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TANDEM COLD ROLLING MILL

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ABSTRACT

Controlling the tandem cold rolling of metal strip is a significant challenge to the control engineer. This is due mostly to complex interactions between the process variables, nonlinearities that change with process conditions, and long speed-dependent time delays. The present technology is limited in its capability for improvement in performance. This is describes a new control strategy that is based on solving algebraic Riccati equation point wise to establish a control law for a MIMO (multiple-input and multiple-output) controller that is augmented by appropriate trimming functions. Simulation testing showed that the tolerance in mill exit thickness compares favorably to the tolerances using existing techniques. The tandem cold rolling mill of metal strip is a complex multivariable process whose control presents a significant engineering challenge. The present technology generally relies on a control structure where in the interactive coupling between process variables in partially reduced by several SISO(single-input-single-output) and SIMO(single-input-multi-output) control loops operating on certain variables to decompose the overall problem into several separate problems to attempt to allow independent adjustment of strip tension and thickness anywhere in the mill.

INTURDUCTION

Rolling is the most widely used deformation process. It consists of passing metal between two rollers which compress it to reduce its thickness. A set of roller is called a stand, and in a mill there may be more than one stands. The roller in contact with the metal are called work roller. Often back up rollers are provided to increase the rigidity of the work rollers for improving the dimensional control. Steel may pass through from one stand to another for a number of times before it reaches the required thickness and shape. Intens of tandem cold mill productivity and product quality. a multi objective optimization model of rolling schedule based on the cost function as process to determine the stand reductions, inter stand tensions and rolling speed for a specified product. The proposed schedule optimization model consists of several single cost functions. which take rolling force, motor power inter stand tension and stand reduction into consideration. The cost function which can evaluate how for the rolling parameters are from the ideal values was minimized using the Elder-Mead simplex method. The process rolling schedule optimization method has been applied successfully to the 5-stand tandem cold mill in Tangent steel. Rolling schedules can be possible with an even and uneven number of passes. Work roll positive and negative bending, Intermediate roll shifting and positive bending are the additional features provided for better shape control. Individual mill output can reach 600,000 tones per year, sufficient for the highest volume of demand within steelmaking companies. Mill model for optimized pass schedule is provided along with Mill Steel is the most useful and cost effective metal. The automation in the steel manufacturing is continuing, hence steel makers expect that more techniques can be incorporated in the processes, particularly after computer technologies came into development.

COLD ROLLING MILL

The purpose of the reversing cold rolling mill is to reduce the thickness of the steel to the customer's specifications. The hot roll band passes back and forth between the rolls until it reaches the specified

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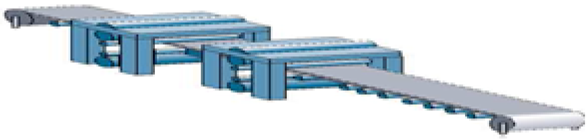
thickness. Like the pickle line, the cold rolling mill is able to handle.



From the test results, it can be observed that the predicted values are very close and follow almost the same trend as the experimental values. The maximum absolute error for training patterns was found to be 0.6 % and the minimum was found 0 % and for 86 % of the cases the predicted values were same with experimental ones. Prediction accuracy is 100 % for training. The maximum absolute error for testing patterns was found to be 13.6 % and the minimum was found 0.4 % and for half of the cases error was less than 4.6 %. Prediction accuracy is 83.1 % for the testing. Training part has much more accurate prediction as it is expected from the results where value of error and its deviation is much greater for testing part. To change the percentages of partitions and the dataselected as testing can improve the results and more accurate results be a port of the some as per can be gained for testing part.

With more than 100 years of experience in metals industry and a wide range of products ABB is the ideal partner for Rolling Mill and Processing Line projects. With our solutions we can offer the following benefits to our customers:Tailor made solutions for green field projects and revamps.Service structure for product and field service available all over the world.Full scope of electrical and automation equipment 'Made by ABB' - from the drive via the Process Automation to the Production Management.Centers of excellence with experienced engineers available in many countriesthe ABB product and service portfolio for cold rolling mills includes.Process automation based on ABB 800xA system.Collaborative Production Management.Rolla Optimize Mathematical mill setup model.Induction and Synchronous Motors & Drives. Instrumentation.Project Management.Basic and Detail Engineering.In-house Test.Erection Supervision & CommissioningOptimization and Consulting.Life Cycle Service.The reversing cold rolling mill is so named because the steel runs back and forth between the rollers, reducing the thickness further with each pass. Steel scope's reversing cold rolling mill employs closed-loop computerized quality control gauges, a unique feature for reversing mills. These gauges ensure close tolerances for thickness and shape, which enables Steel scope to offer cold-rolled steel equivalent to any other U.S. producer.

