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Detailed information on energy research

Extracting fumes in rolling mills

A new oil vapour extraction system halves the energy consumption of the fans when cold rolling aluminium

BINE
Information Service

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Aluminium foils and sheets pass through a cold roll stand during the last processing step of their production. Rolling oils are sprayed on to cool and lubricate the rolls. Some of these kerosene-like hydrocarbons evaporate and vaporise in the ambient air. Large extraction hoods above the roll stand collect the contaminated air and feed it to a recycling plant. Their fans are the largest individual loads besides the actual rolling operation. However, using newly developed extraction hoods plant engineers can almost halve the exhaust air volume and thus the required fan output.

Cast-poured, heavy-weight aluminium bars undergo a whole series of rolling processes before they are transformed into sheets or foils. The initial reshaping is carried out at a temperature of more than 500 °C on a hot roll stand. Two superimposed rotating rolls, whose spacing is successively reduced, draw the material through the nip. The resulting aluminium strip is wound into coils.

The coiled aluminium achieves the desired material thickness in a cold roll stand at room temperature. Depending on the system, millimetre-thick sheets or even aluminium foils just a few micrometres thick are produced for beverage packaging. The low foil thickness and narrow tolerances in the production of foils create considerable expenditure in terms of the process engineering and energy used. Depending on the material characteristics, the plant operator selects the machine settings and uses rolling oil with specially adapted additives. Flat jet nozzles spray the liquid for cooling and lubrication onto the work rolls.

The rolling oil improves the surface quality of the material and prevents the thin foils from adhering to or tearing on the rolls. At the same time, the rolling oil flushes ultra-fine particles away from the roll and thereby prevents deposits ("roll coating"). Last but not least, the lubricant reduces the roll wear.

