

## Extrusion of Aluminium with Liquid Nitrogen

*The use of nitrogen for improving output and quality in the extrusion of aluminium is widely in use today. There are two different ways to use nitrogen: inerting the surface, and cooling of the die.*

*The majority of extruded products are manufactured in small quantities with regular changes in shape, inerting these extrusions with nitrogen via an annular nozzle system or similar means enhances the economy of the process and the surface quality of the extrusion.*

*In many cases, however, cooling of the die opens the way to an even more significant improvement in output while maintaining a consistently high level of quality. Additional equipment and control software is necessary for this process so that the liquid nitrogen can be fed in precisely controlled quantities.*

*This paper shows the use of liquid nitrogen, examples of its possibilities, and the way in which it is used in extrusion plants.*

### Cooling of aluminium with liquid nitrogen

The use of nitrogen is familiar to the aluminium extrusion industry. Plant managers have different levels of experience with handling nitrogen or with applying it to their profiles.

An increase in productivity, better surface quality with less surface damage and a longer die life are the main reasons for using nitrogen. However, the use of nitrogen is not a trivial application. There is a set of rules which has to be followed.

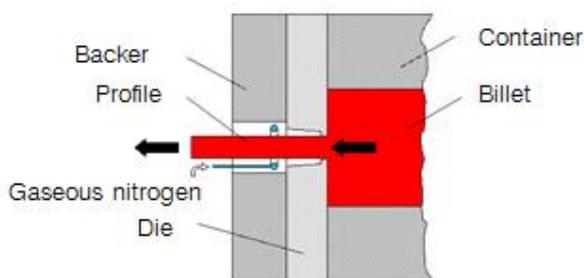


Figure 1: Inerting of the surface

Originally process optimization was necessary to solve quality problems. The use of gaseous nitrogen (Figure 1) avoided or reduced spots on the surface and the surface shone brightly because of the inerting effect of the nitrogen. Injecting the nitrogen was quite simple. A ring nozzle was assembled onto

the exit of the press or a simple pipe was led into the opening of the press (Figure 2).

This construction also enables the use of liquid nitrogen to cool down the surface of the profile. Such systems are still in use but their efficiency is very low as the coldness of the nitrogen cannot be fully utilised due to pre-evaporation. The surface of a profile can be cooled down by 15°C with this method of injection. The manufacturers were not satisfied with this small improvement so the injection had to be adapted.

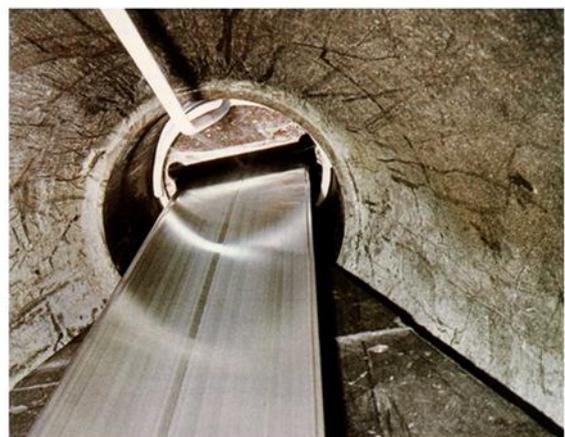


Figure 2: Ring nozzle

The heat has to be removed directly from the bearing zone. In this zone most of the heat is produced by the friction of the aluminium and for this reason the nitrogen has to be as close as possible to this area. [1]

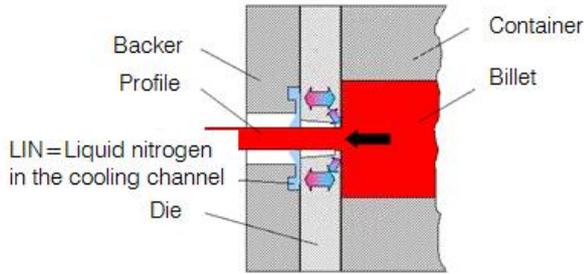


Figure 3: Die cooling

In Figure 3 the cooling channels in the die or in the backer help to transport the nitrogen very close to the bearing zone. The position of the injection depends on the press. There are presses where the injection comes from the bottom or from the top. It is usually possible to inject from the side by drilling holes into the die holder and die carrier as it is shown in Figure 4.

