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Department of Theoretical mechanics, dynamics and vibrations

Robotic Machining

Development & Validation of a Robotic Machining Numerical Model in order to Optimise Cutting Parameters

Résumé

- Objectif: optimiser le choix des paramètres de coupe à l'usinage robotisé
- Modélisation multicorps d'un robot et couplage au procédé d'usinage
- Simulation de l'usinage robotisé sur base d'un modèle numérique
- Validation du modèle dynamique par des essais expérimentaux
- Mise en place d'outils visant la recommandations des paramètres de coupe optimaux suivant le compromis "stabilité-productivité-précision"

Context

- Attractive cost: cost reduction of about 30 to 50 % in comparison with a CNC machine tool having the same workspace
- Machining of large workpiece with complex shapes and difficult access
- Increase of productivity for current manual operations such as composite trimming and chamfering
- However, robot joint stiffness is low: < 1 N/µm (CNC machine tool stiffness > 50 N/µm)
- Machining errors are mainly caused by joint flexibility, backlash and friction losses
- Hence, vibration of the structure, instability and loss of accuracy (chatter phenomenon) [1]

Milling operations

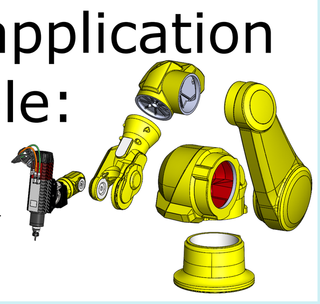
- Operations: deburring, drilling, cutting, polishing, milling, grinding, contouring, ...
- Materials: aluminium, plastic, composite, foam, wood, stone, steel, ...

Simulation environment

EasyDyn

- EasyDyn: multibody framework [2]
- Simulation of a multibody system such as an industrial robot
- Construction and resolution of the equations of motion by application of the d'Alembert principle:

$$[M]\{\ddot{\vec{q}}\}+[C]\{\dot{\vec{q}}\}+[K]\{\vec{q}\}=\{\vec{0}\}$$



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Dystamill

- Dystamill: milling routine [3]
- Macroscopic model of milling

- Simulation of milling operations:
  - prediction of the cutting forces

$$d\vec{F} = \vec{K} \cdot h \cdot da$$

dF: cutting forces
K: cutting coefficients
h: underformed chip thickness
da: elementary cutting length

  - update of the workpiece geometry

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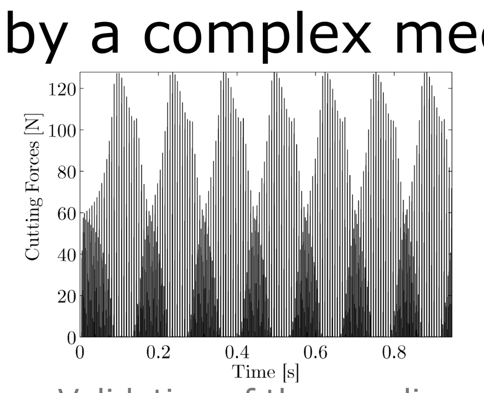
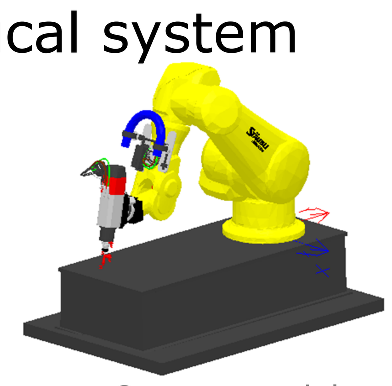
Coupling

- Coupling of EasyDyn and Dystamill [4]
- Simulation of the milling performed by a complex mechanical system



