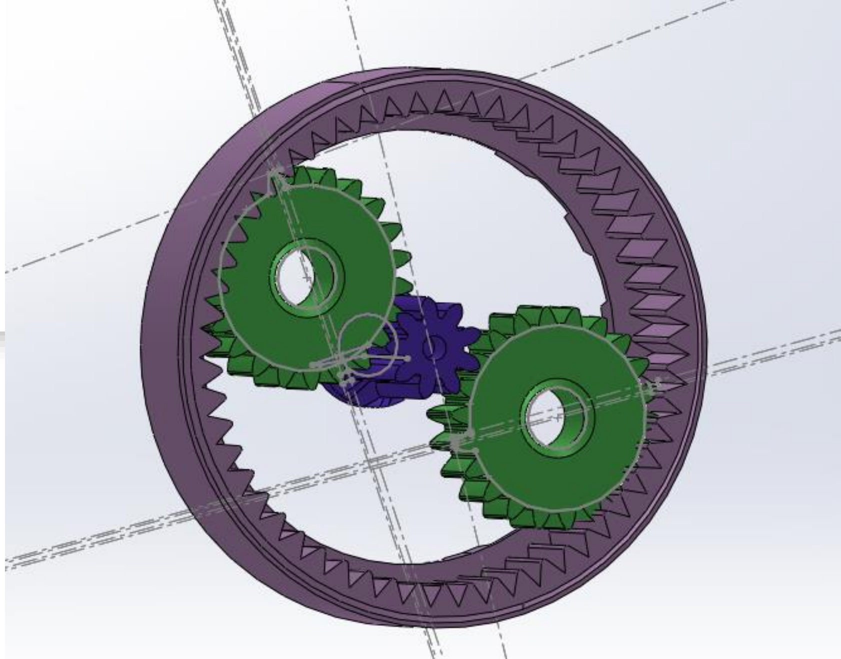
	Drill Driver	Impact Driver Wrench
Data Speed (rpm)	1300	2800
Measured Speed (rpm)	1059.538	2231.055
Speed Rate (%)	81.5	79.68

Gear Ratio

Gear 1
(Sun-input)

Gear 2
(Arm-output)

Gear 3
(Ring-fixed)



Overall view of Gearbox
(Planetary gear train)

	Pitch Radius(R_1, R_2)	Number of teeth
Gear 1	R_1 = 2.5mm	N_1 = 9
Gear 2	R_2 = 7.5mm	N_2 = 23
Gear 3	R_3 = 21mm	N_3 = 55

Satisfies the condition of :

$$N_{\text{ring}} = N_{\text{sun}} + 2N_{\text{planet}}$$

Gear Ratio

① Applicating equations for planetary gear train

$$\frac{\omega_{\text{ring}} - \omega_{\text{arm}}}{\omega_{\text{sun}} - \omega_{\text{arm}}} = -\frac{N_{\text{sun}}}{N_{\text{ring}}}$$

$$\frac{\omega_{\text{planet}} - \omega_{\text{arm}}}{\omega_{\text{sun}} - \omega_{\text{arm}}} = -\frac{N_{\text{sun}}}{N_{\text{planet}}},$$