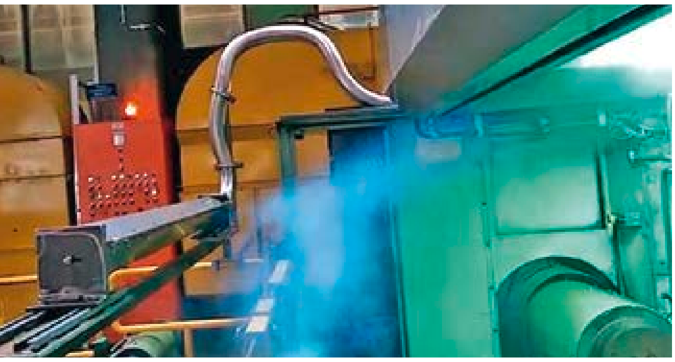

Fig. 1 *Injected smoke shows the barrier effect of the air blade.*

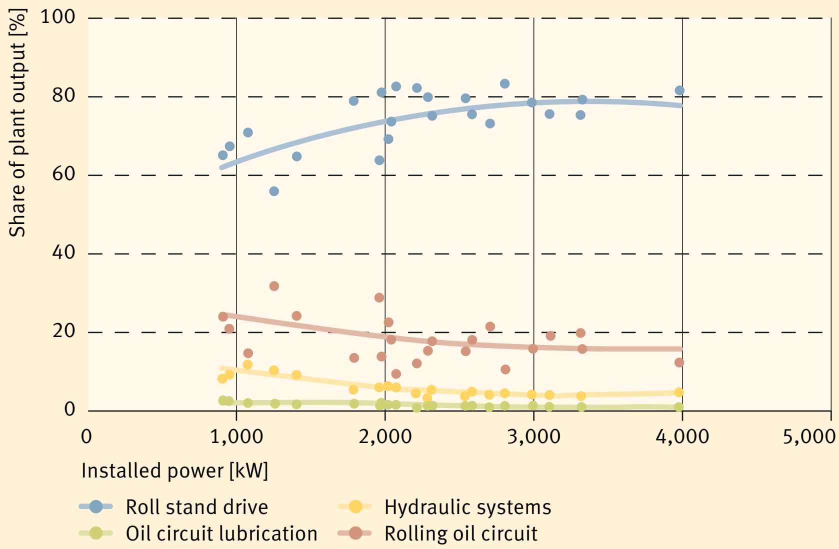

Fig. 2 *Proportion of auxiliary units relative to the installed plant output*

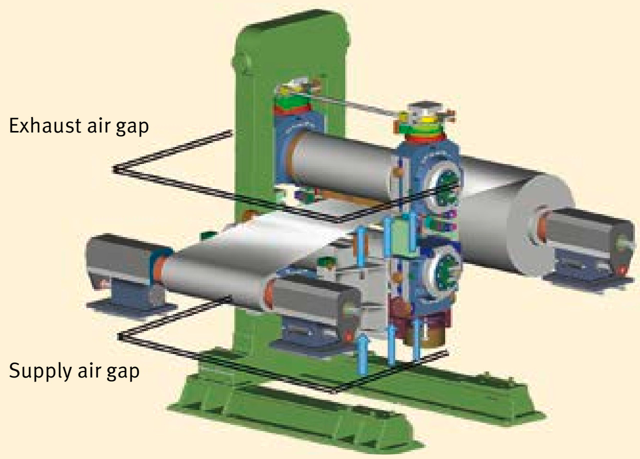

Fig. 3 *Construction of a cold roll stand for producing foils. The supply and exhaust air gaps for the demonstration system are indicated schematically.*

About one per cent of the volatile organic compounds (VOCs) escape into the ambient air through atomisation, vaporisation and evaporation. For some rolling mills, the exhaust air is polluted with up to one gram of VOCs per cubic metre. Large extraction hoods above the roll stand suck up the contaminated air and feed it to a recycling plant. However, until now extraction hoods installed in the input and outlet area of the roll stand have only achieved non-directional extraction. In order to capture as much of the oil vapours as possible, this concept requires very large volume flows. Another reason relates to safety issues: rolling oil is a combustible, hazardous substance. It is therefore essential to prevent a build-up of vapours above the explosion limit, such as in stationary air vortices. Depending on the plant, 60,000 to 120,000 m^3/h of air are extracted from the stand area and passed into scrubbers that wash out the rolling oil from the air.

Large savings potential in the rolling oil circuit

Although plant construction companies cannot considerably influence the energy consumption of the actual rolling process, considerable savings potential is still provided by the rolling oil circuit. In large rolling mills, up to 100 kg of the volatile VOCs are filtered out each hour from the exhaust air and recycled as a valuable raw material. The rolling oil circuit consists of stocking, conveying, extraction, filtering and cleaning. Its share of the total energy consumption of a roll stand can amount to more than 20 % in foil production. After the actual rolling, it is therefore the main energy load in the plant.
The largest individual loads in the circuit are the fans in the extraction hoods for the oil vapour. For large strip rolling plants, their drive power can amount to 200 kW. Scientists from the Achenbach Buschhütten plant construction company have set themselves the goal of halving this energy consumption without sacrificing the quality of the exhaust air purification. According to the researchers' calculations, a typical rolling mill could save up to 330,000 kWh of electrical energy annually.

Push and pull for the oil vapour

In the research project, the engineers are investigating for the first time how oil vapour is generated in the stand area. In addition to laboratory tests on vapour formation and extensive simulation calculations, they carried out measurements on rolling mills with various construction and performance sizes. Based on this, the scientists developed a directional extraction system according to the push and pull principle. Here an exhaust air gap, which circulates in a U-shaped manner inside the hood, is supplemented by a corresponding supply air gap below the band run. This blows directly onto the exhaust air gap. This results in an air curtain similar to a shop entrance. It directs the vapours to the exhaust air gap and also prevents them spreading in the factory.

Swirl pipes and air blades work in unison

The concept requires a uniform suction power over the entire circumferential gap of the extraction hood and also uniform injection from below. The engineers achieved this using swirl pipes for the suction and air blades for the injected flow. The injection is intended to produce a stable air flow over a greater distance that is also tolerant to transverse flows in the environment. In order for this interaction to work, the engineers optimised the ratio of the air volumes, the distance between the two components and the orientation of the air curtain in experiments. The investigations show that it is advantageous to keep the injected air flow as small as possible in order to minimise the overall moving air volume and prevent turbulence.