- A coil fresh from the pickle line sits in waiting for the cold rolling process.
- The coil being processed starts at the entry tension reel, where it is uncoiled and passed forward through the rollers.
- A set of rolls applies pressure to the steel in order to make it thinner, while maintaining its shape and width. The number of passes depends on the customer's specifications for coated product thickness.
- As it passes forward through the rolls, the steel is re-coiled onto the delivery tension reel. From there it goes back through the rolls in reverse, reducing the steel thickness further.
- Thickness gauges measure the thickness of the steel with each pass through the rolls.
- Once the proper thickness is achieved, the steel is again coiled onto one of the tension reels. From there it is ready to enter the metallic coating line.

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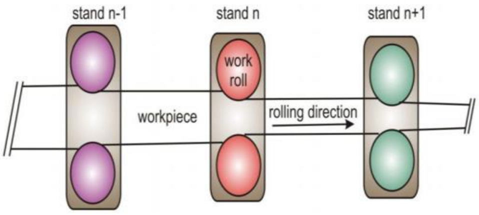
MANUFACTURING PROCESS OF TANDAM COLD FORMING

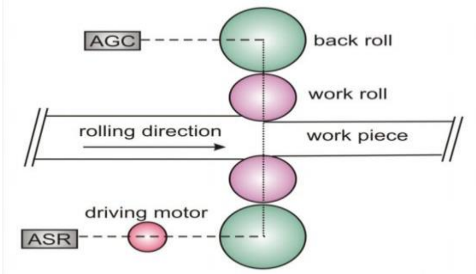
For many applications, the products of hot forming are not satisfactory as perLevers et al (1994). In particular, cold forming is used for the production of thin strip. Additionally, cold rolling is sometimes applied for the production of wires and tubes. However, by far the most important application is the production of cold rolled strip. The advantages of cold forming are,Production of thinner strip than by hot rollingm Production of blank surface with little depth of roughnessProduction of strip with narrow gauge tolerance and even surface over width andlength.Good control of strengtheningControl of physical characteristics.

In cold rolling, usually no heat is applied to the work piece before forming. Only some special steels like spring steel, tool steel, tempering steel or alloyed steels may be subjected to heat treatment before pickling and rolling. However, frictional energy at the contact surfaces of the work piece is converted to heat. this heat may increase temperatures in rapid adiabatic processes over 100°C. The processing of steel in cold rolling mills differs considerably from the production in hot rolling mills. The raw material is first descaled (usually pickled, sometimes shot blasted and pickled), then cold rolled and heat treated. Further treatment steps include slitting, skin-pass rolling, coiling and packing**.** Cold rolling mills usually consist of a number of mill stands arranged in alignment as in Long metal products with different cross-sections, such as strips or bars, are produced basing on the principle of multistage shaping as they proceed through mill stands sequentially. The cross-sections of work pieces, such as blooms, billets or slabs, are reduced in each stand under high pressure.



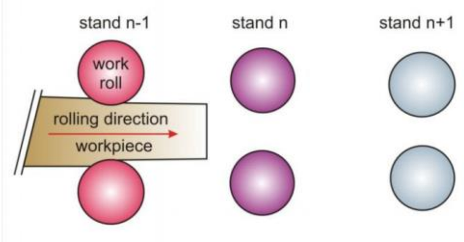
Tandom rolling mills

To meet the dimension requirements, such as thickness, width, flatness and shape, Automatic Gage Controllers (AGC) are employed tocontrol the roll gap and pressure. Automatic Speed Regulators (ASRs) are used to control the mass flow passing the rolling mills. A single stand in tandem rolling mills with dimension and yield regulation systems isschematically illustrated in Figure



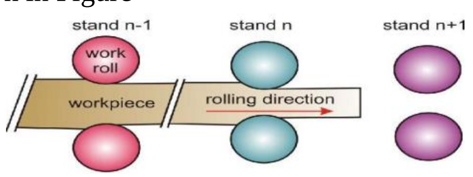
Single stand in tandem rolling mill

According to the rolling processes of a work piece, the operation modes of a stand fall into four categories. Initially, no work piece passes and the stand n works in an idle mode as shown in Figure



