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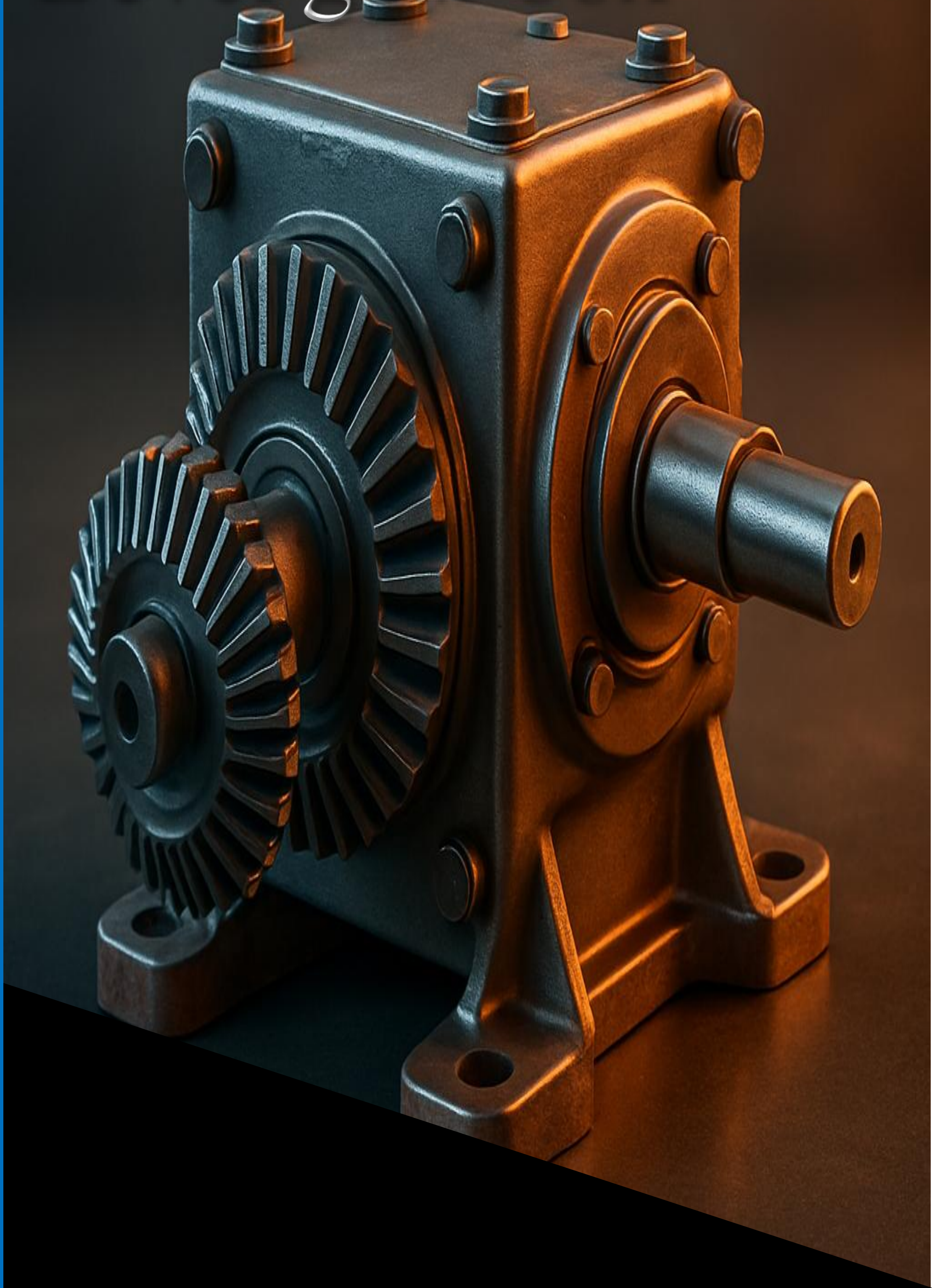
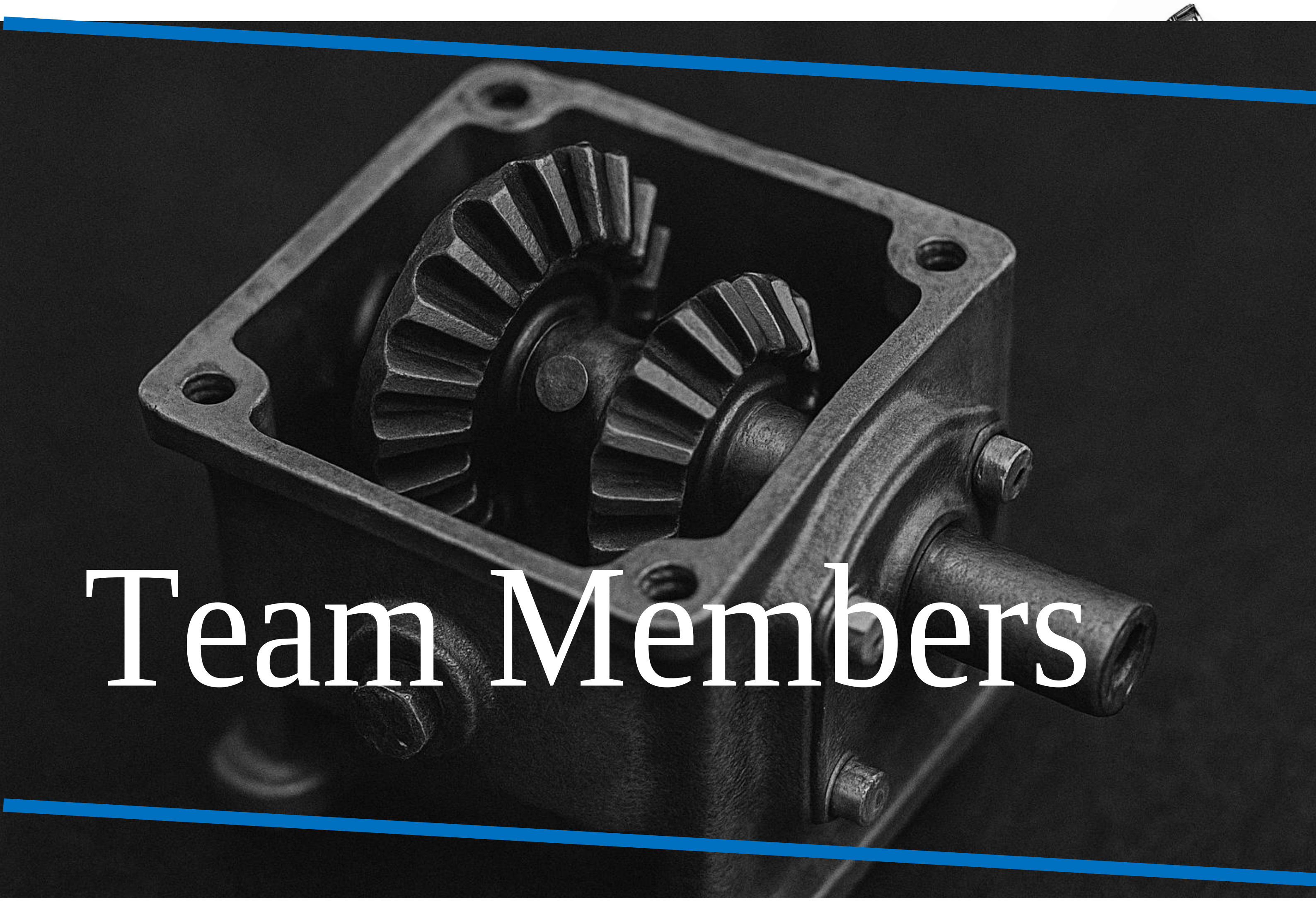
Bevel gear box