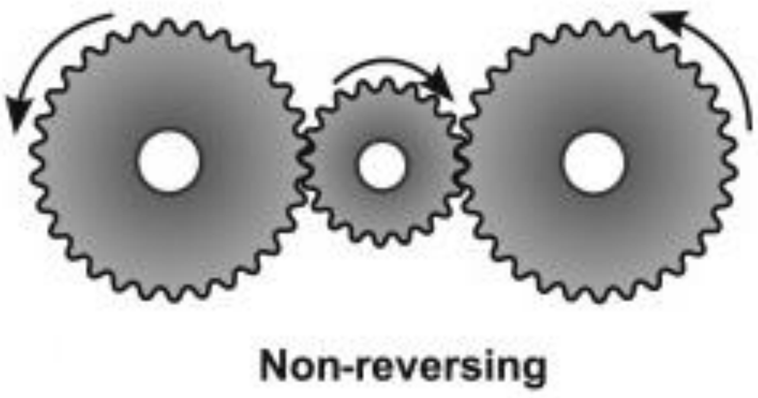
ω_{arm} = 2231 rpm

$$\omega_{sun} = \omega_1 = \frac{64}{9}\omega_{arm}$$

$$\omega_{planet} = \omega_2 = -\frac{32}{23}\omega_{arm}$$

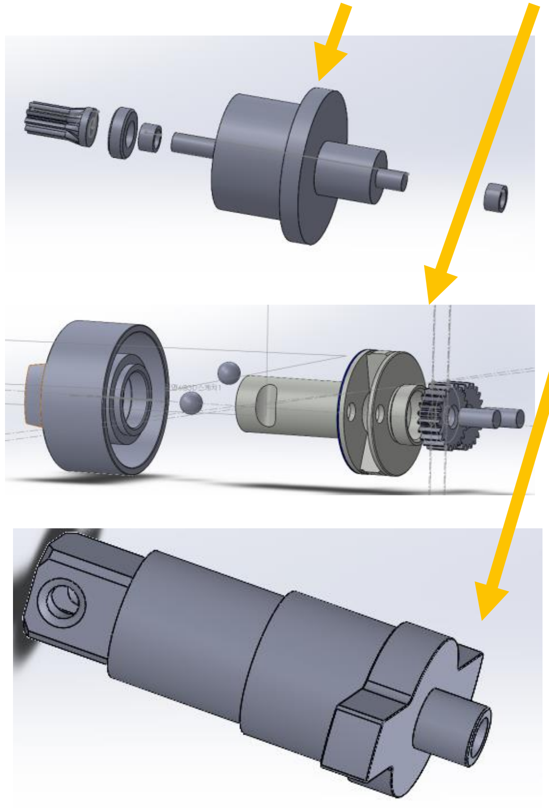
② Angular velocity ratio (Z_p)

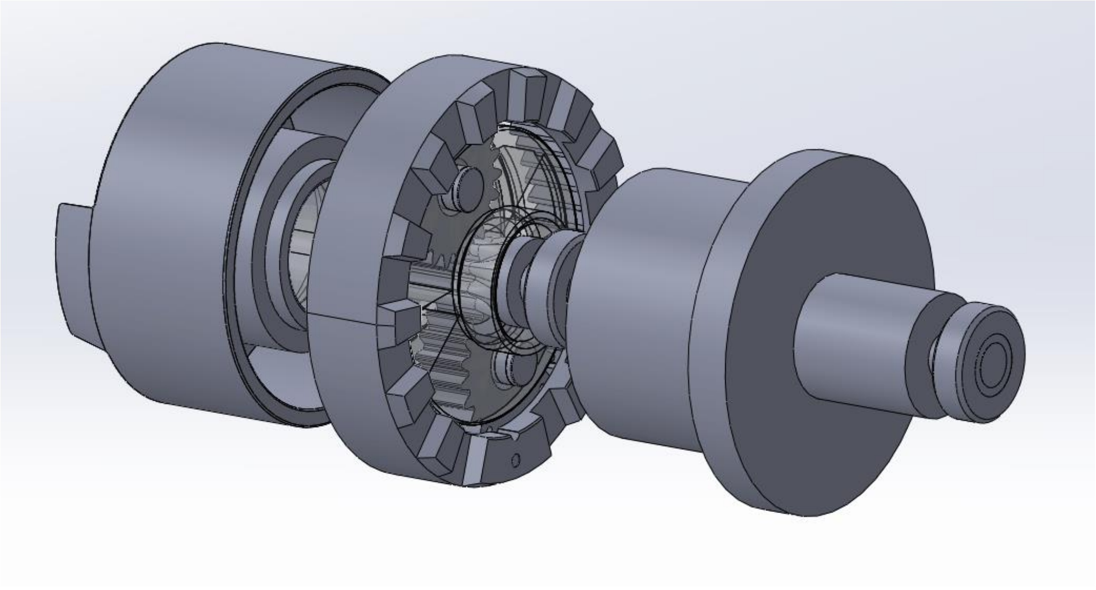
$$Z_p = \frac{\omega_L - \omega_A}{\omega_F - \omega_A} = \frac{\omega_2 - \omega_{arm}}{\omega_1 - \omega_{arm}} = -\frac{9}{23}$$



