Water Pump Housing Lightweighting: DoE-Driven Mass Reduction

An automotive Tier-1 supplier's engineering team optimized a water pump housing, investment-cast in AlSi10Mg-T5 with CNC-machined interfaces, targeting mass reduction through conformal ribbing while maintaining pressure integrity and full casting process compliance. Running a **parametric Design of Experiments (DoE)** across wall thickness, rib geometry, and rib configuration, the team **explored 50+ variants in parallel** and selected an optimized design delivering a **25% mass reduction** from the legacy baseline, with all structural requirements met and die casting manufacturability confirmed at the generation stage.

Engineering Challenge

Automotive water pump housings are a staple of high-volume production: investment-cast, CNC-machined at the interfaces, and under constant OEM cost-down pressure. The hard part of lightweighting a component like this is rarely a single optimization pass; it is exploring enough rib geometry and wall thickness combinations, fast enough, to find a design that is light, pressure-tight, and castable without a foundry rework loop.

The challenges the team set out to address:

- **Breadth of exploration under time pressure**: Conventional workflows produce three to five wall thickness iterations sequentially, by hand, before deadlines force a choice. Rib configurations that could yield a better trade-off are never evaluated.

- **Competing objectives**: Mass reduction increases peak stress at burst pressure and tends to produce thinner walls that are harder to fill reliably. The goal is the best trade-off, not minimum weight in isolation.

- **Keeping castability in the loop early**: Rib geometry, blend radii, and wall thickness interact with die casting solidification rules. Discovering non-castable geometry after optimization forces a full restart.