Mechanical design II

Presented to

Prof. Dr. Ahmed Saleh



Team Members

Ahmed Samy Elsaiid Mohamed Ahmed Elshimy	21010085
Ahmed Saiid Abdelnaby Abdelrahman	21010090
Ahmed Mohamed Ahmed Saleh	21010144
Ahmed Mohamed Refaat Bassiouny	21010158
Ayman Muhammed Hussien El-sayed Muhammed	21010334
Ziad Ashraf Mohamed Ali	21010561
Mohamed Ashraf Ali Mohamed	21011086
Mohamed Alaa Hassan Mabrouk	21011192
Mahmoud Mohamed Abdallah Elnahas	21011285

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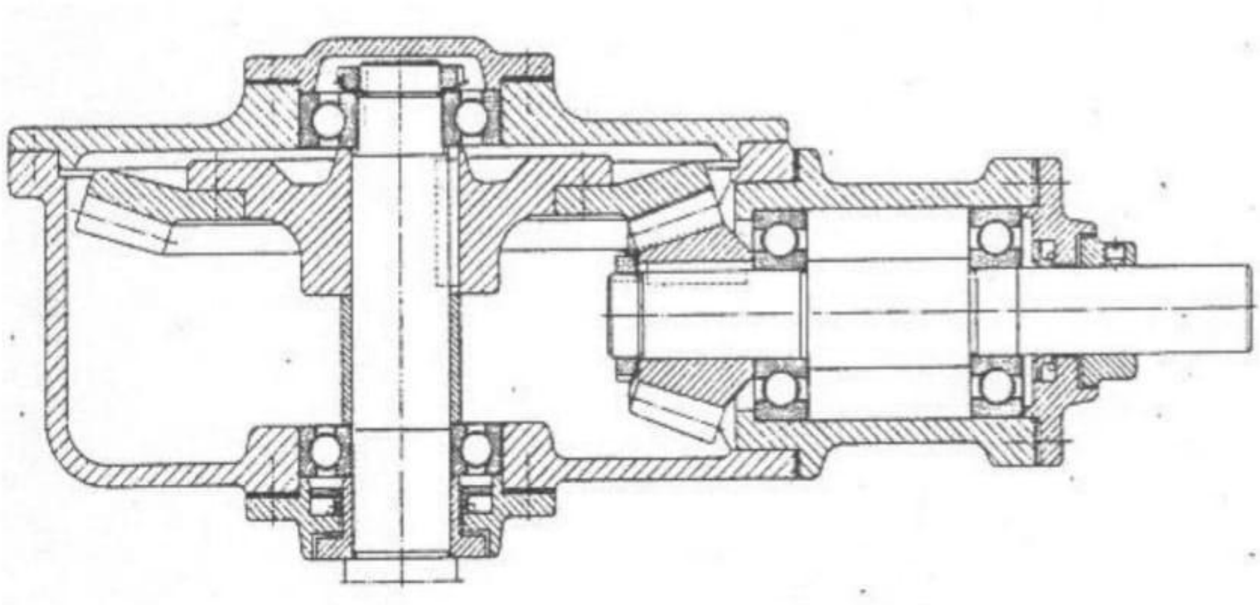

Exercise 9

Gearing Arrangement:	Bevel
Output Torque:	300 N.m
Input Speed:	1200 rpm
Output Speed:	400 rpm

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Team 21	Project	21	Exercise	Exercise 9
Member Name	Member ID	الفريق	Output T.	400 N.m
احمد سامى السعيد محمد احمد الشيمى	21010085	Team 21	Output Speed	300 RPM

Abstract

This technical report presents a comprehensive design and engineering analysis of a bevel gear transmission system developed for efficient power transfer between intersecting shafts. The study focuses on creating an optimal gear pair configuration capable of transmitting 12.57 kW of power while converting an input speed of 1200 rpm (125.66 rad/s) to an output speed of 300 rpm (31.42 rad/s), with a corresponding torque increase from 100 N·m to 400 N·m through a 4:1 reduction ratio.

The research methodology incorporates a rigorous multi-stage engineering approach, beginning with fundamental kinematic calculations to verify speed and torque requirements. Detailed geometric design parameters are then established, including module selection (12 mm), tooth counts (15 teeth for pinion, 60 for gear), and precise pitch diameter determinations (180 mm and 720 mm respectively). The conical geometry of the bevel gears is carefully analyzed, with pinion and gear cone angles calculated at 14.04° and 75.96° to ensure proper meshing alignment.

A comprehensive force analysis forms a critical component of the study, systematically evaluating the three-dimensional loading conditions on the gear teeth. This includes calculation of tangential (1284.14 N), radial (453.43 N pinion/113.36 N gear), and axial (113.36 N pinion/453.43 N gear) force components, which are essential for subsequent shaft and bearing design considerations. The stress analysis employs American Gear Manufacturers Association (AGMA) standards to verify tooth strength under both bending and contact fatigue conditions, with particular attention to load distribution factors and dynamic effects.

The computer-aided design component utilizes industry-standard SolidWorks software for precise 3D modeling of all system components, including detailed gear tooth profiles and assembly relationships. Complementary 2D technical drawings produced in AutoCAD provide complete manufacturing specifications, incorporating geometric dimensioning and tolerancing (GD&T) standards. The integrated design approach ensures proper meshing characteristics while maintaining manufacturability requirements.

Results demonstrate a fully engineered bevel gear transmission system meeting all specified performance criteria while maintaining appropriate safety margins. The complete design package includes detailed gear geometry, force analysis data, and manufacturing documentation, providing a comprehensive solution for power transmission applications requiring shaft angle redirection. This study serves as a valuable reference for mechanical engineers designing similar bevel gear systems, offering both theoretical foundations and practical implementation guidance.

Introduction

Bevel gears are fundamental components in mechanical power transmission systems where torque must be transferred between intersecting shafts, typically at 90 degrees. Their conical geometry allows efficient power transmission while accommodating angular misalignment. This report presents a comprehensive design and analysis of a bevel gear system based on specified operational requirements, including torque, speed, and power transmission efficiency.

Objectives

The primary objectives of this study are:

1. To design a bevel gear pair with a **4:1 gear ratio**, ensuring proper speed reduction from **1200 rpm (input) to 300 rpm (output)** while increasing torque from **100 N·m to 400 N·m**.
2. To perform **force and stress analysis** to validate gear tooth strength and durability.
3. To conduct **shaft design calculations** considering combined bending and torsional stresses.
4. To evaluate **safety factors** using AGMA (American Gear Manufacturers Association) standards for bending and contact stresses.

