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Thermal–Structural and Fatigue Assessment of Ventilated Brake-Disc Geometries under Repeated Motorsport Braking

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INTRODUCTION

Motorsport brake discs experience repeated high-energy braking, causing heat accumulation, thermal gradients, stress and deformation. Drilling, grooves, reduced thickness and two-piece construction can improve cooling, but may also remove load-bearing material or change structural continuity.

The engineering challenge is therefore to improve heat rejection without creating an unacceptable structural penalty.

AIM & OBJECTIVES

Aim: To investigate how ventilated brake-disc geometry affects temperature distribution, thermo-mechanical response and fatigue-related behaviour under repeated braking using FEA.

- Compare eight disc geometries under common loading.
- Derive repeated-braking heat input from MoTeC telemetry.
- Run transient thermal → structural → fatigue analysis.
- Identify the best overall thermal–structural compromise.

REAL-WORLD MoTeC TELEMETRY

Brands Hatch Lap 4 was used to define the braking windows from vehicle speed and brake-pressure traces.



Brake application: 1.599 s



Brake release: 4.199 s

LAP DURATION
91.831 s
6 braking events / lap

REPEATED LOAD
5 laps
30 events • 459.155 s

Event-specific kinetic-energy reductions were converted into heat-flux inputs rather than using one arbitrary constant load.

MODEL INPUTS & BOUNDARY CONDITIONS

Brake Disc	256 mm OD × 20 mm ventilated
Rotor material	EN-GJL-250 grey cast iron
Vehicle mass	≈ 630 kg
Initial / ambient	22°C
Radiation emissivity	0.8
Structural pressure	251 kPa per friction face

LIMITATIONS & FUTURE WORK

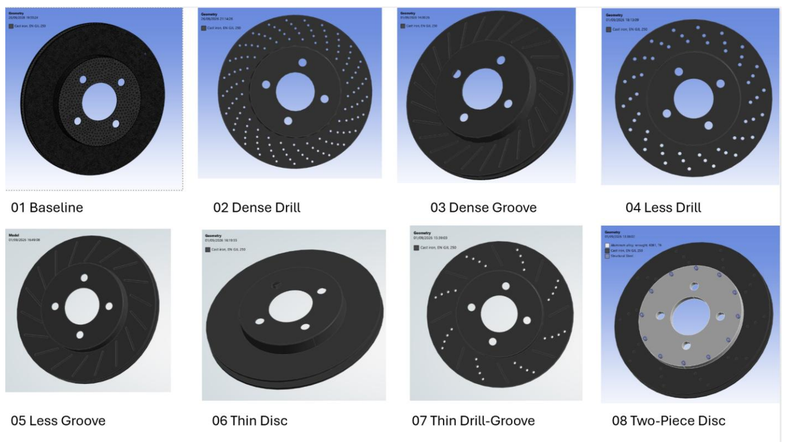
- Prescribed convection rather than geometry-specific CFD.
- Heat flux applied without explicit rotating pad–disc contact.
- Temperature-dependent fatigue data were simplified.
- Two-piece rotor used bonded contacts, not a true floating joint.
- Future work: dyno/track validation, CFD and improved floating-interface modelling.

REFERENCES / ACKNOWLEDGEMENTS

Selected references: Belhocine & Bouchetara (2013); Grzes (2019); Park et al. (2022); Pevec et al. (2014).

Acknowledgement: Andrew Noble and UWTSD for project guidance and facilities.

