AMRC
Process Technology Group

The University Of Sheffield.

Advanced Manufacturing Research Centre

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SAMULET 2
Work Package 4: Coolant trials
(Redacted for Hangsterfer's information)

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Introduction

A coolant study was undertaken investigating the effect of changing the cutting fluid/coolant on the process output. The process used for the basis of this investigation was the Trent 1000 XWB IP compressor rotor 2 aerofoil. 5 coolants were tested including the original coolant production product and the Hangsterfer's 5080 product.

The testing consisted of machining Ti-6Al-4V blocks using each coolant product at the current production cutting parameters for semi-finishing with the current aerofoil semi-finishing tool (Sandvik 316 high-feed inserted tool). The blocks were used to assess tool wear, cutting force and surface finish progression at regular intervals after a specific level of material removal.

The original production coolant was tested at 14% concentration, as currently used in production and at 7% concentration. All other coolants were tested at 7% concentration for comparison against the existing baseline product. When tested, the original coolant product at 7% showed signs of material pick up/plucking which is consistent with the original process development and the reasons behind increased coolant concentration to 14% in production.

The coolant tests showed that the Hangsterfer's 5080 coolant reduced the tool wear by 50% for the same material removal and produced a lower surface finish with an Ra of between 0.015-0.03µm in the direction of the feed which was very well controlled when compared with the other coolants. Due to the reduction in tool wear and the cost of the Hangsterfer's product being lower than the baseline (mainly due to the reduced concentration required) a projected cost saving per annum has been estimated at £133,118. This is based on a single full refill of each product per year because an appreciation of the fluid top-up/maintenance could not be accurately measured during the trials short time-frame.

For this reason it is recommended that the Hangsterfer's 5080 product be taken through to the batch run of components during work package 7 and that further testing be applied to investigate the use of this product within the Rolls-Royce production facility.

Machine tool definition

Current production machine tool – DMG Mori-Seiki NT4250

Trials machine tool – DMG Mori-Seiki Dura Vertical, selected for low cost against trial length

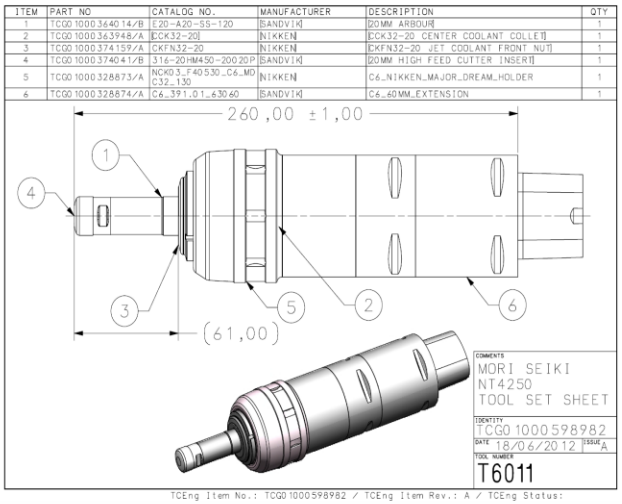
Coolant product details

Coolant	Trial Concentration	pH	Cost (£/l)	Cost per Machine Fill (£)
Product 1 (Baseline)	14	9	7.3	2248.4
Product 1 (Baseline)	7	9	7.3	1124.2
Product 2	7	9	8.34	1284.36
Product 3	7	9	3.356	516.824
Product 4	7	9	3.32	511.28
Hangsterfer's 5080	7	9	7.65	1178.1

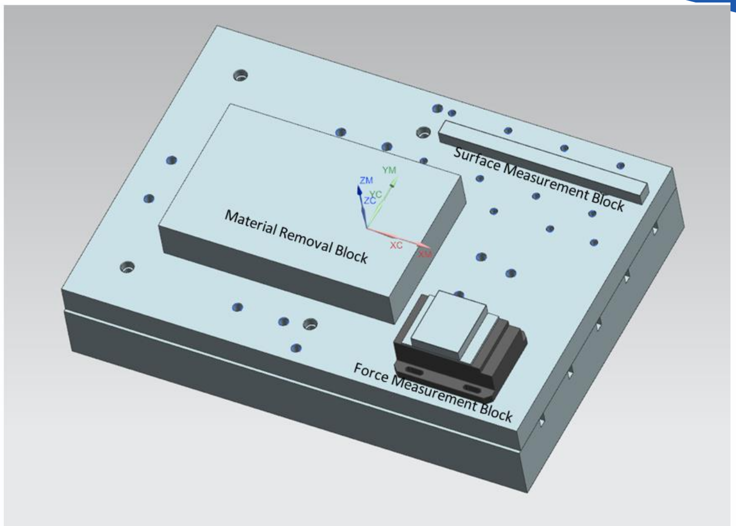
5 distinct coolant products tested, down-selected by the Rolls-Royce IPT from the Rolls-Royce approved products list.

Information has been redacted to protect suppliers.

Trials description



The aerofoil semi-finishing tool was used for the trials as it required an appropriate level of tool wear against material removal to support the trials machine window and minimise the impact of error.