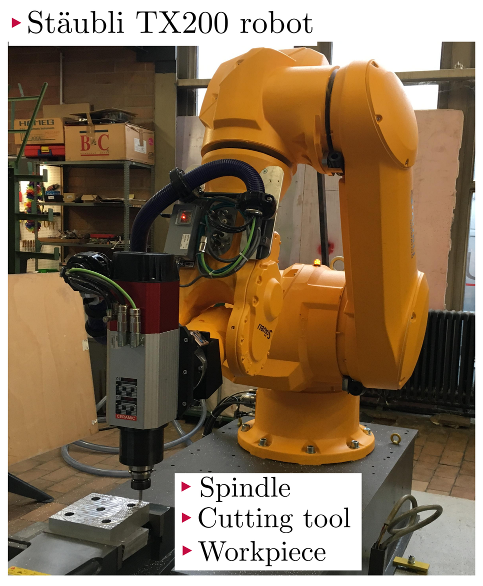
Validation of the coupling



Current model

Experimental setup and milling tests

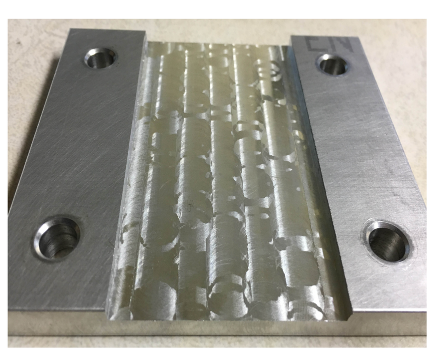
Experimental setup



- Milling tests in aluminium blocks

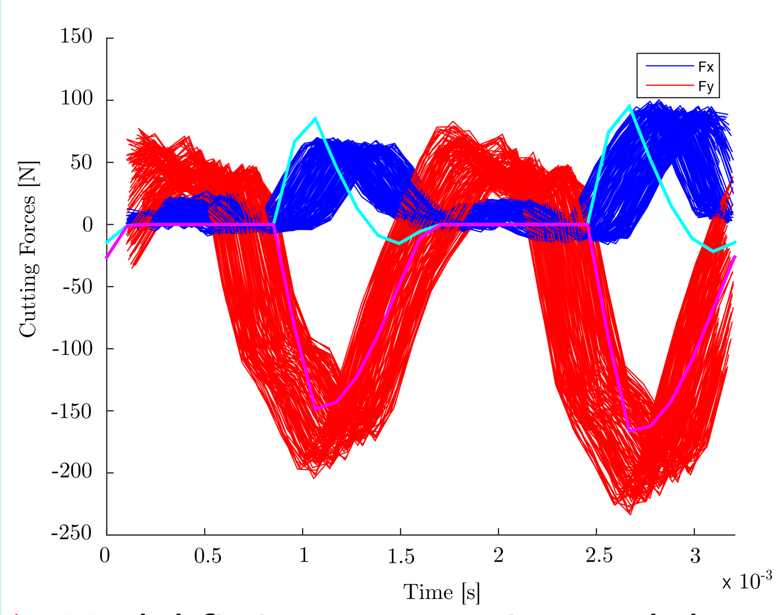
Resulting workpiece

Aluminium 6082 T6



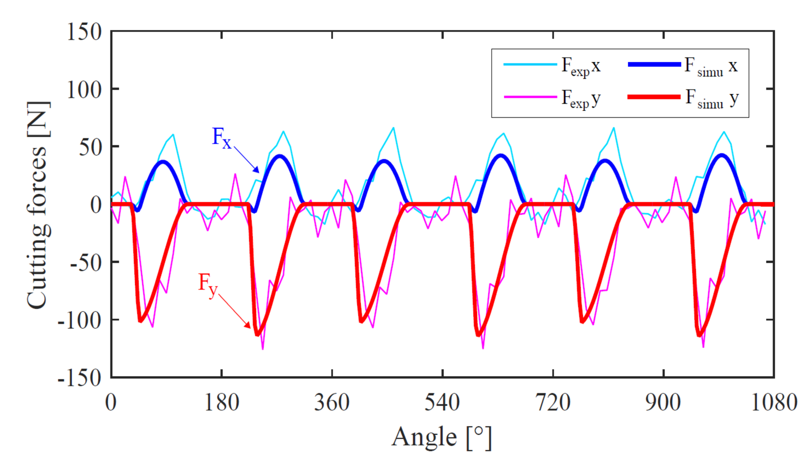
- Surfacing operations: a_p=2 mm, a_e=4 mm
- Overall flatness: 0.228 mm
- Lateral roughness: R_a=0.4-0.8 µm, R_t=3 µm

Cutting forces



- Model fitting to experimental data

Robotic machining simulation

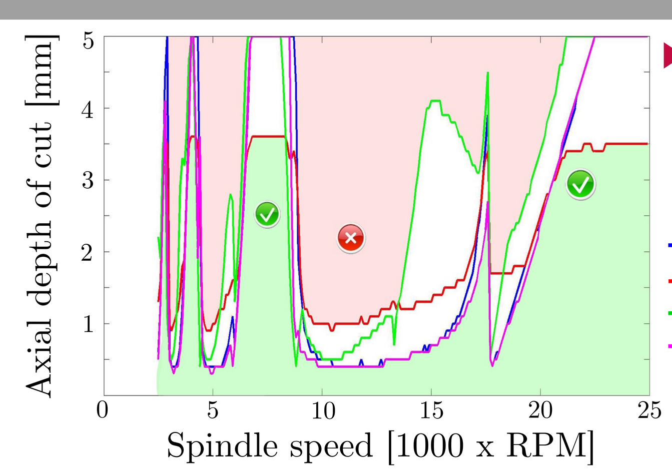


- Simulation VS. experiment
- Good prediction of cutting forces in aluminium milling

Perspectives

- Extension of the multibody model to a robot including control, actuators & flexible links [5]
- Validation of the robotic machining environment on the basis of milling tests
- Analysis of the stability using different criteria
- Development of numerical tools leading to an optimal choice of cutting parameters

Stability lobes



- Stable milling process for the cutting parameters in the green area

Stability limit
Force max. criterion
Vibration max. criterion
Roughness max. criterion

References

[1] I. Iglesias, M.A. Sebastian, J.E. Ares. Overview of the state of robotic machining: Current situation and future potential. *Procedia Engineering, 132:911-917, 2015.*

[2] Olivier Verlinden, Lassaad Ben Fékih, Georges Kouroussis. Symbolic generation of the kinematics of multibody systems in EasyDyn: From Mupad to Xcas/Giac. *Theoretical & Applied Mechanics Letters 3:013012, 2013.*

[3] H.N. Huynh, E. Rivière-Lorphèvre, F. Ducobu, A. Ozcan, O. Verlinden. Dystamill: a framework dedicated to the dynamic simulation of milling operations for stability assessment. *J. Adv. Manuf. Technology, 2018.*

[4] H. N. Huynh, Edouard Rivière-Lorphèvre, Olivier Verliden. Multibody modelling of a flexible 6-axis robot dedicated to robotic machining. *The 5th Joint International Conference on Multibody System Dynamics, 2018.*

[5] S. Mousavi, V. Gagnol, B.C. Bouzgarrou, P. Ray. Dynamic modeling and stability prediction in robotic machining. *The International Journal of advanced Manufacturing Technology, 1-13, 2016.*

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