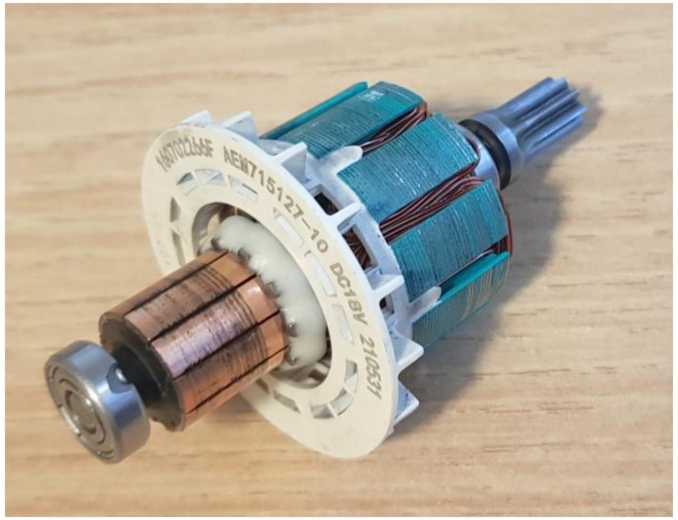
3D Modeling and Assembly

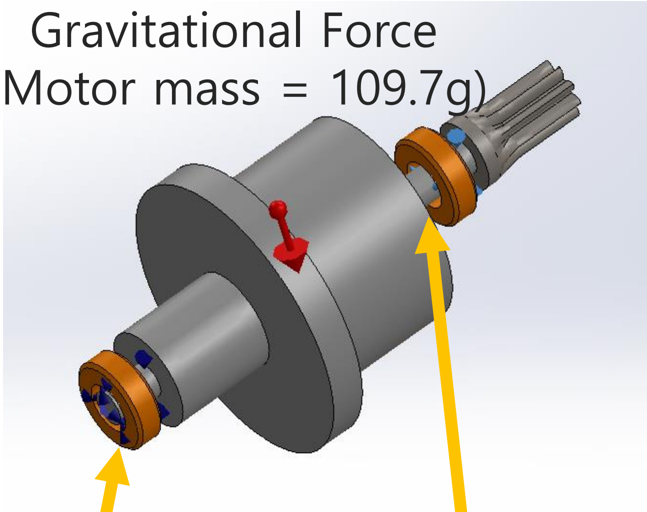
Parts of Interest: Motor, Gearbox, Anvil