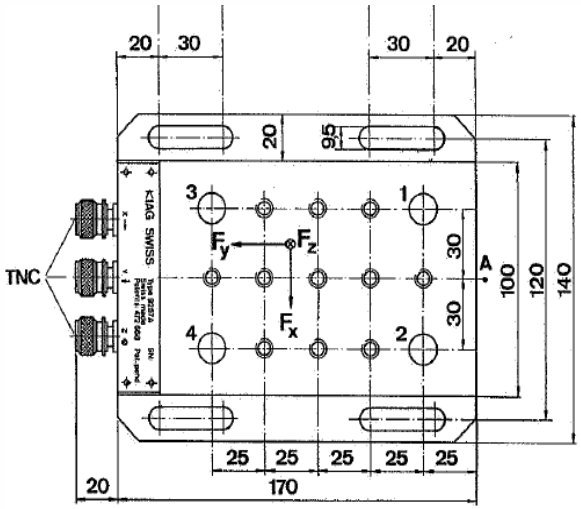
Three blocks were located on the machine bed; a large material removal block, surface measurement block and a force measurement block. After the equivalent material removal rate of semi-finishing one aerofoil component a sample is taken on the force measurement block and the surface measurement block. Additionally the tool wear is measured.

Trial Parameters	
Parameter	
Surface Speed (m/min)	81
Feed per tooth (mm/tooth)	0.2884
Radial depth of cut, Ae (mm)	2.4
Axial depth of cut, Ap (mm)	1

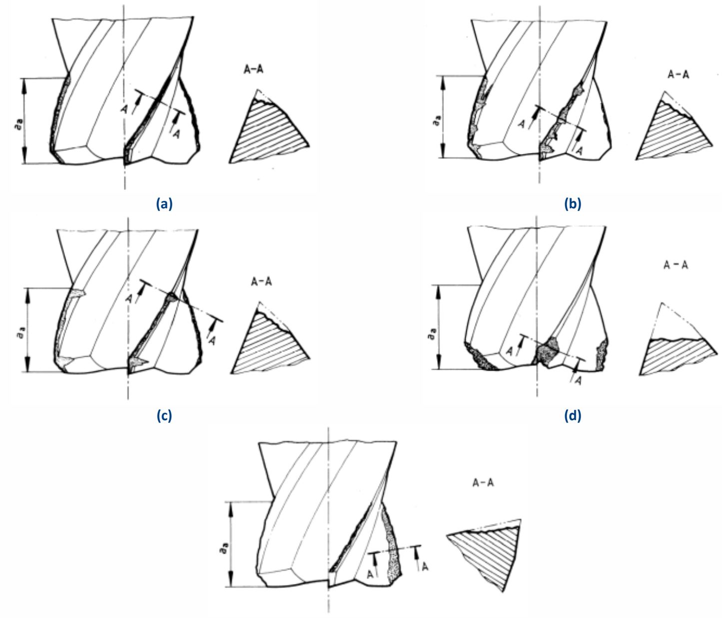
Force measurement

Force measurements were taken using the following equipment

Equipment Type	Model
Dynometer	Kistler three-component dynometer 9257A
Data Acquisition Device	Kistler 5697A DAQ
Connection Cable	Kistler 1685B5 fischer cable
Charge Amplifier	Kistler 5070A10100 4ch charge amp

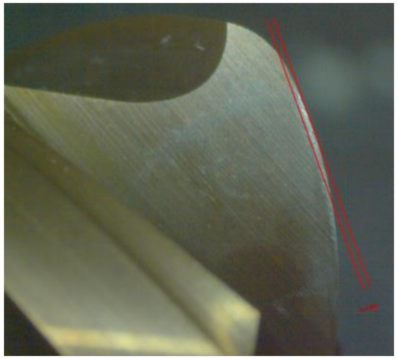


Tool wear measurement

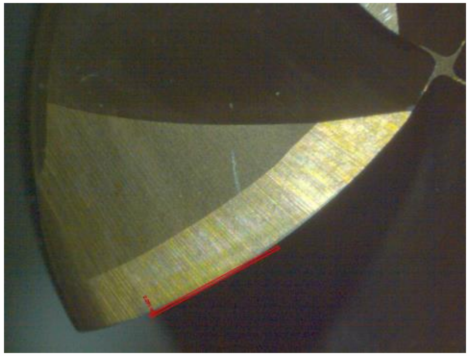


Description of different wear types on a tool (ISO 8688-2), these were used as reference for the tool wear data collected

Tool wear was measured normal to the cutting edge on the flank and rake face of the tool.
The measurements were taken on a Zeiss AxioCam ERc 5S microscope



(a)



(b)

