Metal Pass: Work List - Mill Related Projects

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Metal Pass LLC

Metal Pass Consulting is dedicated to the improvement of steel rolling mill productivity, efficiency and product quality, through accurate rolling mill process modeling and computer integration. For selected project reports on Metal Pass Consulting, see www.metalpass.com/consulting.

Metal Pass Resource provides over 30,000 pages of steel industry, particularly steel mill, related resources online on the website www.metalpass.com. Besides technical papers, there are also a long list of resource applications, which all are the largest in the metal industry. They include Metal Directory, Software Database, Metal Dictionary - Tech Terms, Metal Dictionary - Translation, Metal Books, Metal Articles, Flow stress, High-T properties, etc.

Metal Pass Solution includes steel mill related software development, remote data collection and mill process improvement (for both Level 3 production scheduling and Level 2 production execution), and more. There are several suites of software programs hosted on the website www.metalpass.com.

Abbreviations (in this report)

CSRM	Cascade Steel Rolling Mills	SMS	SMS Schloemann Siemag
OSM	Oregon Steel Mills	SMC	Special Metal Cooperation
LPN	LPN (Thailand)	DFG	Deutsche Forschungsgemeinshaft (German Research Association)
Nanjing (NISCO)	Nanjing Iron & Steel Co.		
Ipsco	Ipsco (USA, Canada)	POSCO	Pohang Iron and Steel Company (South Korea)

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I Level 2 development

No	Name	Description	Client / Employer
1	Cascade Steel EAF Level 2 design and function specification	Joint development with partner (AMI). Level 2 collects data from numerous PLCs and Chemical Lab, populates data in MMI computers to assist operators to run the steel manufacturing. Modeling, scheduling, steelmaking recipes, chemical analysis, personnel, as well as energy and material consumption were the key functions. The MMI applications (Client) were implemented with Visual Basic, while the Level 2 server applications were written with Visual C++ and MFC. The back-end database server was Oracle.	CSRM
2	Cascade Steel LMF Level 2 design and function specification	Similar to EAF Level 2. Some information from EAF was displayed in the LMF Level 2.	CSRM
3	Cascade Steel Caster Level 2 design and function specification	Similar to EAF Level 2. Some summary screens for EAF and LMF were also displayed in this application. There was a graphic display of the cut list of billets, so the user could quickly see how many billets were cut or ready to be cast and cut.	CSRM
4	MFC application for data management of the Level 2 system memory-mapped files (MMF)	Since only a portion of data were sent to the database, more data in the MMFs (Memory-mapped files) were accessed programmatically with customized code.	CSRM
5	Level 2 systems debug and function improvement	After Level 2 systems were put into operation, there was a large amount of work to debug and functional improvements.	CSRM
6	Cascade Steel Level 2/Level 3 Database design and SQL script development	Worked jointly with the development partner to modify the general design to fit the specific plant; helped DBA (who did not have steel industry experience) on design, modification and implementation.	CSRM
7	Development of Level 2 data safety and management systems (to guarantee no data loss)	Data safety management for the Oracle database and data populating to Level 3 business database. Due to the potential that the Oracle database server may lose connection with one of the Level 2 servers and result in data loss, a major design change was made to ensure the data safety. The new design let the Level 2 server hold the SQL scripts for inserting/updating data for up to several days, in case the connection was broken. As long as the system regained the connection, the Level 2 server would immediately re-run the SQL scripts and send data into the database. The DBA could also manually run the SQL scripts to send the data. Another change was to send data into Level 3 database server.	CSRM
8	Development of Level	Oracle data management system, with which engineers and/or	CSRM

	2/Level 3 data quality and history data management system	operators can read and modify data was improved, so, if any modifications occurred, the system moved the original data to the history tables.	
9	Cascade Steel rolling mill Level 2 system design and function specification	The design took references of the Meltshop Level 2 and Danieli Level 2, and proposals on the Level 2 from ABB and Morgan, etc. Functions include: (1) Data collection (PLC, testing lab, user input, Meltshop Level 2, etc.), data communications (between Mill 1 and Mill 2, and between mills and meltshop); (2) Rolling process modeling, roll pass schedule autoload and improvement through learning, etc. Project started right after the Meltshop Level 2 project, but was not completely implemented.	
10	Oregon Steel Mills Level 2 system study	Examination of OSM's Level 2 system, through source code study, log file access and database survey, to find potential weaknesses for improvement. Time spent was about 4 months. Read through source code (about 1 million lines), diagrammed system functions and proposed numerous improvements.	OSM
11	OSM Level 2 force model problem survey to identify source of the force error in certain products	Identification of reasons for the force error in certain model grades, such as the hard and thin products. This work started after the 4 months of basic study of the Level 2 system.	OSM
12	Design of flow stress model coefficients for 2000 model grades and for three temperature regions in each model grade	6000 sets of coefficients (influence factors from material, temperature, strain and strain rate) were calculated for 2000 model grades and three temperature regions in each grade. This project was to fix the logical problems in the learning for the existing Level 2 system. The coefficients were used as the reference values for the adaptive learning.	OSM
13	Calculation for existing flow stress coefficients for every model grade, based on the data matrix of the intermediate factors stored in the Level 2 database	6000 sets of coefficients (influence factors from material, temperature, strain and strain rate) were calculated for 2000 model grades and three temperature regions in each grade. This project was to analyze the weakness of the existing learning procedure and data, in order to provide the fix. Because the Level 2 system only holds some intermediate data, the flow stress coefficients needed to be calculated.	OSM
14	Creation of the force model for the resume pass (the pass right after the hold of steel in the air)	Model was modified to reflect the metallurgical changes (precipitation, recovery, recrystallization and grain growth, etc.) incurred in the holding pass before the resume pass. Those changes caused up to 40% force error before the fix.	OSM
15	Expansion of the flow stress formula valid range (for the passes with draft below 10% or over 30%)	OSM's flow stress model was not valid for the strain below 0.1, and was inaccurate for strain over 0.4. Modification was made to eliminate/reduce the errors in these regions.	OSM
16	Development of a metallurgical engine to	A concept to develop a metallurgical engine for supporting both Level 3 production scheduling and Level 2 production execution	Metal Pass

