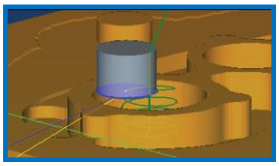


NSERC Canadian Network for Research and Innovation in Machining Technology (CANRIMT2)
NSERC Project Number: NETGP 479639 - 15

Project Interim Progress Report
(Rapport d'avancement de project intérimaire)
May 1 – October 31, 2019

Please submit by October 25, 2019
(Attn: management@nserc-canrimt.org)

Instructions
This progress report, updated milestones and the Form 300 are required as a condition of research funding support from the sponsors of the NSERC CANRIMT. ***Please report for activity in the current reporting period only.***

SUMMARY

THEME IV: ***Adaptive Tooling/Processes & Novel Manufacturing Processes/Applications***	**Leader/ Chef:** *(Veldhuis, McMaster)*
PROJECT ***IV.C.6*****:–** ***Understanding the Role of Coolant in Grey Cast Iron Machining Utilising c-BN Machining***	**Leader/ Chef:** *(Veldhuis, McMaster)*
PROJECT DURATION/DURÉE DU PROJET : 2 years	
STATUS/STATUT: ***(Milestones** to be updated by each Project Leader)*	

Ahead of Schedule		On Schedule	X	Delayed		Cancelled	

PROJECT DESCRIPTION/ DESCRIPTION DU PROJECT
(*Brief description in point form, including role of project in Theme.)*

- Industry has reported that coolant can result in huge differences in c-BN life (up to a 400% improvement).
  - Coolant was not directly addressed in NSERC-CANRIMT Phase 1 but is an important part of optimising the machining process.
  - Coolant represents an excellent way to introduce additional elements into the cutting zone, which can be strategically chosen to control temperature and enhance the formation of beneficial tribofilms and lubricants.
- This project will also make use of the results coming from project IV.D.2 which focuses on effective coolant delivery by rendering a coolant jet to be coherent by conditioning the fluid through mechanical and chemical means.
- This approach is being developed for grinding in IV.D.2 but will be adapted in this project to address the needs of cutting applications.
- High pressure coherent jets will be used to facilitate the precise application of fluid to the tool rake face-workpiece interface for effective control of tool temperatures, and on to the rake face for chip control.

PROJECT OBJECTIVES & METHODOLOGY/ OBJECTIFS DU PROJET & MÉTHODOLOGIE
(Include alignment with Network objectives.)

1- Obtaining a better understanding of the effect of different cooling systems/materials during machining of cast iron

2- Optimising the coolant delivery system for obtaining the best cooling performance and choosing the proper cooling material and conditions for enhancing the cooling action and improving the general cutting performance.

1. RESEARCH TEAM/ ÉQUIPE DE RECHERCHE
(Summary for the current reporting period)

1a: Research Personnel (Supervisors, Co-Supervisors, Collaborators)/ Personnel de recherche

Name, given name/ Nom., prénom	*Organization/ Organisation*	*Sup./Co-Sup./ Collaborator*	*E-mail/Courriel*	*Phone No./ Téléphone*
Stephen C. Veldhuis	McMaster	Sup.	veldhu@mcmaster.ca	905 525 9140 Ext. 27044
Kevin Boyle	CANMETMaterials	Collaborator	kevin.boyle@canada.ca	905 645 0788

1b: Students, Postdoctoral Fellows, Research Assist./ Assoc./Eng., Technical/Professional, Guests *(from outside Ontario; from outside Canada)*/ Étudiants, Boursier de recherches postdoctorales, assistants, techniciens et invites *(invite hors Ontario; hors Canada)*

Name, given nan Nom., prénom	*Position*	*Organization/ Organisation*	*Name/Nom. (S) or /ou (C)**	*Start/ Début*	*End/ Fin*	*CANRIMT Salary/Mo incl ben.*	*Extern. funding amount*	*Extern funding source*
Yousef Shokoohi	Student	McMaster	Stephen C. Veldhuis (S)	Jan 2017	Nov 2018	1340	100	*SONAMI (FedDev)*
Jose Mario Paiva	Postdoctoral	McMaster University	Stephen C. Veldhuis (S)	Feb 2017	Dec 2018		4200	SONAMI (FedDev)
German Fox-Rabinovich	Research Associate	McMaster University	Stephen C. Veldhuis (S)	Mar 2003		5333	5310	SONAMI (FedDev)