Idle mode

When a work piece passes, the stand n is engaged on the upstream stand n-1, but has not entered the downstream stand n+1 yet, stand n is in a run-in mode as shown in Figure



Run-in mode

Following the normal mode in which the work piece passing stand n, is engaged on both the upstream stand n-1 and the downstream stand n+1 as in Figure

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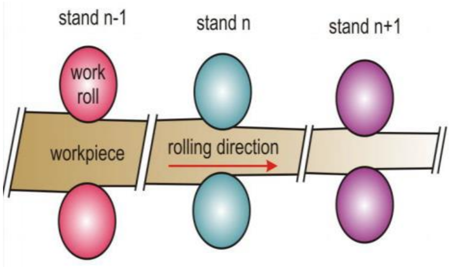
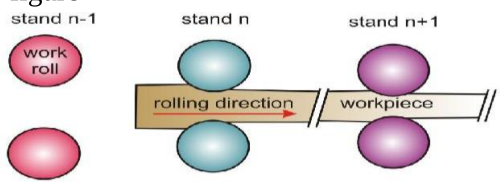


Normal mode

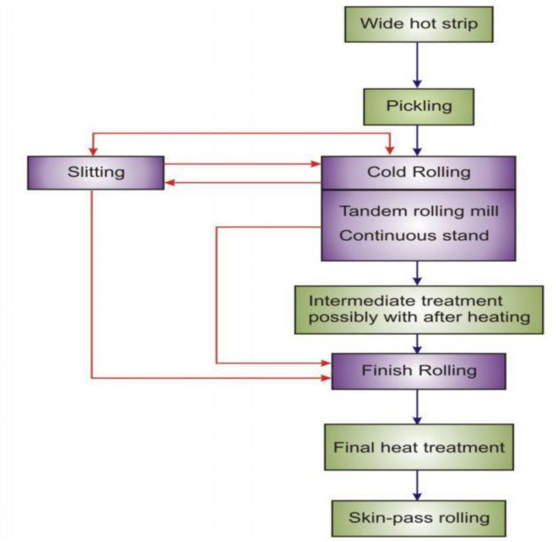
The run-out mode refers to the state when the work piece passing stand n is engaged on the downstream stand n+1 and leaves the upstream stand n-1 as in below figure



Run-out mode

A specific problem associated with tandem rolling mills is the presence of tension, a longitudinal force inside the work piece resulting from the inequality of mass flow of the rolled material between two adjacent mill stands. Tension can cause undesired product deformation such as cross sectional reduction or cobbling. onthe other hand, to optimize the performance of AGC and ASR, it is desirable to keep tension constant by means of additional control action. However, interaction effects, i.e., activities of and such as adjusting the roller gap and stand speed, will incur tension variation and in turn tension maintenance activity, such as adjusting stand speed, will worsen the gage and speed control, and will complicate the situation. Despite the advancements 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.

Hot rolled steel always has a layer of scale of variable structure on its surface, depending on the conditions of hot rolling. In order to achieve good surface quality and better frictional behavior, the strip has to be decaled before cold rolling. Decaling is usually done chemically only or in combination with mechanical means Pickling removes oxides and mill-scale from the surface of steel. Unalloyed steel is usually pickled by the action of an inorganic acid, generally sulphuric or muriatic acid, diluted with water. For stainless steels there is no single acid that is able to remove all types of scale layers. However, most commonly for the pickling of stainless steels nitric acid / fluoric acid mixtures are used. Furthermore, electrolytic pickling enhances the decaling of alloyed steels that are otherwise hard to pickle. Pickling can be carried out by push pickling or by continuous pickling installations. Startup-times of new plants and shutdown-times during modernizations have to be kept at a minimum while the guarantees for product quality, plant availability and throughput are more and more ambitious. Good control performance can be achieved since the processes are mostly linear and PI control allows to optimize the control loops in a straight-forward way. Once those systems are running properly, strip can be threaded into the mill and the technological control functions such as position control, strip thickness, strip tension force and shape control can be set-up step by step. Those control loops are superimposed to the basic control loops so that there is a cascaded control structure.