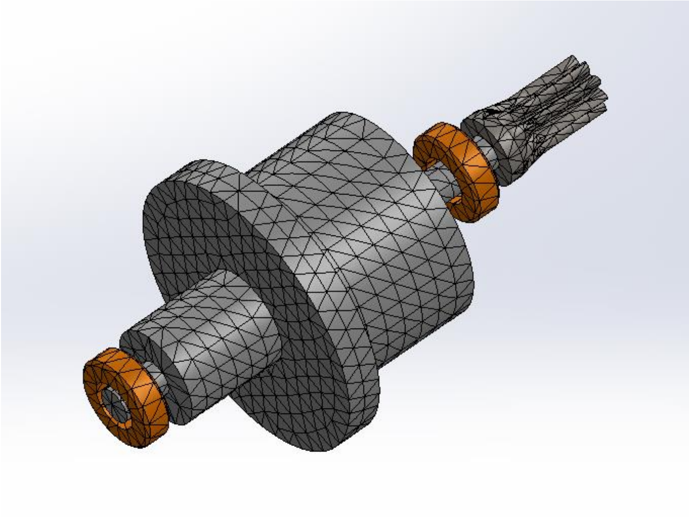




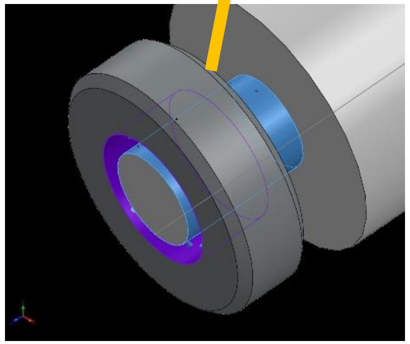
Stress Concentration Simulation

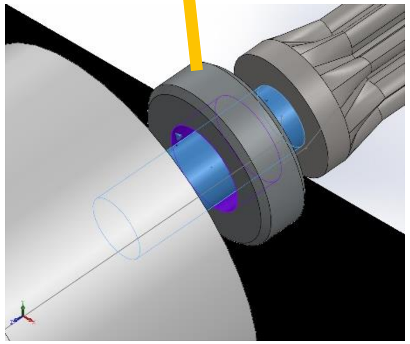






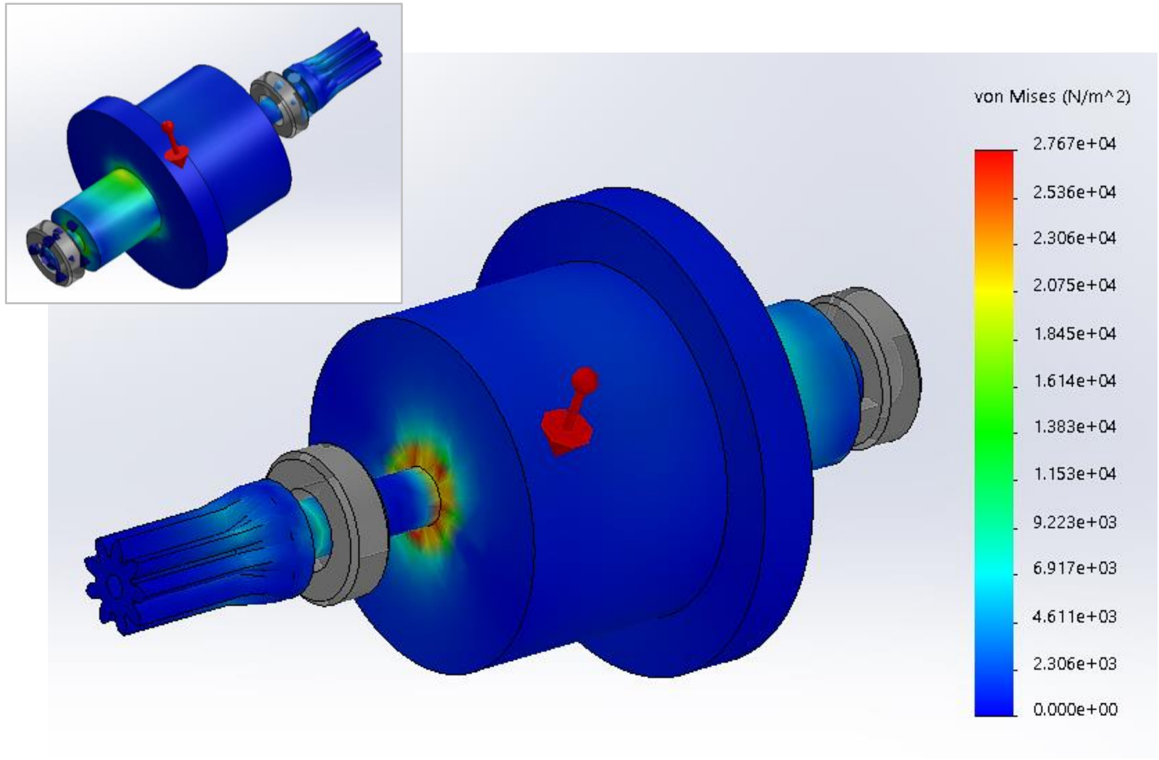
Small Deep Groove Ball Bearing Single Row (695ZZ)



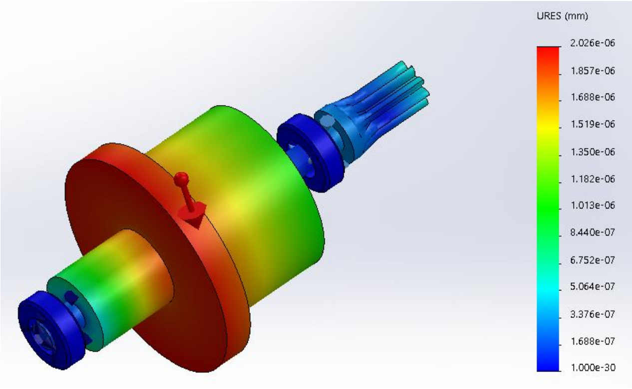


Material: Alloy Steel
E = 210 GPa
G = 79 GPa
ρ = 4421.1266 kg/m^3
(calculated reversely)