(S) – Supervisor
(C) – Co-Supervisor

TOTAL #	**BASc**	**MASc/ M.Eng.**	**Ph.D.**	**PDF**	**Res. Asst.**	**Res. Assoc.**	**Res. Eng.**	**Tech./ Prof.**	**Guests/ outside Ontario**	**Guests/ outside Canada**
3		1		1		1				

1c: Partners & Contributions/ Partenaires et Contributions

Organization / Organisation	*Acronym/ Acronyme*	*Contact*	*Cash/ Espèce*	*In-Kind/ Nature*	*Overhead/ Frais généraux*	*Total*
Honda McMaster-Veldhuis Projects		Mark Earle	120,000	152,500	30,000	150,000

2. RESEARCH PLAN FOR THE CURRENT PERIOD/PLAN DE RECHERCHE POUR LA PÉRIOD ACTUELLE *(Please list both the technical objectives, methodologies and milestones as stated in the previous report.)*

1- Literature review **(Completed)**
2- Machining tests have been done on hardened H13 steel in dry, flood and superabsorbent coolant conditions **(Completed)**
3- Tapping and drilling tests under different cooling conditions has been done on Silicon Aluminium alloy **(Completed)**
4- Turning tests on Inconel718 with superabsorbent coolant include copper and Magnesium oxide nanoparticles to understand the range of function for different materials and machining operations **(Completed)**
5- New portable and in-expensive delivery system has been designed **(completed)**
6- Presentation has been prepared for next VMPT conference **(Completed)**
7- Preparing results for paper with MgO and Copper nanoparticles for submission in scientific journals **(Completed)**
8- Conducting complementary machining tests: grey cast iron **(Completed)**
9- Thesis writing **(Completed)**

3. ALIGNMENT OF RESEARCH PROJECT WITH NETWORK OBJECTIVES/ ALIGNEMENT DU PROJET DE RECHERCHE AVEC LES OBJECTIFS DU RÉSEAU

(Please comment on the alignment of the research project with the overall Network objectives.)

One of the main purposes of this project is to optimise the coolant type and delivery system in order to improve the tribological aspects of the machining process and in turn improve the overall productivity of the process, which is in-line with the final objectives of the network.

4. PROBLEMS and RESOLUTIONS/ PROBLEMES ET SOLUTIONS PROPOSÉES

(Please summarize any problems arising during the current reporting period and their resolution or plans for resolution.)

Problem/ Problème:

Resolution / Résolution:

5. RESEARCH PROGRESS and RESULTS/ PROGRÈS DE LA RECHERCHE et RESULTATS:

(Summarize progress and results below.)

5a: MILESTONES/ÉTAPES

Summarize progress on milestones – including % completed – as outlined in the Research Plan for the current reporting period and any modifications since the last reporting period. (Milestones document also to be updated for

each project.)

MILESTONE/ ÉTAPE: Literature review and summary on coolant composition	
Progress: Literature review completed. Tests conducted on different materials(hardened H13, Inconel 718, Aluminum Silicon alloy and Grey Cast Iron) and new delivery system has been made and applied successfully. **Modifications:**	
% Completed/ Rempli	**100**
MILESTONE/ ÉTAPE: Lab testing and characterisation of different coolants	
Progress: Laboratory tests like thermal conductivity measurements and viscosity have been done **Modifications:**	
% Completed	**100**
MILESTONE/ ÉTAPE: Machinability study relating c-BN tool performance to coolant additives	
Progress: Machining tests on Grey Cast Iron with c-BN tool completed. **Modifications:**	
% Completed	**100**
MILESTONE/ ÉTAPE: Production scale testing	
Progress: SAC technology was discussed with a coolant manufacturer and total consumption of the SAC and its cost was evaluated **Modifications:**	
% Completed	**100**
MILESTONE/ ÉTAPE: Conclusion, technology transfer and publication	
Progress: Reply to reviewers file has been sent and waiting for acceptance of the paper. **Modifications:**	
% Completed	**100**

5b: PUBLICATIONS and PRESENTATIONS / PUBLICATIONS ET PRESENTATIONS

Please list all publications directly arising from Network-funded research during the current period. Do not include abstracts.

