Quality development in the production of strip products

Sendzimir achieved its initial success in 1943 when it succeeded in satisfying consumer demands where others could not. The steel company ARMCO, in Middletown, Ohio, USA, had been asked to find a way to roll 3.5 per cent silicon grain-oriented steel down to 0.05 mm for the production of small transformers that would make airborne radar possible. ARMCO's engineers tried a number of different approaches, all to no avail. Even the use of a narrow four-high mill, with very small diameter sapphire rolls, failed because the high lateral force caused the rolls to snap in the middle.

Dr. Tadeusz Sendzimir had patented a rolling mill that could roll very hard materials down to very light gauges. The first Sendzimir mill was built at the August Schmitz works in Dusseldorf, Germany, in 1932 for Huta Pokoj, in Nowy Byton, Poland. This 32-in wide mill had four-inch work rolls and nine-inch bearings (see *Figure 1*). The design used the idea of a small work roll, but it also transferred the roll separating force to the housing, while supporting the load uniformly across the width of the mill and avoiding any lateral bow effects. Individual sheets of low-carbon steel were welded together into a closed loop and attached to a carriage on rails. As the strip elongated,

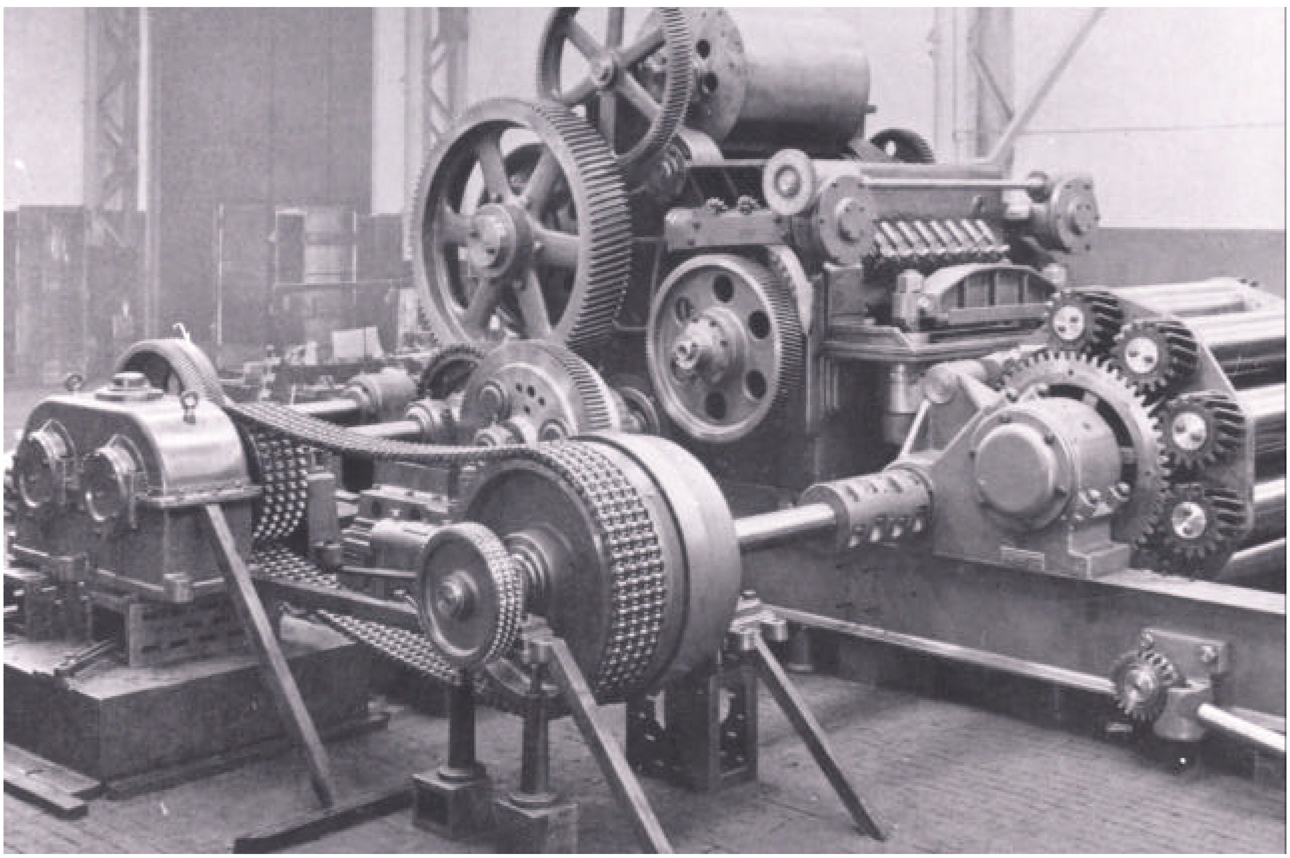

Figure 1. The first Sendzimir mill, built in 1932 in Poland

Figure 2. The first Sendzimir tandem mill, built in 1969 for Nisshin Steel

the carriage moved away from the mill, thus taking up the elongation. Sendzimir's design succeeded in the rolling of grain-oriented silicon steel, paving the way for rapid expansion of this technology, eventually using coilers on each side of the mill in a reversing operation.

In the 1950s, steel demand far outstripped supply, and the consumer was at the mercy of the producer, who, in turn, faced long delivery times for electrical equipment. In several cases, hydraulic mill drives were substituted in order to achieve acceptable delivery to the client. For example, it would have taken three years for electric motors to arrive at the new mills for Arthur Lee in Sheffield and at Empire Aluminum in Glasgow, both in the UK. On the other hand, hydraulic motors were readily available and installed. Tension control was, however, sacrificed.

Hydraulic drives were also inherently inefficient, with big power losses.

