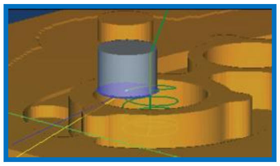


NSERC Canadian Network for Research and Innovation in Machining Technology (CANRIMT2)
NSERC Project Number: NETGP 479639 - 15

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.8: Machining of High-Alloy Powdered Metals	**Leader/ Chef:** *(Veldhuis, McMaster)*
PROJECT DURATION/DURÉE DU PROJET : 2 years (Starting July 2017)	
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.)

- High-alloy powdered metals coming from traditional compaction methods or from welding-based additive manufacturing methods (direct metal laser sintering) represent a significant challenge for machining.
- In many cases these processes produce near net shape parts but require final finishing to meet tight dimensional and surface finish requirements.

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

- Tooling and machining strategies which meet specific material challenges associated with powder metal and welding processes will be considered.
- The objective is to optimize the full production process considering high-alloy powder metal parts taking into account final part quality.

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
Marek Balazinski	Poly Montreal	Collaborator	marek.balazinski@polymtl.ca	514 340 4711 Ext. 4015
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 nam 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*
Pietro Stolf	MASc	McMaster University	Stephen C. Veldhuis (S)	Sept 2017	Aug 2019	1340	100	SONAMI (FedDev)
Jose Mario Paiva	PDF	McMaster University	Stephen C. Veldhuis (S)	Feb 2017			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		Mark Earle	120,000	152,500	30,000	150,000

McMaster-Veldhuis Projects						

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.*)

- **Finish additional set of cutting tests with different machining parameters.**
- **Write results and discussion.**
- **Correlation of wear phenomena to PM process parameters.**
- **Propose machining strategies for tool life prolongation and productivity improvement.**

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.)

- A detailed study related to tool material selection for finishing with a focus on c-BN as well as an optimization study on tool composition, geometry, edge preparation, coatings, feeds & speeds and coolant will be done using the virtual tools developed in Phase 1 research and rapid machining testing procedures outlined in IV.B.10.

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	
Progress: Finished **Modifications:**	
% Completed/ Rempli	**100%**

MILESTONE/ ÉTAPE: Material characterization coming from a wide range of powder metal processes	
Progress: Finished **Modifications:**	
% Completed/ Rempli	**100%**

MILESTONE/ ÉTAPE: Machinability study relating tool performance to alloy composition and microstructure	
Progress: Finished **Modifications:**	
% Completed/ Rempli	**100%**

MILESTONE/ ÉTAPE: Conclusion, technology transfer and publication	
Progress: Finished **Modifications:**	
% Completed/ Rempli	**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*
Stolf, P.	*2019*	*The role of high-pressure coolant in the wear characteristics of WC-Co tools during the cutting of Ti–6Al–4V, Wear*	*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*
		Conference Title, Location and Date (Status: Invited, Not invited)	
		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*
		Conference Title, Location and Date
		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*
		Thesis or Conference Title, Location and Date
		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*

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.)

- Samples preparation (Done)
- SEM (Done)

- Safety training (Done)
- CNC machining (Done)
- Optical microscope Keyence (Done)
- Samples Characterization (Done)
- 3D optical microscope – Alicona (Done)
- Tool wear evaluation (Done)
- Microhardness Tester (Done)

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.)

- **Project concluded**

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.

OAC Poster Competition	Comments/Suggestions

Research Progress

May 1- October 31 2017

According to cited publications the metal sintering process generates materials with challenging material properties which lead to high cutting and feed forces, as compared to materials obtained from other processes, such as casting, as shown in figure bellow. These may lead to higher tool wear rates and affect surface finishing of the workpiece. Studying these adverse effects during cutting processes through FEM modeling can support the identification of ideal conditions (cutting parameters, tool geometry, coatings, coolant) for the machining of these materials, thus reducing these effects.

