Optimization of cold rolling mill process to improve productivity and Product Quality of steel - an overview

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Abstract **- There are many advances on metal rolling technologies over the past half century, but due to intense global competition and the requirements for increasingly thinner, higher quality rolled metal products continue to force metal producers to seek new ways to outperform one another. The need to optimize cold rolling mill to achieve profitability, and the significant costs associated with capital upgrades, mean that the application of innovative rolling technologies presents the most attractive near term solution for many steel manufacturer to improve quality and productivity. Set-up generation or pass schedule is an important aspect in the operation of Single stand reversing and tandem cold rolling mills. It defines speeds and powers for the drives, stand reductions, roll forces and entry & exit tensions and % reduction in each pass for the cold mill control system. This paper focuses on the various optimization techniques used in cold rolling mill process to achieve productivity and Quality of steel through literature review. Various Process models for cold rolling mills have been intensively developed in the last years, hoping to increase quality of steel strip and productivity of rolling processes. Nevertheless, characteristics are only achieved using models sufficiently to be accurate and robust. The availability of accurate models is associated for cold rolling process parameter optimization, has been intensely explored in the literature.**

Index Terms **- Hot rolling, Cold rolling , pass schedule, tandem mil, Taguchi method, micro structural.**

I. INTRODUCTION

Rolling is the process of plastically deforming metal by passing it between hot or cold rolls. It is most widely used forming process, which provide high production and close control of final product. The metal is subjected to high compressive stresses as a result of friction between the rolls and metal surface. Rolling processes can be mainly divided into hot rolling and cold rolling. The initial breakdowns of ingots into blooms and billets is done by hot rolling this is followed by further hot rolling into plate, sheet, rod, bar, pipe, rail. The cold rolling of metals provides sheet, strip, foil with good surface finishes and increase mechanical strength with close control of product dimensions. The purpose of a rolling mill is to successively reduce the thickness of the metal strip and/or impart the desired mechanical and micro structural properties. Hot rolling mills are used for bulk thickness reduction at elevated temperatures, while cold rolling 2-High 4-High 6-High 4-High Tandem 2-High Z-High 12-High 20-High (Temper)6-High (Cluster) mills are employed as secondary rolling operations to achieve more precise dimensional, metallurgical, and mechanical properties. The single-stand type rolling mills are usually operated as "reversing" mills, whereby the strip is successively wound and unwound in coil form as it is repeatedly passed back and forth through the mill. Reversing mills are generally used for smaller scale production of the specialty cold-rolled products. Larger scale production more commonly occurs with tandem-type rolling mills, whereby the strip undergoes a single pass through a train of rolling stands before being wound into coil form. Of all the rolling stand configurations, the 4-high variety is the most widely used both in single-stand and multi-stand tandem mills. The 2-high mill, which consists of two working rolls only and no other supporting rolls are mainly used for "skin-pass" or temper rolling, the purpose of which is mainly to impart the desired mechanical properties rather than to cause significant reductions in thickness. Rolling mills consists of rolls, bearings, housing for containing these parts and a drive for applying power to the rolls and controlling the speed [9].

Optimization for cold rolling mills are continuously being improved due to today's stringent high throughput, quality and low scrap loss requirements for products. To consolidate competitive strengths in the global market, many steel companies are engaged in maximizing the reduction and consequently minimizing the cost of manufacture. Rolling scheduling is an important aspect in the operation of cold rolling mills. It defines reductions in each pass or stand, tensions (Forward & Backward), rolling forces, roll torque (Mill top & bottom drive motor current), mill maximum speeds. The optimized scheduling should lead to improved thickness, surface finish and shape performance of the products.

Despite the advances of numerous metal rolling technologies over the past half century, intense global competition and the requirements for increasingly thinner, higher quality rolled metal products continue to force metal producers to seek new ways to outperform one another. The need to maximize rolling mill utilization times to achieve profitability, and the significant costs associated with capital upgrades, mean that the application of innovative rolling technologies presents the most attractive near term solution for many metal producers to improve quality and productivity. At the same time, the companies that build and deliver new rolling mills face increasing pressure and competition to supply their customers with the latest rolling technologies that ensure competitive sustainability. To help address the needs for better rolling technology, study and optimized process parameters will be an improvement upon the existing process technology for the rolling of high quality flat metals at high rates of productivity.