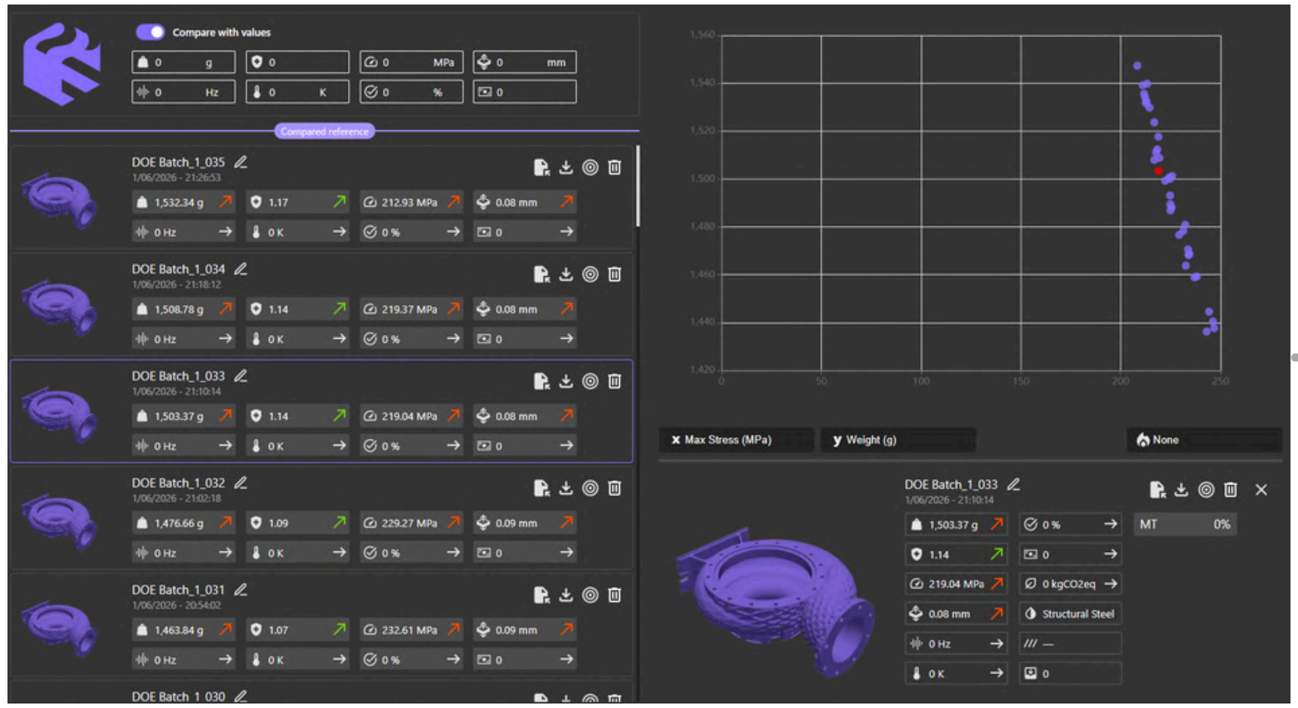
The Solution: Cognitive Design Workflow

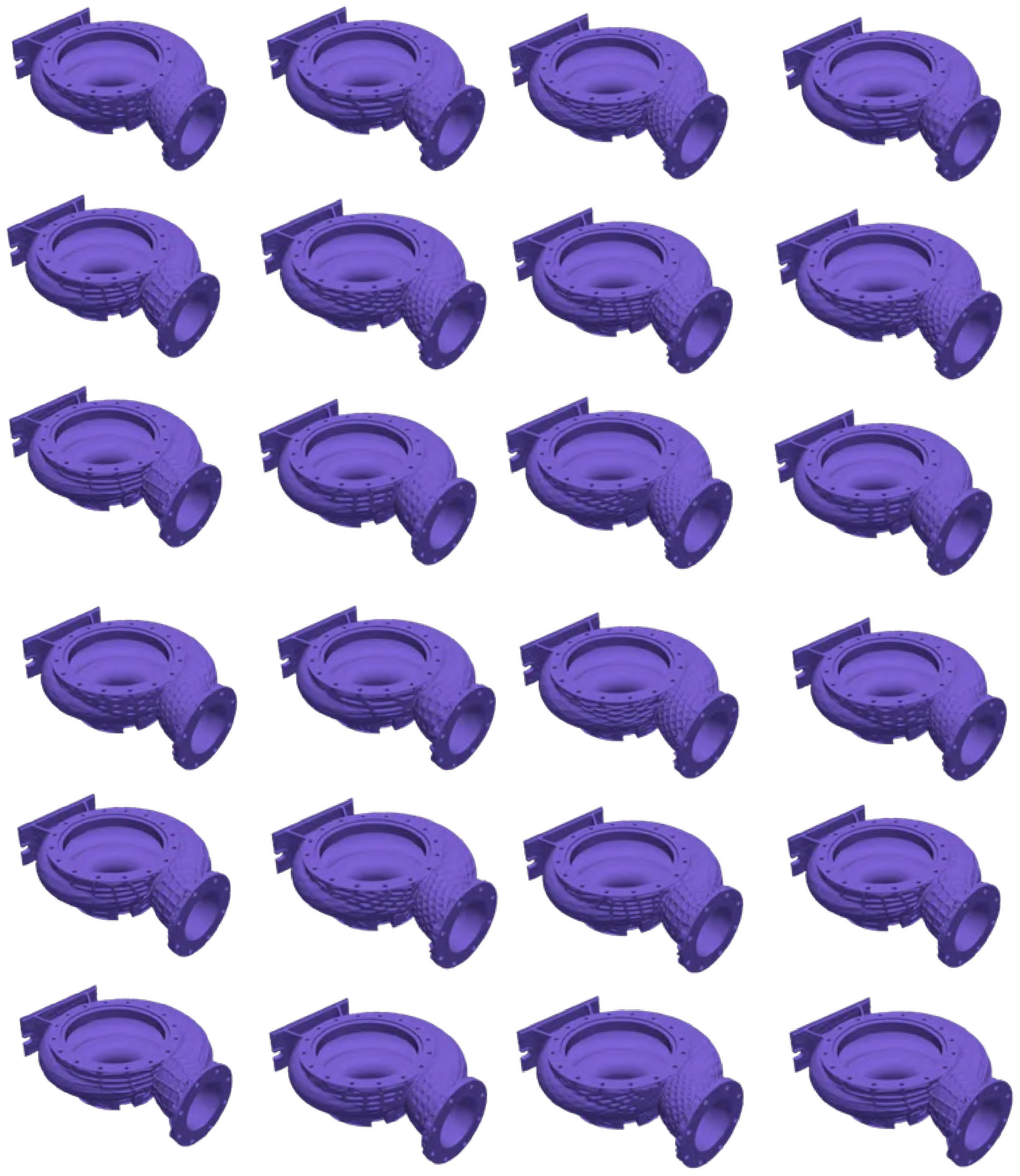
1. Design Space & Load Cases

The engineering team imported the legacy housing geometry and locked all Preservation Zones: coolant port inlets and outlets, the impeller bearing seat bore, the engine block mounting bolt pattern, and the impeller-side sealing face. Load cases were set at 2.0 bar operating and 3.5 bar burst pressure, M8 bolt preload with vibration from 5 to 200 Hz, and thermal cycling from -40 to 130 degrees C. The team selected AlSi10Mg-T5 for its higher yield strength (240 MPa) over the A356-T6 legacy baseline. Die casting constraints were embedded from the start: minimum rib thickness 2.0 mm, blend radius R2.0 at all junctions, external-only rib geometry.

2. Generative Exploration

The core of the workflow was running a parametric DoE sweeping wall thickness (2.0 to 4.5 mm), rib height (3 to 10 mm), rib count (4 to 12 per zone), and root blend radius (R1.5 to R4.0) simultaneously, generating 50+ variants in parallel. A conventional workflow would produce 3 to 5 concepts manually over several weeks. Each variant was ranked on mass, peak von Mises stress at burst pressure, and manufacturability score.
A Pareto front identified the lightest design meeting all structural and casting requirements.





