## Project Interim Progress Report (Rapport d’avancement de project intérimaire) July 1, 2016 - January 31, 2017 Please submit by January 16, 2017 (Attn: Joanne O’Connor [management@nserc-canrimt.org](mailto: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**

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| **THEME :** Digital Machining | | | | | | **Leader/ Chef:**  *K. Erkorkmaz*  *U. Waterloo* | | |
| **PROJECT I.A.4:** Chip Formation, Forces, and Elastic Deformations of Gear Hobbing | | | | | | **Leader/ Chef:**  *K. Erkorkmaz*  *U. Waterloo* | | |
| **PROJECT DURATION/DURÉE DU PROJET :** | | | | | | | | |
| **STATUS/STATUT:** *(****Milestones*** *to be updated by each Project Leader)* | | | | | | | | |
| **Ahead of Schedule** |  | **On Schedule** | **✓** | **Delayed** |  | | **Cancelled** |  |

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| **PROJECT DESCRIPTION/ DESCRIPTION DU PROJECT**  (*Brief description in point form, including role of project in Theme.)* |
| * This project targets the development of a digital machining model for the gear hobbing operation. * It is one of the three virtual modeling projects proposed for digital machining of gears. |

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| **PROJECT OBJECTIVES & METHODOLOGY/ OBJECTIFS DU PROJET & MÉTHODOLOGIE**  *(Include alignment with Network objectives.)* |
| Objective**:** To develop fundamental physics based mathematical models that describe various aspects of the gear hobbing operation, that will enable full digital simulation of the process and enable virtual metrology.  Methodology: Modeling of kinematics, of the kinematics, chip geometry, forces generation (using oblique cutting model) and elastic deformations  The kinematics of hobbing will be modeled and validated using CNC feed drive signals from Liebherr LC382 and LC500 hobbing machines. The cutting velocities at discrete tool edge segments will be used, together with hob geometry, to determine the principal (tangential, feed, and radial) cutting directions, and the normal rake and inclination angles. CWE will be estimated using a tri-dexel solid modeling engine. Uncut chip area associated with each tool edge segment will be estimated by projecting the relevant portion of the CWE onto a plane normal to the cutting velocity. Incremental force contributions local to each segment will be computed using the 3D oblique cutting model. Translational and rotational stiffness characteristics of the tooling and workpiece will be determined through impact testing and modal analysis. Elastic deformations, predicted by the force and torque loading and multi-directional stiffness, will enable the prediction of the gear tooth form and dimensional errors in a virtual environment. These will then be verified experimentally on metrology machines at ODG.  This project aligns closely with the objective of constructing a gear digital machining suite within CANRIMT. |
| **1. RESEARCH TEAM/ ÉQUIPE DE RECHERCHE** *(Summary for the current reporting period)* |

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

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| *Name, given name/ Nom., prénom* | *Organization/ Organisation* | *Sup./Co-Sup./*  *Collaborator* | *E-mail/Courriel* | *Phone No./ Téléphone* |
| Erkorkmaz, Kaan | Waterloo | Supervisor | kaane@uwaterloo.ca | 519 888 4567 x32541 |
| Ismail, Fathy | Waterloo | Co-supervisor | fmismail@uwaterloo.ca |  |
| McPherson, Jamie | Ontario Drive &  Gear | Collaborator | jmcpherson@odg.com | 519 662 2840  x466 |
| Plakhotnik, Denys | Moduleworks  GmbH | Collaborator | denys@moduleworks.com |  |
| Stautner, Marc | Moduleworks  GmbH | Collaborator | marc@moduleworks.com |  |

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

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| *Name, given name/ 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* |
| Van Dorp, Jacob | MASc (part-time) | U.Waterloo | Erkorkmaz (S) | 01/09/15 |  | *$0.00* | *Salary provided by ODG* |  |

***\*(S) – Supervisor , (C) – Co-Supervisor***

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

**1c: Partners & Contributions/   
Partenaires et Contributions**

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| *Organization / Organisation* | *Acronym/ Acronyme* | *Contact* | *Cash/ Espèce* | *In-Kind/ Nature* | *Overhead/ Frais généraux* | *Total* |
| Ontario Drive & Gear | ODG | McPherson, Jamie | $0.00 | $23,820 | $0.00 | $23,820 |

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| **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.)* |
| Research plan for the current reporting period:   * Conducting the literature review on hobbing kinematics and mechanics * Developing a kinematic model of the process (to later predict uncut chip geometry) |

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| **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.)* |
| The research project aligns very well with the network objectives. It falls squarely within establishing digital machining models of emerging high value added and specialized machining processes, such as gear production. |

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| **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:*   * Measuring machining forces during hobbing is highly challenging, due to limitations regarding geometric and mechanical access.   *Resolution / Résolution:*   * Motor current and vibration measurements are being investigated for estimating the cutting forces. |

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| **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.)*

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| **MILESTONE/ ÉTAPE: 1 - Literature Review** | |
| **Progress:**  **Modifications:** No modification | |
| **% Completed/ Rempli:** Literature review is almost complete. | **66%** |

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| **MILESTONE/ ÉTAPE: 2 - Literature Review** | |
| **Progress:**  **Modifications:** No modification | |
| **% Completed/ Rempli:** Kinematics of tool and VP motion have been studied. Verification in progress. | **25%** |

**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.*

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| ***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* |
|  |  |  |  |
| ***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)*** | |
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| ***F: PUBLICATIONS – Not funded by NSERC CANRIMT but related to the Network research focus*** | | | |
| Last Name, Initial | *Year* | *Description/Title* | |
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**5c: PATENTS and LICENSES/ BREVETS ET LICENSES**

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

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| *Category* | *Owner* | *Description* |
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**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.)*

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| *Name, given name/ Nom, prénom* | *Details* | *Date* | *Link or copy attached* |
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| **6. TRAINING/ FORMATION** *(Describe the extent of cross-network and partner involvement in training for the current reporting period.)* |
| CANRIMT partner ODG has been supporting the study of one of its engineers, Mr. Jacob Van Dorp, as a part-time MASc student in this project. Jacob spends extensive time at ODG, supporting regular production on gear shaping, hobbing, and grinding lines. Thus he is extremely well versed on the practical issues and challenges. He also spends 1/3 of his time working with Prof. Erkorkmaz’ team on developing the digital hobbing model, together with two other students (Katz and McCloskey), who are developing the digital machining models for the complementary operations of shaping and power skiving. |

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| **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.)* |
| **Milestone 1 - Literature review:** Investigation of additional papers and theses related to hobbing mechanics and force measurement in hobbing.  **Milestone 2 - Kinematic model & chip formation:** Completion and validation of kinematic model.   * By sweeping the relative motion of the tool with respect to the workpiece blank and inspecting the final geometry * Determining the relative velocity at each point along the tool edge w.r.t. workpiece, and also the radial and feed directions. * Applying oblique cutting force model to predict incremental forces and summing up total forces   **Milestone 3 - Cutting force prediction & experimental validation:**   * Investigation of instrumentation options for cutting force measurement (dynamometer feasibility, monitoring CNC signals during air and metal cutting). * Applying oblique cutting force model to predict incremental forces and summing up total forces |

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

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| *Include any supplemental comments or questions pertaining to the Network here.* |
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**9. NETWORK EVENTS ATTENDED or SUGGESTIONS /  
ÉVÉNEMENTS RÉSEAU ONT ASSISTÉ ou SUGGESTIONS**

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| *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.* | |
| CIRP General Assembly, Portugal (Aug 2016) |  |
| ASPE Topical Conference on Precision Motion Control Systems (Apr 2016) |  |