Step by step procedure of therollingprocess

Thermo Mechanically Treated bar is a manufactured in a process in which the ribbed bar is heat-treated in three stages during the production process itself. the bar is rapidly cooled/ quenched in high pressure water jacket/spray system as it emerges from the finishing stand of the rolling mill. The control of strip thickness is achieved by appropriately adjusting, for example, the screw setting and/or the unwind tension. Nicolas Solar (2008) implemented an adaptive self-tuning gauge control system on a cold-rolling aluminum mill, using an 80286-based micro computer system. The mill process had been modeled as a second order system with oneinput and one output. The model parameters were estimated on-line using a recursive least squares estimation algorithm. The inputs to the estimator were correlated in time so the estimator is not affected by the gauge measurement transport delay. Based on the estimated model parameters and a pole-placement design, a control signal is calculated. The regulator structure used was a filtered version of a discrete controller. The process of manufacturing Bars is explained in the following process flow diagram

LITERATURE SURVEY

In particular, a wide web cannot be guided by means of flange and pulley because of undesirable distortion or damage of the edge. Markey (1957) researched the edge position control of webs In the steel industries. Feiertag (1967) studied steering and displacement type web guides in the rolling process. Shelton (1968) first order model presents the dynamics of a moving web that includes the relation of the lateral velocity to the longitudinal velocity and the input error. Shelton and Reid (1971) had derived the first order and second order model through geometrical by taking the elasticity of webs into account, and represented dynamic behavior by regarding web as Euler beam. Using modified initial conditions, Young and Reid (1993) represented transfer function based on the second order model. Brandenburg (1977) studied the longitudinal dynamics of a moving web, but did not consider the changes, and register errors are described. Reid and Lin (1993) proposed the fixed again and variable-gain control of web tension in the winding section. For variable gain, the control parameters are continuously updated based on the diameter of the roller, which is a major contributor to the system dynamics and uses pole placement techniques. Shelton (1991) had derived the first order and second order conditions, Young and Reid (1993) represented transfer function based on the second order model. Ian Postlethwaite and John Geddes (1994) presented a paper which considers the application of robust multivariable control based on 31" design produced significantly less undershoot in response to skid chill.. zoon Cho et al (1997). The accurate prediction of roll force is essential for product quality. mathematical model. Both networks were shown to improve the accuracy by 30–50%. One difficulty was when promoting the use of the neural network the inability to estimate the A new variable structure control based on a co-ordinatio optimization algorithm (Ringwood 2000). Simulation results verify the effectiveness of the proposed. Recently, some methods have been used to solve such paradoxical problem. Han and Jingling Han (1994) developed a new methodology for web tension regulation based upon a unique Active Disturbance Rejection Control concept. In this approach the disturbances It is designed without an explicit mathematical model of the plant. This controller is designed to be inherently robust against plant variations. Once it is set up for a class Automatic Gauge Control methods have been developed for hot or cold mill processes. Lin and Land (1993) derived a mathematical model for a typical single-stand rolling mill and design Proportional

PARAMETERS

- Silicon carbide
- Full steel body
- Available in manual and automatic modes
- Checked in standard parameters
- High in productivity in low time
- Easy to operate and is accurately monitored through instrumentation

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- Precise control of various parameters such as temparacher gas pressure etc.,
- Optimum gas as well as low power consumption
- Mill speed - 0-30RPM(Approximate)
- Mill speed- 7.5HP, 220V, 3-phase
- Mill dimensions – 48’’L * 24’’W * 48’’H (Approximate)
- Weight – 2,000LBS (Approximate)
- Chamber size – 12’’L*6’’W*2-1/4’’H
- Maximum temparacher – 2250 degree fore heat
- Power – 220 volt single phase
- Oven diameters -48’’L * 24’’W * 60’’H (Approximate)
- Roll width – 2.312

Specifications	Three stand tandem	Four stand tandem	Five stand tandem
Material	Hot rolled and picked	Hot rolled and picked	Hot rolled and picked
Rolling type	Continuous	Continuous	Continuous
In put strip thickness	2.0mm-3.0mm	2.0mm-4.0mm	2.0mm-4.0mm
Output strip thickness	0.5mm-1.2mm	0.4mm-1.2mm	0.3mm-1.2mm
Width	450mm-1250mm	450mm-1250mm	450mm-1250mm
Max rolling speed	480-900m/min	480-1200m/min	480-1500m/min

RICCATI EQUATION

Equations of the form dy/dx = P(x)y2 + Q(x)y + R(x) are called Riccati equations. If y1(x) is a known particular solution to a Ricatti equation, then the substitution v= y − y1 will transform the Riccati equation into a Bernoulli equation.