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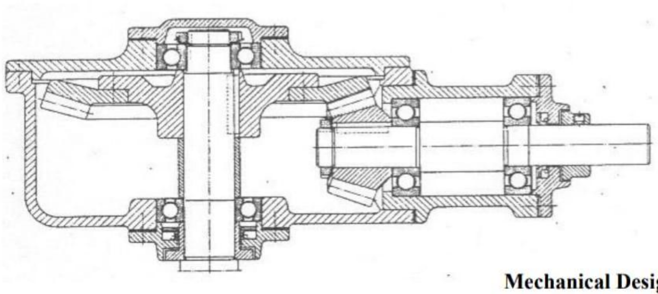


Exercise 9

Gearing Arrangement: Bevel
Output Torque: 300 N.m

Input Speed: 1200 rpm
Output Speed: 400 rpm

Mechanical Design 2 Spring 2025 Mini Project

Team 21	Project	21	Exercise	Exercise 9
Member Name	Member ID	الفريق	Output T.	400 N.m
احمد سامى السعيد محمد احمد الشيمى	21010085	Team 21	Output Speed	300 RPM

Methodology

The design and analysis of the bevel gear transmission system followed a structured methodology, integrating theoretical calculations, computer-aided design (CAD), and validation techniques. The approach ensured a systematic evaluation of gear geometry, stress analysis, and manufacturability. The key stages of the methodology are outlined below.

Design Calculations

The analytical phase involved determining critical parameters to meet performance requirements:

- **Gear Ratio & Kinematics:** Calculated input/output speeds and torque multiplication.
- **Tooth Geometry:** Determined module, pitch diameters, and cone angles based on AGMA standards.
- **Force Analysis:** Evaluated tangential, radial, and axial forces acting on gear teeth.
- **Stress Analysis:** Applied AGMA equations to assess bending and contact stresses.
- **Safety Factors:** Verified design reliability under operational loads.

Computer-Aided Design (CAD)

The gear system was modeled using industry-standard CAD software to validate geometry and assembly:

- **SolidWorks:**
  - Created 3D parametric models of the pinion and gear.
  - Simulated gear meshing and interference checks.
  - Generated technical drawings with tolerances and annotations.

- **AutoCAD:**
  - Produced 2D manufacturing drawings with detailed sectional views.
  - Specified key dimensions, surface finishes, and GD&T (Geometric Dimensioning & Tolerancing).

Design Calculations

The design process follows a systematic approach:

1. **Kinematic Analysis:** Calculation of gear ratio, angular velocities, and power transmission.
2. **Geometric Design:** Determination of module, pitch diameters, and tooth geometry.
3. **Force Analysis:** Computation of tangential, radial, and axial forces acting on gear teeth.
4. **Stress Analysis:** Application of AGMA equations to assess bending and contact stresses.
5. **Shaft Design:** Determination of minimum shaft diameter based on combined loading conditions.

Kinematic and Power Analysis

The power transmission system operates under the following conditions:

Parameter	Pinion	Gear
Speed (rpm)	1200	300
Angular velocity (rad/s)	125.66	31.42
Torque (N·m)	100	400
Power (kW)	12.566	12.566

The power transmission remains constant (neglecting losses), satisfying the fundamental relationship:

$$P = T \times \omega = Constant$$

where:

- $P = Power\ (W)$
- $T = Torque\ (N \cdot m)$
- $\omega = Angular\ velocity\ (rad/s)$

Geometric Design Specifications

Gear Parameters

Design Parameter	Value
Gear ratio (m_G)	04:01
Module (m)	12 mm
Pinion teeth (N_p)	15
Gear teeth (N_g)	60
Pressure angle (ϕ)	20°
Face width (b)	100 mm

Pitch Geometry

1. **Pinion Pitch Diameter (d_p):**
$$d_p = N_p \times m = 15 \times 12 = 180\ mm$$
2. **Gear Pitch Diameter (d_g):**
$$d_g = N_g \times m = 60 \times 12 = 720\ mm$$
3. **Pinion Cone Angle (γ_p):**
$$\gamma_p = \tan^{-1}\left(\frac{N_g}{N_p}\right) = tan - 1(6015) = 14.04°$$
4. **Gear Cone Angle (γ_g):**
$$\gamma_g = 90° - \gamma_p = 90° - 14.04° = 75.96°$$
5. **Average Diameter (d_{av}):**
    - For pinion:
    $$d_{av_{pinion}} = d_p - b * cos\gamma_p = 180 - 100 * cos(14.04°) = 155.75\ mm$$
    - For gear:
    $$d_{av_{gear}} = d_g - b * cos\gamma_g = 720 - 100 * cos(75.96°) = 622.99\ mm$$

Force Analysis

The forces acting on the gear teeth are critical for shaft and bearing design:

Force Component	Pinion (N)	Gear (N)
Tangential (W_t)	1284.14	1284.14
Radial (W_r)	453.43	113.36
Axial (W_a)	113.36	453.43

Force Equations

- **Tangential Force:**

$$W_t = d_{av} * 2T$$

- **Radial Force:**

$$W_r = W^t * tan\phi * cos\gamma$$

- **Axial Force:**

$$W_a = W^t * tan\phi * sin\gamma$$

AGMA Stress Analysis

Bending Stress (σ_F)

$$\sigma_F = b_m W^t \frac{K_A K_v' Y_x K_H}{Y_B Y_{J1}}$$

Where:

- $K_A = 1.35\ (Light\ shock)$
- $K_v' = 1.5\ (Quality\ factor\ Qv = 7)$
- $Y_x = 0.5868\ (Size\ factor)$
- $K_H = 1.156\ (Load\ distribution\ factor)$
- $Y_J = 0.23\ (Geometry\ factor)$

Contact Stress (σ_H)

$$\sigma_H = Z_E \left(\frac{W^t}{b d_p Z_L} K_A K_v' Z_x Z_{xc} \right)^{\frac{1}{2}}$$

Where:

- $Z_E = 190MPa\ (Steel)$
- $Z_x = 0.9295\ (Mesh\ alignment\ factor)$

Safety Factors

- **Bending Safety Factor (S_F):**

$$S_F = \frac{\sigma_F}{\sigma_{FP}}$$

- **Contact Safety Factor (S_H):**

$$S_H = \frac{\sigma_H}{\sigma_{HP}}$$

Shaft Design

The shaft must withstand combined bending and torsional stresses. Using von Mises theory:

$$d^3 = \frac{16}{\pi\, \tau_{all}} \sqrt{\left(K_b\, M_b + \frac{\alpha F_a d}{8}\right)^2 + (K_t\, M_t)^2}$$

Where:

- $\tau_{all} = 47.5\ Mpa$
- $K_b = 2\ \&\ K_t = 1.5$

Bearing Selection

Once the shaft design was finalized and the reaction forces at each bearing location were calculated, the next step was to select suitable bearings that can withstand the applied radial and axial loads while ensuring reliability and longevity.
The primary criteria for bearing selection included:

a. Load carrying capacity (both radial and axial),
b. Rotational speed,
c. Operating life,
d. Ease of installation and availability.

Based on the calculated reaction forces at the shaft supports (as shown in the previous section), and considering the moderate speed and load conditions in our application, we chose to use deep groove ball bearings, which are well-suited for handling radial loads and moderate axial loads with relatively low friction.
Selected Bearing: SKF 6210
We selected the SKF 6210 bearing for both the pinion and gear shafts. This offers the following advantages:

- High radial load capacity, which matches the calculated forces in our system,
- Moderate axial load capability, suitable for the axial components generated by the bevel gear interaction,
- Rated for high-speed applications, aligning with our gearbox's operating conditions,
- Standard dimensions, making it easy to integrate into our shaft design.
- SKF 6210 specifications:
- Bore diameter: 50 mm
- Outside diameter: 90 mm
- Width: 20 mm
- Dynamic load rating (C): 37.1kN
- Static load rating (C_0): 23.2 kN
- Maximum speed: up to 7,500 rpm (depending on lubrication)

This bearing was chosen for its balance between load capacity, speed, and availability, ensuring reliable performance in our gearbox design.