	improve quality of Level 2 modeling and Level 3 scheduling (proposal to the National Science Foundation of USA)	was developed. Functions include: (1) for Level 3 to select slab with low cost and sufficient quality; (2) for Level 3 to schedule temperatures for reheating, holding and controlled cooling, and the time length for the hold; (3) for Level 2 to optimize draft distribution and controlled rolling for both strength and shape, (4) to predict and guarantee the rolled product property.	
17	Proposal to develop next generation of steel mill Level 2 system, with 4-tier architecture, metallurgical consideration and intelligent learning (30 pages, initially for the National Science Foundation of USA)	Currently in the market, no Level 2 system considers the metallurgical processes such as the recrystallization, grain size, retained strain, etc. The new generation of Level 2 should have this feature. In general, it should have new software engineering features and intelligent learning (Neural network, expert system, etc.)	Metal Pass
109	NISCO Plate Mill Level 2 Force Model Improvement	Improvement of head-end and tail-end force model in addition to the general body force model improvement. This is to reduce AGC movement in order to reduce head-end and tail-end defects such as the local cambers existing in the two ends. This project is ongoing until March 2010.	NISCO
110	NISCO Plate Mill Level 2 Head-end and Tail-end Force Model Improvement	Improvement of head-end and tail-end force model in addition to the general body force model improvement. This is to reduce AGC movement in order to reduce head-end and tail-end defects such as the local cambers existing in the two ends. This project is ongoing until March 2010.	NISCO
111	NISCO Plate Mill Level 2 Grade File Improvement	A high performance Level 2 model usually uses about 2000 model grades for a plate mill, and correspondingly, there are about 2000 grades files. Each grade file holds large number of basic data such as metallurgical and physical properties. High-quality data in every grade file is critical for not only Level 2 quality but also various metallurgical operations. This project is ongoing until March 2010.	NISCO

II Level 2 Support

No	Name	Description	Client / Employer
18	Level 2 maintenance routine responsibilities	As a sole administrator to assume full responsibility for Level 2 systems. Guarantee the system is up and running for 24 hours per day; system examination and maintenance during the down day (usually once a week).	CSRM
19	Cascade Steel Level 1/Level 2 shop	After the hardware technician prepared the basic PC hardware, it was connected to the shop computer. The work involved	CSRM

	computer build and setup (hardware, middleware and operating system)	adding middleware (like PLC card), to configure resources (e.g. to make sure the PLC card don't have address conflict with others), and then to install Windows operating system, to setup an automatic logon, to install a touch screen driver, to configure the touch screen, and so on. The operators' computer skills were minimal, so, if anything was wrong, they only needed to reboot the HMI computer and everything should come up automatically.	
20	Cascade Steel Level 1 related software installation	After hardware and middleware installation and configuration, and windows installation and network configuration, Level 1 software was installed into the computer. This included the RSView application and RSLinks application, etc. In the later stage, OPC servers (e.g. Ingear) were used to replace RSLinks. Certain configuration may be needed or necessary. Then the Level 1 application was installed into the computer.	CSRM
21	Cascade Steel Level 2 system installation and setup	Based on the Level 2 design, the shop computer was required to have values of 28 topics through Windows registration, so that the information such as the Level 2 server for EAF, Level 2 server for LMF, as well as topic values for DDE, General, Grid, Logfile, Ping, Reports, Sockets, Grade-SpecFile, etc. would be provided.	CSRM
22	Cascade Steel shop computer maintenance and trouble shooting	Disk clones for every shop computer were made, so, if any computer was dead, only a few minutes were needed to rebuild it. In any pulpit, there were two HMI PCs. Company's pager was carried by system manager. The computer setup was done in this way: for any of the common problems, the computer would send a message to the Outlook server and the Outlook server would call the pager. Based on the phone number from which the pager was called, the type of the problem could roughly be identified.	CSRM

III Mechanical properties improvement

No	Name	Description	Client / Employer
23	Increasing reductions in the later roughing and finishing passes to improve mechanical properties with adjustments in roll bending schedules.	An offline model was used to propose the optimum roughing and finishing passes. Mechanical properties were most improved by increasing the reductions in the passes at about 1/2 the slab thickness and in the final passes. A C++ subroutine to adjust the drafting was used as necessary for higher reductions.	Nanjing, LPN
24	Increasing the accuracy of crown predictions with better models of deflection	A model of the crown of the work roll that predicted the crown changes during each pass was used to improve the prediction of the plate crown and shape. Existing crown models in the level 1 and level 2 were adjusted to reproduce the predictions in the	Ipsco, OSM

	and statistical tuning.	offline model.	
25	Increasing the control of mechanical properties and bow with feed forward laminar quenching model that included balanced patterns of water flow.	A model of the temperature distribution in the plate during cooling by upper and lower laminar headers was used to predict the plastic and elastic strain that was caused by particular patterns of water. The adjustments in the distribution of water from the headers to balance the plastic strain were recommended. The approaches to decrease the plastic strain and avoid turning the elastic strain into plastic deformation in the leveler were recommended. Practices for responding to temperature differences across the plate and between the top and bottom surfaces were recommended.	Bethlehem, Ipsco, Nanjing
26	Decreasing the segregation and cracking on continuous caster by tuning of soft reduction, oscillation and water distribution	Cooling and solidification models for carbon and stainless steel were used for the continuous caster. The detailed models of the soft reduction to control segregation in different types of steel were used to evaluate the conditions. Casting speeds, water flow and setting for the level1 and level 2 parameters were recommended from the models.	Allegheny Ludlum, SMS

