

Liquid Nitrogen Improves Cold Rolling Of Strip Stock

Using liquid nitrogen as a coolant in cold rolling can dramatically increase productivity as well as improve product quality. G. Plicht, H. Höfinghoff, H. Schillak, T. Demski and R. Edwards of Air Products and Chemicals, Inc. and C.D. Wälzholz describe the new Air Products® cool rolling technology.

In an effort to help strip producers attain higher mill speeds and maintain a brighter strip surface quality while reducing downtime, C.D. Wälzholz, a metal strip manufacturer, and Air Products jointly developed a new cooling technique with liquid nitrogen. This technique, the Air Products® cool rolling technology, uses liquid nitrogen as the cooling medium during the final or skin pass rolling step.

Use of the Air Products cool rolling technology in rolling mills has shown that it can increase production rates dramatically compared to traditional dry rolling—in fact, in some cases by up to 50 percent. This technology can also replace conventional lubricants in wet rolling and can reduce strip surface quality issues present with wet rolling. In addition, the Air Products cool rolling technology can reduce the number of work roll changes, can reduce or eliminate the need for any strip cleaning process and can minimize product losses caused by post rolling corrosion.

Conventional cold rolling and its problems

Cold rolling is a process that simultaneously deforms and strengthens metal. It is used as the final stage in the manufacture of metal strip, after hot rolling (Figure 1).

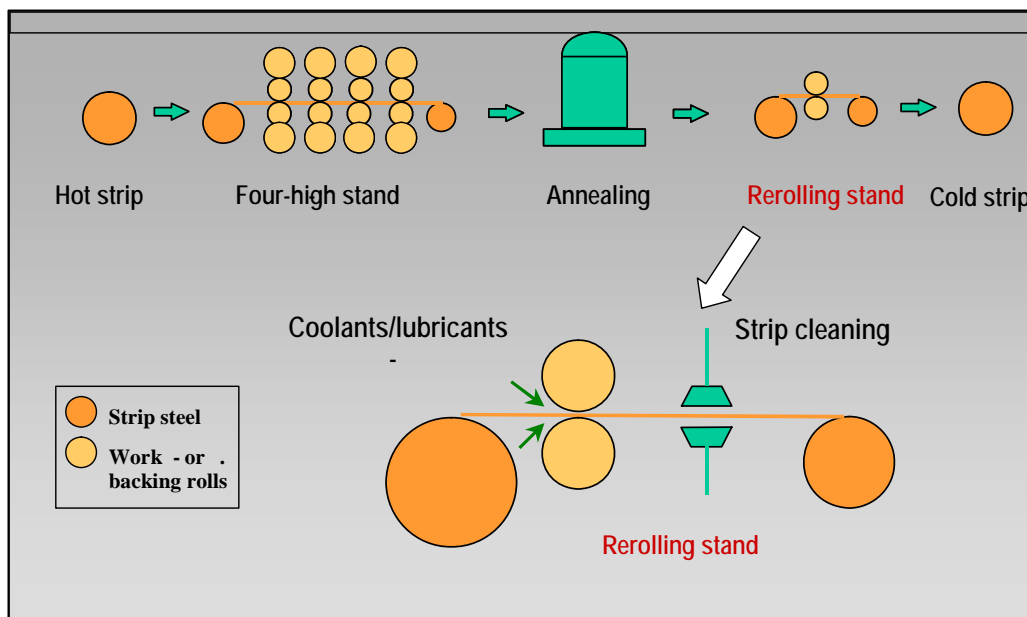


Figure 1:

In the manufacture of strip stock, hot rolling is typically followed by cold rolling.

Hot rolling can achieve large dimensional changes in a single step, but gives poor dimensional control and surface finish. Because it is carried out at temperatures above the re-crystallization temperature of the metal, hot rolling does not increase the strength of the metal.

Cold rolling, on the other hand, takes place without re-crystallization, so the material undergoes work hardening. As a result, cold rolling can be used to fine-tune the mechanical properties of the strip, as well as yield a product with a high-quality surface finish. Cold-rolled steel strip is typically used for motor vehicle bodies and domestic appliances.

There are two types of cold rolling—dry and wet. Dry rolling, as the name suggests, takes place without lubricants. The result is a high-quality bright surface finish, but at the cost of low line speed. The problem with dry cold rolling is the high heat generated in the roll gap by friction and the plastic deformation of the metal (Figure 2).

