Service de Mécanique Rationnelle
Dynamique et Vibrations

Robotic Machining

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

Résumé

- Objectif: optimiser le choix des paramètres de coupe à l'usinage robotisé
- Modélisation d'un bras robotisé 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 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 manuel operations such as composite trimming and chamfering
- On the other hand, robot stiffness is low: < 1 N/μm (CNC machine tool stiffness > 50 N/μm)
- Machining errors are mainly caused by the backlash and friction losses at joints
- Hence, vibration of the structure, instability and loss of accuracy (chatter phenomenon) [1]

Milling operations

- Operations: surfacing, sanding, 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:

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

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DyStaMill

- DyStaMill: milling routine [3]
- Macroscopic model of milling
- Simulation of milling operations:
  - prediction of the cutting forces

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

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

  - update of the workpiece geometry

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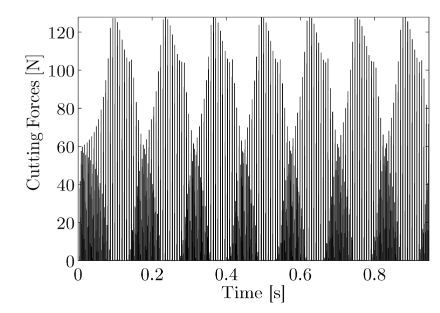
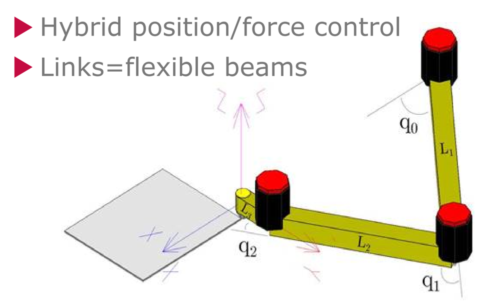
Coupling