Nevertheless, some of those 1950s mills operated for 25 years before being revamped with electric motors, an example of insufficient market pressure on production efficiency.

During the late 1960s and early 1970s, steel supply began to exceed demand and so consumer requirements increased in importance. Steel producers sought better manufacturing methods and equipment capable of producing at lower cost and with higher quality. This often meant a substantial investment in capital equipment. For example, wide strip mills were developed and proliferated rapidly. Although their capital cost was often double that of earlier equipment, these mills realized profitable savings in time, volume, and quality. They rolled strip that could then be slit in two, operated at much higher speeds and tension, could handle larger coils without welds, and had better shape control.

The first Sendzimir tandem mill was installed in 1969 at the Shuhan works of Nisshin Steel Co. The six stands comprise a two-high mill at the front and at the

Figure 3. Sharon Steel's ZR 21-55 mill

end with one ZR 22N-50 and three ZR 21B-50 mills in between. Dedicated to the production of stainless strip, the installation more than tripled production capacity at these works (see *Figure 2*). Eventually, in the 1990s, the introduction of the Direct Roll, Anneal and Pickle (DRAP) line advanced the idea even further.

At Sendzimir, consumer pressure in the 1950s to reduce strip production costs resulted in the creation of the ZR 21 type cluster mill. The oversized geometry of this mill and its doubled housing weight permitted roll separating forces of 22 tons per inch of width and mill powers of over 9,000 hp per mill stand. Speeds, which had averaged 400 feet per minute (fpm) in 1948, exceeded 3,000 fpm by the early 1980s. This type and size of mill was ideal for carbon as well as silicon steels, especially grain-oriented steels, before becoming a standard size for 1,600 mm-wide stainless production. It obviated the need for double-reduced tinplate, finished after intermediate anneal on a more expensive three-stand tandem mill. Granite City Steel in Granite City, Illinois, USA, was the first client to use a Sendzimir single stand ZR 21-44 as a one-way mill directly following initial rolling on a four-stand tandem mill. Sharon Steel Corporation, in Farrell, Pennsylvania, USA, was the second, rolling high-quality

