Analysis and Control of Multipass Processes

J. B. Edwards *and* D. H. Owens

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Analysis and Control of Multipass Processes

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   J.B. Edwards *and* **D. H. Owens**

For

Margaret and Rose

Editorial Preface

For many years the field of control systems analysis and design has attracted substantial research effort. The extension of classical single variable techniques to the multivariable case has often necessitated practically unrealistic assumptions concerning plant behaviour, especially in respect of non-linearities. Discontinuous processes have, for many years, defeated analytical design techniques; however the pioneering research efforts of the authors have produced a cohesive treatment for an important class of such systems, namely multipass processes.

Such systems are more common than might at first be imagined. Metal cutting, automatic ploughing, metal rolling and automatic coal cutting processes can all be considered as multipass systems. The early chapters in this text concentrate on the modelling aspects of this class of system with later chapters developing a theoretical basis for the analysis and design of multipass processes. The concepts introduced by consideration of specific examples are extended to embrace a wide range of systems and the theoretical results are contrasted with existing classical and multivariable approaches.

This volume represents the second in a series of research level monographs under the general title of "Control Theory and Applications Studies". The series aims to provide for the rapid dissemination of research results in the field of control engineering and related topics, including both theoretical aspects and applications likely to be of wide interest.

M.J.H. STERLING

Preface

The term Multipass Process is one which we use to describe a class of recently identified systems that possess two novel properties, these being

(i) Repetitive operation and

(ii) Interaction between the state-and/or -output functions generated during successive cycles of operation.

Each individual cycle of operation we term a 'pass' and through the repetition of these passes as time proceeds we arrive at the term multipass process. In writing this book the authors' objective has been to develop for control engineers, control theorists and systems theorists in general, basic conceptual and mathematical tools for the modelling, analysis and control of these systems. We postpone our attempt to define a multipass process mathematically until Chapter 2 where we formulate a general state-space model for linear unidirectional systems, embracing most of the special characteristics of the physical examples so far encountered and identified in practice.

Rather than taking this general model as our starting point, we have thought it preferable in Chapter 1 to consider each of these known physical systems separately, bringing out their dynamic similarities and additional features as we proceed. In this way we retrace the historical development of the modelling aspect of our work from Edwards' original investigations during the late 1960's and early 1970's of a longwall coal-cutting machine: (a process which then seemed to enjoy a unique dynamic structure), through to the

recognition of related characteristics in a number of apparently distinct processes, industrial and otherwise. The common feature is shown to be the dependence of present-pass behaviour on the behaviour of the process produced on one or more previous passes and the examples considered are the rolling and machining metals, automatic agricultural ploughing and multimachine systems. Time/distance domain simulation results are presented showing a general tendency towards unexpected instability.

Following the formulation of the general state-space model, Chapter 2 continues with preliminary attempts to predict analytically aspects of behaviour noted in Chapter 1, concentrating particularly on the question of stability. For this purpose the interactions between successive passes of the process are modelled approximately by long transport-delays so permitting the conversion of linear, or linearised models to transfer-function matrix (T.F.M.) form and the subsequent production of inverse Nyquist loci.

An alternative intuitive approach again based on transfer-functions and concepts of repeated resonance excitation is also developed. Both techniques are shown to produce analytical results which accord well with those of the simulations of Chapter 1 but the approximations implicit in these frequency-domain approaches and the need for a mathematically rigorous analytical technique are noted. This challenge is taken up in Chapter 3 where the general abstract characteristics of multipass behaviour are identified and rigorous stability analyses performed. This Chapter requires some degree of mathematical sophistication in the form of some elementary functional analysis and operator theory but carries the bonus of clarifying the essence of the stability problem in obvious intuitive terms and identifying the rigorous basis for conceptual ideas, introduced in previous Chapters, in terms of system rejection properties. One aspect of this work is the realization that (at least) two concepts of stability are required in multipass systems analysis.

Research into the novel field of multipass processes is far from complete. Not all multipass processes have been identified and with each new example, or with a deeper investigation of known types,

additional characteristics seem to be revealed, some falling within the scope of the general model of Chapter 2 and some lying outside. Some of these additional characteristics are examined in a preliminary manner in Chapter 4. They include bidirectional operation, interpass phenomena often of an apparently non-causal type, and variable pass-lengths. As shown in Chapter 4, some analytical progress can be made by development of the techniques of Chapter 2 but rigorous solution of the specific examples considered has yet to be undertaken.

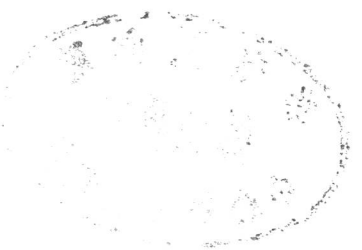
In Chapter 5 we attempt, albeit in a preliminary manner, to link up multipass system dynamics with those of spatially distributed processes of the more conventional type. The link is established by demonstrating that the digital simulation of a spatially segmented distributed process can be regarded as a multipass process, the analytical tools for which can be applied to produce results for stability and control similar to those obtainable by more conventional means. A distillation column and heater exchanger are used as examples.

The text is completed in Chapter 6 with a purely qualtitative review of areas of system study which might benefit from multipass systems analysis.

The authors acknowledge that many of the ideas and methods presented here have been published previously in various journals of learned societies, particularly the Proceeding I.E.E., and conference proceedings appearing in the references. Although it was originally envisaged that large sections of this book would inevitably bear a close resemblance to these source papers, utilising particularly several diagrams published therein, this has not, in the main, proved to be necessary, -or indeed desirable, in the interests of producing a coherent text. Permission received to restate earlier results and to reproduce diagrams is nevertheless gratefully acknowledged.

We particularly wish to thank Mrs. Pauline Turner for undertaking and completing so successfully the typing of both the original draft and the camera-ready copy. Digestion of a research text of this kind

is helped enormously by careful layout and the avoidance of errors in the typescript. In a work of this size the task is far from easy to accomplish.



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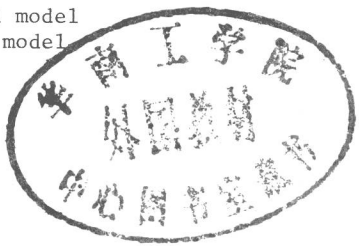

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