The following script is written in **Engineering Equation Solver (EES)** and is used to analyze and design a bevel gear transmission system. The code defines all relevant input parameters, assumptions, and material properties, and performs detailed calculations for gear geometry, tangential loads, AGMA-based bending and wear stress analysis, shaft torque and moment evaluation, shaft diameter sizing under combined loading, and bearing reaction forces. The solution is automated using EES to ensure accuracy, flexibility in parameter variation, and to support design decisions in accordance with standard mechanical design practices.

EES Code

```
{Givens}

T_out = 400
N_in = 1200 / 60
N_out = 300 / 60

{Assumptions}

b = 100

S_F = 2.65
S_H = 2.65
m  = 12
n_p = 15
n_g = 4 * n_p
H_p = 240
H_g = 200
phi = 20
gamma = arctan(n_g / n_p)
L_p = 10 ^ 8
L_g = L_p / 4

{Precalculations}

d_p = m * n_p
d_g = m * n_g
P_w = T_out * N_out * 2 * pi
v = pi * d_p * N_in /1000
W|t = P_w / v
d_av_p = d_p - b * cos(gamma)
d_av_g = d_g - b * sin(gamma)

{Bending based}

k_a = 1
k_v = 1.3
Y_x = 0.4867 + 0.008339 * m
k_mb = 1.1
k_H = k_mb + 5.6 * b ^ 2 * 10 ^ (-6)
Y_b = 1
Y_j_p = 0.24
Y_j_g = 0.18
sigma_F_p = W|t * k_a * k_v * y_x * k_h / (b * m * Y_b * Y_j_p)
sigma_F_g = W|t * k_a * k_v * y_x * k_h / (b * m * Y_b * Y_j_g)
sigma_F_lim_p = 0.3 * H_p + 14.48
sigma_F_lim_g = 0.3 * H_g + 14.48
Y_NT_p = 1.3558 * L_P ^ (-0.0178)
```

```
Y_NT_g = 1.3558 * L_g ^ (-0.0178)
K_theta = 1
Y_z = 1
sigma_FP_P = sigma_F_lim_p * Y_NT_p / (K_theta * Y_z)
sigma_FP_g = sigma_F_lim_g * Y_NT_g / (K_theta * Y_z)

{S_F = sigma_FP_g / sigma_F_g}
{S_F = sigma_FP_p / sigma_F_p}

S_F_p = sigma_FP_g / sigma_F_g
S_F_g = sigma_FP_p / sigma_F_p

{Wear based}

Z_E = 190
Z_x = 0.00492 * b + 0.4375
Z_xc = 2
Z_i = 0.078
sigma_H = Z_E * (W|t * k_a * k_v * k_h * z_x * z_xc / (b * d_p * z_i)) ^ (0.5)
sigma_H_lim_p = 2.35 * H_p + 162.89
sigma_H_lim_g = 2.35 * H_g + 162.89
Z_NT_p = 3.4822 * L_p ^ (-0.0602)
Z_NT_g = 3.4822 * L_g ^ (-0.0602)
Z_w_p = 1
Z_w_g = 1.01
K_z = Y_z
sigma_HP_P = sigma_H_lim_p * Z_NT_p * Z_W_p / (K_theta * k_z)
sigma_HP_g = sigma_H_lim_g * Z_NT_g * Z_w_g / (K_theta * k_z)

{S_H = sigma_HP_P / sigma_H}
{S_H = sigma_HP_g / sigma_H}

S_H_p = sigma_HP_P / sigma_H
S_H_g = sigma_HP_g / sigma_H

{Forces, torques, and moments on pinion}

F_t_p = W|t * d_p / d_av_p
F_a_p = F_t_p * tan(phi) * cos (gamma)
F_r_p = F_t_p * tan(phi) * sin (gamma)
F_tr_p = (F_t_p ^ 2 + F_r_p ^2 ) ^ (0.5)
L_tr_p = 70 + 20
M_t_p = (F_t_p + W_p) * L_tr_p
M_a_p = F_a_p * d_av_p / 2
M_r_p = F_r_p * L_tr_p
M_ra_p = M_r_p - M_a_p
M_p = (M_t_p ^ 2 + M_ra_p ^2) ^ (0.5)
T_p = F_t_p * d_av_p / 2

{Bearing reactions for pinion shaft}
```

```
L_B_p = 100
W_p = 17 *9.81
B_n_t_p = (F_t_p + W_p) * (L_tr_p + L_B_p) / L_B_p
B_n_a_p = M_a_p / L_B_p
B_n_r_p = F_r_p * (L_tr_p + L_B_p) / L_B_p
B_n_ra_p = B_n_r_p - B_n_a_p
B_n_p = (B_n_t_p ^ 2 + B_n_ra_p ^2) ^ (0.5)
B_f_p = M_p / L_B_p

{Shaft design for pinion}

k_b = 1.5
k_t = 1
S_y = 380
{F_s_p = 3}
d_sh_p = 48
d_sh_u_p = d_sh_p - 1
tau_all_p = S_y * 0.75 *0.5 / F_s_p
alpha_p = 1 / (1 - 0.0044 * (4 * (L_tr_p + L_B_p) / d_sh_u_p))
d_sh_u_p = (16 / (pi * tau_all_p) * ((k_b * M_p + alpha_p * f_a_p * d_sh_u_p / 8) ^ 2 + (k_t *
T_p) ^ 2) ^ (0.5)) ^ (1 / 3)

{Forces, torques, and moments on gear}

F_t_g = F_t_p
F_a_g = F_r_p
F_r_g = F_a_p
L_tr_g = 80 + 20
F_tr_g = (F_t_g ^ 2 + F_r_g ^2 ) ^ (0.5)
M_t_g = F_t_g * L_tr_g
M_a_g = F_a_g * d_av_g / 2
M_r_g = F_r_g * L_tr_g
M_ra_g = M_r_g - M_a_g
M_g = B_f_g * (L_B_g - L_tr_g)
T_g = T_p * N_g / N_p

{Bearing reactions for gear shaft}

L_B_g = 300
w_gk = (103 + 27.5) * 9.81
B_n_t_g = (F_t_g + W_gk) * (L_B_g - L_tr_g) / L_B_g
B_n_a_g = M_a_g / L_B_g
B_n_r_g = F_r_g * (L_B_g - L_tr_g) / L_B_g
B_n_ra_g = B_n_r_g - B_n_a_g
B_n_g = (B_n_t_g ^ 2 + B_n_ra_g ^2) ^ (0.5)
B_f_t_g = (F_t_g + W_gk) * (L_tr_g) / L_B_g
B_f_a_g = M_a_g / L_B_g
B_f_r_g = F_r_g * (L_tr_g) / L_B_g
B_f_ra_g = B_f_r_g + B_f_a_g
```

```
B_f_g = (B_f_t_g ^ 2 + B_f_ra_g ^2) ^ (0.5)

{Shaft design for gear}

{F_s_g = 3}
d_sh_g = 62
tau_all_g = S_y * 0.75 *0.5 / F_s_g
alpha_g = 1 / (1 - 0.0044 * (4 * (L_tr_g + L_B_g) / d_sh_g))
d_sh_g = (16 / (pi * tau_all_g) * ((k_b * M_g + alpha_g * f_a_g * d_sh_g / 8) ^ 2 + (k_t *
T_g) ^ 2) ^ (0.5)) ^ (1 / 3)

{Bearing selection}

{basic static load}
{Fa/Fr<0.8 ... Xo=1,Yo=0}

xo=1
yo=0

{normal condition}

Fs=1.2
Po= xo*B_n_p + yo*F_a_p
Co= Fs*Po

{SKF 6210, co=23.2, c=37.1}
{basic dynamic load}
{fo*Fa/co=0.1104 < e=0.17932}

x=1
y=0
{uniform load}
Ks=1
{inner ring rotation}
vo=1
{basic rating life}
L=360
P=x*vo*B_n_p+y*F_a_p
C=Ks*P*(L)^(1/3)
```

Computer-Aided Design (CAD)

After completing the analytical calculations and determining the required forces, torques, and dimensions for the system components, we proceeded to the **mechanical design phase**. This phase is essential for transforming theoretical data into a functional and manufacturable 3D model.

