## Project Interim Progress Report(Rapport d’avancement de project intérimaire)July 1, 2016 - January 31, 2017Please submit by January 16, 2017(Attn: Joanne O’Connor 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 :** Virtual Model-Assisted Machining Monitoring and Control | **Leader/ Chef:** *R. Mayer / Ecole Polytechnique* |
| **PROJECT II.A.10:** In-Process Machine Tool Structural Identification and Precision Controls | **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 new feed drive model identification and precision motion control laws which enhance the dynamic tool positioning accuracy and stiffness. This allows productivity and quality improvement in multi-axis machining operations.
* This project, within Theme II, plays a complementary role to Project II.A.11. While II.A.11 focuses on active damping of chatter vibrations, this project targets improvement of tool positioning accuracy at high feedrates and accelerations. Both projects target machining system performance enhancement, through research into advanced modeling and control techniques.
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| **PROJECT OBJECTIVES & METHODOLOGY/ OBJECTIFS DU PROJET & MÉTHODOLOGIE** *(Include alignment with Network objectives.)* |
| *Upon consultation with industry partner CADlink, the starting date for this projects has been pulled forward, to 2016Q3 (from 2018Q3). Another project, II.A.9 (on real-time trajectory planning), has been postponed to start in 2018Q3 (original start date of this project). This was done to accommodate the most urgent technology development needs felt by the industry partner*.Objectives: This project will investigate joint position control and vibration damping strategies for machine tool feed drives, with the intention of boosting the bandwidth to achieve higher dynamic accuracy and rigidity. The objective is to generalize and automate the design and implementation of joint position and vibration control strategies, so that this technology can be reliably and safely deployed onto CNC machines.Methodology: Lumped (discrete) inertia models will be considered, which lend themselves to clear and easy physical interpretation. Multiple sensors (e.g., encoders) from different spatial locations will enable robust identification of rigid body and vibratory dynamics. Model building and updating strategies will be investigated, which utilize in-process data from the CNC to distinguish vibration mode(s) needing to be actively controlled from those needing suppression through notch- or low-pass filtering. The developed auto-tuning and parameter updating methods will target robust stability and performance specifications. Active damping will be investigated for motor and load side feedback configurations (like those used in ball screw and pinion-rack drives), and also for double-drive (gantry) arrangements. A principal method to be researched is the acceleration of the decay envelope of vibrations, which leaves the actual (damped) frequency of vibration unaltered, in order to avoid wasting actuation energy, or leading to over-aggressive torque inputs.* This project, within Theme II, will help build new expertise in machine tool dynamics modeling and precision motion control techniques. Thus, the project aligns well the CANRIMT’s goal of enhancing the productivity and quality performance of machine tools and machining systems.
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| **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 |
| Reynen, Gordon  | CADlink Tech. Corporation | Collaborator | gordr@cadlink.com | 613 247 0850x214 |

**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/Moincl ben.* | *Extern.fundingamount* | *Externfundingsource* |
| Kalbasi, Hessam | PhD | U.Waterloo | Erkorkmaz (S) | 09/01/15 |  | *$1857.75* |  |  |

***\*(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** |
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**1c: Partners & Contributions/
Partenaires et Contributions**

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| *Organization /Organisation* | *Acronym/Acronyme* | *Contact*  | *Cash/Espèce* | *In-Kind/ Nature* | *Overhead/Frais généraux* | *Total* |
| CADlink Tech. Corp. |  | Gordon Reynen | $12,800 | $15,025 | $3,200 | $31,025 |

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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.)* |
| Milestone 1 - Literature review Milestone 2 - Study of common discrete (lumped) inertia flexible drive models |

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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 well with network objectives. This project will facilitate new machine tool control algorithms to help boost the positioning accuracy, tooling stiffness (i.e., leading to less deformation), and machined part quality. |

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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:** No problems encountered so far.

*Resolution / Résolution:** N/A.
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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:** Majority of relevant modeling and control literature has been reviewed.**Modifications:** |
| **% Completed/ Rempli:** | **50%** |

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| **MILESTONE/ ÉTAPE: 2 - Study of common discrete (lumped) inertia flexible drive models** |
| **Progress:** 2-mass ball screw model has been studied and identified. Discrete gantry models are being researched.**Modifications:** |
| **% Completed/ Rempli:** | **50%** |

**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.)* |
| Mr. Hessam Kalbasi is working on this project as a PhD student. CADlink will be providing two installations of their controller to support Mr. Kalbasi’s research activities. |

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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 * Further literature, on gantry type discrete mass models and suitable identification techniques (multi-sine, superposing white noise while the axes are in motion, etc.)

Milestone 2 - Study of common discrete (lumped) inertia flexible drive models* Estimating lumped single axis and gantry axis models from the router (using experimental data)

Milestone 3 - Principal model parameter tracking based on multiple sensor feedback* Attempting to track change in model parameters as a function of machine tool posture.
* Updating SISO feedback control gains accordingly.
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**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.* |
| *Event* | *Comments/Suggestions* |
| CIRP General Assembly, Portugal (Aug 2016) |  |
| ASPE Topical Conference on Precision Motion Control Systems (Apr 2016) |  |