Surface Integrity

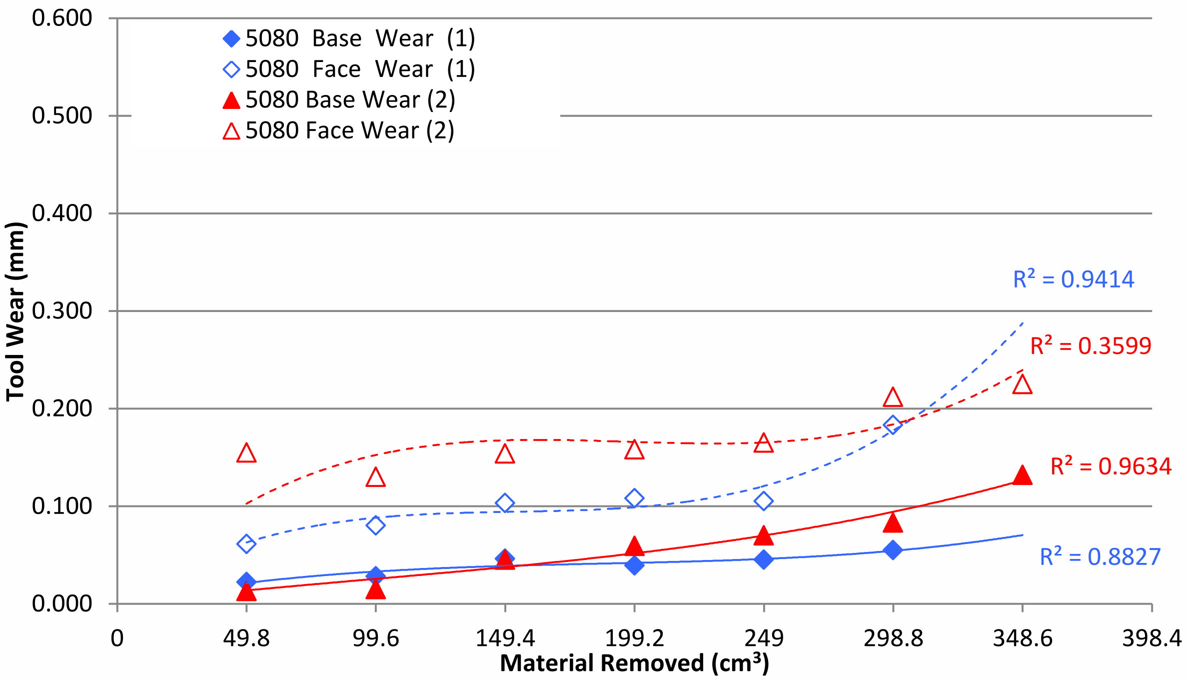
Following the trials there was a surface integrity block that had been machined at regular intervals during each of the coolant trials (as per the test plan). This surface integrity block recorded how the machined surface altered as the tool wear increased during the trials.

The surface integrity for each coolant trial and repeat was checked under the Zeiss AxioCam ERc 5S microscope and measurement software. Two areas approximately 5mm x 5mm from the start, middle and end of the tool passes were inspected to assess visible surface damage and for re-deposited material ("black spot").

The surface integrity blocks were also used to take surface roughness measurements using the Taylor Hobson Precision Surtronic Duo. This is a stylus measurement device used to take a surface roughness measurement in the feed direction. The output screen shows the profile roughness as a measure of Ra.

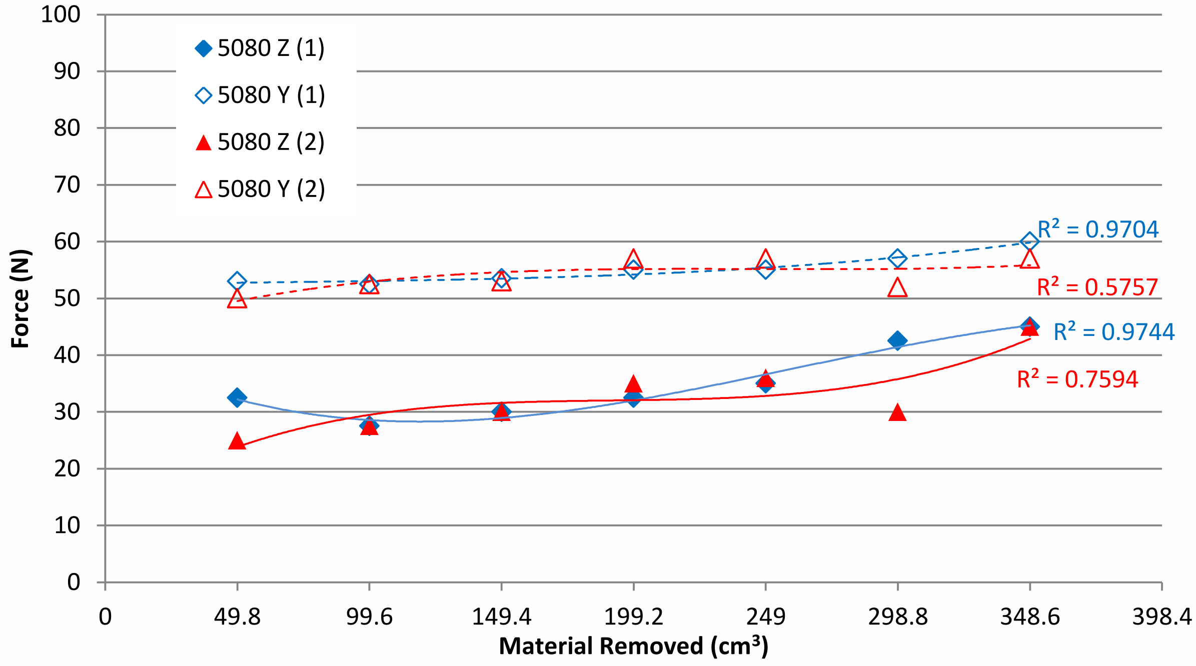
Surface condition is related to the tool wear and forces applied during metal cutting however, it is also dependent on the properties of the coolant employed and their effect on the specific cutting method. For this reason it was important to capture the surface condition and surface roughness resultant from the coolant trials.