Using **SolidWorks**, we modeled each individual part of the system with precise dimensions derived from our calculations. The design ensures mechanical compatibility, proper alignment, and load distribution among gears, shafts, and bearings.

In the following section, each part is presented with its:

- **Name**
- **Dimensions**
- **Material**
- **Function in the assembly**

This step bridges the gap between theoretical engineering principles and practical implementation, ensuring that each component meets the mechanical and operational requirements of the system.

Gear Modeling Using GearTrax

To ensure high accuracy and compliance with gear design standards, the bevel gears were modeled using **GearTrax by Camnetics**, a specialized add-in for SolidWorks. This tool provides a robust and precise method for generating 3D gear geometry based on input parameters such as:

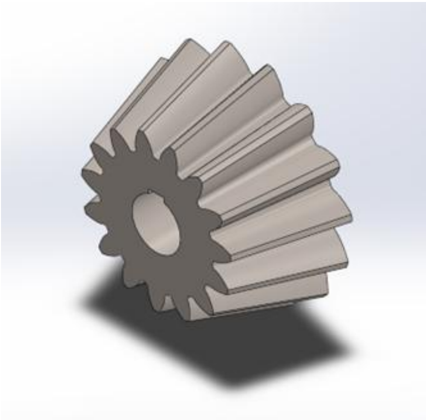
- Number of teeth
- Pressure angle
- Module or diametral pitch
- Gear ratio
- Shaft angle (typically 90° for bevel gears)

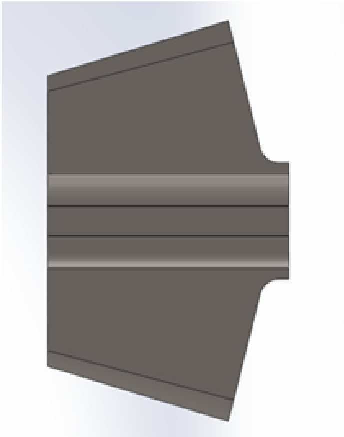
Using GearTrax allowed us to automatically generate the correct tooth profile and gear geometry according to AGMA standards, which significantly improved the quality and reliability of the gear design. The resulting models were seamlessly integrated into the SolidWorks assembly, ensuring accurate alignment and meshing between the pinion and the driven gear.

This approach minimized manual modeling errors and accelerated the design process while maintaining mechanical accuracy and consistency.

Gear 1 (Pinion):

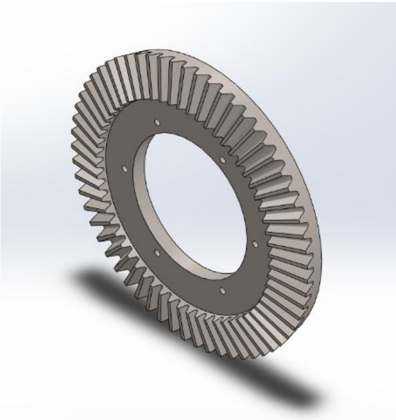
- Number of teeth: 15
- Pitch diameter: 180 mm
- Pressure angle: 20°
- Cone Angle (γ): 14.04°
- Face width: 100mm

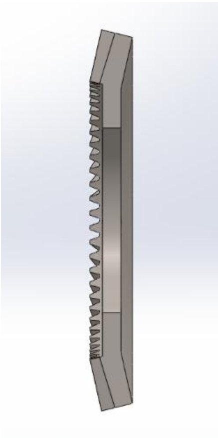




Gear 2 (Gear):

- Number of teeth: 60
- Pitch diameter: 720 mm
- Pressure angle: 20°
- Cone Angle (γ): 75.96°
- Face width: 100mm



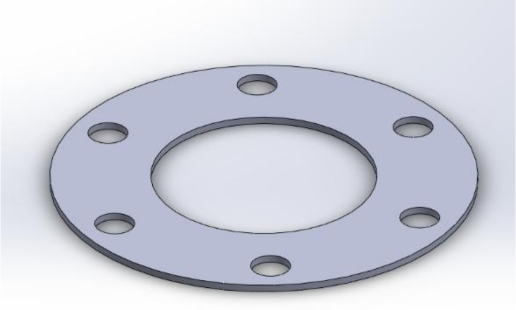


Gasket Set for Bevel Gearbox Assembly

To ensure effective sealing and maintain pressure integrity within the gearbox, four custom-designed flat gaskets were modeled and integrated into the assembly. These gaskets serve to prevent lubricant leakage and protect internal components from external contaminants. All gaskets were designed in accordance with the mating flange profiles in SolidWorks, using precise cutout geometry and bolt hole alignment for seamless installation. Manufactured from **3 mm thick compressed fiber material**, they offer high resistance to oil, temperature, and mechanical deformation, making them ideal for use in gear-driven power transmission systems.

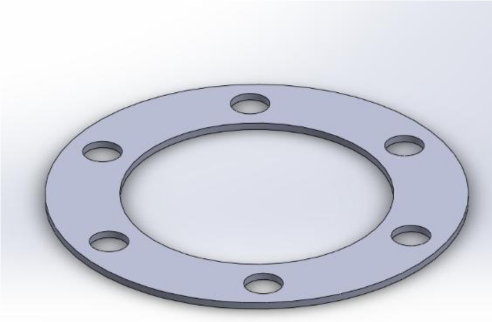
Gasket 1:

- **Use:** Sealing interface between shaft housing, gearbox casing (inlet and outlet sides) and sealing interface for the shaft support flange
- **Dimensions:**
    - Outer diameter: 170 mm
    - Inner cutout: 90 mm
    - Thickness: 3 mm
    - Bolt PCD: 140 mm
- **Quantity:** 3 identical gaskets (inlet + outlet)



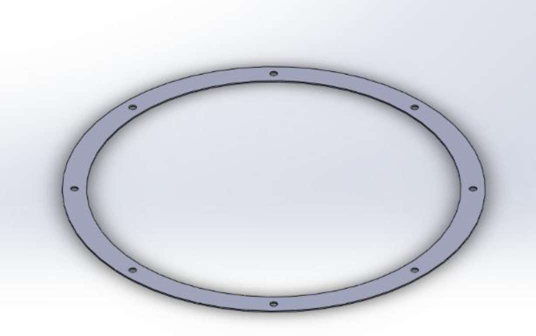
Gasket 2:

