Fujico's CPC/HSS Roll Performance at CMC's Arizona Micro-Mill and in North America

This paper describes the new micro-mill at Mesa, Ariz., and the continuous process for cladding (CPC) process for casting rolls. Roll performance results are presented for high-speed steel rolls in several bar and rod mills in North America. Improved bar surface texture is shown.

Authors

Gene E. Lee
sales agent (retired) and technical consultant, MBI Rolls LLC, Cranberry Township, Pa., USA
genelee@zoominternet.net

Felix Lopez
process engineer/mill services supervisor, CMC Steel Arizona, Mesa, Ariz., USA
felix.lopez@cmc.com

For decades, roll manufacturers have provided rolls of cast iron and cast steel that have performed admirably with good wear resistance, tensile strength and impact strength, all the while demonstrating excellent machinability. For instance, the nodular iron process was discovered in 1948 and is still being used. But in the last few decades, roll manufacturers have adapted more modern materials and adopted or invented other processes, such as spin casting, bottom pouring, hot isostatic pressing and the continuous process for cladding (CPC).

Various tool steels, namely 9V, 10V, high-speed (HSS), semi-high-speed, as well as tungsten carbide, have been produced and used very successfully. Some of these alloys cannot be commercially produced statically, so they must use newer processes.

The scope of this work is the continuous process for cladding of HSS shell material, and its performance in long product mills in North America. Some of the users of these rolls have provided performance results and have asked to remain anonymous. As a result, all mill locations have been kept confidential, with the exception of CMC Steel Arizona.

Description of CPC Process

The machine is loaded with a preheated 4140 steel bar that becomes the core metal of the roll (Figure 1). This bar does not rotate during the process, but it does descend in increments that are controlled by a computer. Guide rollers keep the bar in a vertical position. There are two induction coils: one to maintain the preheated bar temperature and one to maintain heat in the liquid HSS shell metal in the tundish. The second coil also provides some induction stirring of the liquid shell to assist in chemical uniformity.

The pouring furnace feeds liquid shell metal to the tundish in kilogram increments, which is also controlled by the computer. A flux is added and maintained on the top surface of the liquid. With the bar and pouring furnace controlled by the computer, the liquid around the bar begins to cool and solidify as it passes through the water-cooled copper mold and exits to the ground floor of the shop. The solidification rate is very rapid. The resulting small grain size of the shell metal contributes to better strength and better surface finish compared to other cast processes.

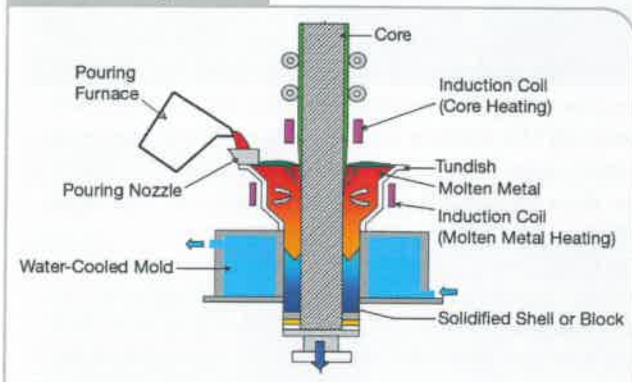
Macroscopically, the casting in the CPC process proceeds in the axial direction of the roll, but the solidification proceeds in the radial direction from the outer surface of the roll to the interior.

Features of CPC Process

The CPC process has three major features: high multi-alloying without segregation, rapid solidification, and a strong and tough core. First, in centrifugal casting, some shell metal alloys contain elements that are heavier than the liquid as the solidification proceeds. These heavier components are thrown to the roll surface layers by the centrifugal force. This means that there can be a noticeable microstructural difference from a new roll vs. a partially worn spun cast roll. Second, the solidification rate is high and a fine structure is obtained. There is much less of a microstructural difference in CPC rolls as the roll is worn/machined to scrap diameter (Table 1). Third, a strong, tough and highly rigid steel base material can be used for the core.