IV Mill application development

No	Name	Description	Client / Employer
27	Development of a roll pass design program based on the full set of roll pass models	With Excel worksheet and the spread models, the a roll pass design program was created during the GST 19" Mill roll pass design, and was then used for several other roll pass design projects.	Morgan
28	Development of a Windows-based roll pass program for pass design up to 28 passes	An initial version of the roll pass software was developed to roll steel from square billet to round in up to 26 - 28 passes (depending on number of stands in the mill). The designs included roughing, intermediate and finishing passes. Developed with VB/VC++.	Metal Pass
29	Development of an application to manage and populate Excel spread sheet onto the intranet web site by reading an excel file as a database	According to the requirements: (1) multiple users should be able to access the most current files, which may be updated frequently by those with privileges to update them; (2) Common users should not be allowed to change the file. The intranet web provided the right solution. The Excel file was displayed on the intranet website, with its look-and-feel exactly like Excel.	CSRM
30	Development of an application to manage engineering drawing files and display the drawings (in AutoCAD format) on the intranet	Requirements: (1) Some AutoCAD drawing should be accessible for view by multiple users; (2) Other files in the same storage location should not be viewed by all the people; (3) Viewable files should provide the most current version. The intranet web was the perfect solution, so an application was developed to load the selected drawing onto the intranet web.	CSRM

	web screen		
31	Development of a software tool to populate PLC data directly onto web screens	Some people want to see the live data of the PLCs. PLC may have more data than Level 1 or Level 2, and the data from PLC were the original. An application was written to access PLCs addresses directly for data. The application was also particularly useful in the debugging period for the Level 1 and Level 2 applications.	CSRM
32	Development of a suite of web-based roll pass design programs - AutoForm to allow the web user to design roll pass automatically	This set of applications allowed the user to do roll pass design without existing experience. The user only needed to fill in the required mill operational data. Two sets of roll pass models were combined in the software: the first set, with few factors considered, to do the first assessment, and the second, with many factors, to perform the high quality design. The combination of the two steps with those two sets of models provides both speed and quality of the roll pass design. See www.metalpass.com/rolldesign.	Metal Pass
33	Development of a suite of web-based roll pass design programs - FreeForm for experienced roll pass designers	This set of roll pass applications were provided with more flexibility (freedom) for the roll pass designer, and the models covered more influence factors such as the tension influence on the spread and forward slip. This set of programs could design multiple passes (e.g. up to 28). The user could also select various design procedures for spread and for forward slip calculations. Data for all passes could be saved and reloaded. See www.metalpass.com/freeform.	Metal Pass
34	Development of a finite-differential program to determine temperature profile during mill production including rolling, air cooling and controlled water cooling	The web-based finite difference program was designed to predict temperature profiles (surface, center, average, middle, etc.) pass by pass, from the furnace dropout until the completion of the water-cooling and airbed cooling. The user could save the input data for all the stages on his local computer, and reload the saved data in the future by reading the saved file. Various optimization steps were done so that the program could run sufficiently fast. Running web-based numerical solution truly demonstrated the technical skills of Metal Pass, both in mill process and IT aspects. See www.metalpass.com.	Metal Pass
35	Development of stored procedures to prepare SQL server database data for the website metalpass.com	Data from database was loaded to the web by running stored procedures, so the internet user had only the right to run the pre-written stored procedures, and could not query through the database. This was critical for data security in the internet applications.	Metal Pass
36	Development of a graphical program to display trend of data in the database (usually millions of records)	This tool was developed to quickly display major influence factors for the force error; it was also aimed at handling large amount of data (about a million records), for which graphical drawing with Excel was not efficient.	OSM
37	SQL script development to query data from Level 2/Level 3 database to send to local SQL Server	For automatic query of data from OSM's Informix database for needed data. Data was queried into local SQL server for further processing and evaluation.	OSM

38	Development of SQL scripts for data calculation and transformation (for force error calculation, data rounding, data selection, etc)	These scripts were to calculate errors, to transform data or to select certain data inside the SQL Server. For example, to study the influence of a factor (e.g. temperature), the other factors (e.g. strain) should remain unchanged. This is, however, impossible in the real, life data. What was done was to round the other parameters (e.g., to round 0.29 into 0.30 and 0.305 into 0.30). The rounding work was done inside SQL Server with SQL scripts.	OSM
39	Development of camber measurement, prediction and elimination system (proposed work plan for OSM Camber team)	Use cameras to measure the camber and then use the model to calculate the drafts for the two sides in the roll gap in order to adjust the roll gap in the two sides (with AGC) and to reduce or eliminate the camber.	OSM
40	Proposal on Solutions for several improvement opportunities	(1) OSM Level 2 Force Model Problem Solution (Work plan, 8 pages, for the meeting on Sept. 2007); (2) Development of OSM Material Processing System (Slab processing + Finish Processing. 16 pages); (3) OSM Reheating Process Improvement (8 pages); (4) Development of a Temperature Simulation System for OSM Heat Treating Furnace (13 pages); and (5) Prediction of Rolled Steel Properties (4 pages).	OSM
112	Development on Pass Manager Application	The program Pass Manager was developed. It is a program used to study total number of passes needed to roll a size, or the size range that can be rolled after certain number of passes. This is also a tool to examine whether a mill is operated in an efficient manner and whether it's feasible to roll new sizes or new grades. The program is developed to satisfy the industry need in collaborate with the Ask a Question in Metal Pass Consulting section.	Metal Pass

