New lubrication technology for the hot strip mill

A new method for lubricating the work rolls during hot rolling has been successfully tested on the finishing mill of ArcelorMittal Dunkerque. The technology sprays low amounts of unemulsified natural oil without additives onto the work rolls using air atomisation, lowering the rolling forces by up to 20% and increasing efficiency of use of oil by 50% in comparison with emulsions.

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ROLLING force, material surface state, roll degradation, and strip texture (important in ferritic steels), are all parameters which are strongly influenced by the friction coefficient in the roll bite during hot rolling. Fine control of this coefficient offers the potential to reduce production cost and increase product quality within certain limits.

	Stirrer Emulsion	Static Tube Emulsion	Pure Oil Box	Pure oil Air Atomised
Lowering of mill force (%)	14.3	10.5	20.5	21.0
Burn out time (roll turns)	7	7	5	5
Oil flow rate ml/min/nozzle	55	10	11	8

Table 1 Results of different lubrication methods on mill efficiency

When lubrication is applied whether using a conventional emulsion system or the new air atomisation system, oil consumption is relatively low. In an emulsion, the concentration of oil in the oil-water mixture is 1 to 5%. But water and oil interact together in different ways depending on such factors as water hardness, oil additives, shear rate in the piping system, all of which make it difficult to maintain consistency of lubrication in the roll bite.

The objective of this research was to have the lubrication under control during hot rolling using a system easily regulated. The new technology is designed to provide greater efficiency, lower maintenance needs and to use low polluting biodegradable lubricants in the form of full esters (natural oil or greases). The benefits in term of process and products aspects are:

- higher mill energy savings,
- longer roll campaign length (decreased roll wear),
- greater width, and
- improved product surface quality.

Atomising Technology

The lubricant is applied by a modified air nozzle. But in order to reach low and accurate flow rates, the oil is applied by control of the flow rate rather than control of pressure. Flow rates with a minimum of 5ml/min on a nozzle width of 120mm can hence be reached.

The air atomiser (**Fig 1**) has three main components: the adapter, the oil nozzle and the air nozzle. The adapter has two functions: to bring the oil and the air to the nozzle mixing chamber and to help easy mounting of the air atomiser on the header (air collector). Inside the mixing chamber, the turbulent air disperses the oil particles and sprays an oil - air mixture through the nozzle onto the rolls. An important advantage of this design is that the oil and airflow rates can be separately controlled. By changing the air pressure the airflow rate is changed, which can be used to control the size of the oil droplets. Changing the oil pump rate will affect the oil flow rate and help to regulate the amount of oil dispatched. A small change in oil viscosity does not affect the flow rate making it unnecessary to heat the oil prior to delivery. Since pure oil is used without additives no soap formation occurs in the lubrication tubes so avoiding nozzle blockage.

Lubrication Efficiency

Plate out test

To know the exact quantity of oil dispatched onto the roll surface, trials were performed on a plate out simulator to characterise the efficiency and evenness of application of pre-selected nozzles and/or changing spraying parameters. Experiments showed that for all the application methods using pure oil, a very high plate out efficiency – greater than 80% – could be obtained, compared to a maximum of 40% with conventional emulsions. This means that when using emulsion at least 60% of the oil is wasted. The main reason is that pure oil can be directly sprayed onto the roll surface and so no oil is washed away by water as when using an emulsion. Another reason for the improvement in distribution efficiency is the absence of emulsifiers which, while they improve mixing between the oil and water, decrease the plate out value on the roll surface.

Continuous mill trials

Pilot trials were performed in the CRM laboratory on a pilot scale continuous hot mill to provide a comparison between two techniques of emulsion application (stirrer and static tube) and two pure oil application techniques (box concept and atomiser). The methods of application are illustrated in **Fig 2**. The lubrication box concept was one of the first trials using pure oil at low flow rates using full cone nozzles and an adaptable diaphragm in combination with oil under relatively high pressures and temperatures.

Table 1 shows the results for the four application techniques tested on the pilot rolling mill. The table shows average results for each application method for lowering of mill force for a given strip reduction, the burn out time (time needed to burn off the complete oil film of the rolls) and the oil flow rate used. With these results it can be concluded that applying pure oil required less oil and gave a greater reduction in roll force indicating that the application of pure oil is 50% more efficient than when using an emulsion.