The rate of solidification of the CPC process can be selected by balancing the drawing speed and the induction heating. Due to the faster solidification rate, the CPC process yields a finer grain size. The finer grain size allows the material to be stronger and provides improved wear resistance. As a roll surface wears, it roughens. HSS materials do not roughen as quickly. They can provide more rolled tons before a pass is changed; and because the roll surface is smoother, the steel product being rolled is smoother.

Figure 1



Sectional drawing of CPC equipment and roll.

Table 1

Comparison Between CPC and Centrifugally Cast Shell Material

Process	Solidification rate, mm/minute	Grain size, µm
CPC	15–30	50–100
Centrifugal	3–7	200–300

Advantages of the CPC Process and HSS Material

The macrostructure photographs in Figure 2 show the uniformity of the shell thickness in any direction, i.e., radial and longitudinal. Table 2 shows the HSS chemistry specification for long product intermediate and finishing rolls.

Figure 3 shows the typical boundary between the shell and core and a typical hardness penetration. The boundary layer is very thin and uniform. Tensile tests in the radial direction across the boundary layer never fracture in the boundary; they always fracture in the core material. The hardness drop as the roll diameter is reduced is typically 3 to 4 Shore points (18 to 24 Equotip points) for a 2-inch shell thickness.

Another advantage of these rolls for the finishing and intermediate areas of mills is that the combination of material and casting process provides a roll that is resistant to rough conditions. As the rolls wear in the pass, the small grain size and matrix hardness of the alloy system resists deterioration of the surface texture. This texture of the roll surface carries over to the steel product

Table 2

Chemical Specification of HSS Shell Material and Core Bar

	Grade	C	Cr	Mo	V	W	Co
Shell	FKC-704	1.7/2.3	3.5/7.0	4.5/8.0	3.5/7.0	2.0/7.0	1.0/4.5
Core	Cr-Mo steel	0.38/0.43	0.9/1.2	0.15/0.30	–	–	–

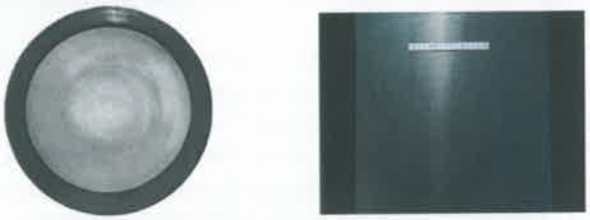
Table 3

Smooth Rounds

		*	Avg. tons/pass	Avg. lathe redress
Oval leader	Stand 13 for 3/4 inch	CPC/HSS	637.4	0.068 inch
Round finisher	Stand 14 for 7/8 inch	CPC/HSS	935.7	0.129 inch
Round finisher	Stand 16 for 3/4 inch	CPC/HSS	347.0	0.066 inch

* No data available for other materials. Customer using only CPC/HSS rolls.

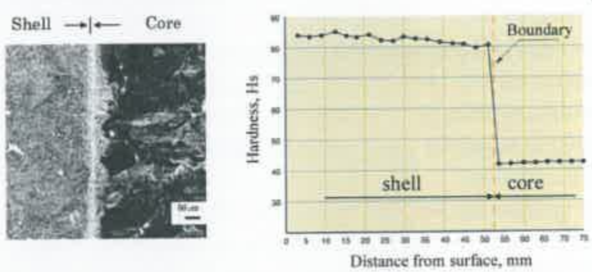
Figure 2



Cross-section | Longitudinal section

Macrostructure of the CPC process.

Figure 3



Microstructure of shell-core boundary of CPC roll | Hardness distribution in the section of CPC roll

Boundary and hardness penetration of CPC cast roll.

Table 4

19-mm Rebar Leader Passes

	CPC/HSS	Nodular iron
Avg. tons/pass	2,718	1,849
Avg. lathe redress	0.088 inch	0.090 inch
Durability ratio index*	1.5X	1.0X

* Durability ratio index is a combination of the lathe redress and the avg. tons/pass.