V Productivity Improvement

No	Name	Description	Client / Employer
41	Decreasing the number of passes in the rolling schedule with fuller use of force and torque.	An offline model was used to search for the optimum utilization of force and torque in rolling passes. Parameters were adjusted in Tippins, Ansaldo, Prosoft and GE models to duplicate the optimum from the offline model. A subroutine in Fortran or C++ was installed in the existing level 2 to adjust the drafting, if the existing model did not have good tuning parameters. Tables for flow stress were adjusted, if needed, after looking at the errors in the force and torque predictions.	SMC, Allegheny Ludlum, Nanjing, LPN
42	Scheduling reheat furnace slab line up and firing	Heating models for billets and slabs were used to project temperatures, as the steel was heated in a reheat furnace. The order of slabs to be charged into the furnace was recommended. The setting for the set points and the time needed before extracting the pieces from the furnace to obtain	SMC, Nanjing, JL Specialty, Green river,

		uniform temperatures along length and through the thickness were also recommended. Conservative practices on the use of energy and the emission of pollutants were provided.	Interstate forge
43	Decarburization and degassing of liquid metal	Models of carbon removal and metal oxidation were used when using oxygen with inert gas in liquid steel. The volume of oxygen and inert gas to achieve specific carbon levels with minimum metal oxidation was recommended. The silicon or aluminum additions needed to recover the metals oxidized during decarburization were recommended.	Allegheny Ludlum, Air products, SMC
44	Maximize production of a plant with flow analysis	Models were created of the layout and flow of material in a production shop to assess the productivity of the shop and the utilization of equipment. The throughputs of each piece of equipment and each alternative layout of equipment were projected. The size of storage areas, yards, rail road tracks, loading devices and other equipment to reach a production target was recommended. The optimum product selection to utilize a particular arrangement of equipment in a shop was also recommended. The practices for scheduling personnel and staging the movement of products to maximize the utilization of equipment in the shop were calculated. The size and the capability for melting, casting, cooling, reheating and rolling processes along with the associated handling equipment were recommended.	OSM, Bethlehem, SMC

VI Rolling and Roll Pass Development

No	Name	Description	Client / Employer
45	Development of roll pass schedule for the first Chinese Tension-Reducing mill for pipe production	The pass schedule was developed to use tension to control the wall thickness of the pipe while the pipe diameter was reduced in the roll gap (the groove of the rolls). Three weeks of tuning in the steel pipe mill was needed to test the designed schedule. Worked with Prof. Yuqiu Lu, a steel pipe production expert and the former dean of the college of Metal Forming of UISTB.	Yantai Pipe
46	Flat rolling of the samples with outer or inner grids	Flat rolling of the DIN 19Mn6 steel samples with outer or inner grids (i.e., surface or cross-section grids). The rolling was done to study the grid behavior during rolling and to obtain the rolling parameters and the local material flow. A so-called “stecker-rolling” was also done by interrupting the roll movement while the stock was still in the roll gap, so that it became possible to establish the form of the work piece in the roll gap. The results from measurement were used to verify FEM model.	DFG
47	Roll pass design for angle steel rolling from square in six passes	Because the hot rolling tests of the angle steel rolling involved several rounds of the tests and used nearly 100 samples with grids milled on the surface or the cross-section, roll pass design for the angle steel rolling was carefully performed based on early rolling experience. A special roll pass sequence was developed through a combination of the butterfly method and	DFG

		the design method for a continuous mill.	
48	Angle steel rolling starting from square and intermediate shapes, with outer or inner grids	DIN 19MN6 steel with the original cross-section of 48x48mm was rolled at 900˚C in six passes until the final form of angle steel 40x40x9mm was achieved. Outer or/and inner grids were milled on the outer surfaces and inner cross-sections for the entry shapes of all passes. For this, a pre-rolling was done to produce entry shapes of all passes. After rolling, the global and local metal flow for all the passes, in outer surfaces and cross-sections, as well as the temperature, force, torque, power, etc. were measured. The results were used to study metal deformation and the force/power requirements, and to verify the FEM model established for angle steel rolling.	DFG
49	Morgan's roll pass design procedure examination to identify weakness	Requested by Morgan's top management to examine its roll pass design procedure, and to make improvements if any problems were identified.	Morgan
50	No-Twist Mill (NTM) field data collection from former ASW	Traveled to former ASW, Cleveland, OH, to collect data from Morgan's high-speed No-Twist mill. Cross-sections, speed, width, etc. for each pass in the mill block were measured. A hole was cut in each stand box to measure the needed data. This work was done together with another others at Morgan.	Morgan
51	Round-square roll pass design for several finishing mills	Several customers of Morgan wanted to adapt the products of finishing mills, usually round products, into squares. The round-to-square passes in the high-speed finishing mills were developed for this purpose.	Morgan
52	Roll pass design for GST 8-stand mill for 28 sizes with two sizes of billet	This mill had 8 stands with the last 4 stands tied (driven by a single motor). Due to the high average reduction, tension had to be used in some passes to achieve the finish size. During the design, a simple roll pass program was created based on MS-Excel by integrating various rolling process models that were developed earlier.	Morgan
53	Coating of Zn-Al alloys on steel and coat quality testing	This was a part of a surface treatment project with Prof. Yuqiu Lu and then Ph.D. Candidate, Angang Hu (now a well-known economist). Used US demonstration equipment to apply the Zn-Al coating on the surface of a plate, and then measured coat quality parameters. A new coating mechanism was proposed based on microscopic observations (800X photographs of the coating layer) and the measured data.	Petroleum Ministry, China
113	Roll Pass and Mill Design/Development for POSCO SS	This was a roll pass design and development project served as the guideline in the mill design for the POSCO Specialty Steel Ltd. A new breakdown mill is to be added into current plant. The mill is under various constrains: (1) Single stand reversing mill, with limited number of grooves cut on the roll; (2) Big ingot (700mm square) and bloom (420mm x 530mm), to be rolled into round 270 ~ 320mm and square 200~300mm, but number of passes to be minimal due to temperature concern; (3) Smallest roll diameter (new/discard) required due to space and bearing restrictions, and so bite condition is hard to meet; (4) Smallest barrel length required due to limited crane capacity; (5) Passes	POSCO

		involves both round and square, minimal number of grooves hard to achieve; (6) Hard steel to be rolled, with strength 30% high than AISI 1080; (7) Some steel with 30% higher spread than average, and so the minimal number of passes hard to reach; (8) Crack to be avoided since some steel has low formability. In addition, number of passes in grooves should be balanced to achieve maximum roll life. Satisfied design was achieved with all conditions met, and corresponding roll force/torque checkup also passed.	
114	Various design and development for Asia	Various design and development for India, Pakistan and Arabian countries, on roll pass and force prediction, etc. The projects were primarily acquired through Metal Pass web presence.	Asia