Hangsterfer's 5080 wear measurements



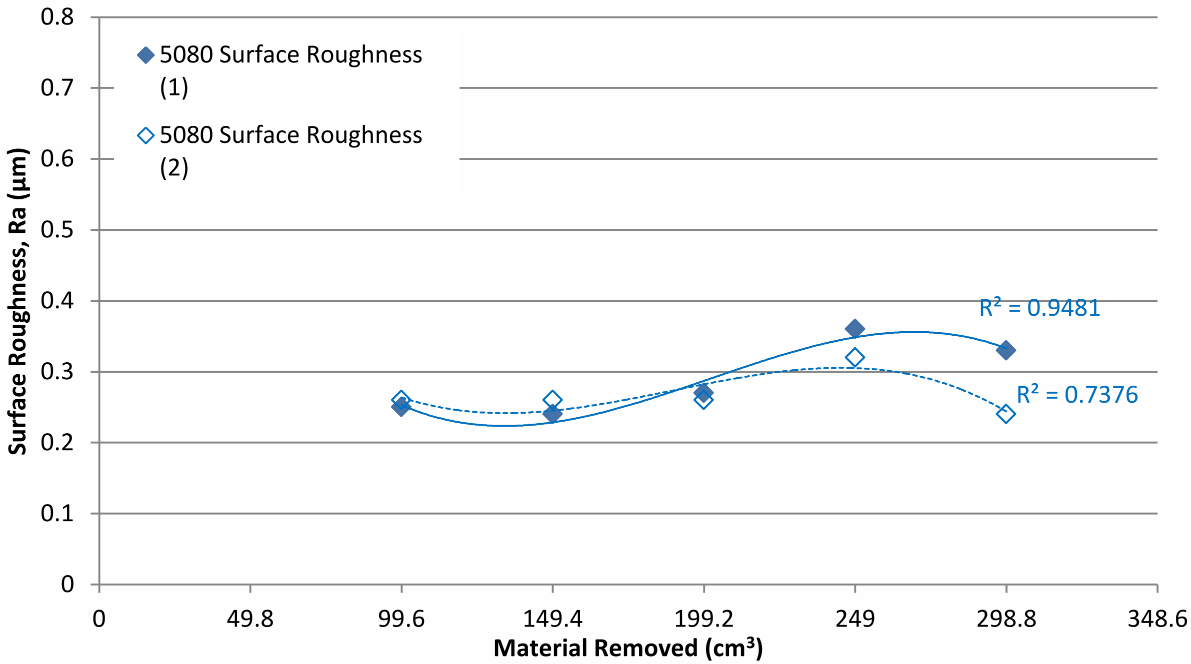
Looking at figure it is possible to see that there is a very good correlation between the base wear results for the first and second tool trialled. The face wear results are quite significantly different in the magnitude as test two is higher than test one (0.061mm compared with 0.155mm initial wear) however the rate of increase is very similar. The wear increases on both faces during the trials at the same rate.

Hangsterfer's 5080 wear measurements

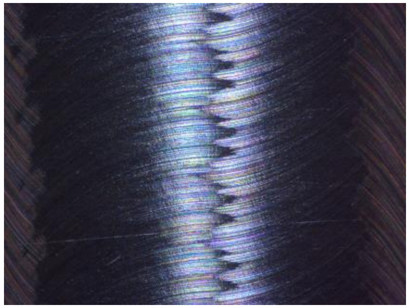


The figure shows very good repeatability of the two tools used for the Hangsterfer's 5080 (7%) trials when measuring forces in both axes.

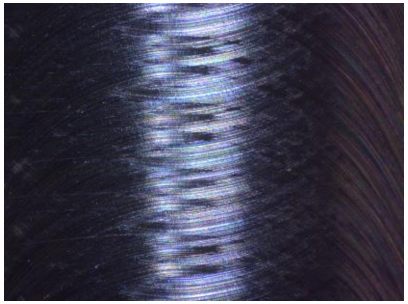
Surface Roughness and Integrity



The figure shows the surface roughness of the two trials in the 5080 shows good consistency, the values are similar and increase in a similar trend during the trials. The final surface finish of test two is a lot lower than that of test one but also significantly lower than the previous inspection point at 249cm³ so it can be concluded that this is an anomalous recording.



(a)



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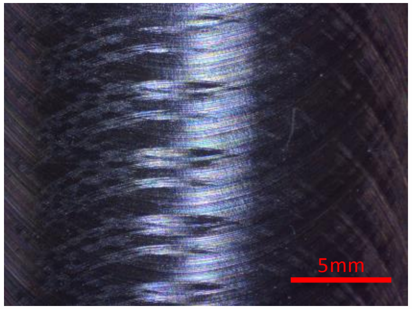

(c)

The Hangsterfer's 5080 product resulted in the best surfaces condition from the trials the surface condition is very consistent and evidence of tool wear effecting cutting conditions only occurs later in the trials. No black spot or re-deposited material was exhibited.