Stress Concentration Simulation

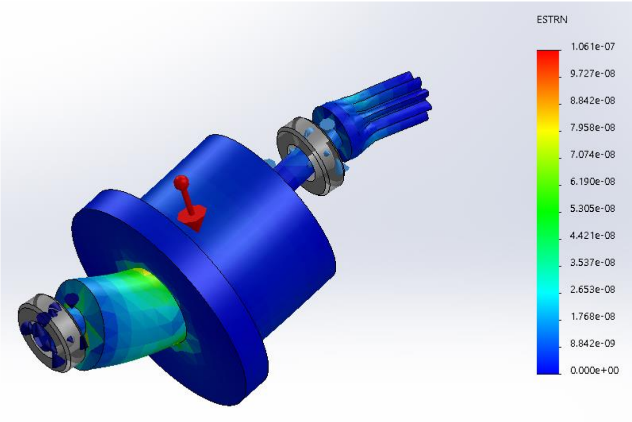


Von-Mises Stress Distribution
Maximum Stress = 276.7 kPa



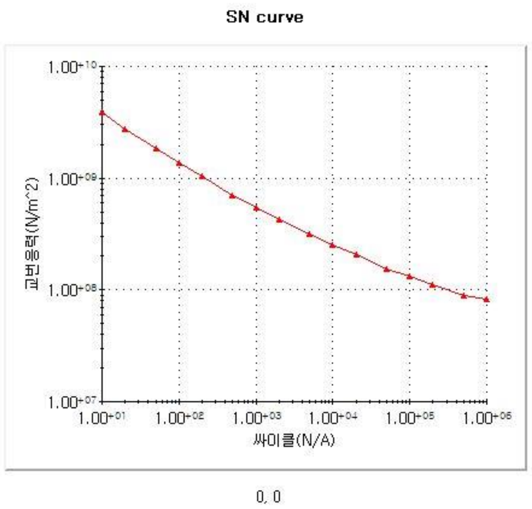
Strain Distribution

Maximum Strain = 2.026e-06 mm

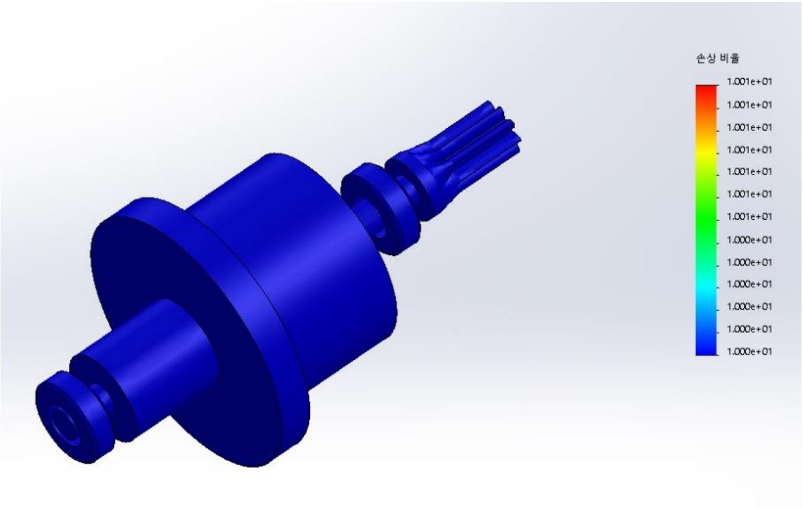


Deformation (Exaggerated)

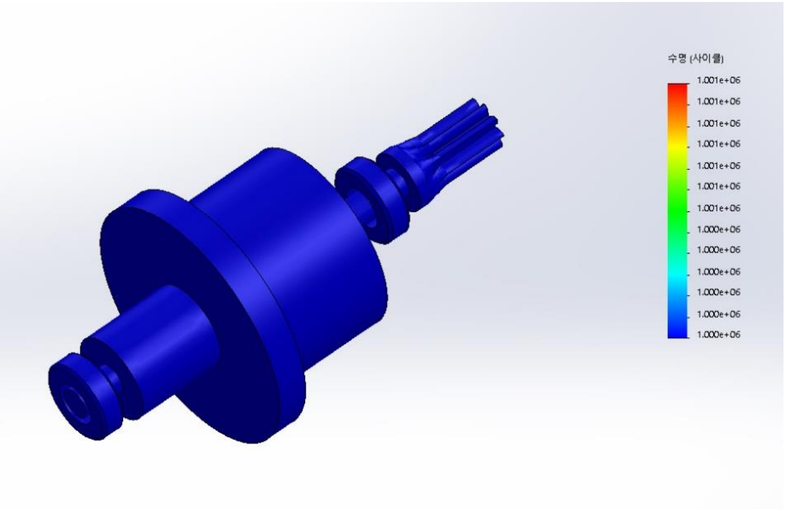
Fatigue simulation



S-N Curve



Damage ratio
(Perfectly reserved)

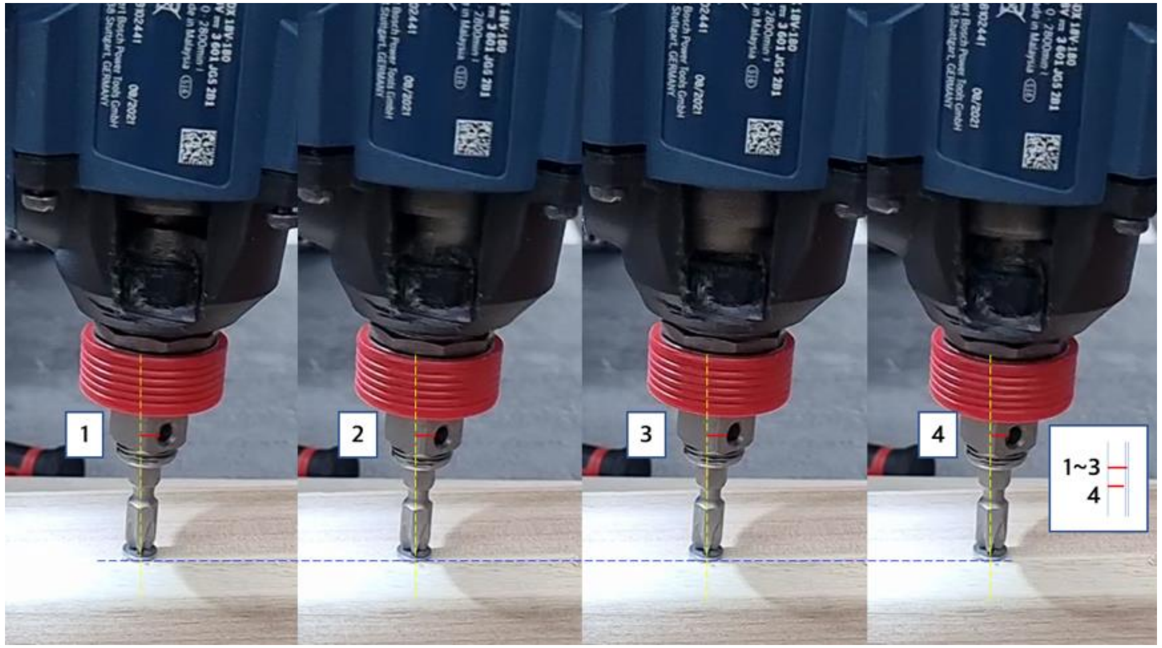


Life
(All region maximum life expectancy)

Screwing Mechanism

(1) Hammer Lifted
Gap between the Hammer and the Anvil

$\uparrow T_{friction} \; \omega_{screw} \downarrow = P_{driver}$



(2) The Rotation of Screw
The Hammer is Lifted to Hit the Anvil.