- **Use:** Between small support case and gearbox wall
- **Dimensions:**
    - Outer diameter: 170 mm
    - Inner cutout: 110 mm
    - Thickness: 3 mm
    - Bolt PCD: 140 mm



Gasket 3:

- **Use:** Sealing between the main gearbox housing and support structure
- **Dimensions:**
    - Outer diameter: 870 mm
    - Inner cutout: 770 mm
    - Thickness: 3 mm
    - Bolt PCD: 820 mm

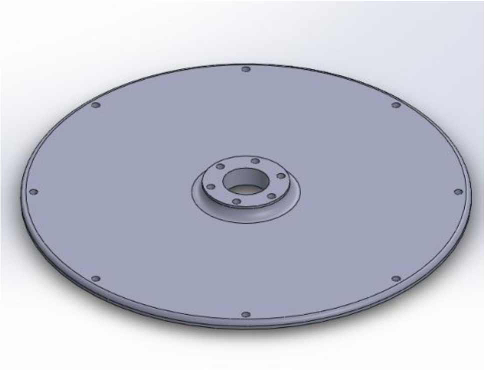


Cap Components for Bevel Gearbox Assembly

To ensure proper enclosure, shaft alignment, and mechanical protection, three distinct cap configurations were integrated into the bevel gearbox assembly. Each cap was modeled in SolidWorks with precision bolt patterns and center bore profiles to ensure compatibility with mating shafts, housings, and gaskets. The designs incorporate flat-faced surfaces and mounting flanges, simplifying installation and minimizing vibration-induced wear. All caps are assumed to be manufactured from **mild steel** unless otherwise specified, offering excellent machinability and structural integrity.

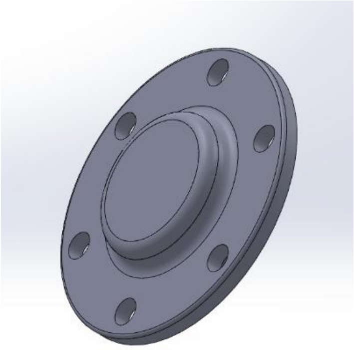
Cap 1:

- **Function:** Fully encloses the large side of the gearbox casing
- **Dimensions:**
  - Outer diameter: 870 mm
  - Boss height: 90 mm
  - Pitch Circle Diameter (PCD): 820 mm
- **Features:** Includes a central hub with through-hole for optional alignment pin or shaft stub, and bolt holes along the outer edge for secure sealing
- **Mounted with:** Gasket (870×770×3, PCD: 820 mm)



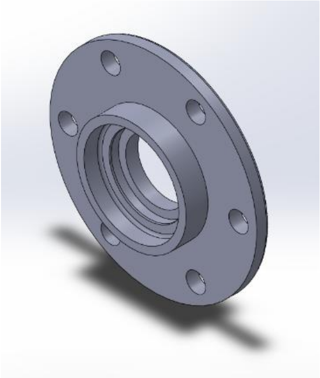
Cap 2:

- **Function:** Closes and centers the shaft inlet region while allowing shaft clearance
- **Dimensions:**
  - Outer diameter: 170 mm
  - Boss height: 0 mm
  - Pitch Circle Diameter (PCD): 140 mm
- **Features:** Flat design for flush mounting against shaft inlet housing; central hole accommodates shaft passage
- **Mounted with:** Gasket (170×90×3, PCD: 140 mm)

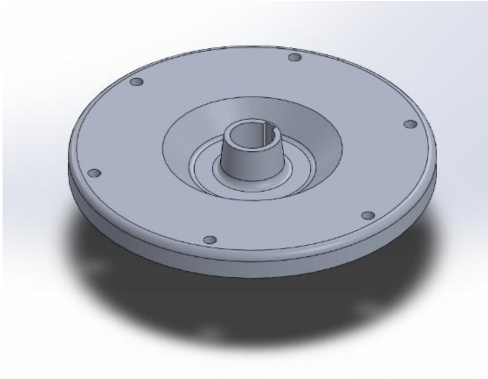


Cap 3:

- **Function:** Closes and centers the shaft outlet while providing axial spacing
- **Dimensions:**
  - Outer diameter: 170 mm
  - Boss height: 50.1 mm
  - Pitch Circle Diameter (PCD): 140 mm
- **Features:** Raised boss ensures proper axial positioning and alignment for the output shaft; bolt holes are evenly spaced for stable fastening
- **Mounted with:** Gasket (170×90×3, PCD: 140 mm)



Gear Mounting Kit



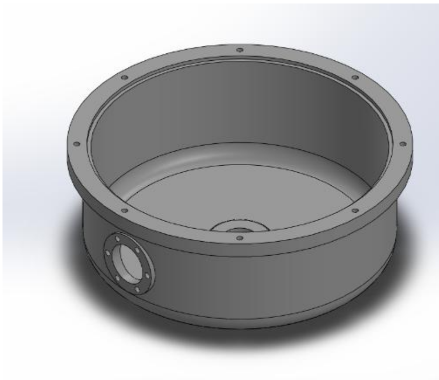
- **Function**: Secures the pinion to the input shaft with anti-rotation and axial retention.
- **Dimensions:**
  - Outer diameter:450 mm
  - Boss height: 50 mm
  - Pitch Circle Diameter (PCD): 400 mm

Gearbox Cases (Housings) – General Overview

Gearbox cases (or housings) are structural enclosures that serve as the foundation for gear systems, providing:

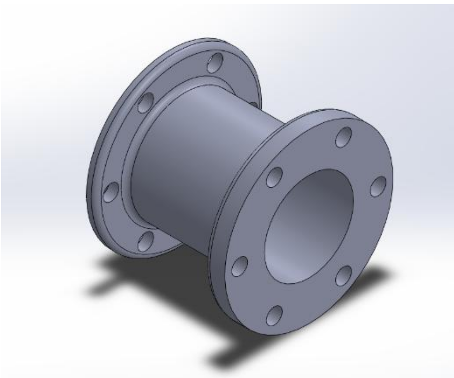
1. **Alignment**: Precise positioning of gears, shafts, and bearings.
2. **Protection**: Shielding internal components from contaminants (dust, moisture) and mechanical damage.
3. **Lubrication Management**: Contain oil/grease and facilitate cooling.
4. **Load Distribution**: Absorb and transmit operational forces (torque, vibrations).