Comparison of Hangsterfer's 5080 to the other products – Rake wear

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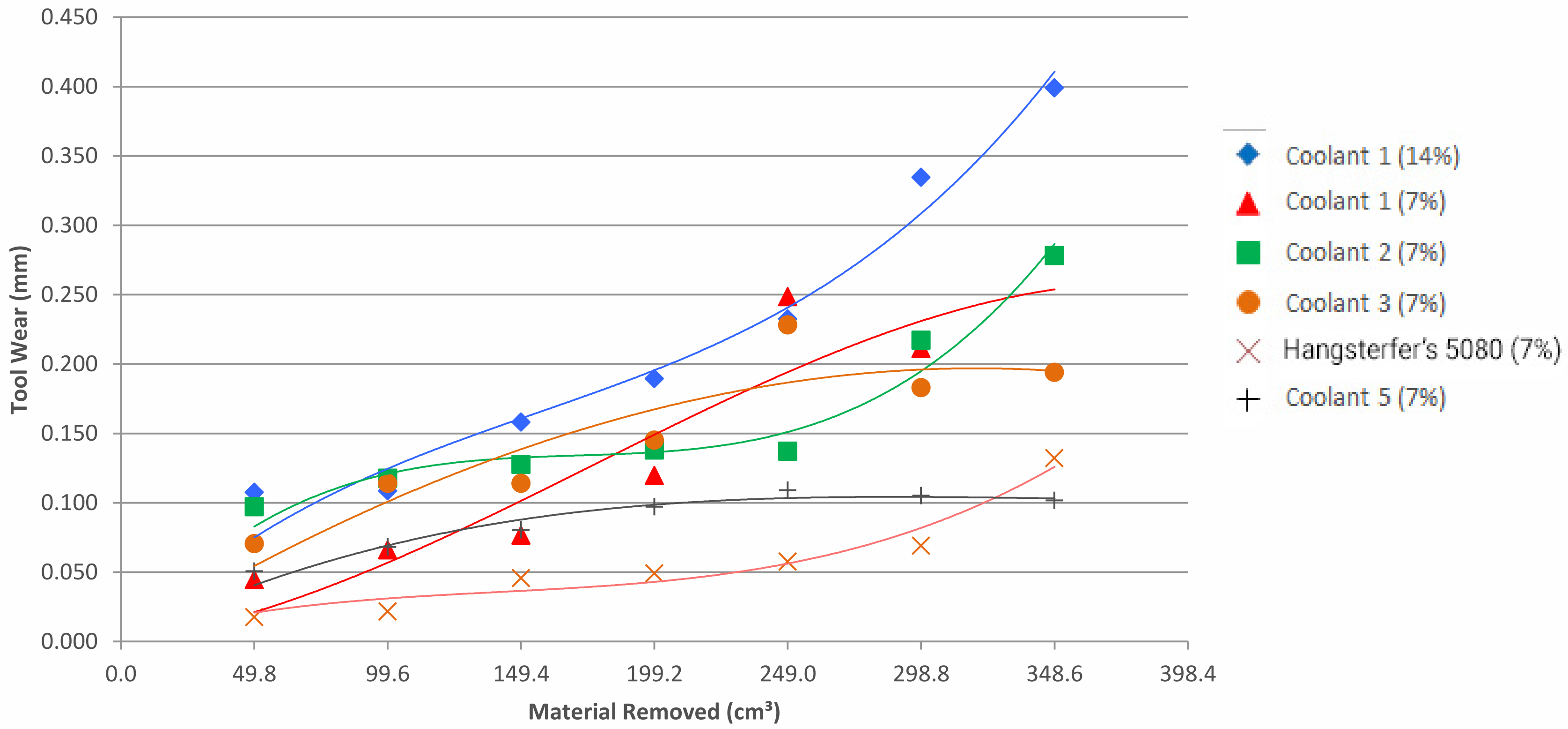
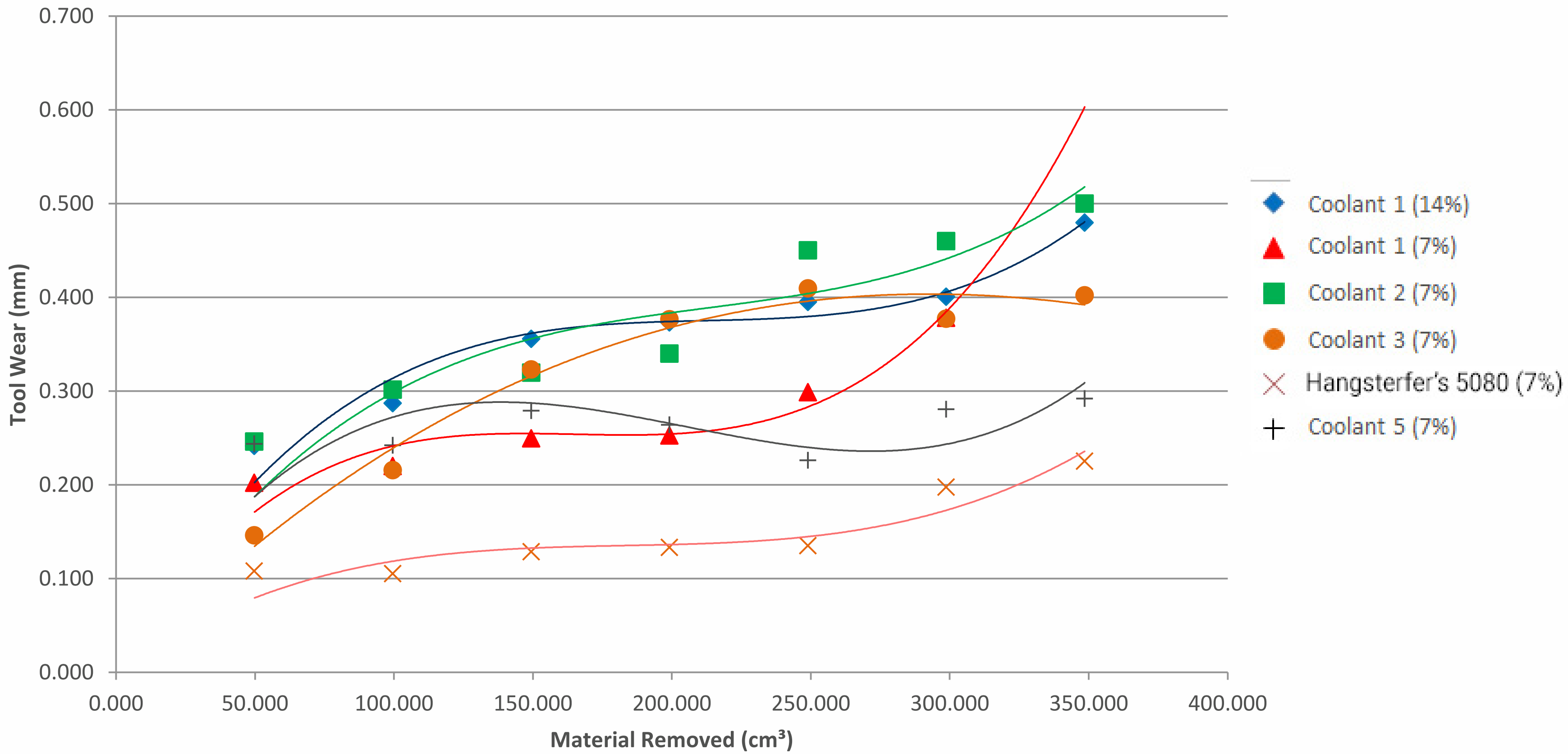


