

Phase - 0 [Planning and learning]

Phase Breakdown

Phase 1: Core Geometry & Engineering Logic

- Implement gear parameter data structures
- Code mathematical gear design equations
- Generate involute tooth profiles
- Validate calculations against textbook examples

Phase 2: CAD Model Generation

- Learn CadQuery/OpenCascade basics
- Generate 3D tooth geometry from involute profiles
- Pattern teeth around pitch circle
- Export to STEP/STL formats

Phase 3: AI Parameter Extraction

- Design LLM prompts for structured JSON output
- Extract gear parameters from natural language
- Integrate AI → Engineering → CAD pipeline
- Build simple CLI interface

Core features of MVP

Feature	Components	Deliverable
Specification Input	- Parameter validation- Data class structure- Sanity checks	<code>GearParameters</code> class
Engineering Calculations	- Pitch diameter formulas- Involute curve generation- Tooth profile geometry- ISO/AGMA standard equations	<code>SpurGearCalculator</code> module

Feature	Components	Deliverable
CAD Generation	- 2D profile creation- 3D extrusion- Circular patterning- File export (STEP/STL)	<code>GearCADGenerator</code> class
AI Interface	- Prompt engineering- JSON schema enforcement- Parameter extraction- Error handling	LLM integration layer
Validation	- Unit tests for formulas- Visual inspection in CAD software- Dimension verification	Test suite

Essential Concepts to master :

Spur Gear Terminology :

Key formulas to identify and implement :

involute Curve mathematics :

Cadquery Basics

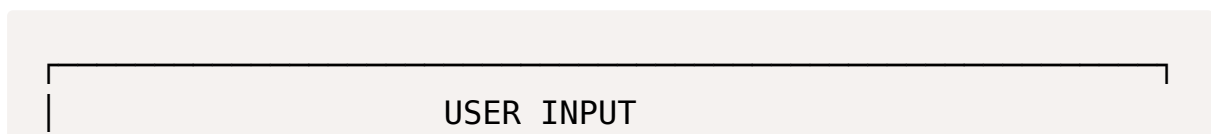
LLM integration

Gear type we are working on :

for mvp we will work on spur gear then we will work on other gear types

Gear Type	Complexity	Tooth Geometry	MVP Scope
Spur Gear ★	Low	Straight, parallel to axis	✅ YES - Primary focus
Helical Gear	Medium	Angled spiral around axis	❌ Future Phase 2
Bevel Gear	High	Conical, tapered teeth	❌ Future Phase 3
Worm Gear	High	螺旋 thread-like	❌ Future Phase 3
Planetary Gear	Very High	System of gears	❌ Future Phase 4
Rack & Pinion	Medium	Linear gear + spur gear	❌ Future Phase 2

Some important things regarding the project :



"Create a spur gear with 20 teeth, module 2mm"



AI LAYER (LLM)

Role: UNDERSTAND intent, EXTRACT parameters

- Natural language → Structured data
- "20 teeth" → {"teeth": 20}
- Fill missing defaults intelligently
- Route to correct tool/component type



DETERMINISTIC ENGINEERING LAYER

Role: APPLY verified formulas (hard-coded)

- Pitch diameter = module × teeth
- Base diameter = pitch × cos(pressure_angle)
- No AI guessing - pure mathematics



CAD GENERATION LAYER

Role: BUILD geometry using CadQuery

- Generate involute curves
- Create 3D models
- Export STEP/STL

▼ Scaling the System for Complex Geometries

Overview

The AI CAD agent does not require hard-coded formulas for every possible design. Instead, it uses a **three-tier architecture** that scales intelligently from simple components to complex systems like Kaplan turbines, IC engines, and custom assemblies.

Three-Tier Architecture

Tier 1: Fully Parametric Component Library (Core)

What it is: 150-200 primitive mechanical components with clear mathematical formulas.

Examples:

- Gears (spur, helical, bevel)
- Shafts and bushings
- Bearings (database lookup)
- Bolts and fasteners
- Springs and washers
- Cylinders, cones, and basic shapes

Tier 2: Parametric Template Library (Assemblies)

What it is: Pre-designed complex assemblies stored as parametric templates. Designed once by humans, modified infinitely by AI.

Examples:

- Kaplan turbine (micro, large, ultra-large variants)
- Francis turbine
- IC engine block
- Centrifugal pump

- Planetary gearbox

Tier 3: AI-Assisted Custom Design (Novel)

What it is: Designs not yet in the template library, handled through AI-orchestrated component composition.

[Full document continues...]

Open source component library for reference :

- freecad gear workbench
 - freecad fasteners workbench
 - mc-master-carr
 - cad - query
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