COMBINING GENERATIVE DESIGN AND ADDITIVE MANUFACTURING FOR NEXT-GEN COLD PLATES (>2000 W TDP)

DIABATIX

POWDER METALLURGY

GENERATIVE DESIGN FOR AM

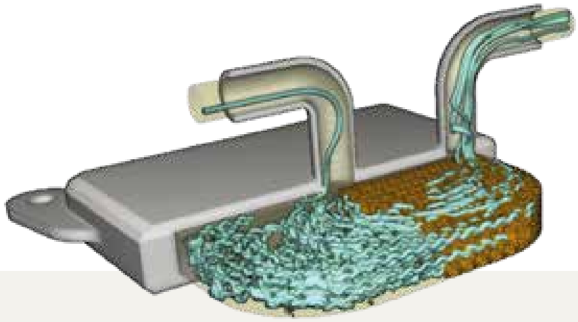
ACHIEVE 42% LOWER THERMAL RESISTANCE

A 2000 W heat load. Identical materials. The same pressure-drop constraint. Yet state-of-the-art generative design reduces thermal resistance by up to 42% while enhancing temperature consistency by up to 40%. This case study demonstrates how generative design redefines liquid cooling performance, particularly in high-power chip applications such as CPU and GPU cooling, where constraints on materials, coolant, and pressure drop allow minimal scope for conventional design strategies.

Conventional fin-style cold plates are reaching their limits as CPU and GPU power densities rise. To demonstrate the performance potential of generative design/manufacturing approaches, benchmark comparisons were performed against high-performance reference designs, a traditional fin design, TPMS based Gyroid, Lidinoid, and GPrimeTwo designs, and a free-form topology, all designed for CuCr1Zr and cooled with a 40/60 water–glycol mixture.

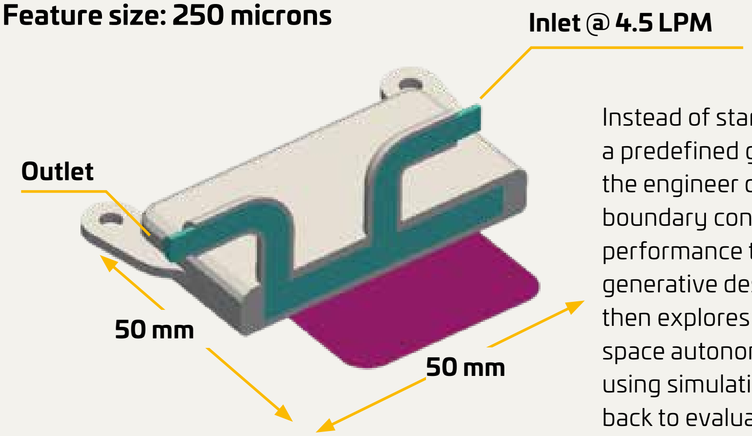
1. Next-Gen Design Thinking

In a conventional design cycle, engineers manually guide each step from concept to final solution. The process begins with a model based on human intuition and proceeds through simulation, post-processing, and performance evaluation. If results fall short, the loop is repeated. Generative design transforms this workflow by minimizing human input. By removing human bias and automating iteration, generative design enables a broader, more objective exploration of possibilities, unlocking solutions that are often unattainable through manual design. This additional design freedom not only expands the solution space, it also helps fully leverage the capabilities of additive manufacturing by producing geometries beyond what traditional methods can conceive or fabricate.



CASE STUDY

Coolant: 40/60 Water Glycol
Solids: CuCr1Zr
Feature size: 250 microns



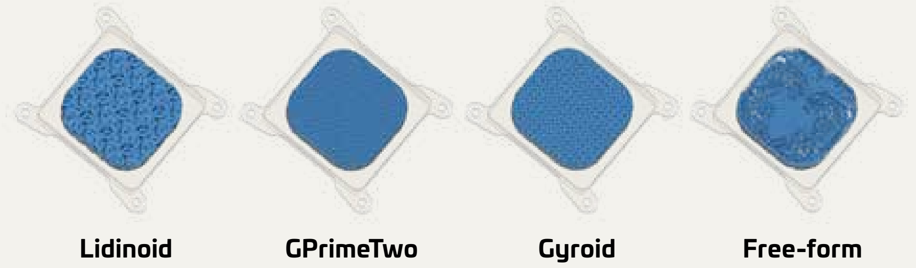
Instead of starting from a predefined geometry, the engineer only defines boundary conditions and performance targets. The generative design engine then explores the design space autonomously, using simulation feedback to evaluate and evolve design candidates.

2.