VII Rolling Process Modeling – Numerical

No	Name	Description	Client / Employer
54	Measurement of flow stress with torsion test	Flow stress of Steel DIN 19Mn6 was measured at 850˚C, 900˚C, 950˚C and 1000˚C, strain of 0.05 to 0.75, and strain rate of 0.05 to 5/s. Measured data was used to formulate a mathematical model for the flow stress, considering the temperature rise during the torsion test predicted by FEM simulation.	DFG
55	FEM simulation of the steel torsion test to determine the temperature profile during the test	FEM simulation of the torsion test was used to measure the flow stress. This is to study the actual temperature profile in every stage of the torsion test. Due to the heat generation, the actual temperature is higher than the initial temperature. This may cause the difference of the temperature pattern between the torsion sample and the sample for the hot rolling and, thus cause the error of the FEM simulation of the rolling process. In prior FEM modeling this negative factor was removed.	DFG
56	Measurement of E-modulus	The E-Modulus for steel was heavily temperature-dependent, so the E-Modulus for steel 19Mn6 used for the FEM investigation for the angle steel rolling was measured at various temperatures, from 200˚C to 1200˚C. A formula modeled with the measured data in the temperature range 850˚C to 1000˚C was used for the FEM calculation for the angle steel rolling.	DFG
57	FEM Modeling for the hot flat rolling with thermomechanical model	This wass a pre-simulation for the angle steel simulation. Due to the high technical challenge of the thermo-mechanical modeling of the angle steel rolling, a hot rolling model for the flat rolling was established at first. Rolling parameters for the FEM model corresponded to the hot flat rolling tests. Calculated data were compared with the testing results, so the model was verified and improved.	DFG
58	FEM Analysis for the 6 passes of angle steel	The input file consisted of the data for mesh generation, material data and boundary conditions, rolling parameters,	DFG

	rolling with thermomechanical model	parameters relating to the output (out-file, post file and restart file), special control parameters for FEM calculations (such as convergence errors for temperature and stress or displacement, time step for each increment), etc. The rolls and stock were taken into account separately as rigid and elastic-plastic. At first, the initial cross section of a groove was estimated. The inputs were the flow stress formula, temperature dependences of E-modulus, specific heat, thermal conductivity, coefficient of thermal expansion and mass density, etc. The directly calculated outputs were rolling force, rolling torque, elastic and plastic strain, elastic and plastic strain rate, plastic work, shape of deformation zone, stress and temperature distribution, as well as the stock geometry during and after rolling. The definitions for partial upsetting, partial spread and partial elongation were provided as input into the MARC main program through a user subroutine, so those forming technical parameters were also calculated. Both integrated and local metal flow, as well as the force and power, showed an excellent agreement of the measured and calculated results.	
59	FEM modeling for hot rolling of the H-beam with thermomechanical model	H-beam rolling, starting with the cast profile, was analyzed for the example of rolling of IPE140. The pass sequence consisted of three universal and two edging passes in a continuous mill. The rolling processes of three universal passes in a continuous mill were simulated. Rolling parameters for the simulation corresponded to those of a practical rolling test: initial temperature was 1000 – 1015°C, and rolling speed was 4 – 6 m/s, etc. The model was improved by comparison of the measured and predicted parameters.	DFG
60	FEM modeling for the cast-rolling with liquid core	A study of the cast-rolling process of a thin slab with a liquid core. At first, the cooling process of the cross-section from liquid state of 1394°C to a state with a thickness of solid shell of 10mm, 15mm, 20mm, 25mm, respectively, was studied by means of two-dimensional finite element simulation in which the liquid-solid interface was determined. Then the three-dimensional simulation of workpieces with corresponding thicknesses of the solid shell was carried out, in which the workpieces were simplified to hollow bodies. Meshing of the cross section with each wall thickness was optimized. A comparison of the analytical results with those of experiments described in the literature followed for each calculation.	DFG
61	Establishment of a simplified FEM model that takes only 5% of computing times	After studies of the relative movement of the stock and the rolls, a special upsetting model for shape rolling simulation was developed through a functional combination of the slab method and the FEM, with direct modeling of the speed and the deformation pattern in the length direction. The simulation of an angle rolling pass was performed in only 5% of computing time of the regular model, with sufficient accuracy. (Due to the great interest in this simplified model from industry, German colleagues spent another year to further study it, after the initial development). The study was financed by DFG. There was a great potential for this simplified model to be integrated into a roll pass design program or a Level 2 model, to describe the microstructure parameters over the stock cross section.	DFG

62	FEM analysis for RD-OV and OV-RD passes for force, temperature, grain size and recrystallization, etc.	Data for the simulation was provided from Morgan's lab mill data. A microstructure model was developed and provided to the FEM. The percentage of completion of the recrystallization and recrystallized grain size, etc. were predicted and graphically plotted, besides regular parameters such as force and temperature.	Morgan