Savings goals achieved

The concept was initially designed and constructed as a demonstration

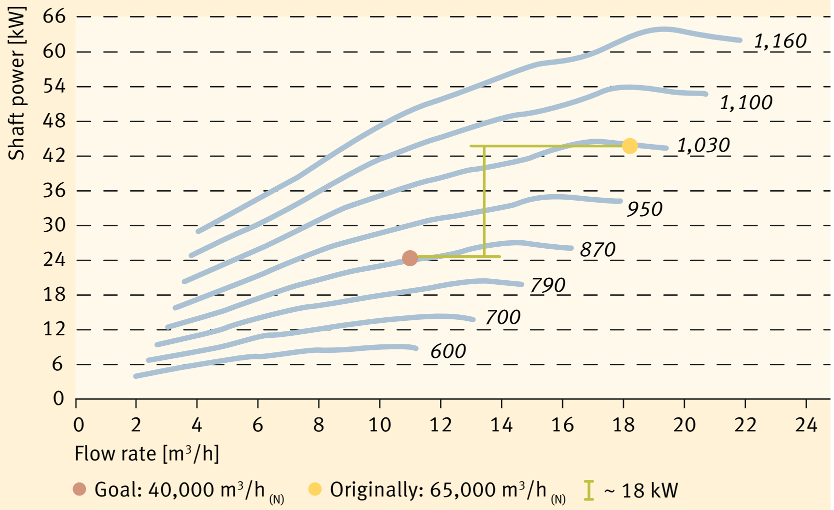

Fig. 4 *Characteristic diagram for the system fans: The new extraction unit reduces the necessary power by 18 kW.*

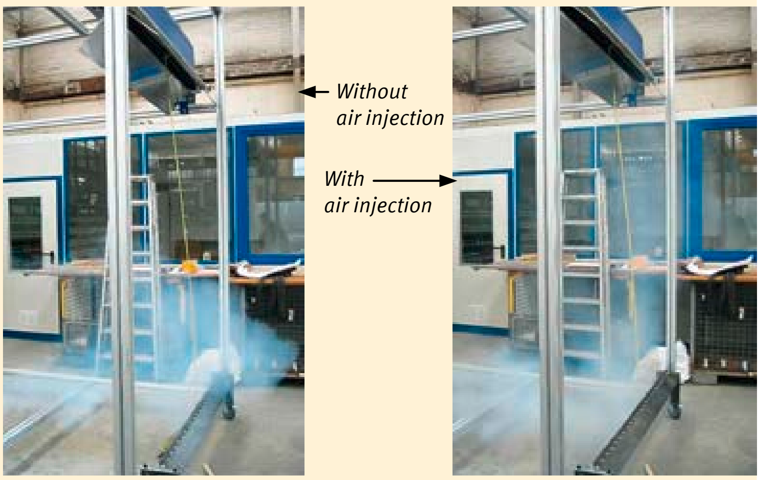

Fig. 5 *Laboratory test of the push and pull principle: The air injected by the air blade from below noticeably prevents the spread of fumes.*

Evolution of extraction hoods

Until the middle of the 1960s, roll stands were equipped with single-walled hoods with central extraction in the middle of the hood. Over the years, the machines became increasingly larger and faster, which meant that the amount of coolant and vapours also correspondingly increased. As a result, rolling oil vapour condensing in the extraction hoods became an increasing problem. This led to the widespread introduction of a new hood design between 1965 and 1971. It consisted of an inner and outer hood with a U-shaped extraction gap for lateral suction. The heat generated during the forming process creates thermals that transport the oil fumes upwards. The fumes are then absorbed by the extraction gaps. Until now, this basic concept has been retained and only further developed in terms of the details.
The newly developed extraction hoods are single-walled and have a circumferential extraction gap on the underside. This is blown at by the air blades below the band run so that an air curtain is formed.

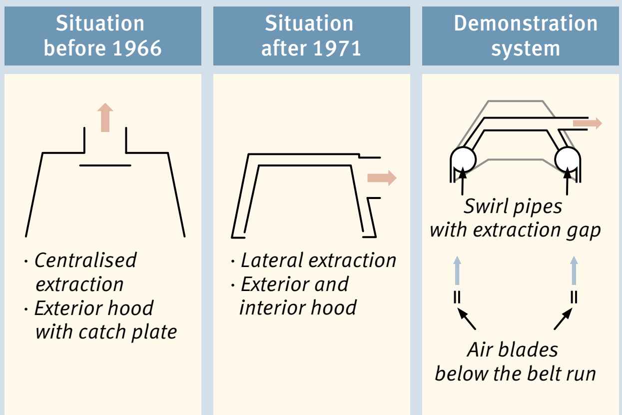

Fig. 6 *Changes in extraction hoods between 1965 and 1971 compared with the new push and pull concept*