Improving of traditional TPMS structures

Triply periodic minimal surface (TPMS) structures such as Gyroid, Lidinoid, and GPrimeTwo are frequently used in additive manufacturing for their combination of structural efficiency, fluid and thermal handling characteristics. In this study, these three TPMS designs were evaluated alongside a free-form generative geometry within the same GPU cold plate setup.

Each geometry was subject to a consistent set of manufacturing constraints, representative of industrial metal 3D printing capabilities. These include limitations on wall thicknesses, overhang angles and minimum feature dimensions, such as the 250 µm feature size used in this case. These constraints significantly influence the internal profile of the cooling structure, which in turn governs fluid flow behavior and heat transfer performance. The images below illustrate the layout of all four designs, highlighting the structural differences.

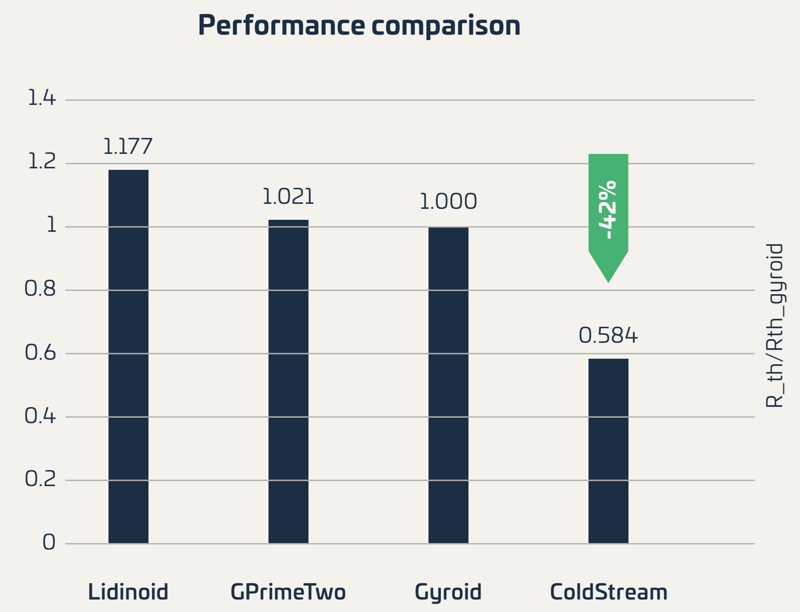


The TPMS design exploration was carried out using ColdStream's generative engine, leveraging its iterative learning capabilities to efficiently identify the highest-performing variant of each structure within the defined design constraints. Unlike traditional optimization techniques, the engine continuously adapts its strategy based on previous outcomes, enabling exploration of a vast parameter space that would be impractical to cover manually or with conventional methods. Each design was evaluated based on its thermal resistance, which was calculated in the most strict sense using the temperature difference between the maximum temperature on the heat source (T_{max}) and the coolant inlet (T_{inlet}), offering a standardized metric for comparison.

$$R_{th}=((T_{max}-T_{inlet}))/Q$$

Close to 1,000 TPMS-based variants were generated and evaluated within this framework. The Gyroid design served as the reference for thermal resistance, against which all other designs were normalized.

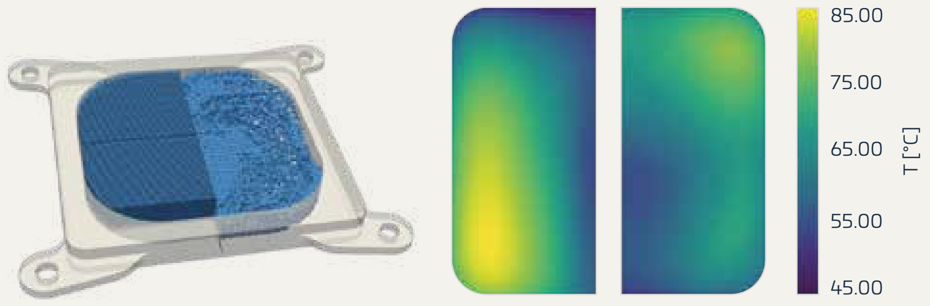
In contrast to TPMS structures, free-form geometries are generated using advanced topology optimization methods. These approaches are not bound by predefined patterns and allow the geometry to vary locally in response to thermal and flow conditions across the design space. This enables precise control over fluid distribution and heat transfer surfaces, tailored to the specific requirements of the application.



As illustrated above, a free-form geometry was generated and evaluated alongside the TPMS designs. The resulting structure achieved a thermal resistance 42% lower than the Gyroid reference. These results demonstrate that while TPMS structures offer a good starting point for performance and manufacturability, significant gains can be realized by advancing to topology-optimized, free-form geometries.