Stress at Screwing Mechanism

Filmed the screwing motion using Galaxy S21's slow motion(240fps)
Since the side face was cut open
Able to count frames for one revolution, frames from the collision to stop

18 frames per revolution

$$\omega_{screw} = \frac{2\pi\ rad}{\frac{18}{240} sec}$$
$$= 83.77\ rad/s$$

3 frames from collision to stop

Stress at Screwing Mechanism

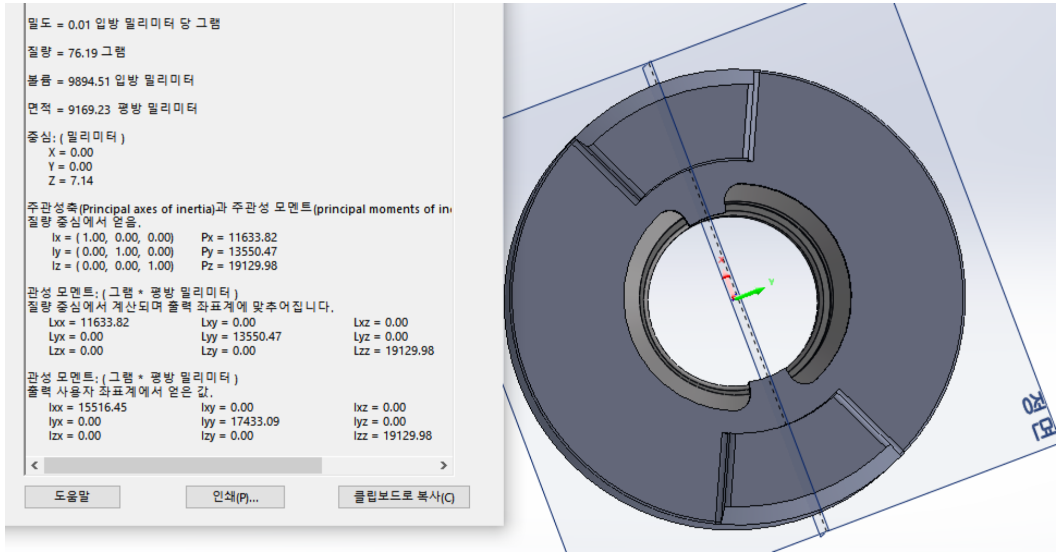
Relationships between Angular momentum and Angular impulse

Angular momentum $L = Iw$
Angular impulse $\Delta L = \int_{t_1}^{t_2} \tau dt$

Assumption: constant torque was acted to the hammer at collision

Using that hammer consisted with Stainless X6Cr13,
Moment of inertia respect to the rotation axis=$19129.98\ g \cdot mm^2$
(With aid of Solidworks)