Dy/dx= P(x)y2 + Q(x)y + R(x)

Before we give the formal definition of Riccati equations, a little introduction maybe helpful. Indeed, consider the first order differential equation

$$\frac{dy}{dx} = f(x,y).$$

If we approximate $f(x,y)$, while x is kept constant, we will get

$$f(x,y) = P(x) + Q(x)y + R(x)y^2 + \cdots$$

If we stop at y, we will get a linear equation. Riccati looked at the approximation to the second degree: he considered equations of the type

$$\frac{dy}{dx} = P(x) + Q(x)y + R(x)y^2.$$

These equations bear his name, Riccati equations. They are nonlinear and do not fall under the category of any of the classical equations. In order to solve a Riccati equation, one will need a particular solution. Without knowing at least once solution, there is absolutely no chance to find any solutions to such an equation. Indeed, let y_1 be a particular solution of

$$\frac{dy}{dx} = P(x) + Q(x)y + R(x)y^2.$$

Consider the new function z defined by

$$z = \frac{1}{y - y_1}.$$

Then easy calculations give

$$\frac{dz}{dx} = -\big(Q(x) + 2y_1R(x)\big)z - R(x)$$

which is a linear equation satisfied by the new function z. Once it is solved, we go back to y via the relation

$$y = y_1 + \frac{1}{z}.$$

Keep in mind that it may be harder to remember the above equation satisfied by z. Instead, try to do the calculations whenever you can.

CALCULATIONS

Theoretical Calculations

Example 1. Solve the equation

$$\frac{dy}{dx} = -2 - y + y^2.$$

knowing that $y_1 = 2$ is a particular solution?.

Answer.

We recognize a Riccati equation. First of all we need to make sure that y_1 is indeed a solution. Otherwise, our calculations will be fruitless. In this particular case, it is quite easy to check that $y_1 = 2$ is a solution. Set

$$z = \frac{1}{y-2}.$$

Then we have

$$y = 2 + \frac{1}{z}$$

which implies

$$y' = -\frac{z'}{z^2}.$$

Hence, from the equation satisfied by y, we get
Easy algebraic manipulations give

$$-\frac{z'}{z^2} = \frac{3}{z} + \frac{1}{z^2}.$$

Hence z' = -3z -1.
This is a linear equation. The general solution is given by

$$z = \frac{-1/3e^{3x} + C}{e^{3x}} = -\frac{1}{3} + Ce^{-3x}.$$

Therefore, we have

$$y = 2 + \frac{1}{-\frac{1}{3} + Ce^{-3x}}.$$

Note: If one remembers the equation satisfied by z, then the solutions may be found a bit faster. Indeed in this example, we have $P(x) = -2$, $Q(x) = -1$, and $R(x) = 1$. Hence the linear equation satisfied by the new function z, is

$$\frac{dz}{dx} = -\left(Q(x) + 2y_1R(x)\right)z - R(x) = -\left(-1+4\right)z - 1 = -3z - 1.$$

Example 2. Check that $y_1 = \sin(x)$ is a solution to

$$\frac{dy}{dx} = \frac{2\cos^2(x) - \sin^2(x) + y^2}{2\cos(x)}.$$

Then solve the IVP?

ANSWER

$$\begin{cases} \dfrac{dy}{dx} = \dfrac{2\cos^2(x) - \sin^2(x) + y^2}{2\cos(x)} \\ y(0) = -1 \end{cases}$$

We will let the reader check that $\sin(x)$ is indeed a particular solution of the given differential equations. We also recognize that the equation is of Riccati type. Set

$$z = \frac{1}{y - \sin(x)}$$

which gives

$$y = \sin(x) + \frac{1}{z}.$$

Hence $y' = \cos(x) - \frac{z'}{z^2}.$

Substituting into the equation gives

$$\cos(x) - \frac{z'}{z^2} = \frac{2\cos^2(x) - \sin^2(x) + \left(\sin(x) + \frac{1}{z}\right)^2}{2\cos(x)}.$$

Easy algebraic manipulations give

$$-\frac{z'}{z^2} = \frac{\left(2\sin(x)\frac{1}{z} + \frac{1}{z^2}\right)}{2\cos(x)} = \frac{\sin(x)}{\cos(x)}\frac{1}{z} + \frac{1}{2\cos(x)}\frac{1}{z^2}.$$

