CHAPTER 7

CONCLUSIONS AND RECOMMENDATIONS

7.1 Conclusions

The investigations done in this dissertation were aimed at the implementation of a controller scheme on a point during the acceleration phase of a simulated multivariable hot rolling mill process. For this purpose a nonlinear plant simulator, developed in [4], was used to identify linear models for controller design, and to serve as plant on which the controllers could be tested.

Three linear models were identified from simulations of the nonlinear plant simulator, i.e.:

i) A first linear model in which the tension model was part of the simulator except for generation of SID data for the transfer function, $g_{11}(s)$. Gauge meter compensation and inner loop tension control, i.e. control at a higher frequency than the control designed for the plant as a whole, were not part of the simulator used for the first linear model.

ii) A second linear model was identified from data of a simulator, in which gauge meter compensation and inner loop tension control was incorporated. However, only the transfer functions on the diagonal were identified for this model.

iii) The third linear model was the same as the second linear model except that in addition, the off-diagonal transfer functions have also been identified, i.e. they were nonzero.

It was found that gauge meter compensation counteracted the phenomenon that tension oscillations result in exit gauge variations. The inner loop tension control was applied to the simulator in addition to gauge meter compensation in order to prevent tensions from becoming negative. From the steady state gain of the transfer function, $g_{11}(s)$, of the three linear models it was found, that a conversion of hydraulic stroke to exit gauge change is 87% when using gauge meter compensation. Without compensation this conversion is only 41%.

A diagonal PID/PI controller was designed for the first linear model while for the second and third LTI models a diagonal and an MIMO H_∞ controller were designed respectively. From the controller designs and from the closed-loop simulations of the three controller schemes and the simulator the following can be concluded.

i) With respect to the first aim in chapter 1 it can be concluded that the controller designs are only valid for the main drive peripheral speed range of $v_{main} = 3.5 \pm 0.2$ m/s.

ii) The first and second LTI models are suitable for controller design because in their case model mismatch does not affect their corresponding controller designs as adversely as in the case of the third linear model. This is so because from the transfer function $g_{31}(s)$ the controller for the third model is designed from the information that for a decrease in exit gauge, i.e. the input to $g_{31}(s)$, the front tension that differs a lot from the average measured front tension (see Fig. 3.40). For the diagonal PID/PI and diagonal H_∞ controller design however only the transfer functions on the diagonal were used.

iii) One of the aims of this work was an investigation of using gauge meter compensation and inner loop tension control. It was found that they make it possible that an LTI model, for which transfer functions were identified only on the diagonal, can be used for controller design, i.e. the process gets decoupled to an extent.

iv) Regarding the fourth aim of this work it can be concluded that a diagonal PID/PI controller, a diagonal H_∞ and an MIMO H_∞ controller could be designed based on the first, second and third linear models respectively. It needs to be emphasized here that the control of the H_∞ controllers is on a plant with gauge meter compensation and inner loop tension control being part of the plant.

v) With the realization of the fifth aim, it was found that when implementing the controllers in C++, the velocity form implementation of the inner loop tension controllers yields slew-rates of coiler speed control actions, which are high. This could be attributed to the nonzero initial control actions of these controllers (PI controllers).

vi) With respect to the sixth aim in chapter 1 it can be concluded from the closed loop simulations with the simulator and the three controller schemes, mentioned under point iv) above, that a diagonal model is sufficient for controller design. This could be seen from the diagonal PID/PI and diagonal H_∞ controller's fulfillment of the specifications in section 5.2 as well as the specification for a switching controller as mentioned in section 6.6. In particular the diagonal H_∞ controller was found to be the most suitable one for a switching control system.

This work shows that control on the speed-up ramp is possible and has the possible advantage of reducing off-specification strip produced during this phase of rolling. Such a benefit can become real when the suited controllers as designed in this work are used within a switching control system valid for the whole speed up ramp.

7.2 Recommendations

For further research on this project recommendations are given concerning identification of a linear model and control system design.

7.2.1 System Identification

Points of linearization that cover the speed range outside the speed range considered for this work should be chosen for system identification of linear models. The models can then be used for the development of various control systems, which control the process during the acceleration phase as mentioned in the next section. It is recommended to do such a system identification on a simulator, which has gauge meter compensation and inner loop tension control incorporated in it, in order to reap the benefit of a process which is decoupled to an extent.

7.2.2 Control System Design

i) H_∞ controllers can be designed for each operating point for which a linear model has been estimated. This should be done because the diagonal H_∞ controller, designed in this work, is only valid for the range $v_{main} = 3.5 \pm 0.2$ m/s of the mill main drive peripheral speed. A switching control strategy can then be developed and employed to be able to run simulations on the whole speed up ramp. It is expected that control error changes such as a front tension set point change from 10 N up to its set up value could be counteracted with the implementation of a switching control strategy during the whole speed up ramp of a rolling pass.

ii) The inner loop tension controller can be implemented in state space with zero initial conditions instead of a velocity form in order to obtain zero initial control actions and thus smoother control action trends for the inner loop tension control.