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METHOD OF MAKING STEEL STRAPPING AND STRIP

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Robert D. Reilly

ROBERT REILLY & ASSOCIATES

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METHOD OF MAKING STEEL STRAPPING AND STRIP - Semi Annual Report

ROBERT REILLY & ASSOCIATES-Robert D. Reilly

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Narrative:

a) The technical progress obtained for this time frame consisted of the awarding of two contracts for determination of metallurgical parameters for heat treatment of strapping and strip which are unavailable from current technology and/or published data in this field.

The two contractors were namely Bricmont, Inc. and the Department of Materials Science and Engineering at the Technological Institute of Northwestern University, Evanston, IL.

Phase 1 of the two stage contract with Bricmont, Inc. which provided a computer analysis of the cooling rates of a typical range of thickness' of strapping was completed. This study was developed for the purpose of determining the time parameters for quenching low carbon steels to a martensitic microstructure within the time frame of the design of the proposed process. It also provides design criteria for cooling to ambient for the total process.

This data is required for Phase 2 of the Bricmont proposal which completes the design and specifications of the total heat treating and cooling system for the process. This becomes the basis for developing the cost and space requirements for this component of the production line. We do not intend to award Phase 2 until the work done at Northwestern University discussed hereafter is completed.

On or about May 1, 1999 a contract for a project entitled "Effects of Steel Composition and Quench Rate on Microstructures and Mechanical Properties of Strapping" to be performed at the Department of Materials Science and Engineering was awarded. The delay in initiating this project was due to the legal interpretation and final agreement of the intellectual provisions of the award by our attorneys, Northwestern's attorneys and the legal representative in the Chicago office of the DOE.

The work to date includes rapid quenching of a number of steel different steel compositions and microstructures on an existing "drop quench" test apparatus.

b) Technical difficulties-It was initially assumed that this procedure would simulate proposed processing line conditions however variations in test results have necessitated further investigations into the nature of cold rolled steel vs. hot rolled steel and electric furnace steel vs. basic oxygen furnace steel as it may apply to heat treating procedures and selection of appropriate steel chemistry for the process.

c) Resolving this problem-In view of this, it has been decided that further testing should take place in a procedure where test lengths of rod are heated, hot rolled on a laboratory hot rolling mill followed by quenching. This will more closely approximate actual conditions as the quenching will take place directly from the "Rolling Heat" with raw materials from electric furnace (mini) mills. These tests should also provide answers to the question of the effect of "Residuals" in electric furnace steels and whether or not they will have to be taken into consideration in our processing. Most of the "Quality" mini-mills are addressing this condition by classifying and/or being more selective in their scrap charges. They are also using or intend to use more "Iron" in their process.

d) Requested schedule change-In addition to the above procedural change, Northwestern's Principal Investigator, Dr. Semyon Vaynman has recently undergone major surgery and at this writing has just returned to work on a part time basis. We have requested a six month extension in the completion date of the project presently scheduled for February 22, 2000.

e) Future activities-We've made overtures to mini-mills who produce low carbon rod and who would be logical suppliers with the objective of becoming partners or licensees. As of this date we have not received any response. Planned and announced price increases in sheet steel by the integrated mills adds a corresponding increase to our favorable processing margins.

It may be desirable to engage the services of a consultant who is familiar with and specializes in mini-mill processing technology to evaluate our direction at this time. This is not to say that there are not alternate processing methods that we can consider that may be more in line with existing technology but are more costly in raw material and processing.

General: As explained above, the project test results should be more definitive with the revised procedure. Martensitic Steels are acknowledged to have superior properties of strength and ductility over previously used structures and this is the reason for this objective. They are being produced at lower speeds on continuous annealing lines with these improved properties for strip and strapping confirmed.

As addressed in the enclosed article, micro-alloyed steels and thermomechanically rolled steels can "attain an excellent combination of high strength and ductility" and are of current interest in the total industry.

We continue to see both of these directions as prudent and obtainable in our process.

The project is currently "on budget".

encl.

An extensive and increasing range of strip products, from low to high-carbon, alloy, electrical and stainless grades, is being produced by Compact Strip Process (CSP) technology. Latest developments involve endless rolling concepts and growing application of thermomechanical treatment for high-strength strip and thin strip by ferritic rolling.