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



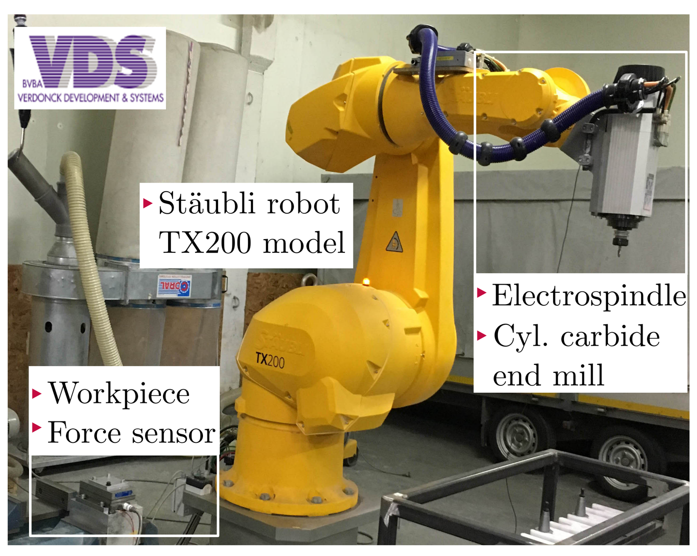
Validation of the coupling



Current model

Experimental setup and milling tests

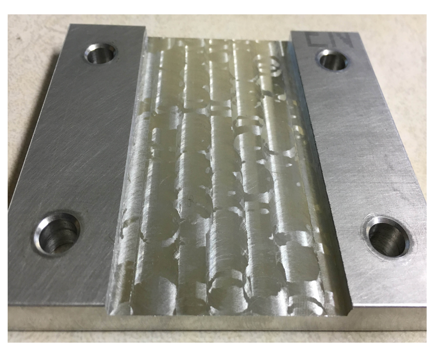
Experimental setup



- Milling tests on aluminium plates

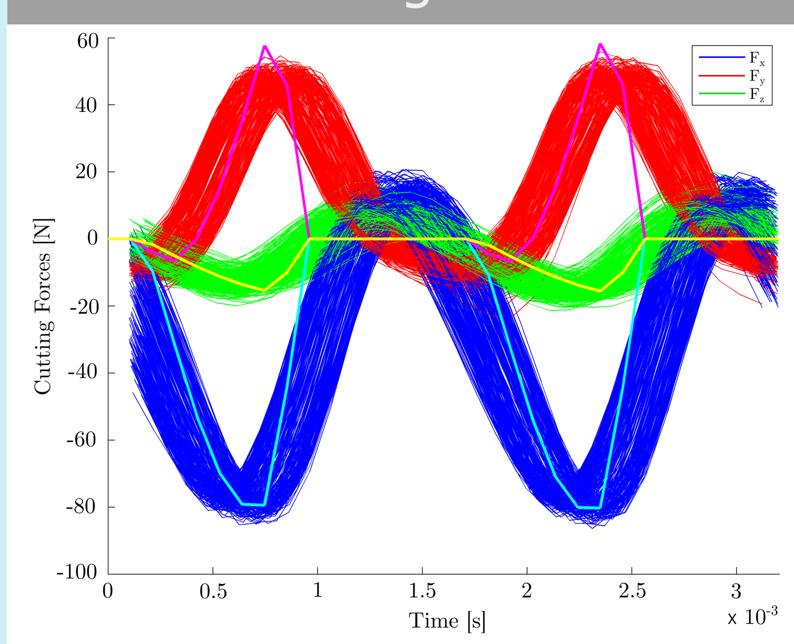
Resulting workpiece

Aluminium 6082 T6



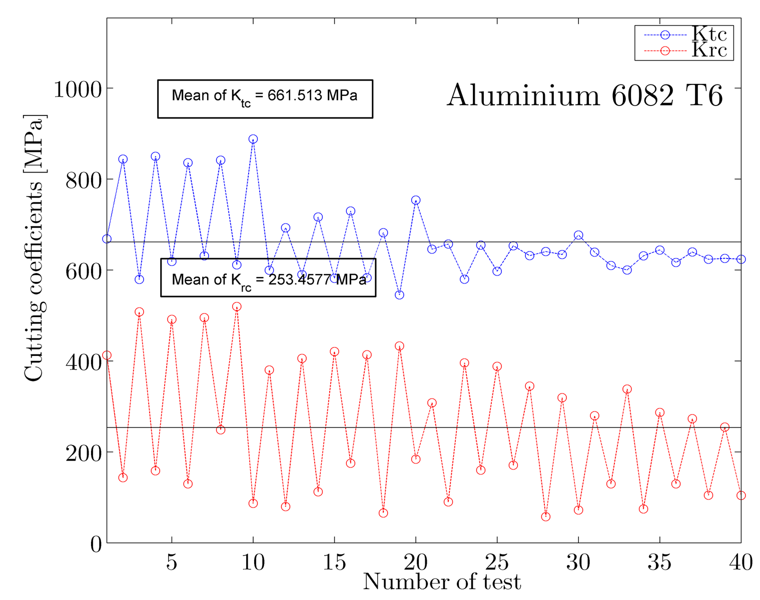
- Surfacing operations, depth of cut ranging from 0.1 mm to 1.6 mm
- Overall flatness: 0.238 mm
- Roughness: R_a=0.4-0.8, R_t=6 μm

Cutting forces



- Model fitting: 18700 RPM at 1.6 mm

Cutting coefficients

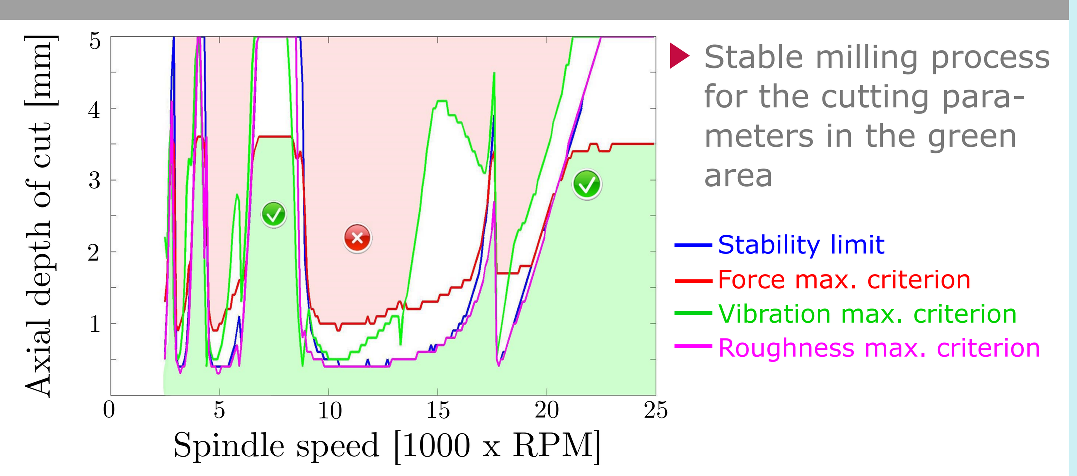


- Identification by inverse analysis

Perspectives

- Extension of the multibody model to a 6-dof robot composed of flexible beams [5]
- Validation of the robotic machining environment on the basis of milling tests
- Analysis of the stability using different criteria
- Development of tools leading to an optimal choice of the cutting parameters

Stability lobes



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

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] Edouard Rivière-Lorphèvre. Etude et simulation de procédés de fraisage grande vitesse: efforts de coupe, stabilité, états de surface. *Thèse UMONS, 2007.*

[4] Hoai Nam Huynh, Edouard Rivière-Lorphèvre, Olivier Verlinden. Integration of machining simulation within a multibody framework: application to milling. *The 4th Joint International Conference on Multibody System Dynamics, May 29 - June 2, 2016.*

[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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