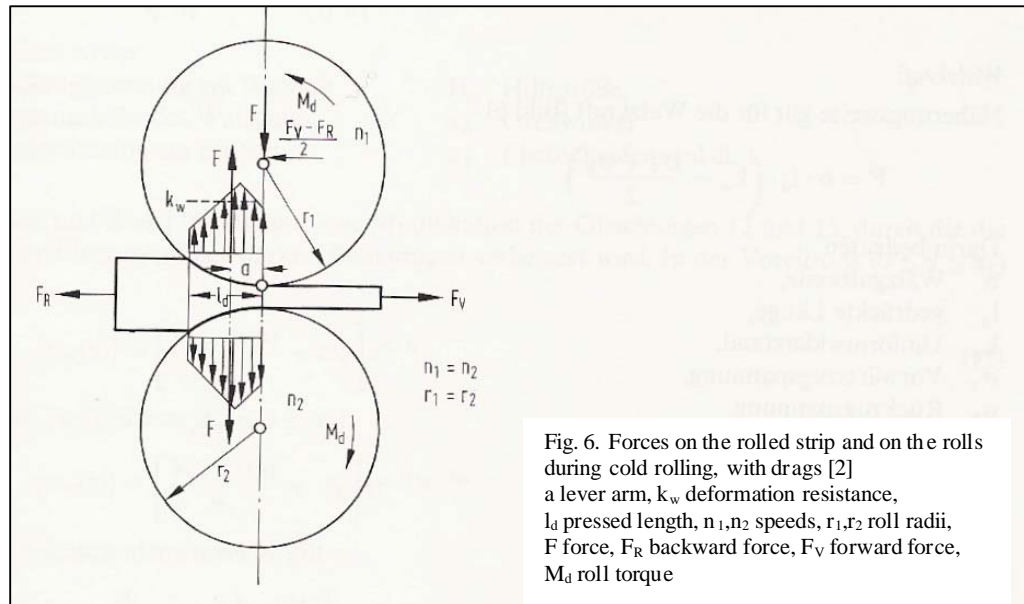


Fig. 6. Forces on the rolled strip and on the rolls during cold rolling, with drags [2] a lever arm, k_w deformation resistance, l_d pressed length, n_1, n_2 speeds, r_1, r_2 roll radii, F force, F_R backward force, F_V forward force, M_d roll torque

Figure 2:

In dry cold rolling, friction and plastic deformation in the roll gap produce heat that slows production and can damage both the product and the rolls.

Most of this heat is dissipated in the rolls and the product. However, if the resulting temperature rises too high, the metal surface of the strip or the working rolls can oxidise. Product that is damaged in this way has to be rejected, while damage to the rolls requires frequent reconditioning.

In practice, strip producers run their rolling mills at the highest speeds possible until the product begins to tarnish. The heat of friction generated between the rolls and strip causes high temperatures and increased wear on the work rolls. As a result, strip producers need to change the rolls frequently, which in turn mean high costs for downtime and regrinding of the rolls. Frequently, the product also suffers heat damage; this can be a significant cost, particularly in the case of valuable materials such as copper or stainless steel.

To reduce friction and remove heat, strip producers often perform wet rolling—cooling the rolls by adding an oil or emulsion, which also acts as a lubricant. This allows them to significantly increase the line speed by reducing the heat of friction between the work rolls and strip. However, wet rolling has issues as well. For instance, the use of rolling fluids results in a matt surface compared to a brighter finish found in dry rolling. Plus there is the capital cost of the lubricant circuit and the ongoing costs of monitoring and adjusting the emulsion composition. With flammable fluids, safety is a critical issue.

The biggest problem at C.D. Wälzholz was rust spots on the strip surface. The downstream cleaning equipment was unable to remove all traces of the emulsion; the resulting moisture caused rust to develop during storage or transport to the customer. The resulting rejections were very costly.

Liquid nitrogen: a better solution

Using liquid nitrogen, C.D. Wälzholz and Air Products jointly developed the Air Products cool rolling technology—a new cooling technique that provides the same or greater productivity as conventional wet rolling, without aqueous emulsions.

Liquid nitrogen is often used in the industry as a special-purpose refrigerant. Its advantages include a large heat capacity, the ability to generate a very low temperature if required, and the fact that it evaporates without leaving any moisture or residues. Nitrogen, also non-flammable, reduces the risk of fires and explosions and can be discharged safely into the atmosphere after use.

The Air Products cool rolling technology (Figure 3) uses spray bars to distribute nitrogen at a preferred temperature, between $-170\text{ }^{\circ}\text{C}$ and $-196\text{ }^{\circ}\text{C}$, over the metal strip as it enters the rolls.