Table 5

Rebar Dogbone Passes

	Nodular Iron	CPC/HSS
13 mm	–	–
Avg. tons/pass	981	1,837
Avg. lathe redress	0.235 inch	0.132 inch
Durability ratio index	1.0X	3.33X
16 mm	–	–
Avg. tons/pass	1,103	2,009
Avg. lathe redress	0.396 inch	0.126 inch
Durability ratio index	1.0X	5.7X

surface so that subsequent processing, such as powder coating or painting, is also improved.

The wear resistance of the HSS material allows for a smaller reduction in the lathe than on nodular iron rolls. Typical reductions are about one-half of nodular iron rolls.

Performance of HSS/CPC Rolls in North America

All of the following performance data has been provided by customers with permission for use in this paper. The performance is listed by type of rolled section.

The mill that provided the 19-mm rebar data realized that it was removing a standard amount of stock. It has now started to remove only the amount needed to clean up the surface and mate it to its partner roll. This mill expects to see improvement soon.

The data in Table 5 is from one mill, but two sizes of rebar.

The CMC Steel Arizona micro-mill is composed of 16 stands: eight cantilever roughers and eight finishing cartridges. Stands 1–3 are 685 mm diameter and stands 4–8 are 450 mm diameter. All finishing rolls are 380 mm in diameter. The mill produces rebar, T-post and rounds.

The plant employs a continuous-continuous process in which the billet caster is directly tied to the mill stands. It is capable of high yield numbers because of this continuous process. It is not uncommon to see a single strand in the mill for 24 hours. After a 24-hour rolling sequence, the submerged entry nozzle (SEN) at the caster must be changed out. At this time, the rolling mill utilizes this necessary downtime to change passes and check guiding, loopers and other equipment on the mill. Changing a pass prematurely during this 24-hour period is costly, since billets must be kicked off-line as the caster continues to feed the mill. This cost must then be appropriately controlled by careful selection of roll materials. Although utilizing carbide rolls throughout the entire intermediate/finishing stands would ensure not having to change passes prematurely, it is also important to keep the initial cost of the investment in rolls to a manageable level. For these reasons, CMC Steel Arizona began operations using a combination of iron, crucible particle metallurgy (CPM) and carbide rolls.

After the start-up process, CPC rolls came up as a viable option for use in the mill. The mill rolls 13- to 36-mm rebar, and to date the CPC rolls have been used on both 13 and 16 mm in the leader stands. They have also been used in the T-post finishing stand. CPC has proven to be a good option for rebar leaders.

Table 6

CMC Steel Arizona Roll Data

		Nodular iron	CPM 9V	CPC/HSS
13-mm leader	Avg. tons/pass	200–250	1,052	1,283
16-mm leader	Avg. tons/pass	300–350	1,440	2,360
T-post finisher	Avg. tons/pass	655	N/A	618
Leader lathe redress	—	N/A	0.060 inch	0.060 inch

Table 7

Small Squares — 5/8-Inch Diamond Pass in Stand 11

	Nodular Iron	CPC/HSS
Avg. tons/pass	1,680	3,477
Avg. lathe redress	0.175 inch	0.104 inch
Durability ratio index	1.0X	3.5X

Table 8

Angle Finisher Data From Two Different Mills

	Avg. tons/ pass	Avg. lathe redress	Durability ratio index
Mill #1: 1.5 inch	—	—	—
Nodular iron	412.1	0.118 inch	1.0X
CPC/HSS	761.3	0.079 inch	2.8X
Mill #2: 1.5 inch	—	—	—
Nodular iron	100.0	N/A	N/A
CPC/HSS	278.0	N/A	N/A

On the T-post application, the results do not seem to be as favorable as would be expected (Table 6).

