1 Introduction

1.1 Motivations and goals

The goals of this thesis are threefold. First of all, nowadays manufacturers are trying to distinguish themselves from their competitors not only by manufacturing at low cost, which is primarily demonstrated by low WIP and high output rate, but also increasingly with a superior logistic performance which is mainly represented by a short throughput time and high schedule reliability in order to achieve business success in a globalised market. Hence, not a single but all the conflicting logistic objectives such as short throughput time, low WIP, high schedule reliability and high output rate need to be achieved simultaneously. Moreover, market demand and environmental pressure create the need for novel manufacturing control systems that are able to manage production disturbances including internal disturbance (e.g. equipment failures and rework) and external disturbance (e.g. variations in demand patterns and unsatisfied raw material delivery) both effectively and efficiently. With the main goal of overcoming both challenges, this thesis, therefore, develops a Dynamic Bottleneck-oriented Manufacturing Control (DBNO) by means of optimizing short throughput time, low WIP and high schedule reliability through a Basic Control Platform (BCP) with the application of feedback, distributed and adaptive control technologies and then trading off four logistic objectives by a dynamic bottleneck-oriented control approach which develops and integrates Dynamic Bottleneck-oriented Control Algorithms (DBNOCA) into the BCP.

Secondly, a systematic and comprehensive configuration of dynamic bottlenecks is developed considering multiple performance criteria and multiple production resources (e.g. workstations and work systems). It is designed to conquer the main drawbacks of conventional bottleneck-oriented approaches (e.g. Drum Buffer Rope (DBR) and Bottlenecks-Oriented Logistic Analysis (BOLA)) in terms of configurating and detecting dynamic bottlenecks. Via discrete simulation experiments, predefined dynamic bottlenecks are modelled, visualized, and their complex dynamics are concretely demonstrated. Moreover, a fundamental application guidance of the configuration and modelling of dynamic bottlenecks is proposed within a broad scope of Production Planning and Control (PPC) methods. The proposed dynamic bottleneck-oriented approach not only overcomes the main drawbacks of conventional approaches, but also expands the application range from a one-time achievement of a single objective to a simultaneous trade-off between multiple objectives.

The third goal of the thesis is to deliver new insights regarding the development of the manufacturing of control systems and the fundamentals of production logistics. These findings are based on the concrete analysis of simulation results. They in-

volve two aspects: The first one focuses on investigating the impacts of interactions of possible manufacturing control functions on the system performance, i.e. with regard to key logistic performance measures (e.g. throughput time, WIP level, schedule reliability and output rate). Secondly it points out the means to simultaneously achieve multiple objectives for developing advanced control approaches in the manufacturing system with more than one kind of flexibilities. The second aspect provides a new understanding of significant relationships among logistic objectives, particularly the scheduling dilemma, so that fundamental basics of the production logistics system can be profoundly comprehended for future development.

1.2 Overview of the thesis

After the goals and overview of the proposed doctoral project are described in Chapter 1, the theoretical basics and research scope of the thesis are illustrated in Chapter 2. It starts with fundamentals of production logistics in order to define basic terms and introduces crucial theories for developing the proposed control system. Furthermore, it defines key terminologies of manufacturing control, classifies manufacturing systems and presents a functional model of manufacturing control systems from the perspective of logistics with the purpose of limiting the research scope.

The literature survey related to the thesis is discussed in Chapter 3. This survey covers three aspects: a release control mechanism, state-of-the-art of manufacturing system architectures and bottleneck-oriented control approaches. In each section, a number of existing methods and concepts are introduced and discussed in order to demonstrate their merits and shortcomings. On this basis, theoretical foundations and attention problems for the development of the Dynamic Bottleneck-oriented Manufacturing Control (DBNO) are pointed out and summarized at the end of each section. The former two sections provide the foundations for the developing of the part of the DBNO, named Basic Control Platform (BCP). The last section of the literature survey lays down the basics for the development of the dynamic bottleneck-oriented control approach as the second part of the DBNO, and the proposed application of configurating and modelling multiple dynamic bottlenecks.

In Chapter 4, the methodologies of the DBNO are illustrated. After its main concept is presented, the focused practical case and its simulation model based on the case study are described. Then, the methods of the DBNO are presented by pursuing its entire evolution process. We start with presenting the concept of the BCP by introducing its main idea and then describing its individual control components. These components include a feedback WIP control, a distributed routing control and an adaptive backlog control. On this basis, the main idea of the dynamic bot-

tleneck-oriented control approach is depicted. Furthermore, a systematic configuration of dynamic bottlenecks regarding multiple performance criteria and production resources is presented in this section.

In Chapter 5, the detailed rules and algorithms of the DBNO are described, according to the methodologies discussed in the previous chapter. The main body of this chapter is organized in two sections which present rules and algorithms of the individual control components of the BCP, and the dynamic bottleneck-oriented control approach which integrates the Dynamic Bottleneck-oriented Control Algorithms (DBNOCA) into the BCP. Moreover, multiple dynamic bottlenecks are modelled and a fundamental application for configuring and modelling dynamic bottlenecks, including a recommended procedure for practical application, is proposed.

Based on the descriptions of approaches, control rules and algorithms of the DNBO, it is validated and evaluated via simulation experiments. Thus several findings and conclusions are developed which are based on the evaluations of the results presented in Chapter 6. It starts with a primary evaluation which traces the entire evolution process of the DBNO from the individual control components of the BCP up to the fully developed DBNO. Afterwards, several comparative control systems are illustrated and assessed. By comparing these comparative control methods, the proposed control methods are then evaluated. This evaluation is based on discussions in former sections. Subsequently, major findings and conclusions of the thesis are stated. Finally, in Chapter 7 the main contributions and shortcomings of this thesis are summarized and future work for overcoming the mentioned shortcomings is proposed.