BGA Project 6 – Phase III

Research Programme 2010/2013 at Design Unit

1. OBJECTIVES AND POTENTIAL BENEFITS

The objective of this programme is to seek practical measures to increase the gear micropitting threshold stress by greater than 20% and reduce the micropitting wear rate by 50% compared to the current representative industry practice. Achieving this will make a significant contribution to reliability improvement and size and weight reduction of power transmission systems needed particularly in wind power, aerospace and defence (Land, Sea and Air) industries.

2. BACKGROUND

The outcome of the previous two phases of work of Project 6 has enabled the BGA Consortium members to gain a better understanding of gear micropitting. It is now clearer what the most influential variables linked to micropitting are and therefore what is worthy of investigation in this, the next phase of work. The most popular topics for further investigation identified by the Consortium members include surface texture, surface coatings, different oil types, micropitting threshold stress, gear material, surface treatments, micropitting wear rate and effects of different geometry modifications. With the support of the Consortium members, the BGA, the MoD (Navy) and QinetiQ, a programme of work covering all of the above topics is proposed.

3. COMBINED TEST MATRIX

Comparative gear rig testing will be the main investigatory tool for this research project. The following Table 1 defines the base level condition. A complete test matrix shown in Table 2 explains how tests are planned, and shared between Design Unit and QinetiQ. Design Unit is to investigate 11 out of the total 16 gear conditions.

Table 1 Definition of Base Level Condition

Note: DU will be Helical (160 mm) and QinetiQ will be Spur (FZG at 91.5 mm)

	Topic	Design Unit	QinetiQ
a.	Gear Type	Helical (33:34)	Spur (16:24)
b.	Material	18CrNiMo7	16MnCr5
c.	Heat Treatment	Case Carburised	Case Carburised
d.	Condition (after H/T)	Shot Peen Roots	Shot Peen Roots
e.	Surface Texture (Standard Ground)	Niles	Niles
f.	Aim Surface Finish (Flank)	0.45 µm Ra	0.45 µm Ra
g.	Surface Treatment	none	none
h.	Lube ('Medium' gear oil from Shell)	Oil 1	Oil 1
i.	Lube Temperature	90 °C	90 °C
j.	Tip Relief / Transition	50 µm, linear *	none

* to be verified.

Table 2 Proposed Test Matrix – Design Unit and QinetiQ Combined

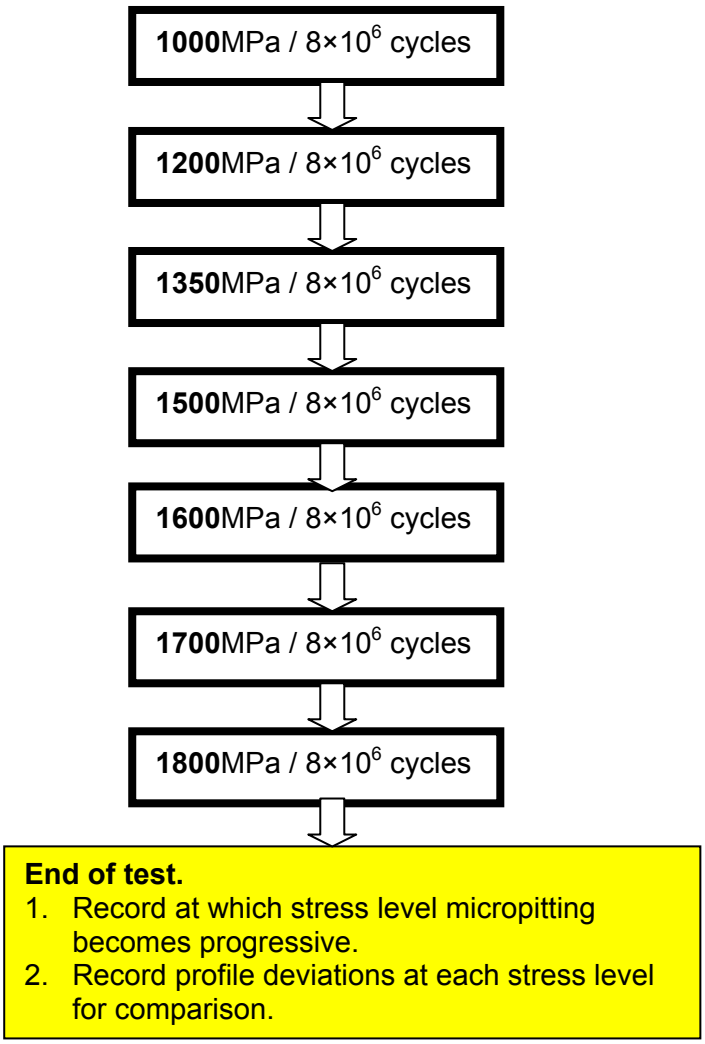
	Title	Design Unit	QinetiQ	Comments
Test # 1	Base Only	✓		Both gears
Test # 2	Material 2	✓		Both gears. [tba. Possibly S156].
Test # 3	Oil # 2		✓	Both gears. ['Good Gear Oil' from Shell].
Test # 4	Form Ground		✓	Both gears. [same Ra but produced on the Holroyd].
Test # 5	Ra Variation		✓	Both gears. [Base or Form ground]. {only 1 value?}.
Test # 6	Micro-Geometry		✓	Both gears. [Tip relief moves micropitting initiation]. {2 values/ 2 tests?}.
Test # 7	Superfinishing 1	✓		Both gears. [Case by MIC]. {study change in the shape/ blend of the tip relief}.
Test # 8	Superfinishing 2	✓		Both gears. [REM]. {study change in the shape/ blend of the tip relief}.