November 1, 2017 – April 30, 2018

Preliminary FEM data is in agreement with previously published findings. From figures 1 (a) and (b), temperatures at the secondary shear deformation zone present an increase in the order of 60 °C when machining materials of same composition (Ti6Al4V) obtained from different methods (cast vs. powder metallurgy). All data was acquired under the same machining parameters. The further variation of such parameters according to appropriate design of experiment (DOE) will allow for a better understanding of their influence on the machining processes' performance. In addition to that, a further refined FEM model will be able to provide important information regarding surface integrity of the machined workpiece, revealing the possible formation of residual stresses originated from the metallurgy process.

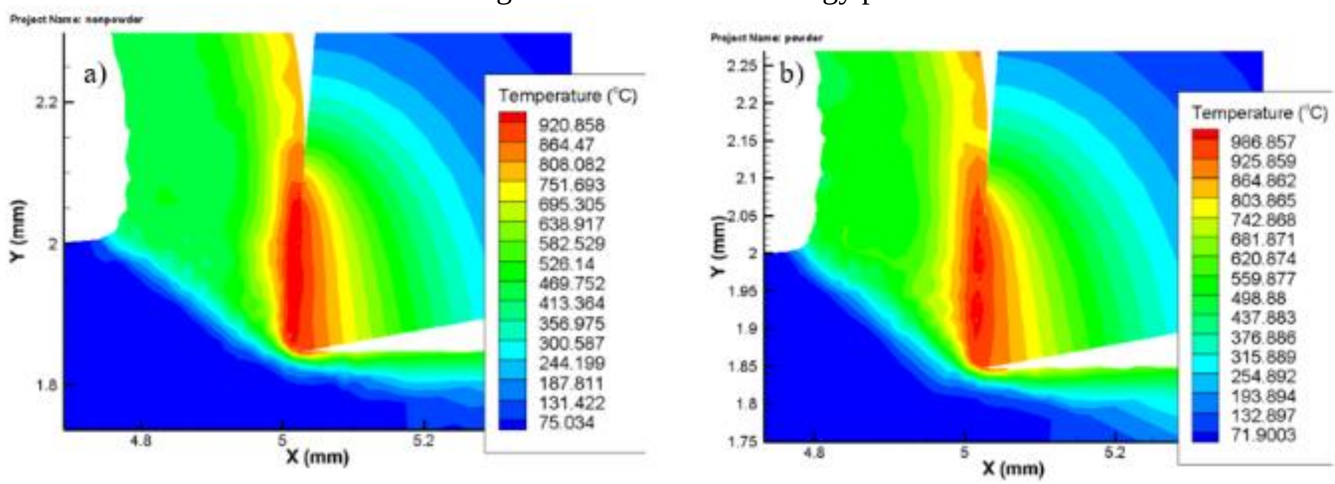
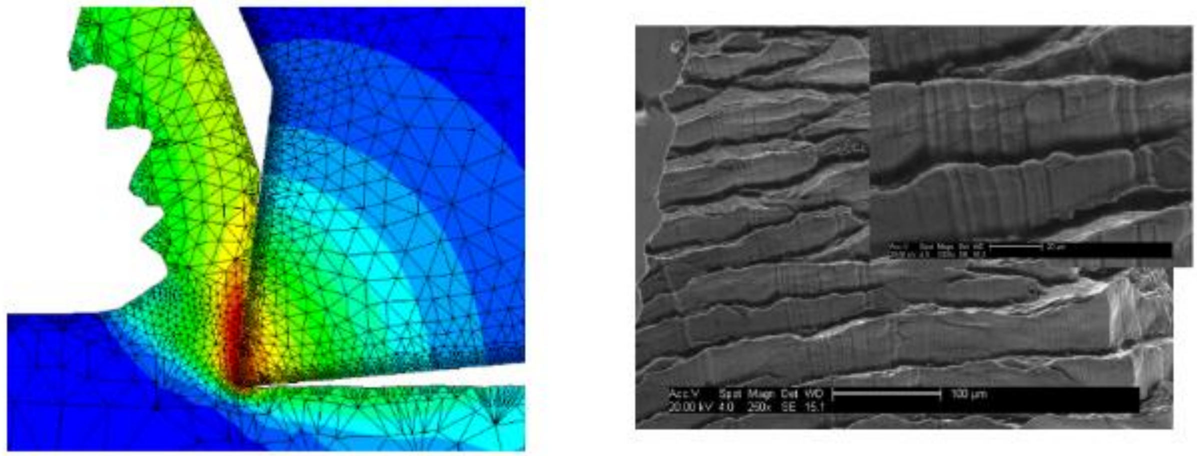