VIII Rolling Process Modeling – Empirical

No	Name	Description	Client / Employer
63	Morgan's roll force calculation procedure examination to identify weakness	Requested by Morgan's top management to examine the force prediction procedure. Attention was also focused to examine the algorithm and material data used for Morgan's roll pass program CAPE. It was found that the procedures used at the time was only valid for the strain rate below 100/s, while the actual rolling process had a strain rate up to 3000/s.	Morgan
64	Analysis of Morgan's lab mill data acquired from five-year rolling tests	Data was collected in a five-year lab mill test, during which about 1000 samples were rolled. For each rolled piece, over 70 parameters, including free radius, cross section area, forward slip, etc. were measured or calculated. It was one of the primary data sources to develop rolling process models. However, due to certain weaknesses in the experiment design and limited understanding of rolling process, the prior engineers who designed the tests had difficulty deriving meaningful models from such large-scale rolling tests. In the new work the missing parts were added from other data sources (e.g., those from 15-year rolling tests from the institute in Germany, in a four-stand high-speed continuous mill), to make the data fully useful.	Morgan
65	Development of spread model, particularly for high speed rolling	The existing Shinokura formula used in Morgan's computer aided design was expanded to add more influence factors. Various spread prediction procedure, such as Hensel, Wusatowski, etc. were studied and verified/modified based on the large amount of experiment data. Spread procedures were later also verified by the field data collected from the No-Twist mills (e.g. ASW mill), etc.	Morgan
66	Development of accurate flow stress models for both low and high speed mills	Traditional flow stress models were verified and improved with the flow stress data I collected worldwide, and with mill results and especially field data. To fit high speed mill, traditional models (valid up to the strain rate 100/s) were extended to including the temperature/strain rate interactive factor to allow it to be valid up to the strain rate 500/s and can be roughly used for the high-speed rolling up to the strain rate 3000/s (100m/s). This is the nearest approach to the highest rolling. Neither formula is available nor the flow stress measurable in the range of 3000/s with constant strain rate values. Flow stress models for major grade groups and key grades were determined based on the new formula.	Morgan

67	Development of empirical models for spread estimation, for RD-OV and OV-RD passes	This was the direct modeling of the spread based on Morgan's lab mill data. Model can be used for the first assessment of the roll pass because it does not need so much geometry calculation as Shinokura formula does. Some colleagues did roll pass design with $\Delta B = k \Delta H$ to estimate width spread from a height reduction, with k ~ 0.33 for OV-RD and k ~ 0.6 for RD-OV. Therefore, I developed a simple formula to determine value of the k by considering several key parameters.	Morgan
68	Development on steel rolling mill force model, with study on mean flow stress, contact area and shape factor.	Roll separating force during rolling actually depends on three primary factors: the mean flow stress, the projective contact area and the shape factor. Mean flow stress depends on material only (including deformation history), and the shape factor is affected by the strain state and stress state in the deformation zone. Accurate prediction of the rolling force requires that all those three factors be accurately modeled, which was one of my primary areas of the rolling process modeling. I also studied various force prediction procedures for flat rolling, which lead to only different shape factor formulas.	Morgan
69	Development of contact area prediction model, particularly for the shape rolling, for accurate force prediction	The shapes of the contact areas for various rolling processes are complicated and are different in various pass sequence. Mathematical description of the actual shape and the projective contact area is critical for accurate force prediction. Contact area models for various pass sequences, such as RD-OV, OV-RD, SQ-OV, OV-SQ, etc., were developed with the formulation of the actual shapes.	Morgan
70	Development of shape factor prediction model for accurate force prediction	Actual modeling for the shape factor needs to consider friction condition and groove geometry. My modeling for the shape factor started from an universal formula that covers all the pass sequences, created by some German colleagues based on the tens years of measurement and modeling. With rich experience results and mill field data at hand, I did verification, modification and simplification, so I established accurate models for RD-OV, OV-RD, RD-RD (For Morgan Sizing Mills), SQ-OV, OV-SQ, etc. The models fit both the low speed rolling and high speed rolling.	
71	Development of forward slip models for RD-OV and OV-RD, for both low-speed and high-speed rolling	Neutral angle models for RD-OV and OV-RD were established based on the lab mill data and followed by necessary modification. On the basis, the forward slips were calculated with Wusatowski procedure. Predicted result fits excellently with the field measurement from ASW NTM, etc.	Morgan
72	Rolling mill friction model development to improve Morgan's design procedure	The model considers factors such as type of groove, temperature, speed, steel grade, etc. As effects of temperature and steel grade, the metallurgical constituent of the scale and its property were also studied.	Morgan
73	Development of accurate temperature prediction model and models for heat transfer coefficients	The model is based on the energy balance between the stock and rolls. Heat transfer coefficients were based on the past measurement in various researches. Thermal properties were all in temperature dependence.	Morgan

