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Generation of optimal trajectories for a pouring Robot considering Control system used in industry

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Metal casting is a highly productive manufacturing methodology. A typical application for metal casting is the production of motor blocks, with a yield of up to 25.000 units per day. There are various molding and casting methods, one such method is the gravitational casting. Gravitational casting can be either performed by a specialized casting machine or by an industrial robot with casting equipment attached, e.g. a ladle. In both cases programming the pouring motion is a tedious task usually performed via a teach-in process by an operator. In this paper we propose a general methodology to generate the casting motion via a process model.

Keywords: *Pouring Process, Robot Control, Optimal Trajectory Generation.*

1. Introduction

In the scientific literature control systems for pouring-robots and -mechanisms are intensely studied. Papers such as [1–4] contribute to solving sloshing suppression and prescribed flow rate assurance by redefining the closed loop control systems of the pouring-robot or -mechanism. This is a well suited approach, however it has the disadvantage that it is not easily implementable on currently used industrial robot controllers and industrial acceptance of any other control system than the classical cascaded torque-velocity-position faces difficulties.

This paper presents an alternative solution to the prescribed flow rate assurance problem. Instead of addressing "how to assure the prescribed flow rate for a pouring process" this paper addresses "how to assure the prescribed flow rate for a pouring process with a

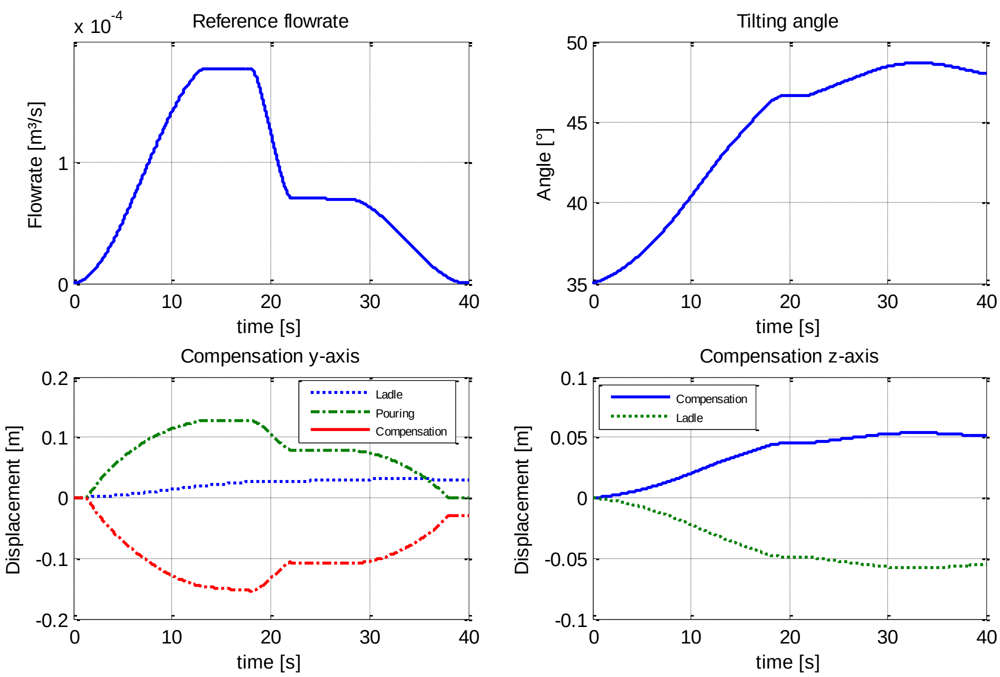

Figure 1: Reference flow rate and Cartesian curves

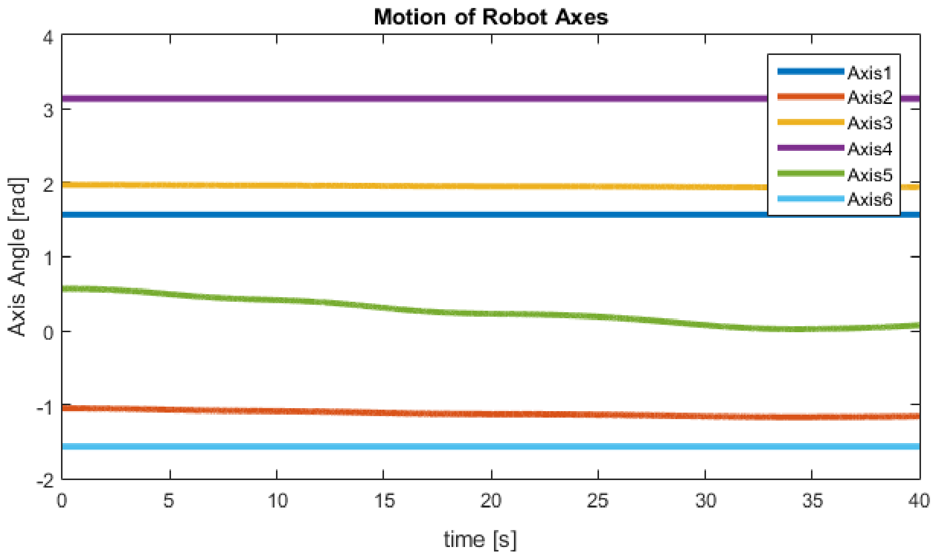

Figure 2: Robot axis movement

currently widely used industrial robot controller". The formulated question shows that a trade-off has been made with regard to performance in order to assure compatibility. The presented method does not perform better than dedicated control systems for sloshing suppression and prescribed flow assurance. However it makes existing robot controllers capable to suppress sloshing and assure flow rate.

2. Model based trajectory generation

To achieve this we have implemented the flow rate estimation equations of [2, 5] in a separate optimization module. This module computes the necessary motion to achieve the desired flow rate pattern. Figure 1 shows a sample pattern and the corresponding Cartesian motion to achieve the give flow rate and pour at a given position.

The Cartesian curve obtained with the above presented module is in function of time and therefore, a robot executing such a task must have the option to accept time based reference values. Major robot manufacturers offer real-time communication interfaces though which a robot accepts reference values both in joint space and in Cartesian space from an external real-time reference values generator. The RSI interface from Kuka and the LLI interface from Stäubli can serve as examples for such interfaces Figure 2 presents the motions of the axis of a Kuka KR-500 industrial robot arm while executing the above presented pouring task. The values are obtained from simulation. Since the reference values only change the coordinates X, Y and Phi, the angles of axis A1, A4 and A6 remain unchanged thought the pouring process.

3. Discussion and future works

As Figure 2 shows, the proposed method is capable of transforming the reference motion, obtained from model equations in Figure 1, directly into inputs for the robot motion controller. The presented method is therefore highly useful for pouring applications utilizing standard robots. It is no longer necessary to program the pouring motion by teach in, the motion can be directly computed from the model equations. Because the robot continuously receives new set points, the method can also be used in a feedback manner. Feedback control will be investigated in future studies.

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