A: REFEREED CONTRIBUTIONS - ARTICLES

Include articles in refereed publications – please specify whether the article has been submitted (S), accepted (A) or published (P).

Last Name, Initial	*Year*	*Title, Journal, Volume*	*Status*
Shokoohi, YS, Paiva, JM, Fox-Rabinovich, G, Bork, CA and S.C. Veldhuis	*2019*	Evaluation of the Superabsorbent Coolant as a New Approach to Semi-Dry Machining, Int'l J. of Adv. Manu. Tech. April 2019, Vo 101, I5 pp2037-2050.	*P*

B: REFEREED CONTRIBUTIONS - OTHER

Include papers in refereed conference proceedings, letters, notes, communications, review articles, monographs, books, book chapters and government publications.

Last Name, Initial	*Year*	*Description*	*Status*
Shokoohi,YS, Paiva JM, S.C. Veldhuis	2018	Superabsorbant Coolant a new Approach to Semi-Dry Machining, 7th VMPT conference, McMaster University, Hamilton, May 2018 (Oral presentation)	P
		Journal/Book/Publication Title (Status: S-submitted; A-accepted; P-published)	

C: NON-REFEREED CONTRIBUTIONS

Include papers in non-refereed conference proceedings, papers, letters and review articles.

Last Name, Initial	*Year*	*Description*
Shokoohi,YS, Paiva JM, S.C. Veldhuis	2018	*Ontario Aerospace Council (OAC) poster competition, Marriott Hotel, Toronto, March 7, 2018 (Invited)*
		Journal/Book/Publication Title
D: SPECIALIZED PUBLICATIONS - PRESENTATIONS *Include theses, presentations, industrial/technical reports, internal reports, discussions of abstracts and symposium records.*		
Last Name, Initial	*Year*	*Description*
		Journal/Book/Publication Title
E: PUBLICATIONS – ***Not originally funded by NSERC CANRIMT but continuing or completed with Network funding***		
Last Name, Initial	*Year*	*Description/Title* ***(include start date of NSERC CANRIMT funding)***
F: PUBLICATIONS – ***Not funded by NSERC CANRIMT but related to the Network research focus***		
Last Name, Initial	*Year*	*Description/Title*

5c: PATENTS and LICENSES/ BREVETS ET LICENSES

Non-disclosure agreements signed, patent applications filed, patents issued, copyrights, licenses under negotiation, licenses granted, etc.

Category	*Owner*	*Description*
Patent	Yousef Shokoohi, Stephe Veldhuis, German Fox Rabinovich, José Mario Fernandes de Paiva Junior, Carlos Alberto Schuch Bork	Superabsorbent Coolant; A New Approach to Semi-Dry Patent has been filed. Patent Cooperation Treaty (PCT) submitted successfully.

5d: OTHER COMMUNICATIONS, AWARDS/ AUTRES COMMUNICATIONS, PRIX

Provide information on additional communications related to your work, such as awards and distinctions, news stories, interviews, public forums, press releases, etc. for the current reporting period (please provide copies or links.)

Name, given name/ Nom, prénom	*Details*	*Date*	*Link or copy attached*

6. TRAINING/ FORMATION

(Describe the extent of cross-network and partner involvement in training for the current reporting period.)

Honda has been supplying a large amount of workpiece material for which they are experiencing machining challenges.
SEM training passed.
Alicona microscope training passed.
CNC turning training passed.
CNC Okuma mill training passed.
CNC Nakamura training passed.