A second series of trials were carried out on the pilot mill to investigate the impact on lubrication efficiency when using different types of oil. The classic oils for the finishing hot strip

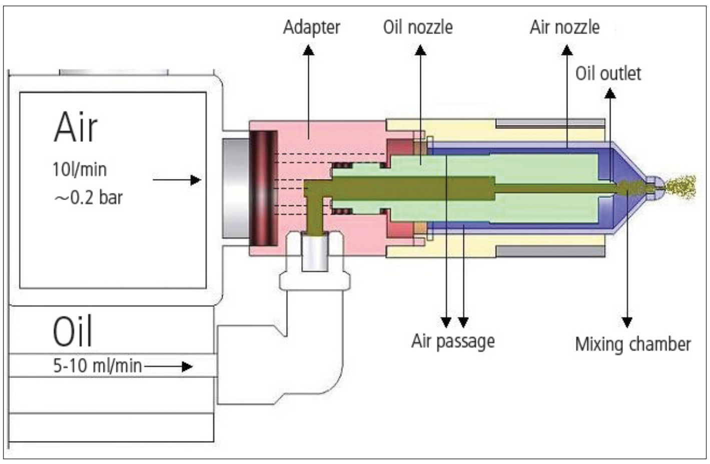

Fig 1 Design of air/oil atomiser

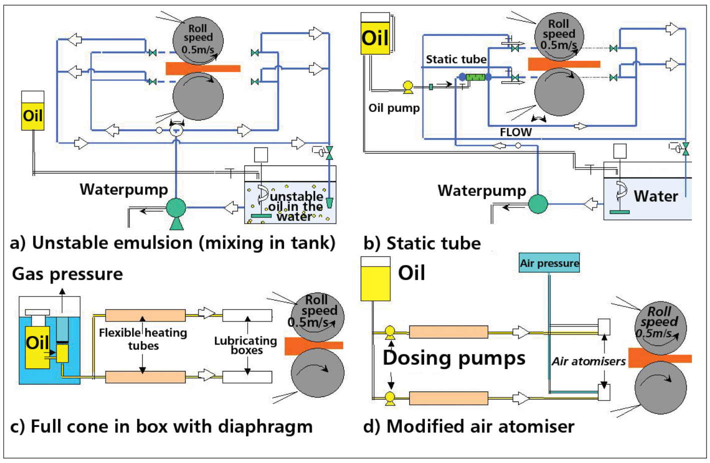

Fig 2 Methods of oil and emulsion application on the CRM pilot mill

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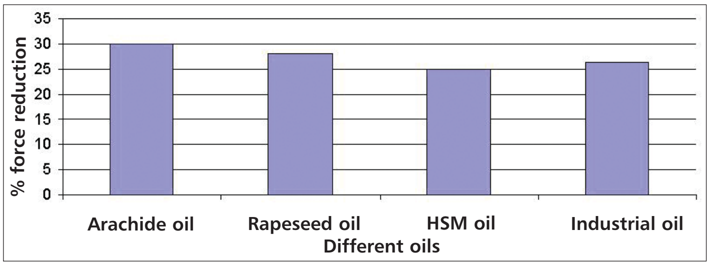


Fig 3 Comparison of different oils on mill force reduction

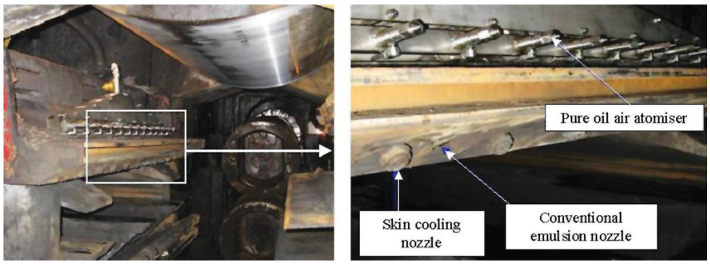


Fig 4 Pure oil atomising header and conventional lubrication header mounted above the top work roll of stand F2

mill are mainly composed of mineral oil, natural esters and EP (extreme pressure) additives. In order to use a low cost oil with a good lubricating performance, the main products of interesting are natural esters such as beef tallow and vegetable oils. Considering that the number of double bonds in the product can be an important characteristic in controlling the cleanliness of the rolls (for example by avoiding macromolecule formation and so avoid an oil film difficult to remove from the work roll surface), it was useful to study other natural esters. Natural oil presents important advantages such as lower cost and less pollution than classical oils used in emulsions and have the same or better lubricating properties than hot rolling oils with additives. Continuous mill trials were performed to determine the difference in efficiency of various natural oils. Four oils were selected: natural arachide oil (from peanuts), rapeseed or natural colza oil (field or turnip mustard), HSM oil and industrial oil. To see the difference between these oils, the mill parameters were kept as constant as possible in each of the trials. **Fig 3** gives a summary of the trials, concluding that lubrication with natural oils is as good or better as when using industrial oils and oils with additives.