II. LITERATURE REVIEW

Many Physical Models for optimization of process parameters for cold rolling were developed to increase quality of steel strip and productivity of rolling mill. These two characteristics can be achieved if models are sufficiently accurate and robust. The availability of accurate & Robust models intensely explored in the literature.

Wang et al (2000) [7]Presents optimal scheduling for tandem cold rolling mill based on Genetic algorithm and results are investigated for cost function minimization. Nedler ad Mead (1965) [11]employed simplex algorithm. Main function force taken in consideration.

Pires et al (2006) [2] has applied nonlinear simplex optimization method for cold rolling mill process parameters which reports good results.

Pires C.T.A. et al (2006) developed set up optimization system to calculate cold rolling process parameters ie reduction for each stand for a 4 stand cold mill installed at Cosipa Plant Brazil. The set up generation system consists of two phase, 1 st phase is of non iterative calculation procedure and optimization phase based on Nedler & Mead simplex method . Which takes in to consideration quality & productivity as a objective function of cold rolling mill. He propose non iterative algorithm which in fact non iterative version for betafactor iterative algorithm presented by Guo (1997) [4]which is proprietary iterative algorithm used to implement set up generation phase. For optimization phase Nedler & Mead (1965) [11]simplex algorithm has been used where variable related to quality and productivity like force, power & tension are defined by objective function. The process variable are calculated using classical model. Experiment result Cosipa Plant Brazil shows high quality and productivity.

Pires C.T.A. et al (2008) [1]present adaptation procedure for set up generation of 4 stand cold rolling mill at Cosipa plant Brazil. The objective function minimized taken into consideration, friction and yield stress coefficient by using Nedler & Mead (1965) simplex method. Simulation results shows that the method adapted is robust and can be refined very easily leading to expected result but most part of force error is certainly due to change in the hardness of steel strip. Hence we cannot say that the process is Robust.

Henrique C. Ferreira optimize cost function on his set up generation system considering power drives, rolling force & tensions as most important variables associated to quality and productivity. The result of set up generation uses process models prepared by Bland & Ford employed during normal operation shows that reference generated are very close to the measured data during rolling of the coils for tension and force. Greater difference found in stand speed & motor power. His propose set up generation system was carried out in Matlab using model propose by Bryant for cold rolling process. The performance results of two models were compared average deviation in % taken as base system in the main system. Despite of propose system set up generation to be simpler than usual set up generation system is suitable to be used in emergency operation mode as it is quick, safe & sufficiently accurate.

Ali Heidari (2011) [5] developed two combination method used for optimization of rolling process parameters according chatter phenomenon. Friction factor, reductions, tensions and strip, speed were selected as design factors. First combination method is central composite design of experiment and response surface methodology. The result shows 29% increase in rolling speed using first method. Taguchi method of design of experiment and neural network technique used in second combination method. More than 26% growth in critical speed achieved using second method. He infers that increasing all reductions and rolling speed, increases the risk of chatter severely. However tensions have very little effect on chatter phenomenon while friction coefficient should be maximize to avoid chatter.

Dadang Wong (2002) [5]presented computational Intelligence based process modeling and optimization for tandem cold rolling mill process in order to maximize throughput and minimize cost and crop losses. He applied computational Intelligence based optimization for the first time to the rolling schedule of tandem cold rolling mill. Rolling schedule is a set of multiple rolling parameters such as reduction, roll force, torque, rolling speed and tension. Different combination of parameters generates numerous rolling schedules. It is very hard to declare which one is best solution. Optimization of rolling schedules done by intelligent searching mechanism by assessing rolling constraint and combined cost function of tension, shape & power distribution. The results were compared with existing rolling practices base on empirical model. Proposed model can be reduced cost and maximize throughput. The proposed model was generic complex engineering problem of optimization can capable of solve multi objective problem. It employs heuristic optimization approach. The propose model & simulation beneficial for fine tuning if process parameters & effective in achieving significant cost saving & product quality improvement.