74	ASW NTM data processing and Model verification	Processed ASW data pass by pass; used the models I had developed to re-predict the measured data and so, to verify and improve the developed models.	Morgan
75	Development of the microstructure model for steel hot rolling processes to predict recrystallization, grain size, etc.	The model was developed by combining the major models (both formulas and data) published worldwide. Quite a portion of my $10,000 research funds was spent for acquiring publications. The model consists of the sub-models to determine: (1) strain or time, for start and 50% completion of the dynamic and static recrystallizations; each of those may consist of two or more ways of prediction; (2) volume fractions of, and grain sizes after, the dynamical and static recrystallizations; and (3) grain growth, equivalent grain sizes at the start and end of a pass, and the equivalent inter-pass time under temperature modification. Over 10 formulas and overt 30 coefficients were used to describe the model of a steel grade. Microstructural models for over 10 steel grades were collected. Models were examined with data collected from publications.	Morgan
76	Development of tension correction model to modify spread, forward slip and roll force	Tension correction to spread and forward slip is critical for roll pass study of existing No-Twist Mill (NTM) because all stands are tied (driven by a single motor) and it is very hard to avoid tension. Without this correction, any field data from the NTM would not lead to any meaningful model. In the development, German results were accepted but Japanese formula (definition of tension and tension correction formulas) were used. However, Japanese results, which were based on products of larger size, didn't fit the NTM data and thus were filtered out.	Morgan
77	Development on interstand tension determination	The development involved the definition of tension. Many German results on tension effects were based on the definition of tension as the relative difference of the speed. The actual tension, calculated from the specially modified flow stress model was used (even the best flow stress formula available still doesn't work for a small strain below 0.05).	Morgan
78	Modeling of the free-contours of the stock after rolling	The free contour was modeled based on the measurement in Morgan's lab mill data. This model was used for accurate calculation of the rolled cross-section area.	Morgan
79	Flow Stress Modeling Program to create flow stress models based on the data in the flow stress database	The program accesses database to read in the flow stresses in various strains, strain rates and temperatures, and calculates flow stress coefficients for temperature, strain and strain rate. The calculation was based on various criteria. See www.metalpass.com/bli/L2Net/FSModel.htm. The program determines factors m1 to m5 and A1 to A3, and Kf0, through both linear and non-linear regression. It also allow user to select special needs for modeling, such as min-mid-max, best peak strain, best R-square, etc.	Metal Pass
80	Extensive data collection on mill test results from reports, publications, etc.; data storage in database	Mill test results on rolling and controlled cooling, collected in past years as published or unpublished reports, published papers, books, Ph.D. dissertations, etc., were processed and stored in the relational database. Great portions of the data were roll pass related measurement, force measurement, controlled cooling data, rolled product properties and a portion	Metal Pass

		of the microstructure data. Further data would be added into the database.	
81	Collection of flow stress data for about 2000 steel grades	Flow stress data and models were collected from various available sources. Currently about 2000 models are available on the web. Other data, another 2000 sets, et., would soon be processed and uploaded.	Metal Pass
82	A Coordinate Measuring Tool to read data from curves (e.g. flow stress curves)	This application was initially developed to measure flow stress from flow stress curves. The scanned picture with the curves is to be measured for coordinate. Mouse clicking is made against the points on the existing curve to draw another curve, in order to make sure the clicking is not off the line. For every click, the coordinate is recorded. The coordinate is immediate calculated into the physical value based on an initial setup against the coordinate system in the picture. The value from every click is displayed on the form for double-checking. When the Submit button is clicked, the data is sent to the database.	Metal Pass
83	Compilation of data list for the metal properties (about 3000)	Compiled data list for the metal properties. Particular focus was on high temperature properties while room temperature properties were also collected.	Metal Pass
84	Development of heat transfer coefficient models for rolling, controlled water cooling and controlled air cooling	For interface between rolls and hot metals during rolling, for steel cooling in the air in the function of the travel speed and environment temperature, and for the controlled water cooling depending on water flow volume, water pressure, water temperature and turbulence, etc. For example, for the water box cooling alone, several hundred pages of the field-testing reports were used. High quality models were derived from the rich mill data.	Metal Pass
85	Development of spread model for various steel grades during various type of rolling	Some stainless steel may have twice as high as spread as the plain carbon steels, while other stainless steels may have low spread. Different metals have different spread tendency.	Metal Pass
86	Development of forward slip model for various steel grades during various types of rolling	This part of the model focused on the steel grade influence on the forward slip. It was the further development based on the unpublished writing of Dr. A. Hensel. Data for over 30 steel grades were developed. Not to be published but is available in the further mill projects.	Metal Pass
87	Friction model further development - to create a one-for-all friction model for steel rolling	Different materials have different friction values; for the same pair of the materials, friction depends on surface condition (roughness, amount and type of the lubricants, etc.), groove type, speed, and temperature. Temperature has different effects to friction in different temperature range. Formulas were collected and further developed with available new data.	Metal Pass
88	Publishing a book on the computer simulation of steel hot rolling process (Germany 1996)	Compared Experimental and Theoretical Investigations of Forming Technical Parameters in Shape Rolling with Example of the Hot Rolling of Angle Steels. TU Bergakademie Freiberg, Freiberg, Germany, 1996 (in German). ISBN 3-86012-029-8.	

89	Wrote a book - Steel Mill: Process Modeling and Computer Application	Broad topics, with fundamentals, technologies and industrial project examples. The book is not yet intended for publishing. Contents may be available for clients or work colleagues. See www.metalpass.com/bli/home/book2.htm (under updating).	Metal Pass
90	Rolling mill resource collection and processing	Collected rolling mill modeling resources for over 20,000 pages; processed over 10,000 pages of the resources	Metal Pass

IX Shape and yield improvement

No	Name	Description	Client / Employer
91	Decreasing hooking and camber with better shape control in the later passes with adjustments in roll bending and force distribution on passes.	Several C++ subroutines that calculated the work roll bending for each pass were used to achieve slightly long centers. The bending subroutines also calculated the adjustments of bending during the dynamic changes in the forces. The level 1 approach to dynamic adjustments of bending during the passes was reviewed and corrected for problems of gain or response. Code to ramp the roll bending in level 1 on the head and tail to avoid reaching the upper limit of the roll bending and maintain good shape was also provided. The ramping of the roll bending for thermal changes in the crown during the first 15 seconds of reversing passes was recommended. The centerline gage was often used to track the progress of the effect on the hook and camber. The operators were trained to learn to setup and adjust the steering better.	Bethlehem, OSM, Ipsco, Nanjing, SMC
92	Decrease edge wave and center wave with adjustment in force distribution and roll bending.	This work used the same tools and adjustments described above in item 91. There were edge and center wave measuring tools that could be used to provide feedback to operators and the level 1 and 2.	Bethlehem, OSM, Ipsco, Nanjing
93	Decreasing the turn down of the head on later passes that cause missed slots, kinks, knuckles or other defects.	Literature references on the effects of the differential speed between the top and bottom rolls were used to provide guidance on head end delta speeds. The percentage differences in speeds and the length of the sustained differences to avoid turn down were recommended. Both positive and negative differences, depending on the thickness and the reductions of the passes, were recommended. The tools to measure the turn down and ways to store and use the measurement to minimize the problem on specific products were recommended.	OSM, Nanjing, Allegheny Ludlum
94	Decreasing wave and bow by setting hot and cold leveler	Models for retained strain after roller leveling were used to set up the leveling. Gap settings to maximize flatness without exceeding the limits of leveler were recommended. The level 1 and level 2 software to perform the correct settings was tuned and adjusted.	Bethlehem, Nanjing