Hangsterfer's exhibited the lowest rake wear throughout the trials until the equivalent of 7 parts were machined.

Comparison of Hangsterfer's 5080 to the other products – Flank wear



Hangsterfer's exhibited the lowest flank wear throughout the trial.

Comparison of Hangsterfer's 5080 to the other products – Force Z

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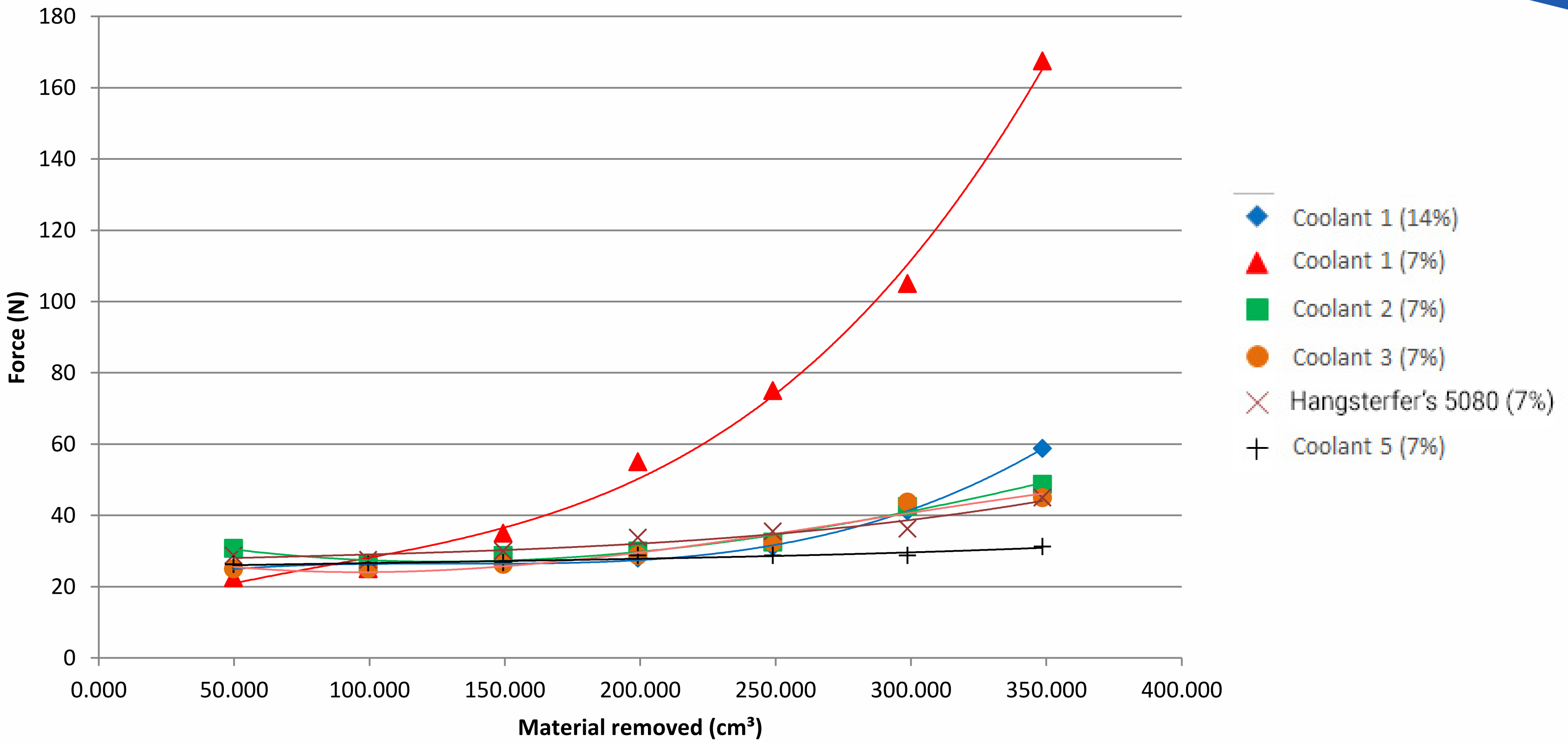
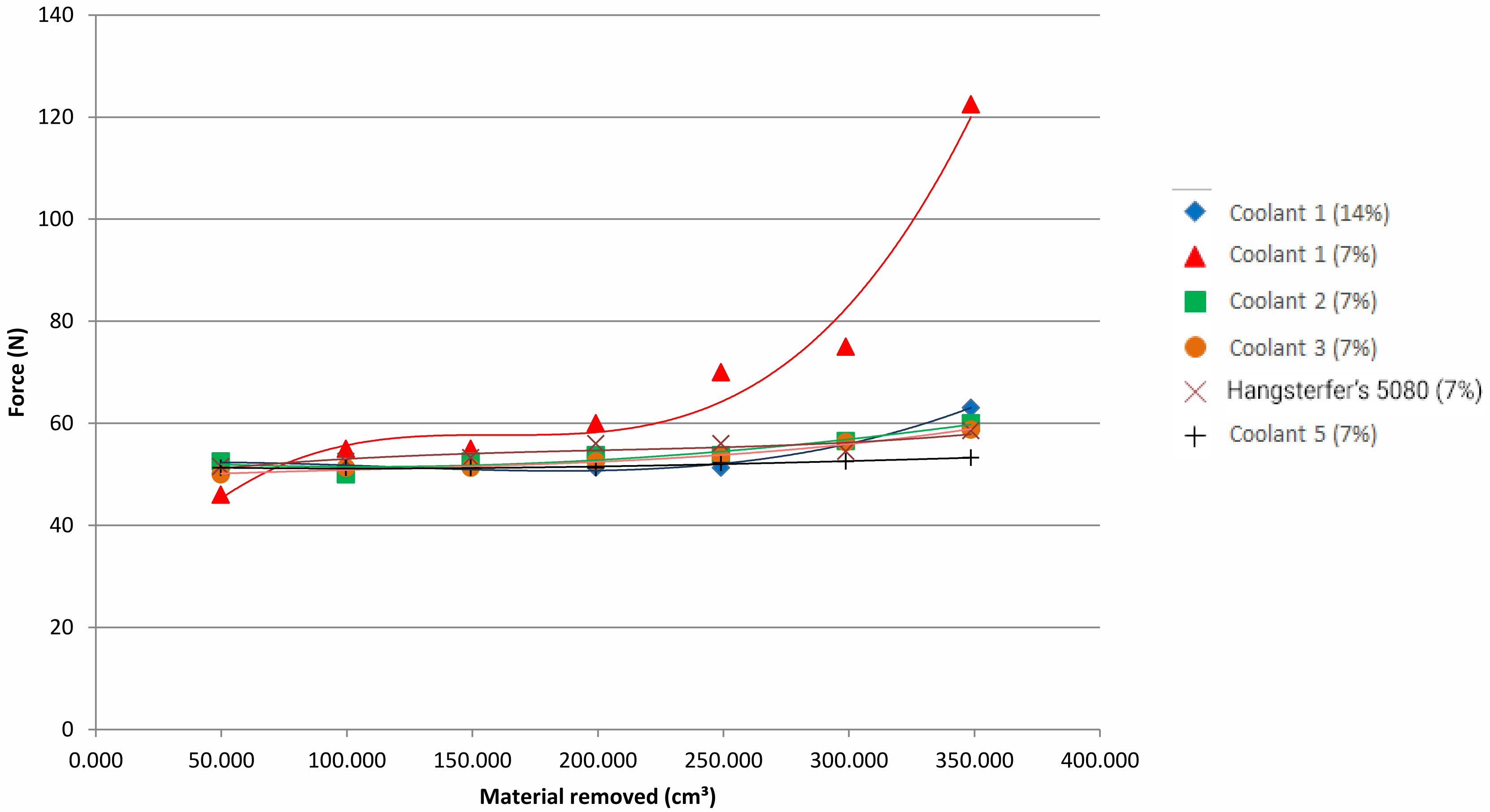