Hence

$$z' = -\frac{\sin(x)}{\cos(x)}z - \frac{1}{2\cos(x)}.$$

This is the linear equation satisfied by z. The integrating factor is

$$z' = -\frac{\sin(x)}{\cos(x)}z - \frac{1}{2\cos(x)}.$$ S

PRATICAL CALICULATIONS

Example 1 Orginal Dimensions Of Aluminium Plate In Mm
Length =150 MM
Width=50MM
Thikness = 5MM
One pass 360˚=1mm
Strain = change in length/original length

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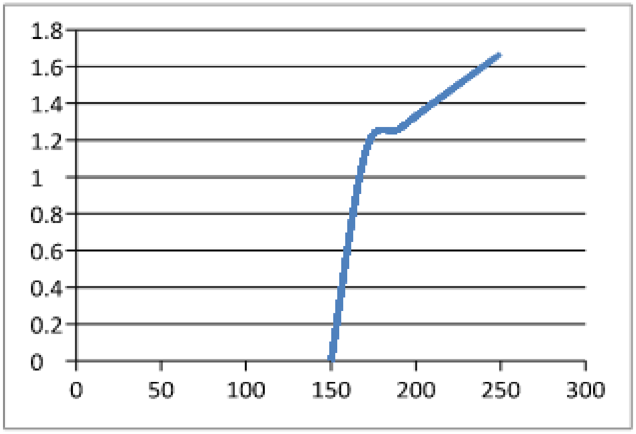
PASS	THIKNESS	LENGTH	WIDTH	STRAIN
PASS 1	5.0	150	50	0
PASS 2	4.5	170	57	1.13
PASS 3	3.0	190	64	1.26
PASS 4	2.5	210	66	1.40
PASS 4	2.0	250	72	1.67
PASS 5	1.5	270	79	1.80
PASS 6	1.0	290	84	1.93

GRAPH1

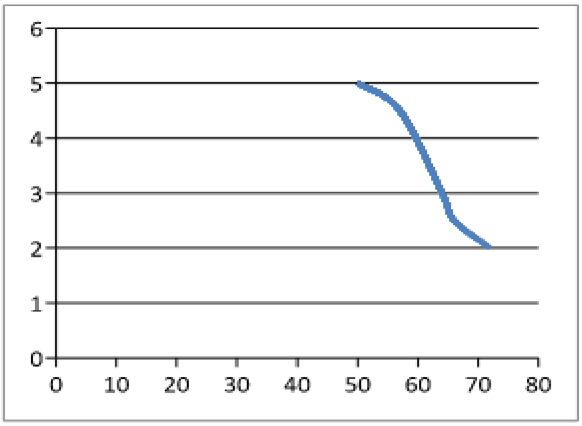
Length vs strain



x axis:- length **Y axis**:- strain

GRAPH2

Thickness vs width graph



x-axis :-width **y-axis** :- thickness

FEATURES SCOPE

- Starting from 2 stand Mini Blocks we manufacture upto 10 stand Wire Rod Blocks working at a max. speed of 75 m / sec.
- Delta / V type, state of the art design.
- Ideally suited for Stainless and Special Steels with 18 % average reduction.
- Low to medium reduction enables superior size control, and tolerances.
- All key parts are manu
- factured on CNC machines, and all gears, manufactured
- The highest accuracy levels, are imported from Germany.
- Identical Roll units on both sides, enables operators to keep a min. stock of spare
- Roll units. These roll units are the most expensive spares of a Wire rod Block.
- Identical bevel gears in all stands, again, ensures ease of spares.

SPECIFICATIONS

- Standard Roll size for 5.5mm 175 - 155 mm.
- Input size required to roll 5.5 mm – 6.5 to 7.0 mm.
- Speed range : 5 – 15 m / sec. for Pre Finishing Blocks and Garret Coiler Lines, of 215 / 240 / 280 mm.
- 25 – 80 m / sec. for Finishing Blocks of 175 mm.

RESULT

Based on the current experience, the new linked facility has proved to be a highly flexible solution, covering production requirements of highest product qualitystandards even for a wide range of strip thicknesses andwidths as well as for soft to high strength steel grades.This project has been realized within a very short time.

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CONCLUSION

In addition to the benefits noted herein, the new technique appears to be especially useful for a continuous mill where the speed is changed for weld passage and the product characteristics change quite rapidly on the fly. This conclusion is based on the results of our recent work (Pittner and Simaan, 2007) involving the control of continuous mills. Further, the possibility for expansion of the new technique to improve the control of strip shape, flatness in particular, is recommended as an important issue for future investigation.

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