115	NISCO Plate Mill Head-End and Tail-End Quality Improvement	This project is to reduce NISCO plate mill head-end and tail-end cambers. When there is high error in the head-end or tail-end force prediction, the calculated initial roll gap will be inaccurate. AGC has to move in a big scope to adjust the roll gap. In this process, any weakness in the mill control and operation may trigger significant head-end and/or tail-end defects. Therefore, the first attempt would be the force model improvement in this aspect. In addition, based on the parameter variation in the head-end and tail-end, thickness gradients will be created in the two ends, in order to achieve the equal thickness throughout the length. NISCO's Level 1 system from Siemens doesn't have sufficient features for head-end and tail-end to coordinate with the Level 2, so both Level 1 and Level 2 should be improved.	Nanjing

X Web and web resource

No	Name	Description	Client / Employer
95	Cascade Steel intranet website design and development	The intranet website includes company site and department sites. There are about 10 department sites. (The general layout and look-and-feel were similar to the site www.bli1.com or www.metalpass.com/bli, in which the left frame was for company's general page, and the top frames were for department pages).	CSRM
96	Cascade Steel internet website design and development (www.csrm.com)	See www.csrm.com. Worked as the Web master. The csrm.com online now was my final version. Development included the site layout, contents, logo (worked with an artist), etc. Several pictures followed the design from the parent company. The sales support and customer interaction sections were started but not finished.	CSRM
97	Website www.metalpass.com design and development	The work includes the interface design, content determination, business model, and features not mentioned elsewhere. This site is one of the largest open resource-site in the metal industry.	Metal Pass
98	Website URL Parser to catch all URLs of a website and store URLs into database	It is a valuable tool to collect online URLs from any website, such as Yahoo. When the root URL of a website (www.xxxx.com) is given, the tool will access the website, read its HTML code and retrieve all the URLs in the entire website. All the retrieved URLs and related information will be saved into a database. This tool was initially developed using www.steellinks.com as test site, which was then with nearly 4000 URLs. It took about half an hour, for example, to download all URLs of the website www.steellinks.com into a local database. (However, some tricks were used so the others cannot download metalpass.com URLs in the same way.)	Metal Pass
99	Development of a suite of web-based	A set of programs were developed to calculate roll separating force for various pass sequences. The calculations were based	Metal Pass

	programs to predict rolling force and power in various pass sequences	on the procedures developed in recent years, which are considered more accurate than the traditional ones. The programming was fully object-oriented, so a parent class was created for common force calculation, and a derived class was created for each pass sequence to handle only those different from the common procedure (e.g. contact area, and sometimes shape factor).	
100	Compilation of data list for Metal Dictionary - Tech Terms (5500 entries)	Dictionary entries include over 5500 of metal/steel related technical terminologies that are explained in the website (www.metalpass.com/techterm). This is the largest online dictionary for metal terms.	Metal Pass
101	Compilation of data list for Metal Dictionary - Translations (4100 entries among five languages)	Dictionary entries include over 4100 technical terms that are translated from one language to another, among five languages (English, German, French, Italian and Spanish). See www.metalpass.com/translate. This is the largest online dictionary for metal term translation among languages.	Metal Pass
102	Compilation of data list for the Metal Directory (30,000 records; the largest one in the metal industry)	With about 30,000 records, the Metal Directory (www.metaldir.com, or www.metalpass.com/metaldir) is the largest directory in the metal industry, for example about three times of www.steellinks.com. There are over 1200 product categories in the directory. User is allowed to submit his/her own listing. Search for a product or a company is available.	Metal Pass
103	Compilation of data list for the software database (about 400)	A collection of the lists of the software used in the metal and steel industry. This is considered to be the largest online collection of the metal industry software. It is also one of the Metal Pass categories that Google selects and puts on the right frame of many websites, for Google's own popularity, without Metal Pass paying anything.	Metal Pass
104	Compilation of data list for the metal technical books (1800 books)	A collection of over 1800 metal technical reference books in the metal and steel industry, listed by category in metalpass.com, also www.metalbooks.com.	Metal Pass
105	Compilation of data list for the article abstract	Article abstracts from the major trade magazines in the metal/steel industry worldwide (several thousands).	Metal Pass
106	Creation of metal technological contents for metalpass.com	Technical papers were written and populated in the metalpass.com (about 400 papers, in about 30 categories)	Metal Pass
107	Development of an application to gather metal patent information and populate the patents onto the website (www.metalpass.com/patent)	Over 15,000 patents, displayed in the mill technical terminology such as flat rolling, wire rod rolling, shape/pipe rolling, roll pass design, mill automation, etc.	Metal Pass
108	Development of an online payment and	Payment related data was verified forward and backward for several times, to maintain a high level of security.	Metal Pass

	data validation system for metalpass.com.		
116	Development of near 200 satellite websites to support the main site	Near 200 satellite websites are under development, such as www.millconsultant.com, to support the main site www.metalpass.com. A satellite website usually has near 30 pages and focuses on related topics. After that it will link to the main site. About 100 sites are done while the rest are in the process of development.	Metal Pass