plant and later installed in a rolling mill. In practice, the demonstration system has shown very good extraction.
In the adaptation process, the operators managed to reduce the extraction rate on the roll stand from the previously 65,000 m³/h to 40,000 m³/h, i.e. by almost 40 %. This has therefore resulted in savings of around 18 kW. This corresponds to 42 % of the original fan output. The air blades consume about 0.4 kW for the air injection, which means they are negligible compared with the other electricity loads. With a rolling mill availability of 95 %, the electricity savings accumulate to almost 150,000 kWh per year. Further savings can be achieved by modifying the details of the design, so that the scientists expect 50 % savings with the next prototype. This does not take into account additional savings in the rolling oil circuit. The reduced amount of exhaust air means that the subsequent exhaust air purification can be smaller in terms of the size and energy requirements.

Clean indoor air – lower oil losses

The directed extraction not only reduces the energy requirement but also ensures that fewer oil fumes are released into the ambient air. “This has a very positive effect on the air quality of the factory,” says project manager Matthias Stähler. “However, we have not been able to record the extent to which the lower oil losses have improved the recycling. This would require monitoring over longer periods of time.”

The scientists were pleasantly surprised, however, by an additional effect of the new hood construction: since the inner cladding is no longer a flow-carrying component, it is not cooled by the air stream. It is thermally insulated from the rest of the hood and during operation heats up to the temperature of the oil vapour. This means that hardly any rolling oil condenses on the inner hood. “With some rolling plants it is known that oil condenses there, which creates drip points. The oil drips onto the rolled strip and leads to quality deficiencies,” explains Stähler. “This cannot happen here due to the construction.”

Aluminium plant becomes a virtual battery

Not only the rolling process but the entire value chain in the aluminium industry is very power-intensive. This applies in particular to the production of the light metal. Researchers are investigating how such large loads can take over electricity grid services. To this end, industrial processes must respond flexibly to the fluctuating energy supply provided by renewable energy sources. With temporal load shifting, they act on the grid like a battery.

The „Virtual battery“ project is investigating how aluminium electrolysis can be operated to provide such flexibility. This will then enable a Hamburg-based aluminium plant to provide a targeted demand-side response, thereby contributing significantly to securing the energy supply for the metropolitan region.

Aluminium is obtained from naturally occurring aluminium oxide by means of fused salt electrolysis. At almost 1,000 °C, the thermal equilibrium is maintained through joule heating. In this case, very large currents of 150,000 amperes or more flow into the electrolysis cells. Until now, electrolysis furnaces have been designed for specific current intensities and energy supplies. When changing the current intensity and energy supply, the very sensitive energy balance of the furnace also changes. If a furnace works outside the operating conditions for which it was designed for more than a few hours, this could cause efficiency losses, massive process disturbances or even irreparable failure of the furnaces.

In order to adapt the aluminium production to the electricity supply, the scientists want to make the heat balance of the individual electrolysis cells controllable. To this end, they are developing controllable heat exchangers that maintain the energy balance in the furnace when the electricity input is changed.

If fully implemented, the aluminium plant would, if required, increase its regular load of roughly 240 MW by 40 MW for up to 48 hours or lower it by 20 MW for up to 96 hours. The maximum capacity for the load displacement would therefore be 3,840 MWh. This energy quantity corresponds to the storage capacity of one of the larger pumped storage plants in Germany.

The project forms part of the „Showcase for intelligent energy – Digital agenda for the energy transformation“ funding programme, which is being run by the German Federal Ministry for Economic Affairs and Energy. As part of this programme, customised solutions for intelligent power supplies based on renewable energies are being developed and tested for five model regions. As a large energy consumption centre, the metropolitan region of Hamburg has formed the „NEW 4.0: Norddeutsche EnergieWende“ showcase together with the wind energy region of Schleswig-Holstein. One of the development goals is to better control local electricity surpluses through the export of electricity to other regions and through load management, storage systems and sector coupling.

Project participants

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- **Flow simulations::** Universität Siegen, Institut für Fluid- und Thermodynamik (IFT)

Links and literature (in German)

- www.achenbach.de
- Stähler, M.: Reduktion des Energie- und Rohstoffverbrauchs an Aluminium-Walzgerüsten durch eine gerichtete Dunstabsaugung. Abschlussbericht zum Forschungsvorhaben 03ET1067A. Achenbach Buschhütten GmbH & Co. KG, Kreuztal (Hrsg.). Oct. 2016. 79 S.

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