# Department of Mechanical Engineering

# Carbon Steel Ball Mold for Casting, Iterative Learning Control

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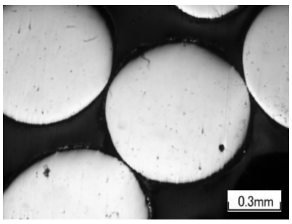
## Research Outline

### Carbon Steel Ball Mold for Casting

The carbon steel boll mold that has merit of the metal mold and the sand mold was produced. Steel balls were heated and joined to produce the carbon steel ball mold.

The steel ball mold is expected to reduce the occurrences of chill because thermal conductivity is smaller than the metal mold due to the existence of the air gap between steel balls. Furthermore, the mold can be used repeatedly if its strength is strong more than a sand mold. The mold is taken apart by adjusting joining strength between steel balls like a sand mold and it is possible to reuse used steel balls. From these features, this steel boll mold is suitable for the casting of a small quantity, or the production of the prototype.

It is assumed that the mechanism of joining due to heating the steel ball molds as follows. Steel balls after the heating are covered with the thin oxide film, furthermore, steel balls have joined through the oxide film. When steel balls are heated in the high temperature in the air, it oxidizes steel balls and the oxide film are formed to the surface of steel balls. Oxidization doesn't happen easily in the point of contact at the early stages of heating, because there is no supply of oxygen. But when oxidization progresses in the surface except for the contact point, oxygen are supplied from the oxide in the neighbourhood of the contact point, oxidation occurs even in the point of contact. Namely, the oxide film is formed, and steel balls are joined.

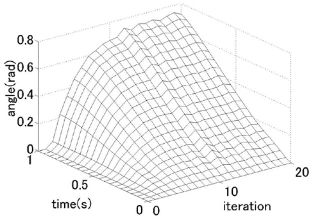



### Iterative Learning Control

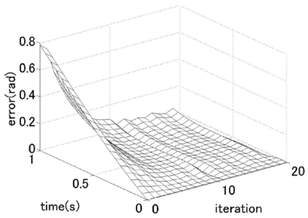
Iterative control is a method to track the output of a dynamic system to the desired trajectory by modifying the input based on the trial error. For example, iterative learning control systems (ILCS) and linear multipass processes (LMP) are known as iterative control.

Iterative control systems can be viewed as 2D systems because that systems have two kinds of dynamics: the one along time direction for each repetition index, and the one with respects to the repetition index. In iterative control systems, it is noted that, though there is no limit for the iterative index, the iterated passes are always bounded in finite time intervals. In consideration of these characteristics, authors have solved the asymptotic tracking problem of nD discrete systems whose input and output signals are bounded in, at most, one dimension. We call it the practical tracking problem of nD systems.

Very complicated algebra calculations are necessary to solve the practical tracking problem. So we have developed Symbolic Control Toolbox and nD Control System Toolbox. nD Control System Toolbox is an integrated CAD Toolbox for nD system theory for use with the software product MATLAB and Symbolic Math Toolbox. It consists of several functional packages which provide various basic tools and facilities for both numerical calculation and symbolic manipulation required in analysis and synthesis of 2D control systems such as stability test, factor coprime factorizations and solution of various linear matrix equations, etc. Symbolic Control Toolbox is a algebraic equation solution package for 1D system.




angle of robot arm




tracking error