7. RESEARCH PLAN FOR NEXT 6 MONTHS/ PLAN DE RECHERCHE POUR LES 6 PROCHAINS MOIS

(Describe Planned Research Activities for the next 6 month period and include any modifications made during the current reporting period.); also please list both the technical objectives and milestones.)

1- **Thesis defence**
2- **Providing a future plan and recommendations for next students who are interested to work on this idea**

8. OPTIONAL – Comments, Questions and/or Feedback/ OPTION – Commentaires, questions et/ou des commentaires

Include any supplemental comments or questions pertaining to the Network here.

9. NETWORK EVENTS ATTENDED or SUGGESTIONS / ÉVÉNEMENTS RÉSEAU ONT ASSISTÉ ou SUGGESTIONS

Please list any Network-related events attended and include comments and suggestions for events which may be helpful and informative for Network members to attend in future.

Event	*Comments/Suggestions*
Attend the MMRI Industry Open House	
Attend VMPT 2018 conference	
Attend METRIC 2018 conference	

Progress:

July 1 - Jan. 31, 2016

Different coolants and approaches to cooling systems are being evaluated. Figure 1 shows the two novel cooling methods that would be tested in the feasibility phase. As a beginning, the

focus for first step would be on the second part of the Figure 1. It should be mentioned that the tests will be conducted using c-BN tools, based on industry demand.

