Product Design Specifications (PDS)

Lecture 9 Module 2

Dinesh Kumar
Assistant Professor

School of Engineering
D. Y. Patil International University, Akurdi, Pune (DYPIU)

Course: (BME4109) - Product Design and Development, Generative AI
Program: B.Tech Mechanical Engineering, 7th Semester

September 15, 2025

Section 1: What is a Product Design Specification?

Definition

A Product Design Specification (PDS) is a detailed document that defines the complete set of requirements, constraints, and performance metrics a new product must satisfy.

- It translates abstract customer needs into concrete, measurable engineering targets.
- Acts as a "design contract" for the entire project team (design, manufacturing, etc.).
- It is a **living document**, updated and refined as the project progresses.
- For a Mechanical Engineer, it's the **single source of truth** for all design decisions.

Section 2: Why is the PDS Crucial in Engineering?

Provides Clarity & Focus

- Establishes a shared vision.
- Prevents "scope creep".
- Guides every team member.

Forms a Benchmark

- Allows objective evaluation of design concepts.
- Essential for Verification & Validation (V&V).

Reduces Risk & Cost

- Identifies constraints early.
- Minimizes expensive late-stage changes and rework.

Drives Decision Making

- Justifies choices for materials, mechanisms, and manufacturing.

Role of PDS in the Mechanical Design Process

The PDS is the bridge from Problem to Solution

Customer Need $\rightarrow$ **PDS** $\rightarrow$ Concept Generation $\rightarrow$ Concept Selection $\rightarrow$ Detail Design (CAD/CAE) $\rightarrow$ Manufacturing

- Without a robust PDS, the design process lacks clear direction and goals.
- It ensures that the engineering solution is directly tied to the market requirements.

Section 3: Key Elements of a PDS (Mechanical Focus)

1. Performance & Functionality

- **Loads & Stresses:** Static/dynamic loads (N), Torque (Nm), Pressure (Pa).
- **Kinematics:** Range of motion, velocity, acceleration.
- **Service Life:** Expected operational lifetime in hours, cycles, or years.
- **Thermal Properties:** Operating temperature range (°C), heat dissipation (W).

2. Geometry & Dimensions

- **Size & Envelope:** Overall dimensions (L x W x H), max allowable volume.
- **Weight:** Target mass (kg) and constraints on weight distribution.
- **Interfaces:** How it connects to other parts (e.g., bolt patterns, shaft dia.).

Key Elements of a PDS (Continued)

3. Materials

- **Mechanical Properties:** Yield Strength (S_y), Hardness (HRC), Fatigue life.
- **Physical Properties:** Density (ρ), Corrosion Resistance.
- **Cost & Availability:** Target material cost per kg, approved suppliers.

4. Manufacturing & Assembly

- **Processes:** Preferred methods (e.g., CNC, casting, molding, 3D printing).
- **Tolerances:** Geometric Dimensioning and Tolerancing (GD&T).
- **Quantity:** Expected production volume (e.g., 100 vs 1,000,000 units/year).

Key Elements of a PDS (Concluded)

5. Safety, Standards, and Ergonomics

- **Safety:** Fail-safe mechanisms, Factor of Safety (FoS), regulatory compliance.
- **Standards:** Must meet specific ISO, BIS, or industry standards.

6. Environment & Sustainability

- **Operating Environment:** Temperature, humidity, IP rating (Ingress Protection).
- **Sustainability:** Recyclability, end-of-life disposal, energy use.

7. Target Cost & Timescale

- **Cost:** Target manufacturing cost per unit.
- **Timescale:** Project milestones and final delivery date.

From Needs to Metrics: The Engineering Task

The core of a PDS is converting qualitative needs into quantitative specifications.

Customer Need	Engineering Metric	Target Value & Unit
"Must be strong."	Yield Strength (S_y)	> 350 MPa
"Should be light."	Mass	< 2.5 kg
"Needs to last long."	Fatigue Life	$> 1 \times 10^6$ cycles
"Must fit in the box."	Volumetric Envelope	$< 150 \times 100 \times 50$ mm
"Should be affordable."	Manufacturing Cost	$< 500 rupees/unit$

- Each metric must be **unambiguous, measurable, and verifiable**.

Section 4: Example - PDS for a Bicycle Hydraulic Brake Caliper

Part 1: Performance and Materials

Primary Function: To convert hydraulic pressure into clamping force on a rotor.

Clamping Force: Min. 4000 N at max lever pressure.

Operating Pressure: Must withstand 10 MPa without failure.

Fatigue Life: Survive $500,000$ full-force braking cycles.

Material (Body): Forged Aluminum Alloy 6061-T6.

Material (Pistons): Phenolic composite for thermal insulation.

Weight Target: Mass of caliper assembly < 150 grams.

Example - PDS for a Bicycle Hydraulic Brake Caliper

Part 2: Manufacturing, Safety, and Standards

Manufacturing: Body by forging, then CNC machining. Cpk > 1.33 on critical dims.

Assembly: Serviceable with standard tools; bleed time < 10 mins.

Interfaces: Must conform to IS or Post Mount standards.

Safety Standard: Must pass all tests specified in ISO 4210-4.

Factor of Safety: Minimum FoS of 2.5 on yield for all stressed components.

Operating Environment: Operate reliably from -15°C to 45°C; IP65 rating.

Target Cost: Ex-factory cost $<$ |1200 per unit @ 50,000 units/year.

Section 5: PDS and the Role of Generative AI

The PDS provides the essential **prompts and constraints** for Generative AI in engineering.

How AI Leverages the PDS

- **Topology Optimization:** PDS defines loads, boundaries, materials, and keep-out zones. The AI generates the most efficient structure within these rules.
- **Material Selection:** AI algorithms can suggest optimal materials that satisfy all PDS constraints (strength, weight, cost, etc.) from vast databases.

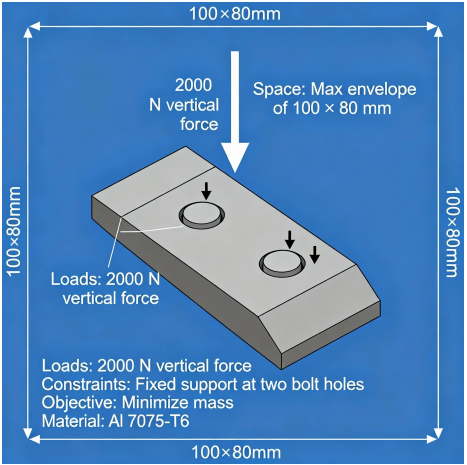
Generative AI does not replace the engineer; it requires a precise PDS from the engineer to function effectively.

Visualizing AI-Driven Design from PDS

PDS Inputs for AI:

- **Space:** Max envelope of 100×80 mm.
- **Loads:** 2000 N vertical force.
- **Constraints:** Fixed support at two bolt holes.
- **Objective:** Minimize mass.
- **Material:** Al 7075-T6.

Generative AI Output



Summary & Key Takeaways

- The PDS is the most critical document in product development.
- It transforms subjective wants into objective engineering targets.
- A comprehensive PDS covers performance, materials, manufacturing, safety, cost, and more.
- A well-defined PDS is essential for reducing errors, managing projects, and ensuring product success.
- In modern design, the PDS provides the foundational constraints that enable powerful tools like Generative AI.

A good PDS is the blueprint for success.

Thank You

Dinesh Kumar
Assistant Professor
School of Engineering, DYPIU