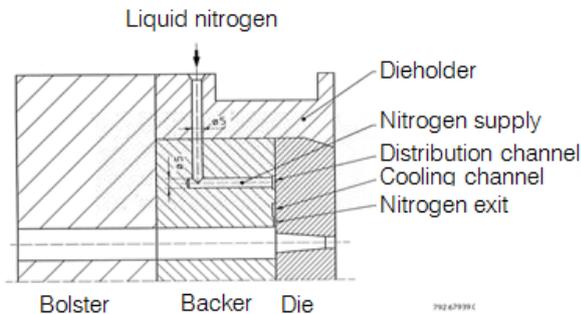


Figure 4: Providing the nitrogen to the cooling channels

For cooling it is important to get not only gaseous nitrogen but also liquid nitrogen into this area. The change from the liquid to the gaseous phase has more cooling potential because the evaporation heat is greater than the coldness from the gas (Figure 5).

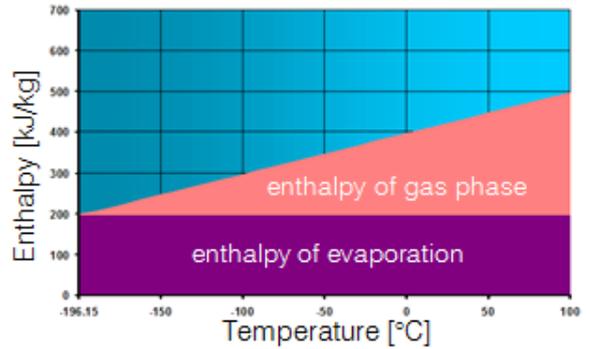


Figure 5: Enthalpy of nitrogen

Another very important point is to ensure that a majority of the liquid nitrogen arrives at the die. The nitrogen has to be cooled down. At the pressure in the storage tank (5 bar) the nitrogen has a temperature of approximately  $-180\text{ }^{\circ}\text{C}$ . If the nitrogen were to be expanded under these conditions there would be a lot of gaseous nitrogen. Therefore, this process has to be separated. This can be done with a sub-cooler (Figure 6) which transfers the nitrogen from 5 bar/ $-180\text{ }^{\circ}\text{C}$  to 5 bar/ $-196\text{ }^{\circ}\text{C}$ . The so called sub-cooled nitrogen produces less gas through expansion and thus more liquid can arrive at the die.

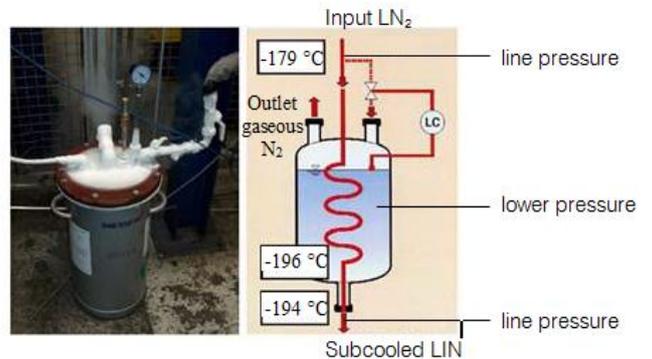


Figure 6: Sub-cooler [2]

A special configuration as it is shown in Figure 7 of the cooling channels helps to distribute the nitrogen uniformly into the die. The kind of channels and their exits, together with all other parameters of the sub-cooler can be planned based on 35 years of experience [3]. These types of cooling channels have nothing in common with the cooling channels you can find for inerting.

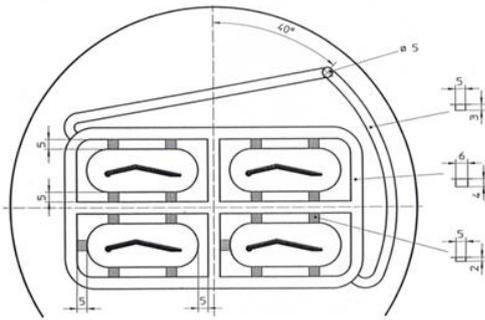


Figure 7: Cooling channels

The change in temperature close to the bearing zone achieved through the use of cooling channels is significant (Figure 8). Scientific tests carried out with and without liquid nitrogen showed a difference of 33 °C (Figure 8) [4].