3. Free-Form vs. Skived Fin Design

To evaluate performance against conventional manufacturing techniques, a skived fin heatsink was selected as a baseline for comparison. This design approach is widely used in high-performance thermal management due to its manufacturability and low pressure drop. The same boundary conditions and design envelope were applied to both the skived and the free-form geometry. High-resolution CFD analyses were performed on each configuration to obtain detailed thermal and flow behavior under identical operating conditions.



The image above shows a side-by-side view of the two geometries: the conventionally manufactured skived fin design and the free-form topology generated through generative design. The accompanying temperature field visualization illustrates the differences in thermal distribution, clearly showing the significant improvement of the hot spot coverage and temperature uniformity of the free-form design.

-10%

Thermal Resistance Improvement

The free-form design showed a reduction in thermal resistance of approximately 10% compared to the skived reference. This improvement is attributed to more effective flow guidance throughout the design domain, enabling better coverage of local hot spots on the heat source. The design redirects the coolant more effectively, enhancing the overall heat extraction in the component.

-39%

Temperature Uniformity Improvement

Beyond the peak temperature difference, the free-form design significantly improved thermal uniformity. Measured as the variance in local chip temperature, the generative design reduced the temperature spread by 39% relative to the skived design. This tighter temperature distribution is crucial for temperature sensitive components, helping to mitigate thermal stress and improve the overall reliability.

4. Design for Additive Manufacturing

The designs in this study were developed with DfAM principles accounted for, enabling the direct fabrication of the geometries. GKN Powder Metallurgy supported the process by providing input on DfAM constraints and by manufacturing the final part. It is worth noting, however, that the generative design approach itself is not limited to a single manufacturing method and can be adapted to a wide range of production techniques and constraints.

GKN ADDITIVE

Your engineering and contract manufacturing partner to enable next-gen cold plates.

KEY FACTS

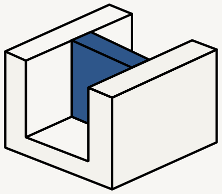
- Global production sites in USA, Germany and China
- Automated additive manufacturing production lines
- Structural integrity of microchannels
- 100% quality control: (He-Leaktest, thermal performance)
- 2M AM serial parts/year
  Serial products across Automotive, Industrial and Consumer markets
- Quality certified (IATF16949, ISO 14001, ISO 5001, ITAR)
- Focusing on semicon, automotive and defense industry
- Qualified and field tested material properties → CuCrZr1
- >99.6% density
- 89.3% ± 1 IACS electrical conductivity
- Thermal conductivity (heat capacity = 382 J/k*K)
  - 356 ± 4 watts per meters kelvin @ 30 °C
  - 393 ± 4 watts per meters kelvin @ 100 °C
  - 390 ± 4 watts per meters kelvin @ 200 °C
- Thermal diffusivity
  - 0.825 ± .013 cm2/s @ 21 °C
  - 0.751 ± .012 cm2/s @ 100 °C
  - 0.709 ± .014 cm2/s @ 200 °C

Material properties	**Symbol**	**As built**	**After heat treatment**
Density [g/cm^3]	ρ	8.91	
Density [%]	%	99.6	
Ultimate tensile strength [MPa]	UTS/R_m	238±5	230±7
Yield strength [MPa]	YS/$R_{p0.2}$	200±4	191±6
Fatigue endurance limit [MPa]	FEL/6_D	Fatigue properties are available upon request	
Young’s modulus [GPa]	E	95±15	108±6
Fracture elongation [%]	A	15.9±1	17.3±1.1
Hardness	HV0.1	107.9±3.6	85±1
Electrical conductivity [%]	%IACS	23.3±0.7	89.3±1
Surface roughness in z-direction after sand blastung	R_a	4.3±0.4	
	R_2	22.7±5.5	

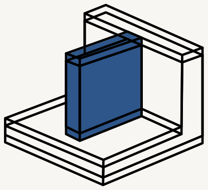
DESIGN FEATURES

AM Design Guidelines for generative designed cold plates

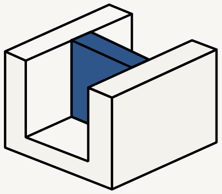
Min. supported wall
0.2 mm



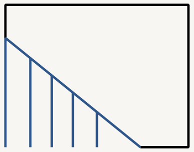
Min. unsupported walls & spacing
0.2 & 0.25 mm



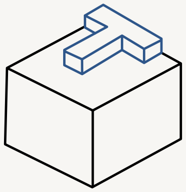
Max. wall thickness
<35 mm



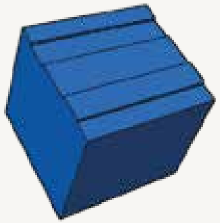
Overhanging surfaces
45° min. without support structures