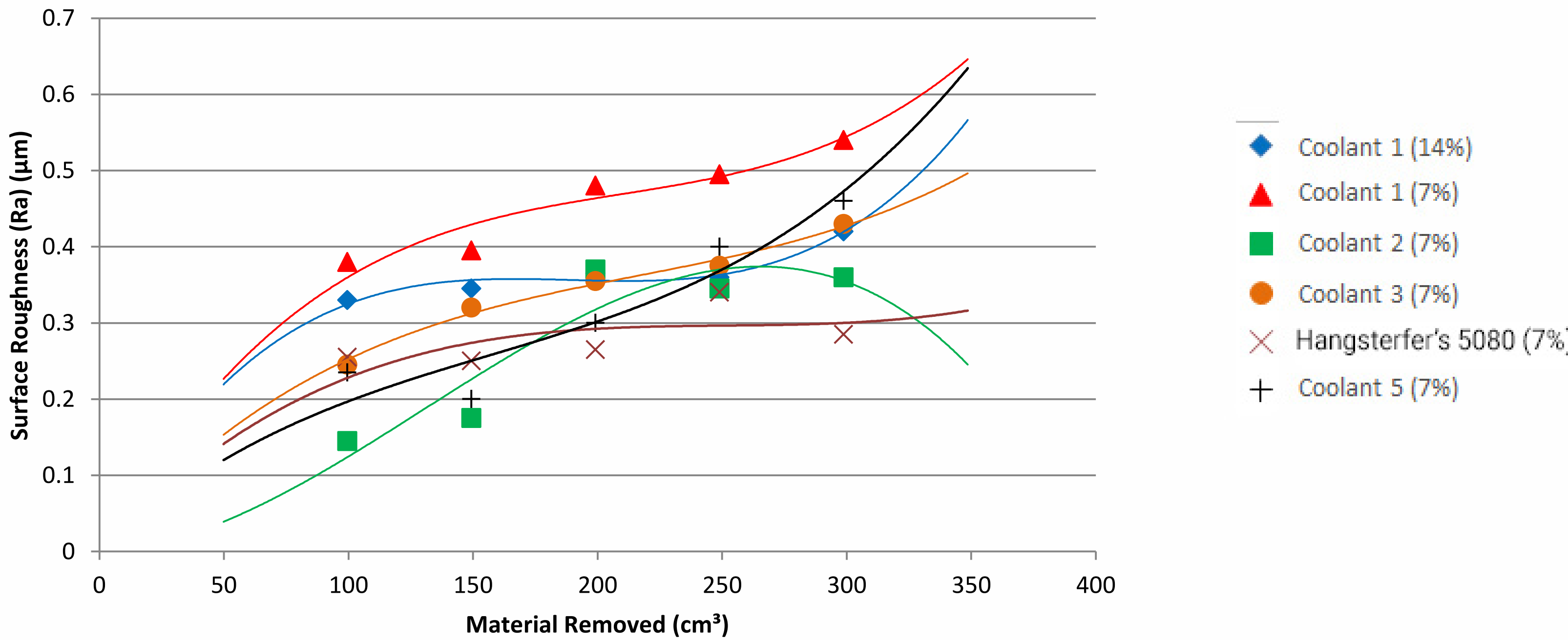
The forces applied during the trials were similar for all coolants except product 1. Hangsterfer's 5080 was positioned in the middle of the other coolant products.

Comparison of Hangsterfer's 5080 to the other products – Force Y



The forces applied during the trials were similar for all coolants except product 1. Hangsterfer's 5080 was positioned in the middle of the other coolant products.

Comparison of Hangsterfer's 5080 to the other products – Surface Roughness



The surface roughness measurements showed that Hangsterfer's 5080 improved the surface roughness of the test pieces produced compared to the baseline coolant and produced a much more consistent result than any other product.

Projected savings

Coolant	Trial Concentration	Cost per Machine Fill (2200 litres)	Tool Wear range (mm)	Surface finish range (Ra) (µm)	Projected tool cost saving per year (assuming 35 parts per week)
Product 1 (Baseline)	14	£2248.4	(0.357 - 0.402) 0%	0.29 – 0.45	Original production coolant
Product 1 (Baseline)	7	£1124.2	(0.187 – 0.327) 19%	0.38 – 0.63	18.8%
Product 2	7	£1284.36	(0.070 – 0.301) 25%	0.13 – 0.41	25.2%
Product 3	7	£516.824	(0.013 – 0.277) 31%	0.24 – 0.52	31.3%
Product 4	7	£511.28	(0.040 – 0.303) 25%	0.26 – 0.33	24.9%
Hangsterfer's 5080	7	£1178.1	(0.010 – 0.200) 50%	0.15 - 0.36	50%

The Hangsterfer's 5080 product produced a much lower tool wear regime which if projected results in a far greater tool life. It is anticipated that the cost saving will not be fully realised although it is indicative of the potential. When this is considered against the improved surface finish and integrity exhibited on the test pieces then the Hangsterfer's 5080 was clearly the best coolant product to propose for further trialling within RR Inchinnan.

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