Big Case



- **Function**: The main housing encloses and supports the large bevel gear and output shaft, providing structural rigidity, bearing alignment, and lubrication containment while handling high torque and radial loads.
- **Dimensions**:
  - Outer diameter: 870 mm
  - Boss height: 750 mm
  - Pitch Circle Diameter (PCD): 820 mm

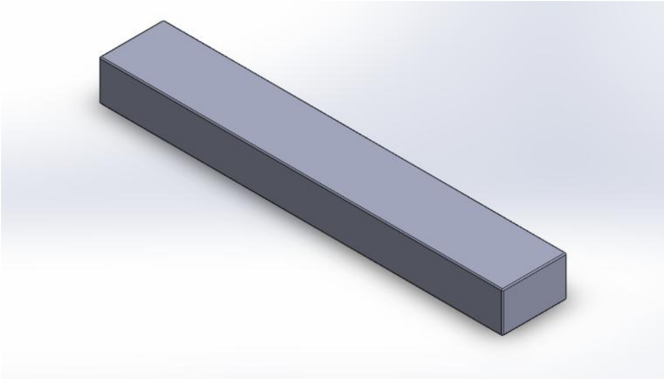
Small Case



- **Function**: The pinion housing secures and aligns the input shaft and bearings, ensuring precise gear meshing and sealing against lubricant leaks and contaminants.
- **Dimensions**:
  - Outer diameter: 170 mm
  - Boss height: 90 mm
  - Pitch Circle Diameter (PCD): 140 mm

Keys

- **Function**: It allows the shaft and gear to rotate together, transmitting torque from one to the other and prevents the gear from slipping or rotating independently on the shaft under load.
- **Dimensions:**
    - Width:16 mm
    - Height: 10 mm
    - Fillet radius: 0.3 mm

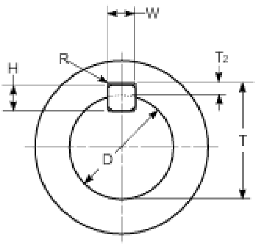


Key & Keyway Dimensions – Millimeters											Coupling Hub Keyway Dimensions – Inches							
Shaft Diameter "D"		Key Size Nominal		Keyway Width Hub "W"			Keyway Depth Hub "T2"		Keyway Radius "R" †		Shaft Diameter "D"		Keyway Width Hub "W"	Keyway Depth Hub "T2"		Keyway Radius "R"†	
Over	Thru	Width "W"	Height "H"	Nominal	Min	Max	Min	Max	Min	Max	Over	Thru		Min	Max	Min	Max
6	8	2	2	2	-.0125	+.0125	1.0	1.1	0.08	0.16	0.2362	0.3150	0.0783 /0.0792	0.0394	0.0433	0.004	0.006
8	10	3	3	3	-.0125	+.0125	1.4	1.5	0.08	0.16	0.3150	0.3937	0.1176 /0.1186	0.0551	0.0591	0.004	0.006
10	12	4	4	4	-.0150	+.0150	1.8	1.9	0.08	0.16	0.3937	0.4724	0.1569 /0.1581	0.0709	0.0748	0.004	0.006
12	17	5	5	5	-.0150	+.0150	2.3	2.4	0.16	0.25	0.4724	0.6693	0.1963 /0.1974	0.0906	0.0945	0.007	0.009
17	22	6	6	6	-.0150	+.0150	2.8	2.9	0.16	0.25	0.6693	0.8661	0.2357 /0.2368	0.1102	0.1142	0.007	0.009
22	30	8	7	8	-.0180	+0180	3.3	3.5	0.16	0.25	0.8661	1.1811	0.3143 /0.3157	0.1299	0.1378	0.007	0.009
30	38	10	8	10	-.0180	+0180	3.3	3.5	0.25	0.40	1.1811	1.4961	0.3930 /0.3944	0.1299	0.1378	0.010	0.015
38	44	12	8	12	.-0215	+.0215	3.3	3.5	0.25	0.40	1.4961	1.7323	0.4716 /0.4733	0.1299	0.1378	0.010	0.015
44	50	14	9	14	.-0215	+.0215	3.8	4.0	0.25	0.40	1.7323	1.9685	0.5503 /0.5520	0.1496	0.1575	0.010	0.015
50	58	16	10	16	.-0215	+.0215	4.3	4.5	0.25	0.40	1.9685	2.2835	0.6291 /0.6308	0.1693	0.1772	0.010	0.015
58	65	18	11	18	.-0215	+.0215	4.4	4.6	0.25	0.40	2.2835	2.5591	0.7078 /0.7095	0.1732	0.1811	0.010	0.015
65	75	20	12	20	-.0260	+.0260	4.9	5.1	0.40	0.60	2.5591	2.9528	0.7864 /0.7884	0.1929	0.2008	0.016	0.023
75	85	22	14	22	-.0260	+.0260	5.4	5.6	0.40	0.60	2.9528	3.3465	0.8651 /0.8672	0.2126	0.2205	0.016	0.023
85	95	25	14	25	-.0260	+.0260	5.4	5.6	0.40	0.60	3.3465	3.7402	0.9832 /0.9853	0.2126	0.2205	0.016	0.023
95	110	28	16	28	-.0260	+.0260	6.4	6.6	0.40	0.60	3.7402	4.3307	1.1013 /1.1034	0.2520	0.2598	0.016	0.023
110	130	32	18	32	-.0310	+.0310	7.4	7.6	0.40	0.60	4.3307	5.1181	1.2586 /1.2611	0.2913	0.2992	0.016	0.023
130	150	36	20	36	-.0310	+.0310	8.4	8.7	0.70	1.00	5.1181	5.9055	1.4161 /1.4185	0.3307	0.3425	0.028	0.039
150	170	40	22	40	-.0310	+.0310	9.4	9.7	0.70	1.00	5.9055	6.6929	1.5736 /1.5760	0.3701	0.3819	0.028	0.039
170	200	45	25	45	-.0310	+.0310	10.4	10.7	0.70	1.00	6.6929	7.8740	1.7704 /1.7729	0.4094	0.4213	0.028	0.039
200	230	50	28	50	-.0310	+.0310	11.4	11.7	0.70	1.00	7.8740	9.0551	1.9673 /1.9697	0.4488	0.4606	0.028	0.039
230	260	56	32	56	-.0370	+.0370	12.4	12.7	1.20	1.60	9.0551	10.2362	2.2033 /2.2062	0.4882	0.5000	0.047	0.063
260	290	63	32	63	-.0370	+.0370	12.4	12.7	1.20	1.60	10.2362	11.4173	2.4789 /2.4818	0.4882	0.5000	0.047	0.063
290	330	70	36	70	-.0370	+.0370	14.4	14.7	1.20	1.60	11.4173	12.9921	2.7544 /2.7574	0.5669	0.5787	0.047	0.063
330	380	80	40	80	-.0370	+.0370	15.4	15.7	2.00	2.50	12.9921	14.9606	3.1481 /3.1511	0.6063	0.6181	0.079	0.098
380	440	90	45	90	-.0435	+.0435	17.4	17.7	2.00	2.50	14.9606	17.3228	3.5416 /3.5450	0.6850	0.6969	0.079	0.098
440	500	100	50	100	-.0435	+.0435	19.5	19.8	2.00	2.50	17.3228	19.6850	3.9353 /3.9387	0.7677	0.7795	0.079	0.098

★ Keyways will be furnished per ISO/R773 and Js9 width tolerance unless otherwise specified. (Dimensions comply with DIN 6885/1)
† Requires use of chamfered keys.

Surface Finish — Sides and bottom of keyways shall not exceed 250 micro inches.