The first sampling of data was received about six months before the data in Table 6. The rebar data has held steady, but the T-post data has improved a lot. It was initially 250 tons for iron and 497 for CPC. The mill personnel worked toward improvement and will continue to work to see if the higher technology materials have more to offer in this application.

Machining data for mill #2 is not available. Mill #2 is also rolling some larger angles, but has no official data at this time. The indication is that the difference in performance is even larger because the larger bar is heavier.

Another customer rolling 1- to 4-inch angles would not divulge the tons/pass, but informed the authors that the CPC/HSS produces 3–5X the tons vs. nodular iron. The average lathe redress is 0.086 inch for CPC and 0.138 inch for nodular iron. The surface finish on the bars is greatly improved, such that the downstream blasting operation is no longer backlogged like it used to be. CPC/HSS rolls are now all that are used for angle finishers here.

Summary of CPC/HSS Rolls

In North America, there are CPC/HSS and other modern materials in use for rolling rounds, rebar, channels, angles, squares, T-post and flats. The overall performance of the higher-technology roll products is proven to be 2–5X better than nodular iron. In all cases, the texture of the steel product surface is smoother than with the older iron technology.

CPC Material in Roughing Stands

There are nine mills in Japan using 74 rolls or rings of this new material, FKC-705, in the roughing stands. The information below is from Japanese mills.

The new material for the roughers will not be explained, except to say that it was chosen to resist fire cracking. It is cast by the CPC process onto a 4140 steel bar just as the HSS is cast.

Trials of HSS in the roughing train of a mill showed the expected: it fire-cracked along and through the carbides. After four years of testing in Japanese mills, it is proven that the new rougher material resists fire cracks much better than either Adamite cast steel or nodular irons. Data is shown in Tables 9 and 10 for the new material vs. other materials.

Figure 4 shows the pass of the new FKC-705 material across the top, after rolling 12,000 tons on the left and after 22,000 tons on the right. The lower photograph is nodular iron after only 10,000 tons. The new material provides a better texture than nodular iron.

The compact roughing mill stand 4V is shown in Figure 5, wherein 5a, 5b and 5c are of the FKC-705 material after 10,000, 25,000 and 50,000 tons, respectively, while 5d is the semi-high-speed steel after 13,000 tons. These are all pretty good, but it is obvious which is better. They both outperform nodular iron.

Summary

The new materials for long products are great improvements over the cast steels and irons that have been used for many decades. The underlying properties (grain size