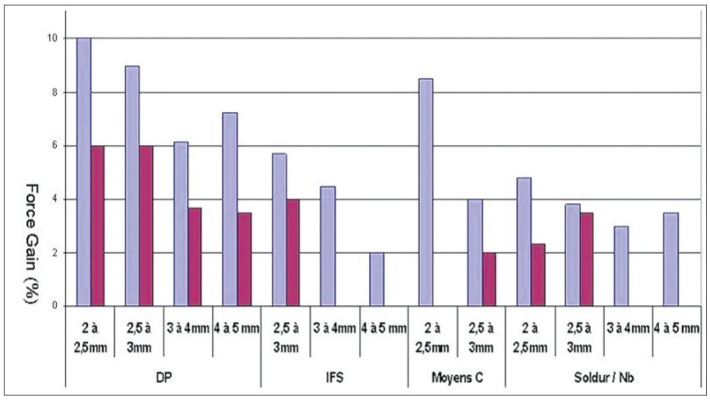
Industrial Implementation

To operate several atomisers in a row along a header to cover the total width of the roll, it is necessary to have an accurate and robust method of division to supply a small amount of oil to each nozzle. A solution was found in using a progressive manifold that can divide one inlet oil flow into several equal outlet flows connected to each air atomiser. Without water disturbance, the sprayed oil is directly transferred to the roll surface and, due to oil polarity, is not washed away by the roll cooling water. Because air is used as the carrier of the oil instead of water, it is unnecessary to rinse the circuit with hot water to avoid soap formation which otherwise results in blockages. Also, in some mills, the long term stopping of water circulation can cause the risk of health problems due to legionella bacteria, which is not a problem if using air distributed pure oil lubrication.

A typical HSM using industrial oil emulsion with additives will use more than 100t in a year. This could then be replaced by less expensive natural oil without additives and less of this will be used contributing not only to a cost saving but also to lower environmental impact.

An industrial header prototype was developed that could resist the harsh environment in the finishing mill. To supply each individual nozzle with the same amount of oil, a division manifold was used to control and regulate the oil flow rate. The only disadvantage of this method of distribution is some pulsation in delivery caused by the pistons inside the manifold operating each cycle expelling a volume of oil at each piston stroke. This was simulated in the continuous pilot mill and showed no adverse effect on mill force reduction. This is explained by the formation of an oil layer on the work roll surface causing an oil burn off time of about five roll revolutions, depending on plate out efficiency and lubricant type. This enables very low amounts of oil to have a relatively high reaction time during switch on/off and to minimise the risk of nozzle blockage.

Fig 5 Mill force expressed as % gain of lowering when using pure atomised oil compared with emulsified oil for various steel grades and strip reductions



The oil orifice has a diameter of 1.5mm and due to the constant passage of air across this (10l/min per nozzle) it is unlikely that dirt can block the oil outlet or nozzle tip. A large advantage of this technology is that the oil does not necessarily have to be heated to increase fluidity as was the case with early experiments using flat and full cone nozzles. Tubes and fittings are protected in case of collision with other materials. The header is completely manufactured in stainless steel, except for a few Viton O- rings in the manifold, and can perfectly resist a temperature of 165°C. For safety reasons, in the finishing mill the direct use of electricity inside the stand is not permitted so the oil flow rate has to be controlled at a distance of more than 5m alongside the mill. An oil flow rate with a minimum of 60ml/min and a maximum of 120ml/min can spread over a roll width of 1.5m and achieve a plate out of 0.4 to 0.8g/m^2.

The prototype was implemented on the top work roll of stand F2 in the hot strip mill at ArcelorMittal Dunkerque (**Fig 4**). Twelve nozzles were used to lubricate the work roll at a nozzle to top of roll distance of about 120mm. The prototype oil lubrication header was installed above the conventional emulsion header and roll cooling header. With this configuration it was possible to switch between the two application methods and so make direct comparisons. Also, the trials could be performed with or without roll cooling. Trials were continued for three weeks.

Results

Fig 5 shows the comparison between the application of conventional emulsion lubrication using industrial oil and the use of atomised pure natural oil. The oil flow rate for the two applications was similar: 90ml/min for the emulsion and 80ml/min for the pure oil. The graph gives an average level of the lowering of mill force (expressed as % gain) during trials on various steel grades and for various reductions. Even with roll cooling water on, the same improvement in lowering the mill force was achieved when using atomised pure oil.

Due to the higher lubrication efficiency of atomised pure oil, a significant energy saving and longer campaigns between roll changes can be obtained as well as a lower environmental impact on disposal and lower consumable costs. Another positive effect is that low pressure roll cooling water sprays do not influence the lubrication properties as an oil film initially forms on the dry roll and cannot be washed away. After the industrial campaigns, no individual nozzle was clogged.

The oil flow rate can be separately controlled on the top and bottom rolls.

Before implementation, the system was tested in terms of fire risk and health. ■

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