Present and future CSP technology expands product range

Gunter Flemming, Vice President—Research and Development, and **Karl-Ernst Hensger**, Manager—Research and Development, SMS Demag AG, Dusseldorf, Germany

COMPACT Strip Production (CSP) is a technology for producing hot rolled strip at low production costs in combination with high productivity and product quality.

A typical CSP plant and process parameters are illustrated in Fig. 1.

Hot rolled strip applications

Since the commissioning of the first CSP plant by Nucor Steel—Indiana, Crawfordsville, more than 40 million tons of hot rolled strip have been produced worldwide.

A summary of typical steel types, grades and examples of product applications presently processed in CSP plants, appears in Table I. The steel grades were processed in different plants under routine operating conditions.

Low-carbon — Unalloyed, low-carbon hot rolled strip was the first type of CSP product. Present-day developments in this product group include, for example, boron-alloyed special grades featuring improved deformation behavior.

Structural and HSLA — Recently, the production of CSP hot rolled strip from a wide range of standard and high-strength structural steels has been of particular interest. Special attention has been paid to low-carbon microalloyed grades that are thermomechanically rolled and attain an excellent combination of high strength and ductility. Hot strip made from these steels is used for the construction of plants, machines and vehicles. Currently, the so-called peritectic grades can also be produced with high yields.

Line pipe — The production of hot rolled strip (skelp) for welded line pipe is considered to be a major challenge by CSP and conventional hot strip producers, alike. Through the consistent application of metallurgical principles with regard to both steel composition and processing conditions,

the stringent demands of material for this application have been met. In addition, there is continued development of steels with higher strength and ductility, especially at low temperatures, as well as the retention of weld reliability.

Heat treatable, spring, tool and wear-resistant — Recently, interest in the production of higher carbon and alloyed hot rolled strip grades of the heat-treatable, spring, tool and wear-resistant group of steels has increased. All of these steels have been produced in CSP plants with a high degree of process reliability. The material is widely accepted by customers.

Electrical — In the case of electrical steels, magnetic properties such as permeability (high magnetization with small magnetic fields) and low hysteresis losses can be guaranteed. Nonoriented silicon steels, after cold rolling and final annealing, have been applied, for example, in generators. Electrical strip steels having a pronounced texture are used mainly in transformer cores. Texture control by secondary recrystallization is achieved by specific phases such as MnS. Control of these phases is of considerable importance in thin-slab casting and subsequent rolling with direct-charged slabs. Development continues in this area, opening up interesting possibilities for the future.

Stainless — The production of stainless hot rolled strip is also especially important with regard to chemical resistance in various aggressive media. Chromium ferritic hot rolled strip has been produced utilizing an AOD converter and processed into catalytic converter casings. The manufacture of austenitic strip is being attempted under operational conditions.

The summary of steel grades and applications shown in Table I illustrates the wide diversification of CSP products that has been achieved. Besides the relatively simple,

Fig. 1 — Principle of CSP technology.

TABLE I Typical applications of CSP hot rolled strip

Steel group	Representative grade	Example of application
Mild low carbon		
Cold forming	StW24 (+B)	Longitudinal beams
Rerolling	St24	Strapping material
Structural and HSLA		
Plain carbon	St52-3	Structural tubes
HSLA with improved formability	QStE550TM	Wheel rims, shell elements
Fine-grained structural for welding	StE500 WStE420 TStE500, EStE500	Car frame components Strapping material Propane gas cylinders
Weathering	WStE52-3	Sheet piling
Phosphorus alloyed	-	Reroller
Line pipe	StE480.7, X70	Pipeline
Heat treatable		
C	Ck50	Strapping, washers
C-Cr	41Cr4	Clutch plates
C-Mn	28Mn6	Tubings
C-Mn-B	(30MnB5)	Stampings, stand construction
C-Cr-Mo	42CrMo4	Brake elements (aeronautical)
C-Cr-Mo-V	(30CrMoV4)	Steering column assembly lever
Spring		
Unalloyed	Ck67	Bending, spiral springs
Alloyed	50CrV4	Rulers
Tool		
Unalloyed	C70W C85W C100W	Knives, shears Plough blades Files
Alloyed	75Cr1 56NiCrMoV7 75NiCrMo553	Wood saws Carrier blades for saw teeth Saw blades
Wear-resistant	90Mn4	Harrows, cultivators
Electrical		
Nonoriented and grain-oriented	Si = 1.2-3.2	Motors, generators, transformers
Stainless		
Ferritic	X6Cr17	Converter casings
Austenitic	X5NiCr18 10	Under development