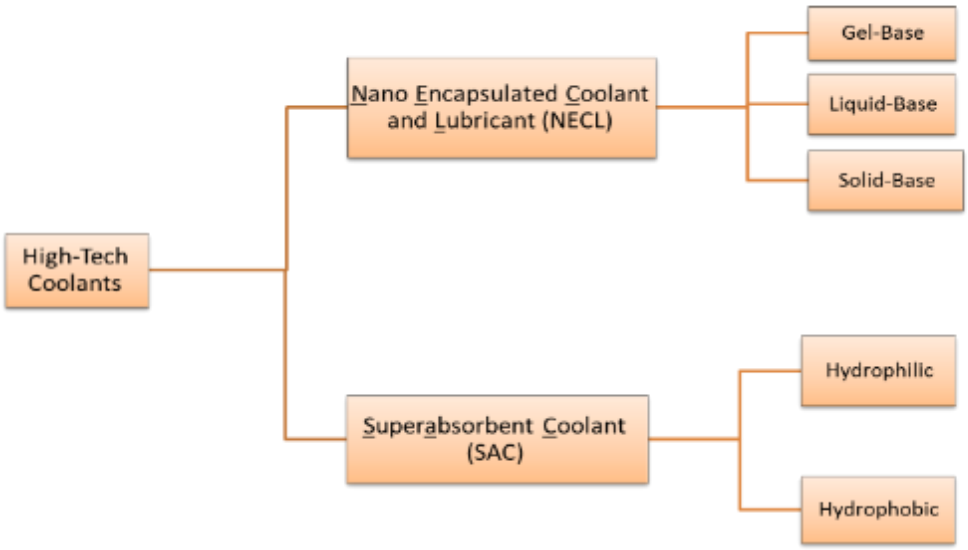


Figure 1- Novel coolants which are going to evaluate

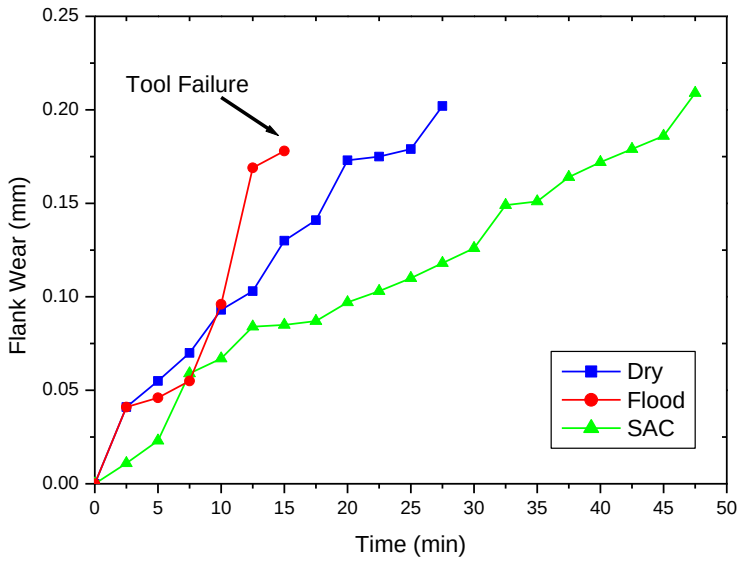
Feb. 1 – June 30, 2017

One of the most important parts of superabsorbent coolant (SAC) is the preparation method which is a completely different than with usual coolants. In this case, because this approach is using nanoparticles it is important to disperse the nanoparticles in base oil using an ultrasonic bath to ensure good mixing and then after 1.5 or 2 hours disperse the oil-nanoparticle mixture into water. Again ultrasonic agitation is needed to make the mixture uniform and then it can be added to the superabsorbent powder and then wait for 15 min for the powder to absorb the mixture. Figures below show the preparation process.

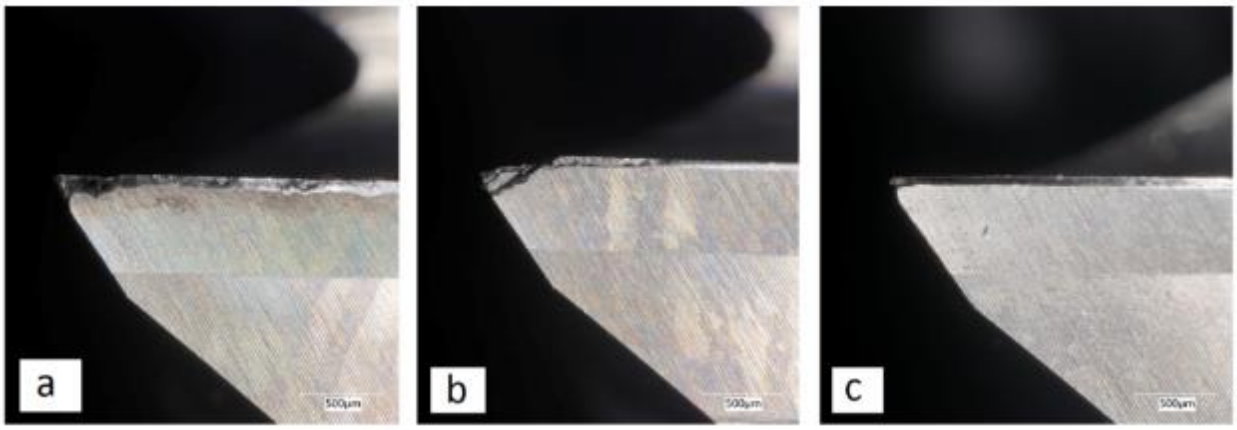
May 1, 2017 - October 30, 2017

After preparing the SAC, couple of machining tests has been done on different alloys. First of all, SAC include graphite nanoparticle has been applied during milling hardened H13 and after that same coolant composition applied during drilling and tapping of Aluminium Silicon alloy. Recently, SAC includes Copper and MgO were used in turning Inconel 718. In all of the experiments except tapping, SAC with different nanoparticles shows superior cooling and lubrication. It is understandable from tool wear results and chip undersurface roughness as well.
Superabsorbent coolant gives us this opportunity to add any type of nanoparticle (based on workpiece material) and deliver it to the cutting zone with minimum environmental and occupational concerns.