Test # 9	Std & Superfinished	✓		Gears different. Best of 7 or 8 against Base gear.
Test # 10	Just Shot Peened	✓		Gears different. Shot peened (for hard gears) Pinion against Base gear (Wheel). Navy interest.
Test # 11	Coating 1	✓		Both gears. Balzers 1.
Test # 12	Coating 2	✓		Both gears. Balzers 2.
Test # 13	Coating 3	✓		Gears different. Coated Pinion against Base gear (Wheel). Navy interest.
Test # 14	'Best of' Series 1	✓		Both gears. Best of Coating (test 11 to 12) on top of Best of Superfinishing (test 7 to 8).
Test # 15	'Best of' Series 2	✓		Gears different. Best of Coating (test 11 to 12) on top of Best of Superfinishing (test 7 to 8) against Base gear.
Test # 16	Base Only		✓	Both gears

4. DESIGN UNIT TEST PROGRAMME

A Design Unit 160 mm back-to-back gear test rig will be used for this project. Two pairs of gears will be tested at a time (one pair at each end of the rig) and there will be 2 data points generated in each run (test). The test method proposed by Design Unit is a stepwise method as explained below. Two data points will be generated for each of the 11 gear conditions and gear micropitting performance in terms of threshold stress and wear rate will be evaluated based on a total of 22 data points.

Stepwise micropitting test: A stepwise micropitting test involves running gears at incrementally increasing contact stress levels with each stage running for up to 8 million cycles as illustrated by Flowchart 1. The starting contact stress level will be 1200MPa and the contact stress of each load stage is 10% higher compared to the previous one. Gear profile deviation will be monitored after each stage of running, in order to quantify the damage from micropitting. These values will be used to differentiate the micropitting performance of gears with the different variables. The stepwise test will also reveal at which stress level a substantial increase in the level of micropitting damage is seen. This will give an indication of the threshold stress for progressive micropitting and assess how quickly micropitting develops (wear rate) at a certain contact stress level.



Flowchart 1. Procedure of stepwise micropitting test

5. COSTS

The outline programme of work given in sections 3 and 4 includes 11 micropitting stepwise tests to generate 22 data points, for which a total of 22 test gear pairs will be required.

Assuming that gear material, heat treatment, surface engineering and lubricants are provided by the Consortium members as in-kind support, the cost of the work to be performed by Design Unit (i.e. not including Administration costs) will be as follows:

i.	Gear design (preparation of manufacturing drawings)	£ 1 500
ii.	Manufacture of 22 test gear pairs at £1000 per pair (including detailed metrology/materials characterisation)	£ 22 000
iii.	11 micropitting stepwise tests (22 test points) at £6 000 per test	£ 66 000

iv.	Monitoring , analysing & reporting at £1500 per test point, 22 test points	£33 000
v.	Attendance of DU staff at 3 project meetings at £950 per meeting at DU, 3 project meetings at £1500 per meeting away.	£ 7 350
vi.	Final report preparation and presentation	£ 5 000

Total cost of work programme at Design Unit: **£134 850**

Design Unit will provide BGA with support for this research in the form of a 25% discount from our normal commercial rates detailed above, thus:

Total cost of work programme for BGA research at Design Unit: **£101 138**

6. TIMESCALES

Gear manufacture and testing will require at least 2 years to complete. Therefore, it is proposed that the work outlined above will be completed over a 3 year period. The work is directed by the Project Co-ordinator in conjunction with the project consortium who, by a majority vote, may alter the direction of the research as the project progresses and the results become available.

The initial milestones are as follows:

End of Project Year 1: Complete Items i & ii as specified in Section-5 Costs.
End of Project Year 2: Interim report for Item iii (50% of tests) as specified in Section-5 Costs.
End of Project Year 3: Complete Item iii as specified in Section-5 Costs.

Items iv and v in Section-5 overarch the whole three years of the Project.

Design Unit
27th September 2010