See Page 2 for Optional P9 & D10 Keyway Dimensions

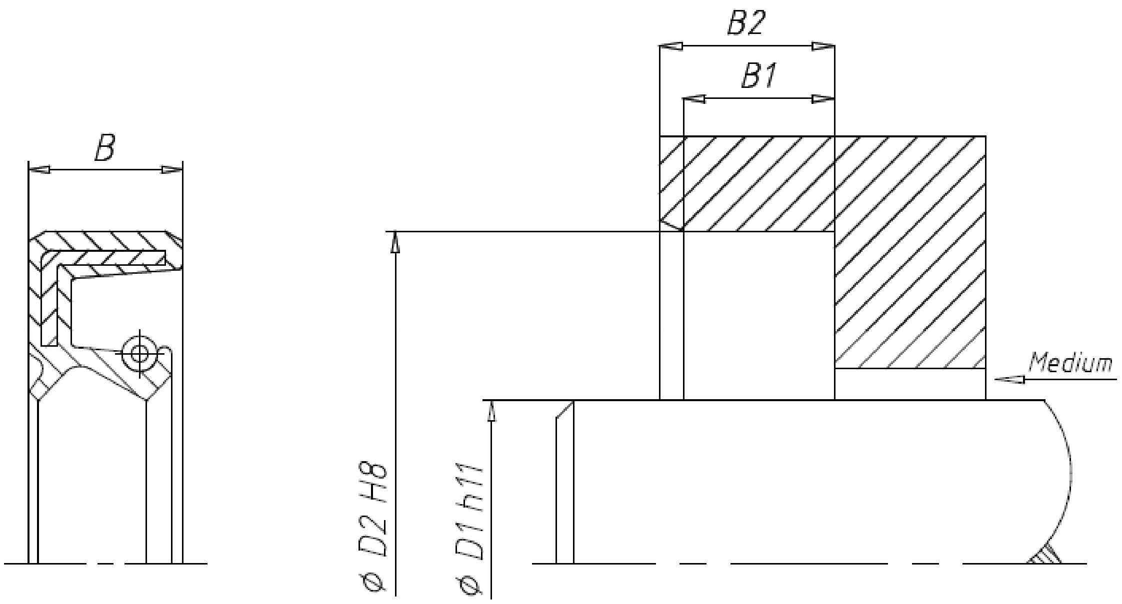


$T = D + T_2$

Radial Sealing

- **Function of a Mechanical Seal**: Prevents leakage of process fluids and blocks contaminants while allowing shaft rotation, improving equipment lifespan, efficiency, and safety by maintaining proper lubrication and sealing.
- **Construction Overview**: Consists of a rotating face (hard material), stationary face (soft material), secondary seals (O-rings/gaskets), and a spring mechanism to maintain contact under pressure and misalignment.
- **Dimensions:**
  - Outer diameter: 62 mm
  - Boss height: 50 mm
  - Width: 7 mm

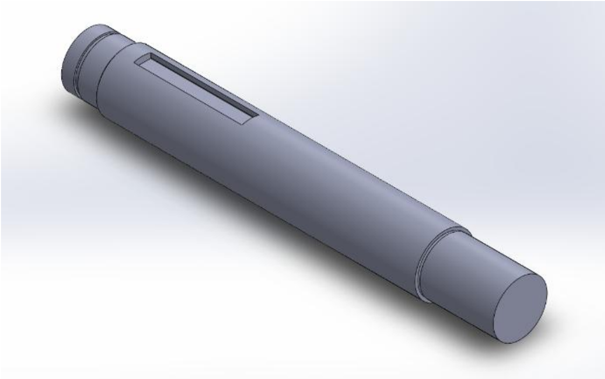
Technical drawings



Shafts

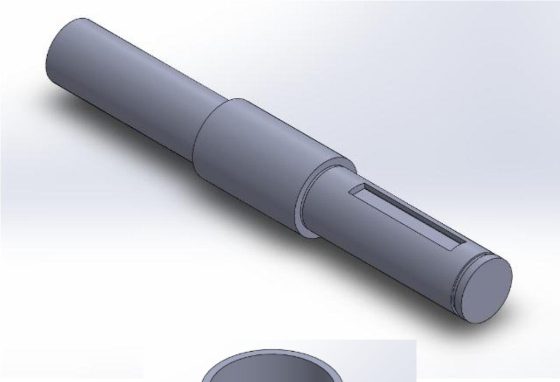
The shaft serves as the backbone of mechanical systems, primarily transmitting torque and rotational motion between components like motors, gears, and couplings. It provides a mounting surface for critical elements such as bearings, pulleys, and seals, with features like keyways ensuring secure torque transfer via keys. Designed to withstand bending and torsional stresses, the shaft's stepped shoulders and grooves facilitate precise bearing placement for axial and radial support, while its dimensions (diameter, length, and tolerances) dictate load capacity, alignment, and compatibility with mating parts.

Gear shaft:



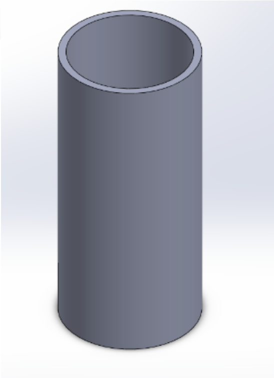
- **Function**: Drive the motion to the gear.
- **Dimensions:**
  - Minor diameter: 50 mm
  - Major diameter: 55 mm

Pinion shaft:



- **Function**: Transmit the motion to the Pinion.
- **Dimensions:**
  - Minor diameter: 50 mm
  - Major diameter: 62 mm

Collar:



- **Function**: Support the gear kit.
- **Dimensions:**
  - Outer diameter: 55 mm
  - Inner diameter: 62 mm
  - Height: 135mm

Selection

Gears:

Gear	Face width	Gear diameter	Pinion diameter
Calculated	74.39	720	180
Used	100	720	180

Bearings:

4 Bearings SKF 6210

Bearing	Basic dynamic load	Basic static load
Calculated	20368	3436
Used	37100	23200

Shafts:

Shafts	Pinion	Gear
Calculated	29.92	37.72
Used	48	62

Conclusion

This comprehensive study successfully designed and analyzed a **bevel gear transmission system** capable of transmitting **12.57 kW** at a **4:1 reduction ratio**, converting **1200 rpm (125.66 rad/s) input** to **300 rpm (31.42 rad/s) output** while increasing torque from **100 N·m to 400 N·m**. Through **kinematic, geometric, and stress analyses**, the system was optimized for **strength, durability, and manufacturability** in compliance with **AGMA standards**.

Key achievements include:

- **Precision gear design** (module **12 mm**, **15/60 teeth**) with proper **cone angles (14.04° & 75.96°)** for optimal meshing.
- **Force and stress validation**, ensuring safety factors (**S_F = 2.65**, **S_H = 2.65**) under bending and contact fatigue.
- **Shaft and bearing selection** (e.g., **SKF 6210**) to withstand combined **radial/axial loads**.
- **3D CAD modeling** (SolidWorks, GearTrax) and **2D manufacturing drawings** (AutoCAD) for seamless production.
- **Integrated sealing solutions** (gaskets, mechanical seals) to prevent leaks and contamination.

The final design meets all **performance, reliability, and safety** requirements, providing a robust reference for similar **bevel gear applications**. Future work could explore **dynamic simulations** or **prototype testing** for further validation.

References

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2. **ISO.** (2019). *ISO 6336-1:2019: Calculation of load capacity of spur and helical gears — Part 1: Basic principles, introduction and general influence factors*. International Organization for Standardization.

3. **Klingelnberg, J.** (2016). *Bevel Gear: Fundamentals and Applications*. Springer. *(Covers bevel gear geometry, manufacturing, and load analysis)*

4. **Maitra, G. M.** (1994). *Handbook of Gear Design* (2nd ed.). Tata McGraw-Hill. *(Classic reference for gear theory, stress calculations, and design rules)*

5. **SKF Group.** (2022). *SKF Bearing Catalogue: Radial Ball Bearings*. *(For SKF 6210 bearing specifications; include URL if accessed online)*

6. **Camnetics.** (2023). *GearTrax User Manual: Bevel Gear Design Module*. *(Cite as software/documentation; add version number if available)*