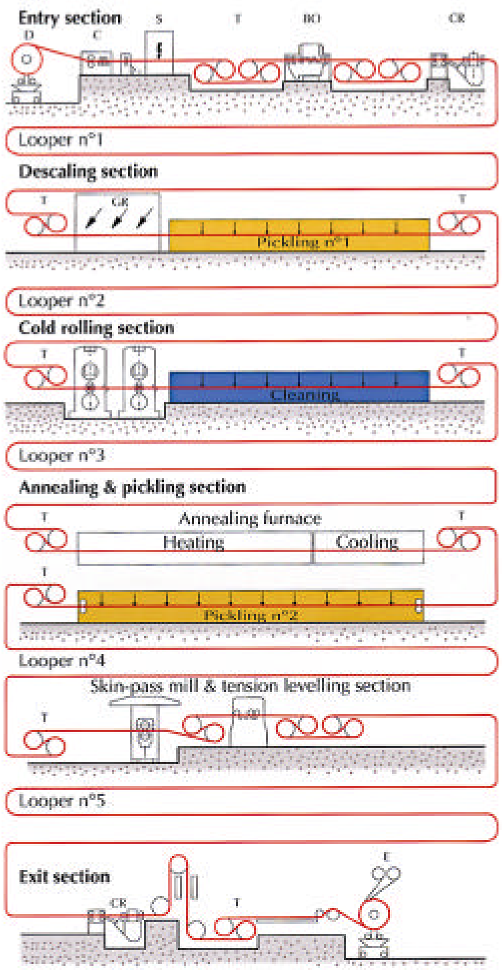

Figure 4. Two Sendzimir Z-High mills are at the core of Ugine's new process line in Isbergues, France (picture courtesy of Metals Journal)

Figure 5. Two-stand Z-High mills in the DRAP line at J&L Specialty Metals, Midland, Pennsylvania, USA.

carbon grades (see *Figure 3*). Sharon Steel's ZR 21-55 mill was sold to Duferco Farrell in 1998. The mill, built in the mid-1960s, currently rolls high-carbon steel from 2 mm down to 0.25 mm.

Sometimes, ideas are developed in response to market forces but are ahead of demand requirements and have to "wait their time". For example, in the 1970s, Sendzimir developed and patented a method for linking saddles. This improvement permitted more backing assemblies to be changed with fewer movements, thus saving on downtime. However, the idea did not catch on, as the market preferred robotics. Today, Sendzimir is rethinking the twin saddle arrangement because of market pressure, not only to minimize downtime, but also to maintain mill integrity through the incorporation of other new technologies that prevent damage to the saddles and the mill during the extraction and insertion processes.

Quality standards for cold-rolled strip involve its surface finish, flatness, uniformity of gauge, and proper metallurgical composition and structure, and considerable attention is given to the cold-rolling process for achieving consistently high-quality standards. Today, both mechanical and technological equipment exists to enable the mill to achieve high standards, such as automatic gauge and shape control and one-minute work-roll exchange. However, just as important as the cold-mill equipment and automation is the quality of the hot band that will be cold-rolled. Black band with poor metallurgy or shape often cannot be used without significant investment in the rolling capability of the cold mill. It thus makes most sense to focus on producing high-quality hot strip.

Today, almost all steel processed for flat products comes from continuous slab casting, a process that will continue to be the production method of the foreseeable future. The curved mould was introduced at Atlas Steels in Tracy, Canada, in 1950 with the production of 5-in thick stainless steel slabs installed in a direct line with a 51-in wide planetary mill.

The concept of the mini-mill for flat products was first advanced in the late 1950s with the idea of developing a thin-slab caster followed immediately by a Sendzimir planetary mill in tandem. The process was patented jointly by Dr. Benteler and DR. H. Tanner of Concast in Zurich, Switzerland, and was followed by a project at US Steel, in which a thick, continuously cast slab was followed by a special US Steel reduction unit, a reheat furnace, and a planetary mill used as a roughing mill. The outgoing strip of 4.75 mm was