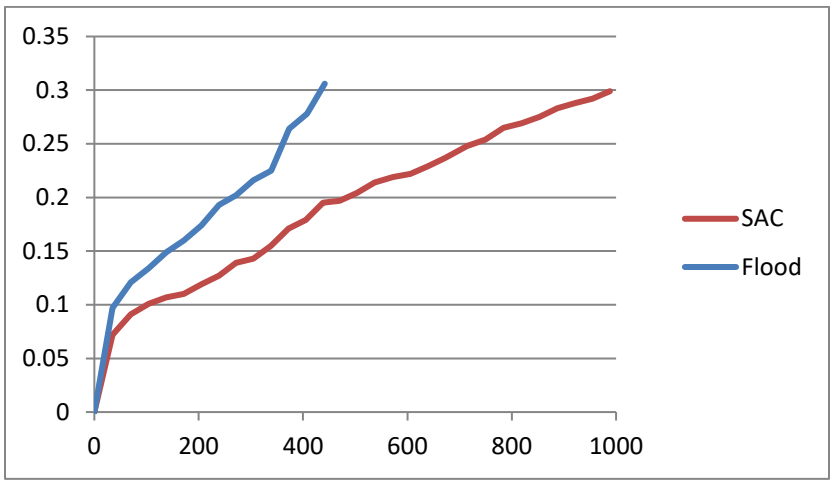
Without nanoparticles With 2% nanoparticles



Growth of flank wear during machining of H13 under dry, flood and SAC conditions



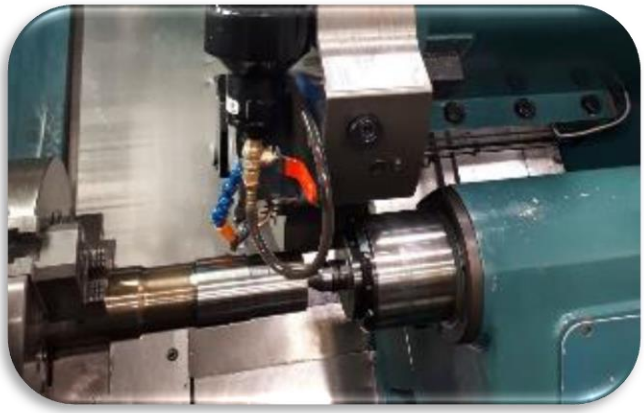
Optical microscope images of tool wear under different conditions; a: Dry, b: Flood and c: SAC



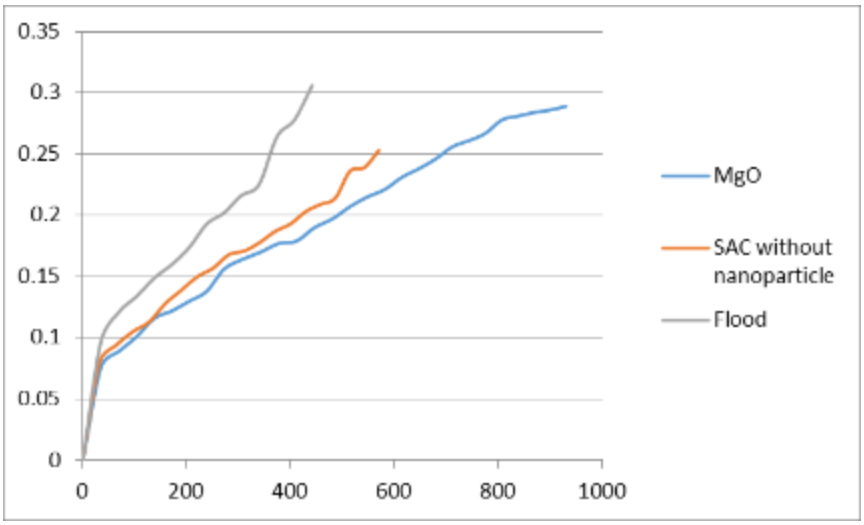
Growth of flank wear during turning of Inconel 718 with flood coolant and SAC include copper nanoparticles