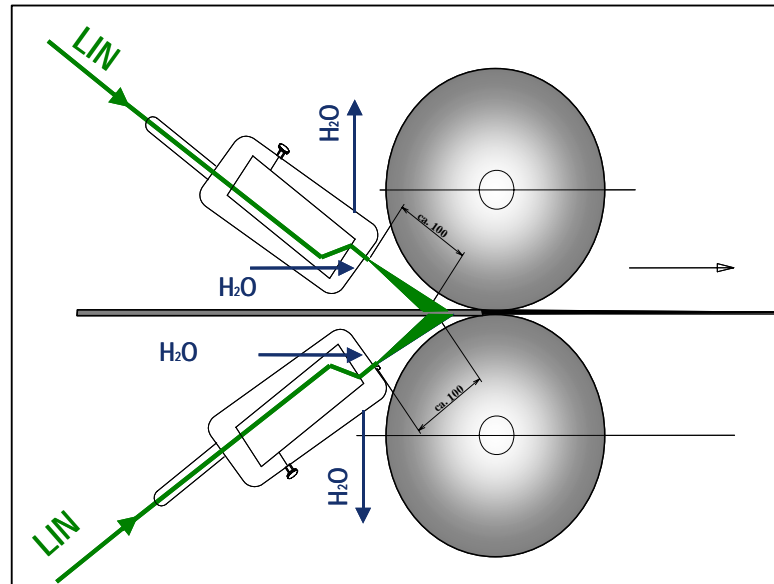


Figure 3:

The Air Products cool rolling technology uses liquid nitrogen to cool the rolls and the product. The rapid removal of heat allows the line speed to be increased—in some cases dramatically.

Conventional emulsions also work as lubricants, reducing the generation of heat by minimising friction. In contrast, liquid nitrogen has little lubricating effect; instead it removes frictional heat due to its very high heat capacity. Once its work is done, the liquid nitrogen evaporates, leaving no residue.

Counting the benefits

Using the Air Products cool rolling technology during the final pass, C.D. Wälzholz was able to eliminate rejects caused by rust spotting, which had been a serious problem with emulsions. The use of nitrogen also creates an oil-free strip surface. As a result, the company was able to eliminate the post-cleaning step, which for technical reasons had limited the rolling speed. The result was a line speed increase of up to 200 percent, greatly increasing overall productivity.

Analysis shows that conversion to the Air Products cool rolling technology reduced the costs of final-pass rolling by around 25 percent. This savingd includes the operating costs of the Air Products cool rolling technology itself.

Liquid nitrogen has also been used on a dry cold rolling line at C.D. Wälzholz. Again, it increased the line speed by up to 200 percent, the maximum speed that the current machinery is capable of operating at.

Table 1 shows the typical benefits from an Air Products cool rolling technology installation. Air Products developed analysis software to predict the economics of the Air Products cool rolling technology in any given circumstance.

Safety	Minimises fire and explosion hazards
	Eliminates noxious oil vapour
	Minimises emulsion residues in the work area and the associated slipping hazard
Capital expenditure	Higher line speed, hence higher productivity, with little investment and no need to expand the plant
	Eliminates emulsion circuits, downstream cleaning systems and CO ₂ extinguishing systems
	Increases work roll life
Maintenance	Eliminates emulsion monitoring and cleaning system or emulsion circuit maintenance
	Decreases the number of roll changing and refurbishing
Consumables	Eliminates emulsions or additives and filter preparation
	Decreases electricity consumption
Quality	Improves consistent surface quality
	Increases uniform roughness
	Decreases rejects due to rust
	Allows mirror-finish surfaces at higher line speeds
	Enables the possibility to expand product ranges due to the oil- and grease-free process

Table 1:

Typical benefits to be expected from the Air Products cool rolling technology.

Experience has shown that liquid nitrogen is usually cheaper than emulsion per tonne of rolled material, even at the existing line speed. Any speed increase or other production benefit can then be counted on top of this basic savings.

For more information

Corporate Headquarters

Air Products and Chemicals, Inc.
7201 Hamilton Boulevard
Allentown, PA 18195-1501
USA
Telephone: 800-654-4567
Fax: 800-272-4449
E-mail: gigmrktg@airproducts.com

Europe

Air Products PLC
Hersham Place
Molesey Road
Hersham
Walton-on-Thames
Surrey KT12 4RZ
UK
Telephone: 0800 389 0202 (from within the UK)
or +44 (0)1270 614114
Fax: +44 (0)1932 258502

tell me more
www.airproducts.com/metals