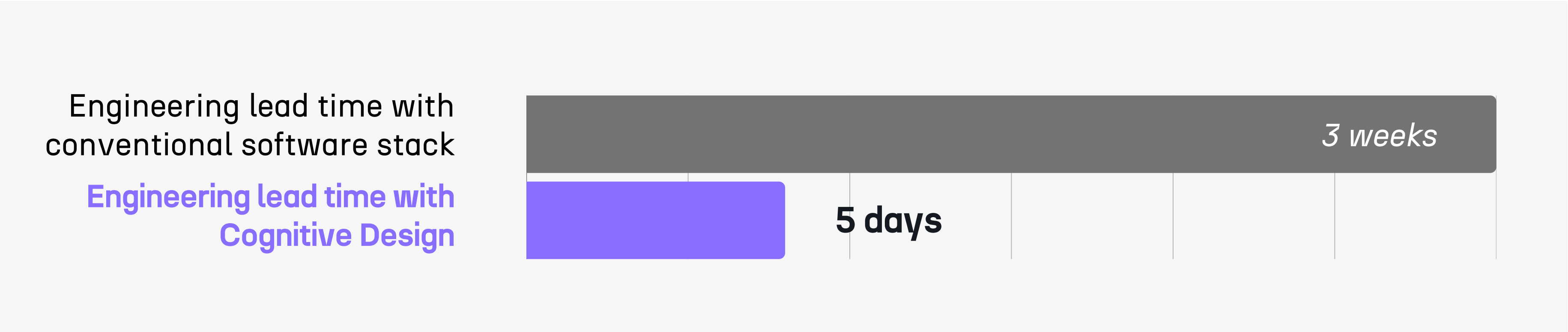
The Solution: Cognitive Design Workflow

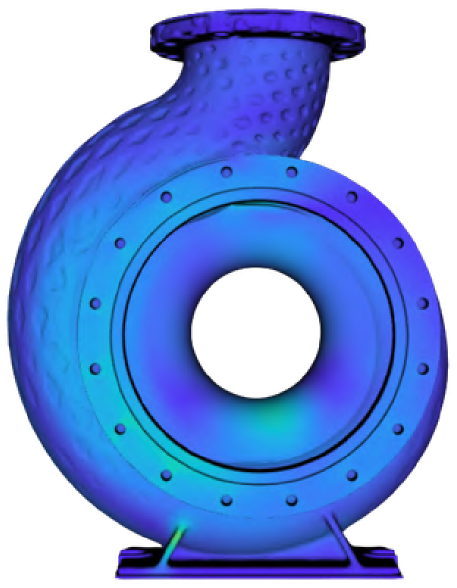
3. Finding the Best Trade-off

The initial Pareto front revealed that the lightest castable geometry raised peak stress from 82 MPa to 118 MPa, well within the 240 MPa yield limit but above the original safety margin. Rather than accept the heaviest safe candidate, the project team used **Simulation-Driven Design (SDD)** to add wall thickness back only where **meshless FEA** showed it was needed: two bolt boss regions and the highest-pressure dome zone. This localized reinforcement brought peak stress to 98 MPa while preserving a **25% mass reduction**.

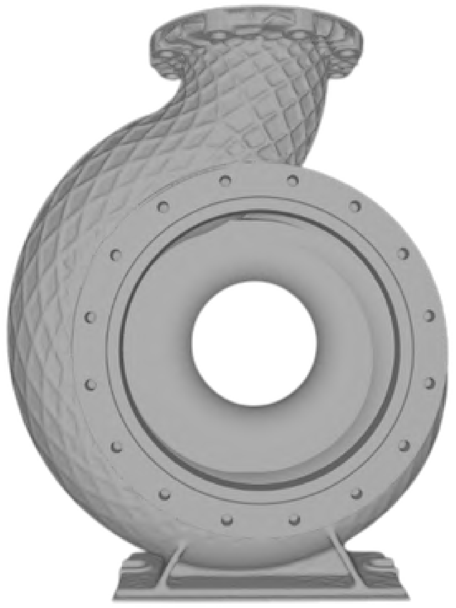
4. Manufacturability & Final FEA

Every candidate in the DoE was assessed through **Manufacturing-Driven Design (MDD)**, which enforced casting rules at generation and eliminated non-castable variants before ranking. The customer's engineers confirmed the selected design with a full FEA run at 3.5 bar burst. Peak von Mises stress reached 98 MPa against a 240 MPa yield strength, giving a safety factor of 2.4 versus 2.9 on the legacy baseline, recovering the structural overcapacity without sacrificing integrity.





FEA Validation



Optimized Model

Key Metrics Comparison

Metric	Legacy (A356-T6)	Optimized (AlSi10Mg-T5)	Improvement
Mass	1.85 kg (Est.)	1.38 kg (Est.)	-25% (Est.)
Max Von Mises Stress	82 MPa (Est.)	98 MPa (Est.)	Within allowable
Safety factor	2.9 (Est.)	2.4	Optimized, requirement met
Concepts explored per part	3-5 (manual, sequential)	50+ variants (parallel DoE)	10x more design options
Engineering lead time	~3 weeks (Est.)	~5 days (Est.)	~4x faster