November 1, 2017 – April 30, 2018

After designing new portable delivery system for turning machine, couple of tests have been done on Inconel 718 with MgO nanoparticles and also some tests with SAC without any nanoparticles. The idea is to see the effectiveness of nanoparticles and figure out how much improvement we will have without nanoparticles. The results have been plotted in figure below. It is clear that MgO nanoparticles can work almost as good as copper nanoparticles. Furthermore, it seems superabsorbent particle itself can improve tool life and reduce the total amount of coolant usage. The reason would be during cutting Inconel 718 because of high temperature SAC before reaching to the cutting zone is like gel but when it reach to the point with high temperature and shear rate it starts to melt and slightly burn and penetrate to the cutting zone. Hence, it moves nanoparticles better to the cutting zone and when it comes out of the tool-chip interface it becomes again like gel and prevents nanoparticles distribution to the air and minimal the pollution of the machine tool. The phase change due to high temperature and specifically shear rate change is because of non-Newtonian behaviour of the SAC.



Machining setup for turning tests

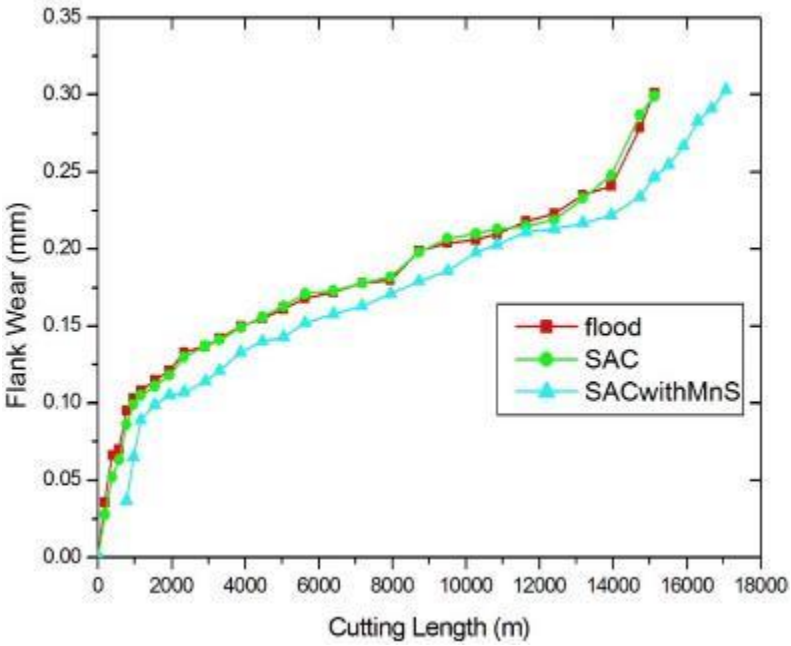


Growth of flank wear during turning of Inconel 718 with flood coolant, SAC without nanoparticle and SAC include MgO nanoparticles

May 1, 2018 – October 31, 2018

Further tests with SAC were conducted on grey cast iron with c-BN tool to address the requirement of this report. Machining tests were conducted in three different conditions; Flood (semi- high pressure coolant), SAC without nanoparticle and SAC with MnS micro particles. Since coolant pressure in first condition is 300 psi which is more than flood cooling and less than high pressure cooling technique so it is called semi-high pressure coolant. Based on the literature existence of MnS in cast iron can improve the machinability of the material so in this case in order to compensate the lack of MnS in grey cast iron, it was added (1% wt.) to SAC. The graph below exhibits the performance of three conditions. It seems Manganese Sulfide as additive could improve tool life and SAC without nanoparticles showed almost the same result as semi-high pressure coolant. One of the good benefits that SAC provides during machining cast iron is chip collection. Grey cast iron is a brittle material and during cutting it generates very small chips and dust. When flood coolant is used, chip agglomeration happens and it can block the filtration and circulation system. But SAC due to adhesive nature of the gel collects the chips and

provides cleaner machining environment. Furthermore, SAC prevents MnS sedimentation over time.



Growth of flank wear during turning of Grey Cast Iron with flood coolant, SAC without nanoparticle and SAC include MgO nanoparticles

Figure below shows the flank wear of the c-BN tool. It is clear that wear volume of tool under semi-high pressure coolant is more than SAC.

Optical microscope images of tool wear under different conditions; a: Flood, b: SAC without nanoparticle and c: SAC with MnS additive