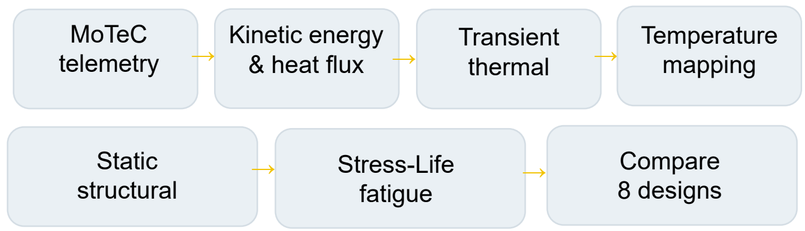
EIGHT BRAKE-DISC GEOMETRIES



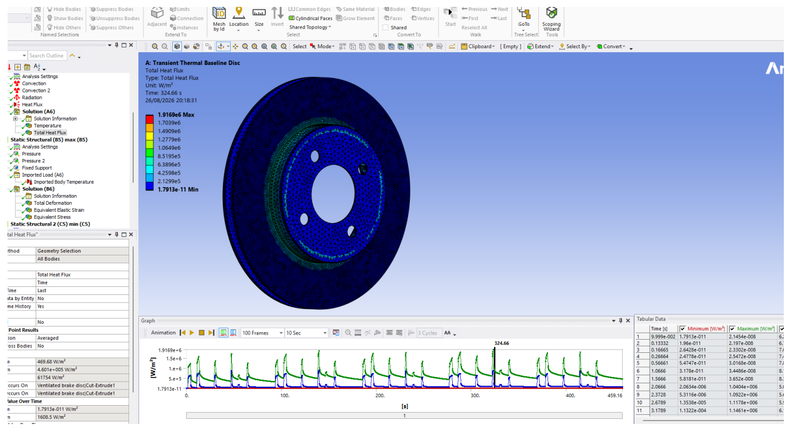
01 Baseline • 02 Dense Drill • 03 Dense Groove • 04 Less Drill • 05 Less Groove • 06 Thin • 07 Thin Drill-Groove • 08 Two-Piece

Geometry was the principal design variable; the two-piece concept also introduced an aluminium bell and steel fasteners.

METHODOLOGY

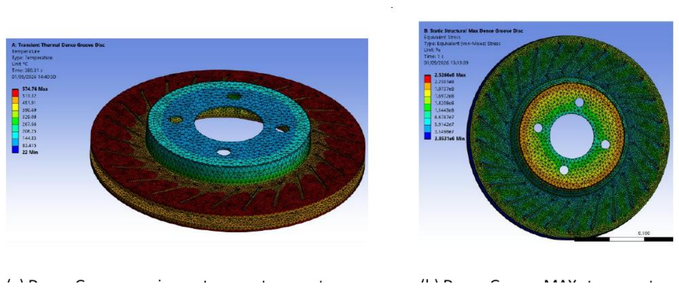


Repeated heat-flux history used in ANSYS



Transient thermal solution over five repetitions of the 91.831 s lap.

DENSE GROOVE — BEST OVERALL COMPROMISE



Dense Groove: maximum-temperature and MAX equivalent-stress contours.

PEAK TEMP.
574.74°C
−7.80% vs baseline

FINAL AVG. TEMP.
329.72°C
−13.24% vs baseline

MAX STRESS
252.66 MPa
−1.13% vs baseline

MAX DEFORMATION
0.74969 mm
≈ baseline level

ENGINEERING INTERPRETATION

Cooling improvement and structural performance must be judged together. Dense Groove retained more structural continuity than through-drilled designs while still reducing temperature.

- Dense Drill: best peak-temperature control, but higher stress.
- Thin Drill-Groove: best accumulated cooling, but higher stress/deformation.
- Dense Groove: strong thermal reduction with near-baseline or slightly improved static structural response.

KEY RESULTS

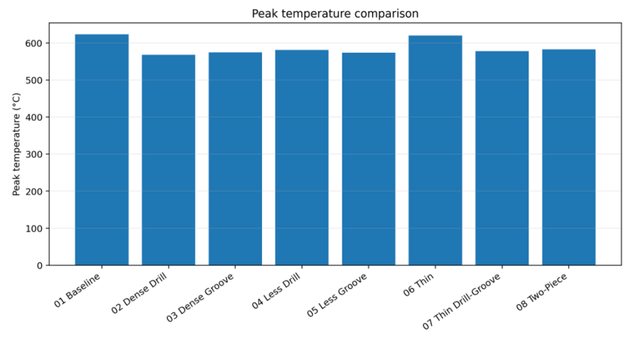
LOWEST PEAK TEMP.
568.37°C
Dense Drill • −8.83%