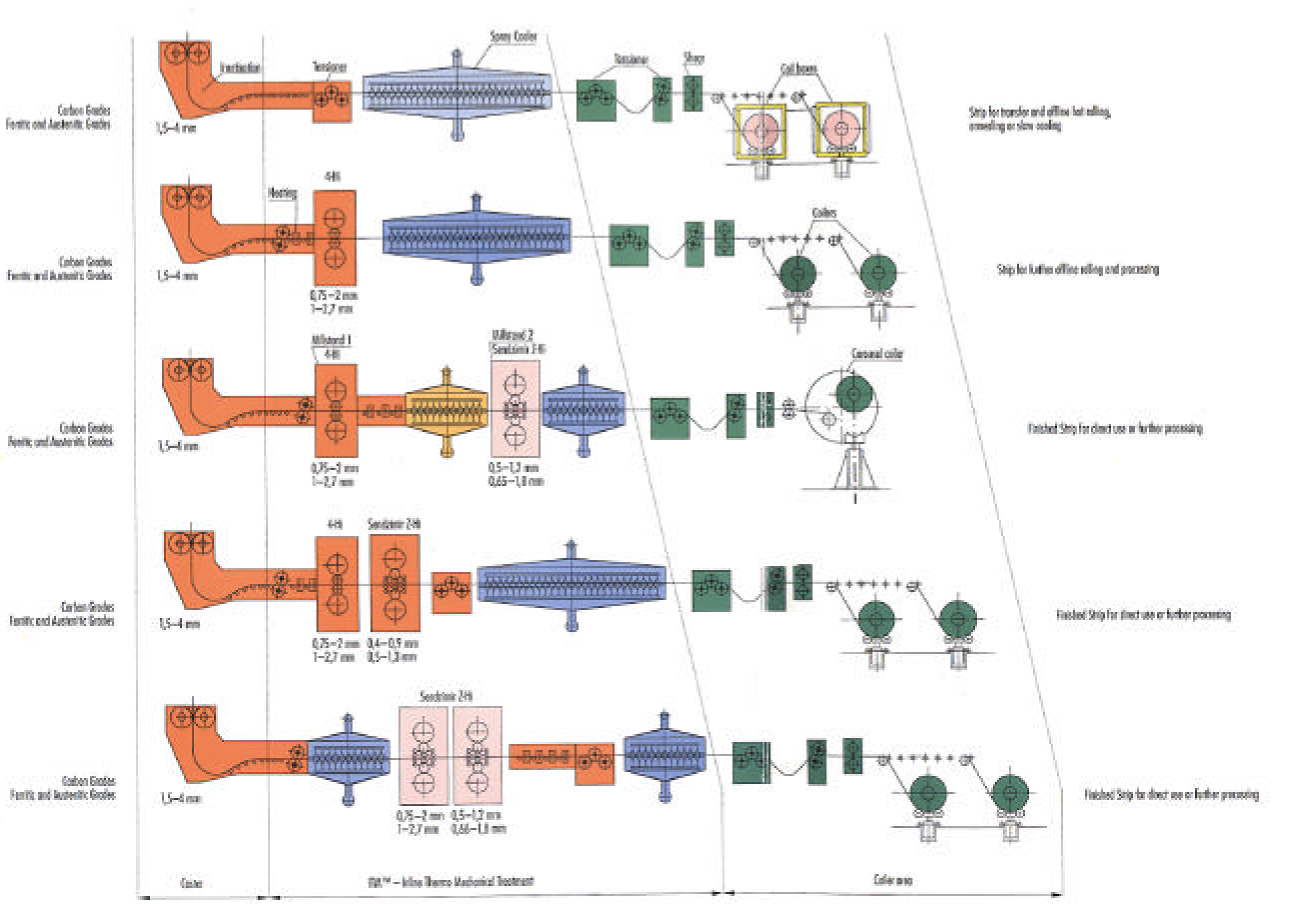

Figure 6. MTAG Marti-Technologie AG's continuous casting proposal (courtesy of MTAG Marti-Technologie AG)

reduced by three finishing stands, and the strip was wound into single 60 ton coils in approximately 600 mm widths.

More recently, the thin slab caster has been developed. In the Compact Strip Production (CSP) process, for example, slabs 50 mm to 70 mm thick are rolled to hot strip gauges, down to 1.0 mm or less, by using five to seven mill stands in tandem. Nearly thirty of these installations have been sold worldwide, and several are running very successfully in the USA.

There are also competitive and very interesting processes being promoted, such as the In-line Strip Production (ISP) process at Arvedi in Cremona, Italy, and by Danieli for carbon steel at Algoma Steel in Sault Ste. Marie, Canada.

Two Sendzimir Z-High mills are at the core of Ugine's new stainless steel process line in Isbergues, France. The line begins with hot band that is cleaned, cold rolled on the 63-in Z-High mills, then annealed and pickled, all in one continuous operation. The process line is shown in *Figure 4*. The Z-Highs are located in the cold-rolling section and produce up to a 60 per cent reduction in strip thickness.

Figure 5 shows the two-stand Z-High mills located in the DRAP line at J&L Specialty Metals in Midland, Pennsylvania, USA. Two automatic roll changers are in the center of the picture, and two Z-High cartridges are shown on the right.

MTAG Marti-Technologie AG envisages one or more Sendzimir Z-High mills as finishing stands in a thin-strip continuous casting process. The Z-Highs would impart shape and gauge control to the hot band (see *Figure 6*).

The authors are convinced this technology will break through on a much bigger scale to supplant existing integrated works, as well as for small steel plants, acting as their independent source of supply or as an addition to existing facilities.

The stainless steel plant of AvestaPolarit at Tornio in northern Finland, where chrome and nickel ore and steel scrap enter the single plant building form one end, and finished stainless steel sheets exit from the other, appears to epitomize the mini-mill concept, combining production efficiency with high quality.