Table 9

Comparison of Materials in Horizontal/Vertical Roughing Mill

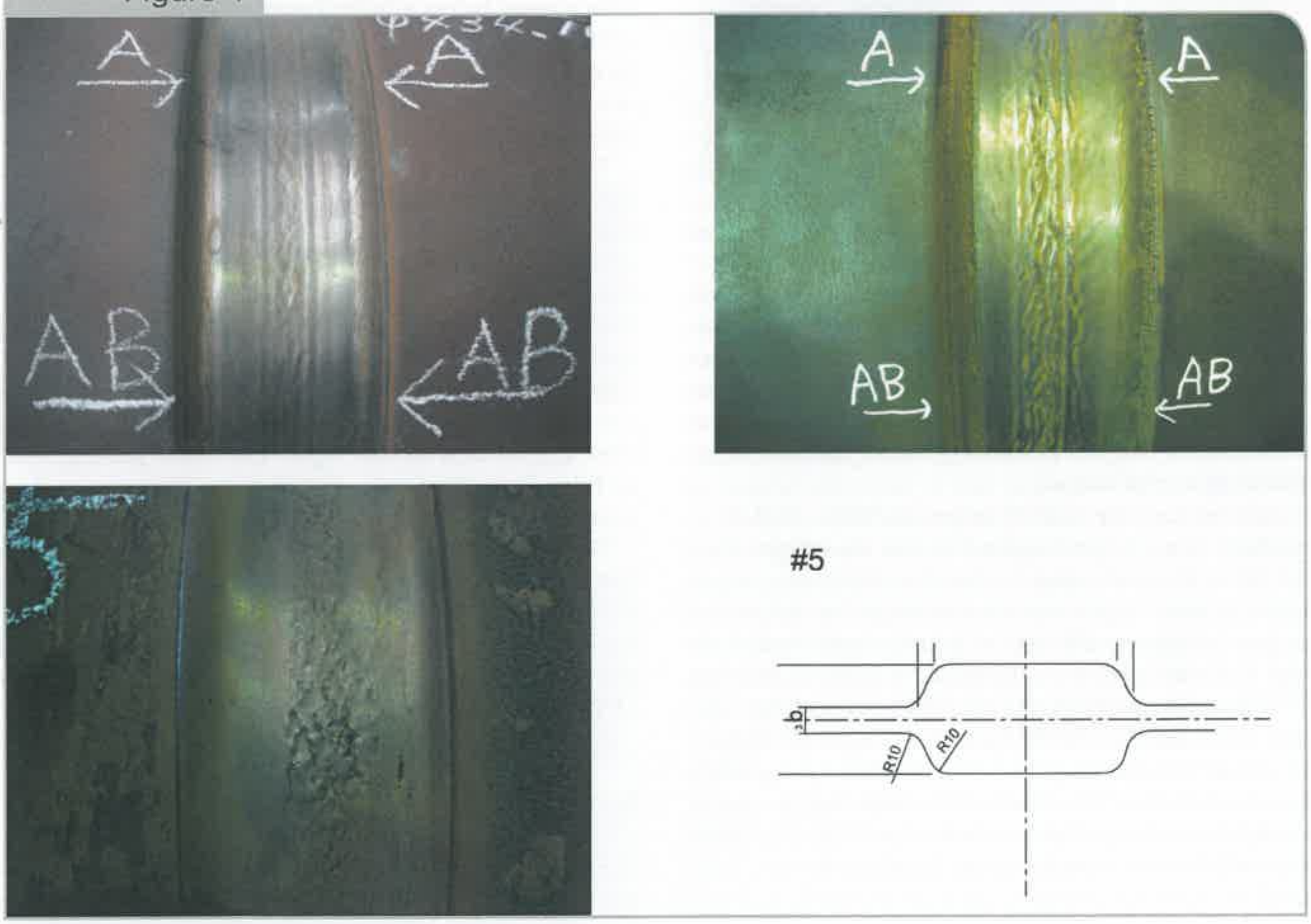
Stand	Material	Avg. tons	Avg. lathe redress	Times in mill	Durability ratio
4V	Nodular iron	11,000	8	6	1.0X
4V	FKC-705	25,000	8	7	2.7X
5H	Nodular iron	11,000	11	6	1.0X
5H	FKC-705	25,000	9	9	3.4X
6V	Nodular iron	11,000	9	7	1.0X
6V	FKC-705	25,000	7	9	2.9X

Table 10

Comparison of Materials in a Compact Roughing Mill

Stand	Material	Avg. tons	Avg. lathe redress	Times in mill	Durability ratio
2V	Nodular iron	20,000	17	4	1.0X
2V	FKC-705	40,000	10	7	3.5X
3H	Nodular iron	20,000	19	4	1.0X
3H	FKC-705	42,000	10	7	3.7X
4V	Semi-HSS	35,000	10	6	1.0X
4V	FKC-705	53,000	10	6	1.5X

Figure 4



Photographs of stand 5H of H/V roughing mill.

Figure 5

Photographs of compact mill stand 4V rolls.

and strength) of the new materials are also better. Of the newer roll manufacturing processes, CPC has the best properties to show improved wear resistance and surface texture that imparts surfaces being sought by many steel buyers today.

Newer materials hold the pass shape longer than older materials. So, in many instances, the wear resistance of newer materials is now allowing mills to schedule roll changes when other maintenance delays are taken, thereby attaining more uptime on the mill for increased productivity.

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