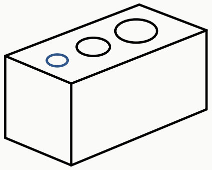
Min. proud/ embossed size
0.15 mm



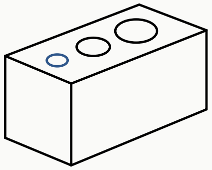
Min. engraved/ debossed size
>0.15 mm



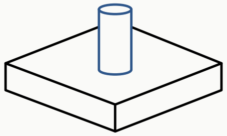
Min. holes dia
0.4 mm



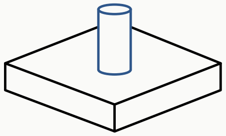
Hole aspect ratio
xy:z, 5:1



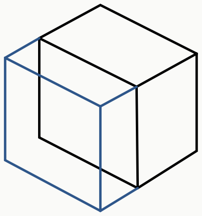
Pin min. size
0.3 mm



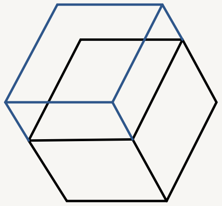
Pin max. aspect ratio
xy:z, 8:1



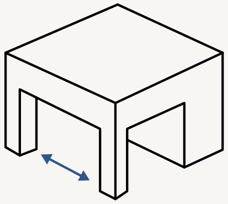
Overall tolerances of features of size
IT 11–13 (±0.15)



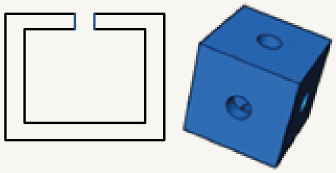
Max. part size
390 x 390 x 380 mm



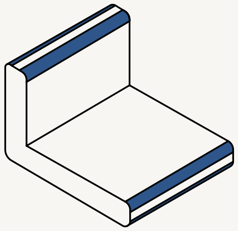
Min. unsopprted edges
0.5 mm



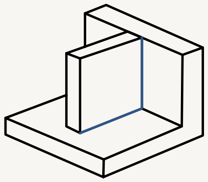
Internal cavities and channels
2–4 mm / 2 channel min



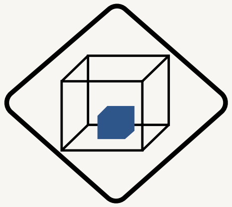
Corners/chamfers/ edgebreaks
0.1 mm



Internal fillets
0.5 mm



Target part size
100 x 100 x 80 mm
(larger parts possible)



5. Summary

This study demonstrates how generative design can significantly enhance the thermal performance of CPU and GPU cooling components. Compared to conventional TPMS-based structures, a topology-optimized free-form design achieved a 42% reduction in thermal resistance by adapting the geometry to obtain the desired local thermal and flow conditions. In a second benchmark, the same free-form design outperformed a skived fin heatsink, delivering a 10% lower thermal resistance and a 39% improvement in temperature uniformity, critical for managing hotspots in high-power devices.

The design conditions used in these comparisons, such as the operating conditions, the skived fin layout, heat load, and boundary conditions, were selected to provide a clear and representative benchmark. While many variations of the above can be explored, the study clearly illustrates how generative design methods can adapt to specific thermal and geometric constraints. The results demonstrate that, starting from any defined design space and operating conditions, ColdStream can automatically generate high-performance cooling solutions tailored for additive manufacturing.

These complex designs are then manufactured in automated additive manufacturing production lines at GKN Additive in Europe or the USA. Typical production volumes range between 5,000 and 100,000 cold plates per year.

About Diabatix

Diabatix is a technology leader in generative design software for thermal management. Its flagship platform, ColdStream, is redefining how engineers approach cooling challenges by automating the creation of high-performance, manufacturable designs across a wide range of industries.

About GKN Powder Metallurgy

GKN Powder Metallurgy is a global leader in powder metal solutions, producing innovative, high-performance components for various industries. With 28 manufacturing locations worldwide, GKN Powder Metallurgy specializes in powders, sintered metals, and additive manufacturing.

Authors

Dilsher Dhillon
Business Development Manager USA
GKN Powder Metallurgy
dilsher.dhillon@gknpm.com

Dr. Patrick Köhnen
Business Development Manager Europe
GKN Powder Metallurgy

Eduard Ulrich
Business Development Manager Europe
GKN Powder Metallurgy

Ine Vandebeek
CTO
Diabatix

Lieven Vervecken
CEO
Diabatix

For more information, visit:

diabatix.com **gknpm.com**

GKN POWDER METALLURGY AT A GLANCE

World leading provider of metal powder solutions

gknpm.com

POWDER METALLURGY