Dadong Wang (2000)[7] develop Heuristic Optimum Design Of Rolling Schedules for Tandem Cold Rolling Mills Scheduling for tandem cold mills refers to the determination of inter-stand gauges, tensions and speeds of a specified product. Optimal schedules should result in maximized throughput and minimized operating cost. He presented genetic algorithm based optimization procedure for the scheduling of tandem cold rolling mills. The optimization procedure initiates searching from a logical staring point an empirical rolling schedule and ends with an optimum cost. Cost functions are constructed to heuristically direct the genetic algorithms searching, based on the consideration of power distribution, tension, strip flatness and rolling constraints. Numerical experiments have shown that the proposed method is more promising than those based on semi empirical formulae. The results from his case study show that the proposed approach could significantly improve empirically derived settings for the tandem cold rolling mills.

H.T. Zhu(2005) [8]presented paper on Optimization of Cooling Spray Water in Cold Strip Mill to optimize the amount of cooling spray water that can contribute to the shape performance of the final strip products. Using neural network a detailed crosssectional shape in cold strip mill was calculated with many input variables. He has proposed two strip shape prediction models to measure the strip shape performance against the factors involved. He introduced principal component analysis for shape prediction model to overcome the correlation effects among the process variables and the problem of dimensionality. The model predicts the dynamic shape of the strip across the width and length compared very well with the measured data of a cold rolling mill. He developed another strip shape prediction model to analyze the relationship between the strip shape quality, rolling parameters and amounts of cooling spray water on the strip and on the work rolls. From this model, a table of optimized settings of water pressure was recommended for the cold rolling process. Shape Quality Analysis Model Based on Neural Network. From this model, a table of optimized settings of spray water pressure was recommended for the cold rolling process.

Malik, Arif Sultan. (2007) [9]in his thesis Ph.D presented improved technology for attaining high quality rolled metal strip. The new technology is based on an innovative method to model both the static and dynamic characteristics of rolling mill deflection. It applies equally to both cluster type and non cluster type rolling mill configurations. By effectively combining numerical Finite Element Analysis (FEA) with analytical solid mechanics, his devised approach delivers a rapid, accurate, flexible, high-fidelity model useful for optimizing many important rolling parameters. The associated static deflection model enables computation of the thickness profile and corresponding flatness of the rolled strip. Accurate methods of predicting the strip thickness profile and strip flatness are important in rolling mill design, rolling schedule set-up, control of mill flatness actuators, and optimization of ground roll profiles. The corresponding dynamic deflection model enables solution of the standard eigen value problem to determine natural frequencies and modes of vibration. The presented method for solving the roll stack deflection problem offers several important advantages over traditional methods. In particular, it includes continuity of elastic foundations, non-iterative solution when using pre-determined elastic foundation moduli, continuous third-order displacement fields, simple stress-field determination, the ability to calculate dynamic characteristics, and a comparatively faster solution time. Consistent with the most advanced existing methods, the presented method accommodates loading conditions that represent roll crowning, roll bending, roll shifting, and roll crossing mechanisms. Validation of the static model is provided by comparing results and solution time with large-scale, commercial finite element simulations. In addition to examples with the common 4-high vertical stand rolling mill, application of the presented method to the most complex of rolling mill configurations is demonstrated with an optimization example involving the 20-high Sendzimir mill.

III. CONCLUSION

The availability of robust & accurate models is associated for cold rolling process optimization has been intensely explored in the literature. Various Process models for cold rolling mills optimization have been intensively developed in the last years, hoping to increase quality of steel strip and productivity of rolling processes. Nevertheless, characteristics are only achieved using models sufficiently to be accurate. The availability of accurate models is associated to process parameters or set-up optimization and adaptation methods, and, in function of this, has been intensely explored in the literature. As per literature review various Models for optimization of rolling parameters ie set-up generation system considers Reduction, power drives, rolling forces and tensions as the most important variables associated to quality and productivity. Reductions, tensions, rolling forces, powers drives and speeds associated to the minimum of the cost function are taken as the optimum set-up for the cold rolling mill. Most of the models develop are sufficiently accurate but not robust.

In practice input coils have many defects Disturbances such as hardness variation and thickness variations along the length of the strip due to Hot Rolling defects which were not considered while optimizing the rolling parameters for Quality performance. The optimization considering these disturbances needs to be developed to make cold rolling process robust. Still there is a scope to develop optimization techniques for cold rolling process which will insensitive to these disturbances and make process robust.

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