tonnage steels, exacting products are also being produced to an increasing extent, meeting a wide range of mechanical, physical and chemical service requirements.

Characteristics of CSP technology

The integration of three factors has contributed and will continue to contribute to the future growth and adoption of CSP technology:

- Equipment design and automation.
- Technological practices.
- Material characteristics (composition and microstructure).

Significant differences are inherent in the engineering design and material processing of CSP plants, in contrast to conventional hot rolled strip production. It is these differences that provide considerable potential advantages for the future manufacture of high-performance hot rolled strip.

The principal features of CSP technology that have a major effect on the metallurgical properties of the hot rolled finished product are:

- Thin-slab casting.
- Direct charging and rolling of a thin slab.
- Laminar cooling and coiling.

Thin-slab casting — One of the important characteristics of thin-slab casting is the higher solidification rate, in comparison with conventional slab casting. The faster solidification rate results in smaller secondary dendritic arm spacing and considerably less macrosegregation. This feature is a major factor contributing to the superior constitutional homogeneity of CSP hot rolled strip.

Direct charging and rolling of a thin slab — The direct charging and rolling of a hot thin slab without a roughing mill has a significant effect on the microstructure. For example, in the case of rolling a hot thin slab, the steel passes through a series of phase transformations from the liquid state to the delta solid phase, δ , to an austenite phase identified as γ_1 which exists when the slab enters the CSP rolling mill. In conventional hot strip mills, where the slab is generally charged cold or hot, the steel passes through a different series of phase transformations, eg, liquid through the delta solid phase, δ , through the austenite phase, γ_1 , through a cold or hot ferrite phase, α , and subsequently, following slab reheating, to an austenite phase, γ_2 . In addition, the thin slab enters the CSP rolling mill with an as-cast structure, γ_1 , whereas in a conventional rolling operation the transfer bar entering the finishing mill has a recrystallized structure. This dissimilar thermomechanical history leads to differences in microstructure. For example, the grain size of austenite γ_1 is larger than that of austenite γ_2 . There are also differences in precipitate formation (microalloying elements, MnS, etc).

During the deformation process in the CSP rolling mill, two objectives must be met in addition to establishing the necessary geometry for the hot rolled strip (width, thickness, flatness, profile). First, the dendritic as-cast microstructure has to be compacted and transformed into a homogeneous recrystallized microstructure; and, second, the austenite has to be conditioned so that the subsequent polymorphic transformation results in an extremely fine-grained ferritic phase. Plastic deformation is deliberately used in CSP rolling to control the subsequent solid-state reactions during laminar flow cooling and at the coiler.

Laminar flow cooling and coiler — A high nucleation density for the subsequent austenite transformation can be achieved by finish rolling below the recrystallization stop temperature. This transformation takes place on the runout table to the coilers. Thus, the laminar cooling section can be employed as an efficient instrument for heat treatment and, consequently, the desired final structure can be adjusted.

In ferritic rolling, the polymorphic transformation has already occurred prior to the end of rolling. Consequently, the cooling section is kept as short as possible for coiling at high temperature and ensuring annealing with substantial softening inside the coil.

Thus, there are many possibilities for controlling the solid-state reactions with appropriate selection of the pass schedule in the CSP rolling mill and cooling conditions in the laminar flow cooling section, as well as the coiler. Both the microstructure and properties of the strip can be established in a well-defined manner with considerable variation in range possible.

The following examples illustrate the wide range of control possible with CSP technology.

Hot rolled strip quality

The microstructure of hot rolled strip is established to meet the future application or processing requirements. The required microstructure, in turn, is obtained by selecting the cooling conditions that achieve the appropriate