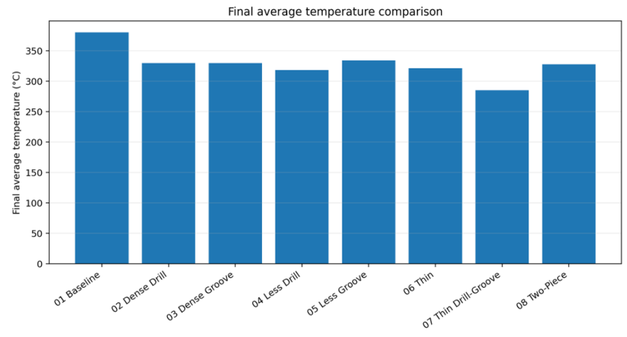
LOWEST FINAL AVG. TEMP.
284.97°C
Thin Drill-Groove • −25.02%

LOWEST MAX STRESS
252.66 MPa
Dense Groove • −1.13%

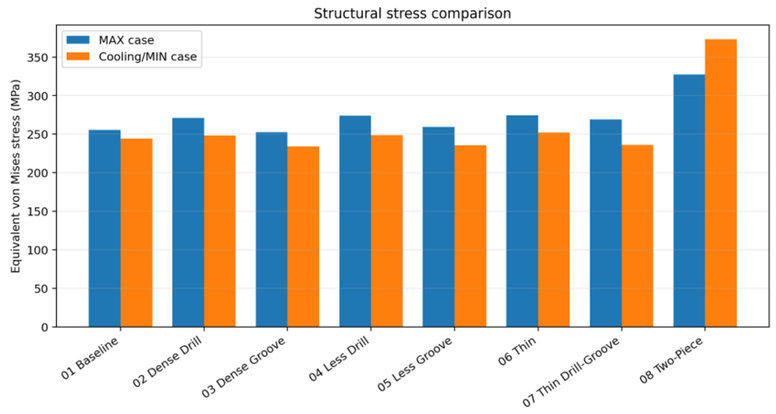
BEST OVERALL
Dense Groove
Thermal–structural compromise

THERMAL PERFORMANCE

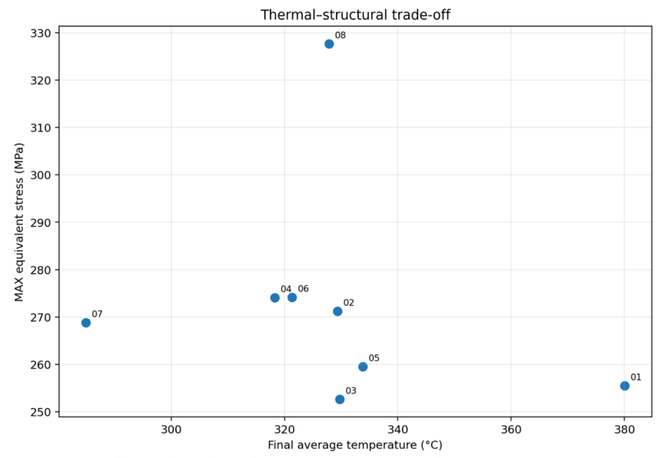




STRUCTURAL PERFORMANCE



THERMAL–STRUCTURAL TRADE-OFF



Best direction: lower temperature + lower stress.

CONCLUSION

- Brake-disc geometry significantly changed both thermal and structural response under repeated braking.
- All seven modified designs reduced final average temperature relative to the baseline.
- The design with the strongest thermal performance did not necessarily provide the strongest structural performance.
- Within the model assumptions, Dense Groove provided the most favourable overall thermal–structural compromise.

KEY FINDING

Better cooling did not automatically produce better structural performance.

Dense Groove provided the best overall thermal–structural design-screening result.

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