

CHAPTER 1

INTRODUCTION

Together with forging, casting, drawing and other processes rolling classifies under primary conventional manufacturing processes. Unlike machining it is a process used to change the shape of material using plastic deformation. This is accomplished by passing the material to be rolled between rollers revolving at the same speed but in opposite directions. Deformation then occurs as a result of compression of the material in the roll gap between the rollers. This compression is caused by actuators, forcing the rollers above and below the roll gap towards each other.

1.1 Background

After 1949 the first generation of Steckel mills were built mainly for industrial countries to roll carbon steel in smaller works where the high investment cost for a mill with continuous finishing train would not have been appropriate, because of the limited demand of the market [1].

At the end of the 1960s some developing countries were equipped with Steckel mills. These mills were designed for a large product mix. For a long period the field of Steckel mill building showed no significant activity until the 1980s when several Steckel mills of the second generation were built. Technological and design improvements made them different from the earlier mills.

Modern Steckel mills can be grouped into two main categories. A production capacity of 150000 to 450000 t/year of exclusively stainless steel, characterizes one group of mills. High flexibility and low investment cost makes the Steckel mills suitable for these steel grades which can either be austenitic, ferritic or martensitic [1]. For the second group production of a wide product mix, regarding strip sizes and grades is typical. Its production program includes stainless steel as well as carbon steel of a wide variety. Non ferrous metals can also be rolled by Steckel mills [2].

Because variations in rolling force are typical for the Steckel rolling process, appropriate control systems are used to ensure that requirements on thickness and profile of the strip are met. Systems used for this purpose are [2].

- Automatic gage control (AGC) : The purpose of this is to counteract the effects that e.g. temperature drop at the strip head and tail can have.
- Roll alignment control (RAC) : RAC is employed to avoid a loss of tracking of the strip which can be caused by temperature differences across the width of the strip.
- Profile, contour and flatness control : Control of these properties of the strip is achieved through a continuously variable camber (CVC) shifting system of the work rolls in contact with the strip as well as work roll bending.

The drives of hot strip mill automation and modernization are e.g. the need for an improved quality and increased productivity [3] with the quality measured in terms of dimensional accuracy, surface finish, flatness and strip's physical properties [4]. Automation projects of modern Steckel hot rolling mills focus on [1].

- material tracking,
- automatic slab and coil storage control,
- re-heating furnace control,
- automatic control of the rolling process with mill sequence control, mill set-up and correction, pass schedule calculation and optimization, automatic crop shear control, automatic gauge control, automatic crown and shape control, finishing temperature control and
- data logging.

Attention will be given to the control of strip thickness and tension in this work using the model of Scholtz [4] of the Steckel hot rolling mill process. Establishing controllers for industrial processes typically have the identification of opportunities and modeling of the process as an initial stage followed by the design of a control system. The general control problem is to obtain a mathematical model from the real plant in the real world, to design a controller in the mathematical world and to finally implement the designed controller in the real world [39]. Within this framework the focus of this dissertation is on the design of the controller, which takes place in the mathematical world.

1.2 Motivation

Rolling mills represent large assets in the steel making industry, which generate significant income. They are therefore of interest when it comes to upgrading. In particular this is the case for Steckel mills considered in this work. As mentioned in section 1.1 the main motivating factors for upgrading are to improve strip quality and increase mill throughput, as profitability is a function of both these factors [6].

Quality can be improved by maintaining a strip thickness control within narrower tolerances. Throughput can be increased by an improvement of tension control. This is so because larger reductions are possible with the application of an increased tension [7], which will be explained in more detail in chapter two.

Although in [5] it is reported that the Steckel mill makes use of tension rather than rolling to reduce the strip thickness, tension just aids the reduction of the strip thickness in the Steckel hot rolling process [4].

The literature often deals with thickness control, but for multi stand rolling mills [8][9]. Tension control for these types of mills is accomplished by loopers as actuators. Not much literature on tension control in Steckel hot rolling mills exists. In many of the literature sources [10][11][12] on rolling mills it is reported on control of the mill output at threading speed. However in [13] the speed up and slow down phases now also become relevant in order to reduce the amount of off-spec product which may be the result of insufficient control during these phases.

With respect to control research on rolling mills the current trend is towards the application of multi-input-multi-output (MIMO) control [8]. Although rolling mills are very complex multivariable systems, the most commonly implemented control systems are multi-loop controllers. The main reason for this is the simple and separate commissioning of the individual controllers. Taking the interaction between the strip thickness and tension into account these controllers are however not ideal. Multivariable control structures are better suited for the group of processes into which the rolling process falls. Several reasons can be quoted to motivate the investigation into a modern advanced MIMO control structure [14].

- i) The nonlinearities associated with the actuators need to be considered with the development of a control system for this process.
- ii) In general the rolling process is time variant because of thermal and mechanical changes due to wear on the rollers. In addition the dead times in this process vary during the speed up and slow down phases.
- iii) A controller is needed which accounts for uncertainties attached to the numerous parameters used to model the process.
- iv) Assumptions made to simplify the otherwise complex process, need to be considered in an advanced MIMO controller.
- v) Handling of dominant dead times between the stands and thickness sensors make the application of classic controllers difficult.

Above mentioned points can be considered in long term research but are not accounted for in this work. As an initial step in controller design the method used for the control of the Steckel hot rolling process, as investigated in this work, is multi-loop control and H_∞ control. Further research can however be launched with the model developed in [4] as basis.

1.3 Aims and Contributions

Using the model in [4], not only for the identification of a linear time invariant (LTI) model, but also for the design of a multivariable controller, provides more insight into the

process itself. In addition to this the extension of the existing simulator with a control structure is seen as a contribution to knowledge in this field. In particular this work contributes the following.

- In this work controller designs are performed for a reversing mill for an operating point on the speed up ramp, which is different from research found by the author in literature in the field of hot rolling mills.
- Identification of LTI models and investigation of their suitability for controller design purposes.
- An investigation of controlling the plant in which the tensions are already controlled and which has gauge meter compensation incorporated in it.
- Design of a diagonal controller as well as H_∞ controllers for the identified LTI plants.
- A procedure representing an H_∞ controller has been incorporated in the existing simulator in a C++ environment.
- Simulations of the Steckel rolling process for diagonal as well as H_∞ controllers by means of which an evaluation of the controller schemes is possible.

In brief the aims and contributions of this dissertation are diagonal and H_∞ controller design work and application to a non linear simulator which was developed by [4] as a basis for a larger project in which potential benefits of a modern advanced control method to a Steckel hot rolling process are being investigated. This work is thus a continuation of the project in which a rolling process was modeled for control.

1.4 Organization

The process, which becomes the object for controller design in this dissertation, is first described in the following chapter. The description includes a brief overview of where the Steckel type mill fits into the hot rolling process. In succession a closer look will be taken at the Steckel mill itself and in particular the roll gap physics.

In chapter 3 linear models are then identified from step test data produced with the nonlinear simulator. The data will be presented in the form of graphs accompanied by a heuristic justification for the transfer functions of the linear models.