$$\therefore \tau = \frac{I\Delta w_{screw}}{\Delta t} = 0.1282 N \cdot m$$

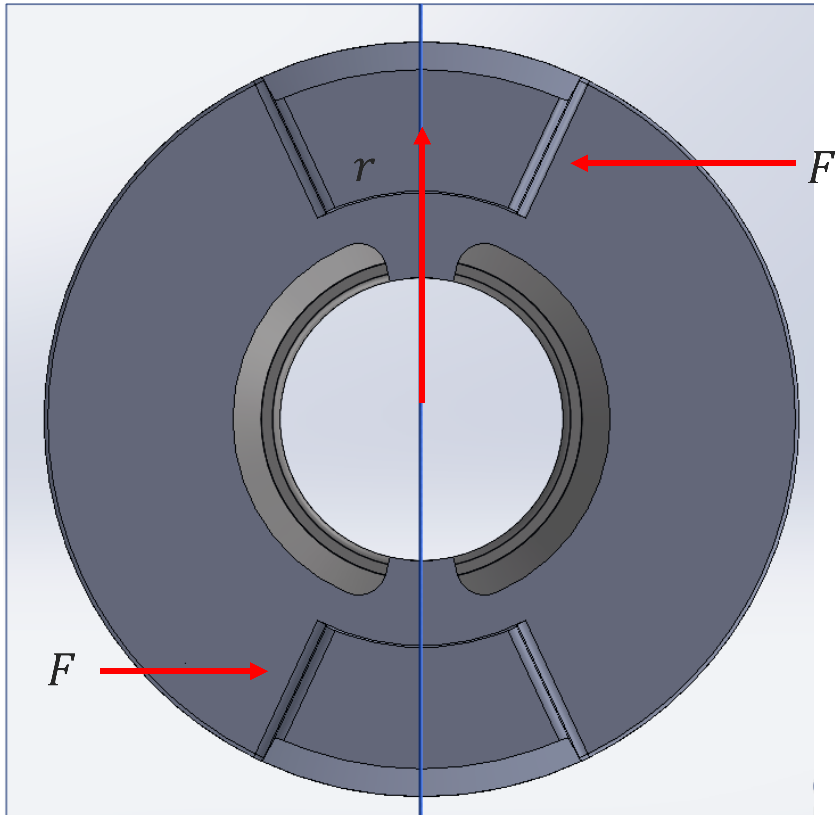


Stress at Screwing Mechanism

Assumption: torque to the hammer is caused by constant force acting at the center of hammer

$$\tau = 2rF,\ r = 30mm$$
$$F = \frac{\tau}{2r} = 2.137N$$

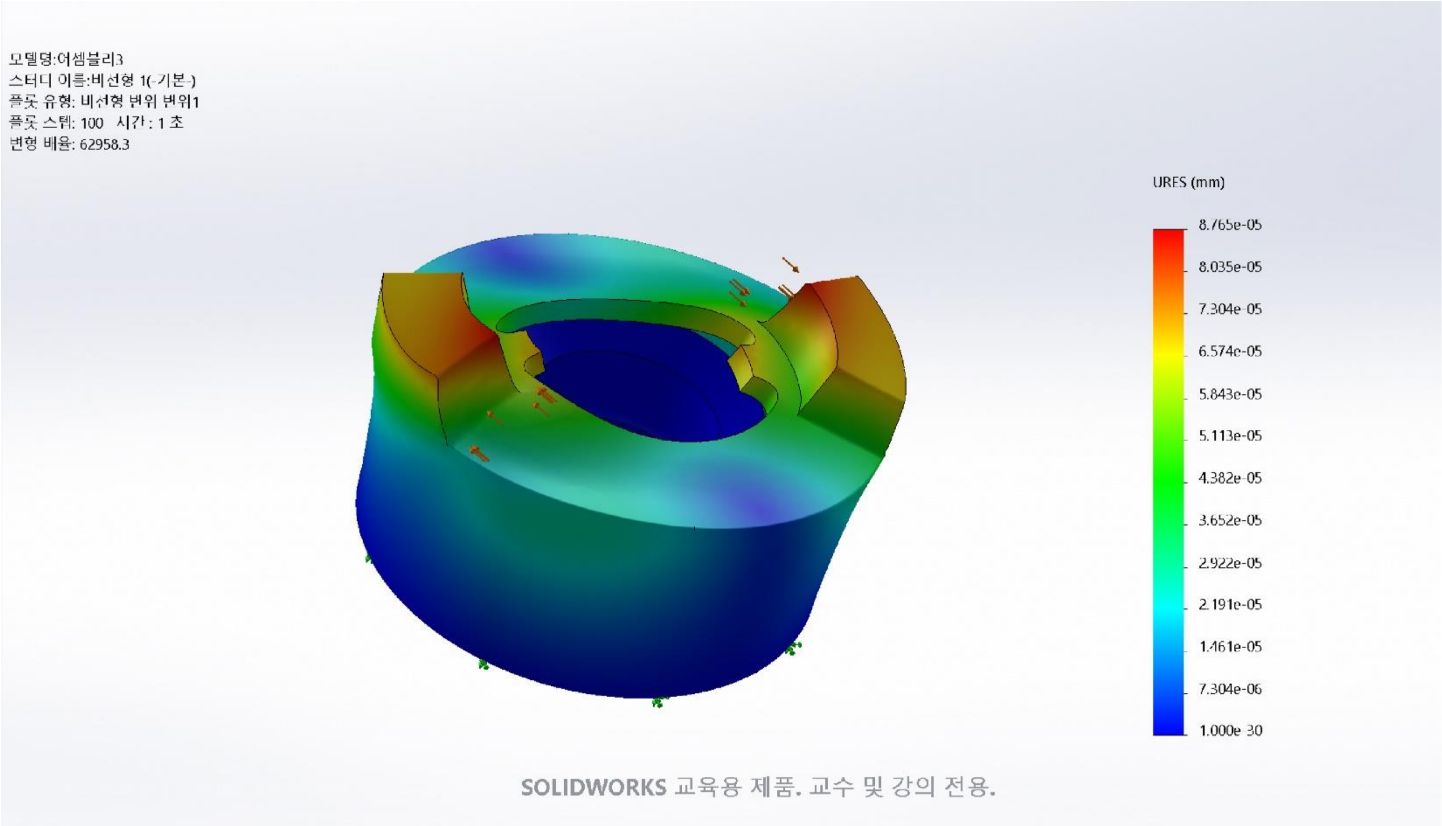
=>Simulated on Solidworks with these dimensions for stress distribution