Figure 1: Temperature profile for Ti6Al4V obtained by (a) Casting and (b) Powder metallurgy processes

May 1, 2018 – October 31, 2018

Cutting tests of the benchmark cast alloys have supplied the following data: Tool wear modes, rates and cutting forces. Further SEM analysis of tools and chips enabled a correlation between these and the mechanisms behind them.

Cutting tests have also contributed with crucial data for the enhancement of the FEA model, which has been modified to account for the formation of serrated chips, common outcome of Titanium machining. SEM images taken from the chips, also provided an accurate comparison between model and experimental results, as shown in figure 1.



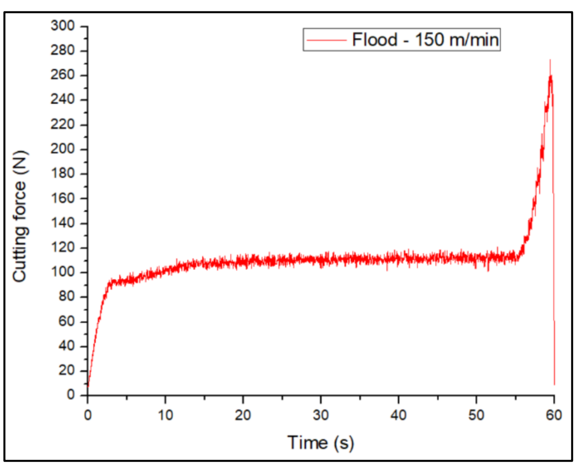
(a) (b)

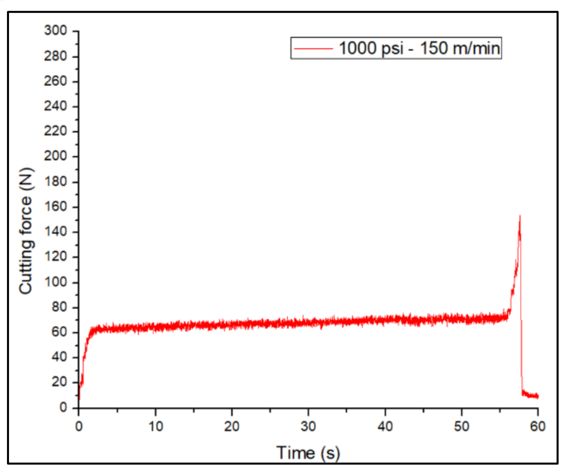
Figure 1: Ti6Al4V chip morphology obtained by (a) FEA (b) Experiment

Once the powdered samples are ready, cutting tests will be conducted and results will be compared. Such comparison, allied to microstructural data, will provide a better understanding of the mechanisms taking place during the machining of powdered alloys.

Nov. 1, 2018 – April 30, 2019

Further cutting tests have introduced the use of High Pressure Coolant Supply (HPC). This addition had significant impact on tool life, chip control, crater wear and adhesive wear phenomena. Cutting forces are displayed below for both conditions (Flood and HPC).





SEM and white light interferometry images were taken and compared to previous tests, supporting the observed improvements.
FEA simulations have also demonstrated a decrease in tool chip contact length and reduction in maximum cutting temperature on the order of 10%.

May 1 – October 31, 2019

Results were compiled and discussed. Highlighting the effects of High-Pressure Coolant supplies in the machining of such alloys. A paper was published and following conclusions could be drawn:

- Oxidation wear is reduced by the application of HPC.
- An increase in the heat generation by plastic deformation for the HPC condition.
- Coolant pressure and maximum flank wear are inversely proportional to each other.
- The chip formation process is facilitated by the application of HPC.
- Chips are strain hardened with the application of HPC.

The following image displays the phenomena taking place on the rake face of the cutting insert before (a) and after (b) the application of High-Pressure Coolant.