Stress at Screwing Mechanism

Maximum deflection was $8.765 \times 10^{-5} mm$

=> Steady enough for normal usage

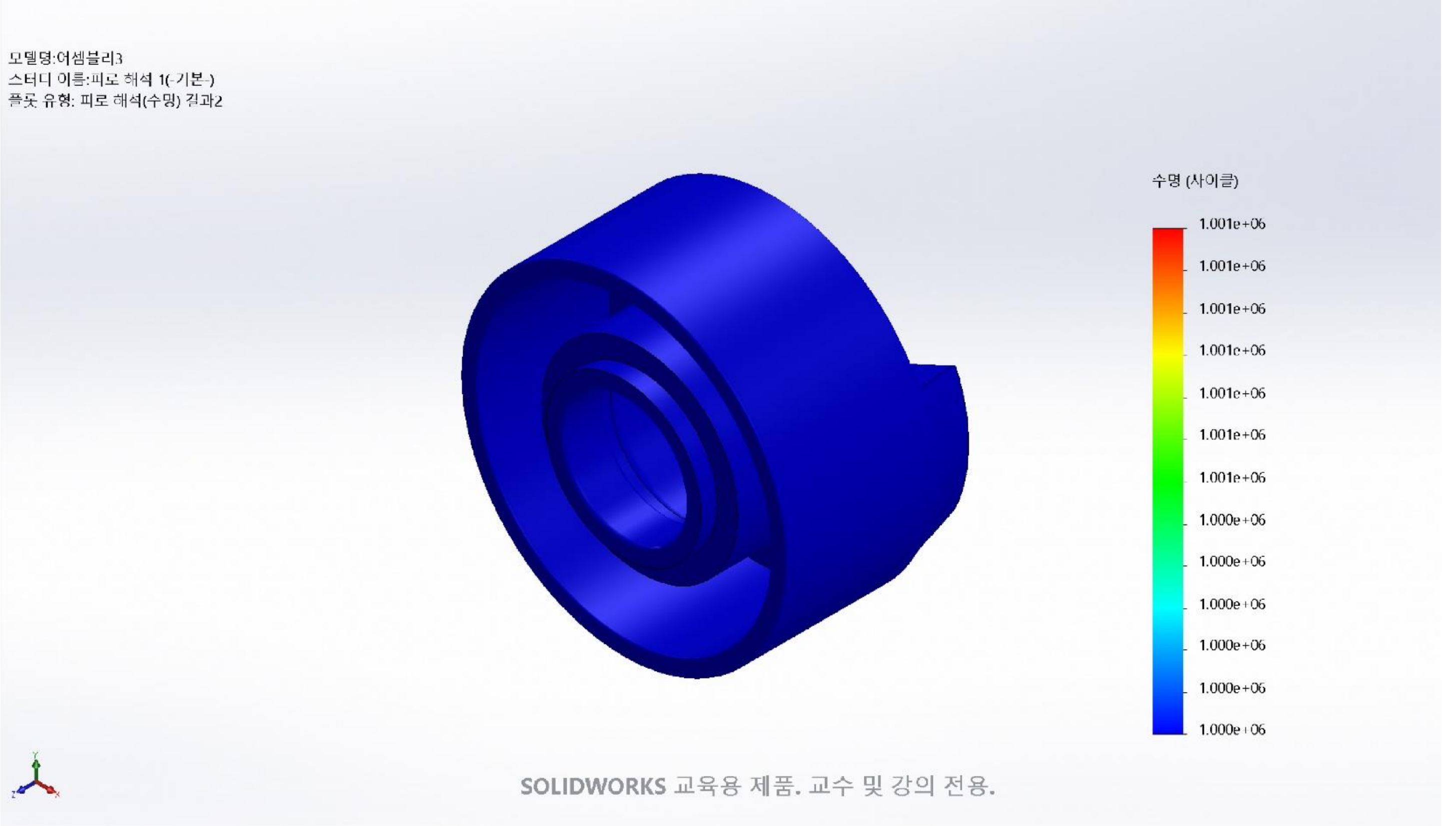


Stress at Screwing Mechanism

Fatigue analysis on constant Force for $10^7\ cycles$

⇒ Every part is almost half-permanent

*same result for its theoretical maximum angular velocity of 2800 RPM



What if..?

What if we utilize 4 hammers instead of two?

Same $\tau = 4rF$

$$F = \frac{\tau}{4r}$$

=>Reduces the stress acting on the single hammer, and expected to have a longer life.

But, it may have problem since it has little time for the spring to go up and down between these hammers.

Since the hammer is expected to act half-permanently with 2 hammers, it's unnecessary.