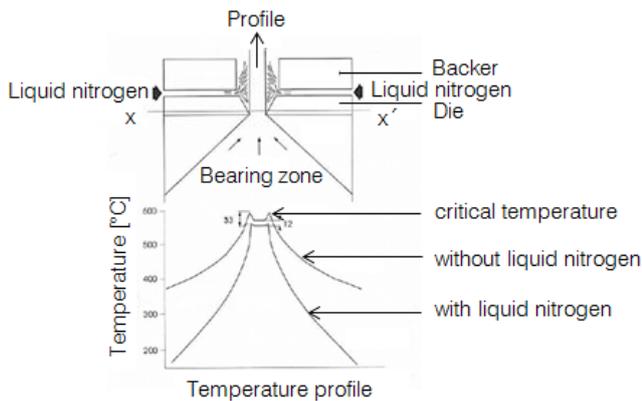


Figure 8: Temperature at the bearing zone with and without nitrogen [4]

This temperature advantage can be used to either protect the surface, increase the speed or both (Figure 9).

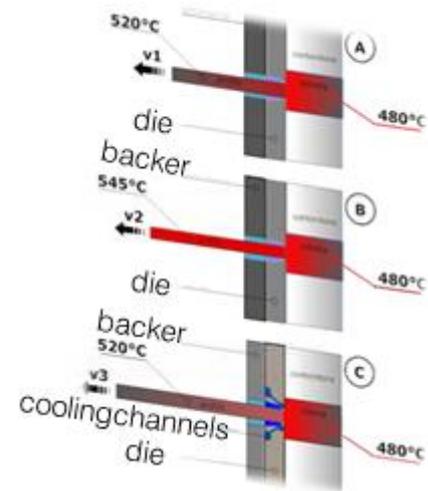


Figure 9: Effect of liquid nitrogen

The visual change can be seen immediately during the extrusion process (Figure 10). As soon as the nitrogen is switched on, the surface shines brightly. For the process it is not only essential to have a nice surface but to avoid overheating of the bearing zone. Once heated above a critical limit it cannot be changed; not even with liquid nitrogen!



Figure 10: Effect on the surface

The first steps were carried out without any control of the nitrogen flow. Later it could be shown that the process can be optimized by measuring profile temperatures and controlling the flow of nitrogen. For this reason special software which reproduces the optimal billet run and corrects the flow with real time parameters is essential. This is necessary because the time lag between measuring the temperature and the influence of the nitrogen is quite big. The reaction time of the nitrogen will be as slow as the profile runs.

A programmed setting of the nitrogen injection of the best billet run with the best temperature profile is absolutely necessary and has to be part of the nitrogen control system. The previous "on – off" switch with a simple solenoid valve for the nitrogen becomes more complex to achieve best results.

The average increase in speed and thus productivity is quite high. Around 50% more speed is possible how it is shown in Figure 11. Of course this depends on the alloy, the profile and the surface quality. The figure shows the result of a two holes die. The increase of speed/productivity is compared to standard production settings without nitrogen and with the same or higher level of quality regarding surface and dimensions.

[1] [ Busse, Juergen, Gas aktuell 24, Messer Griesheim GmbH, 1982]  
 [2] [Thorwarth, Ulrich, Busse, Juergen, Greater Economy in the Extrusion of Aluminium Sections, Messer Griesheim GmbH, 2002]  
 [3] Published Patent Publication 2211645 10.März 1972, Verfahren und Vorrichtung zum Strangpressen von Werkstücken insbesondere Aluminiumlegierungen,  
 [4] [Selines, R.J., Goff, C., Cienciwa, P. and Lauricella, F. : Extrusion cooling and inerting using liquid nitrogen, ET '84, BdI, S. 222/226]  
 [5] [A.t.i.e. Uno Informatica S.r.L. International Aluminium Journal, 09/2008]

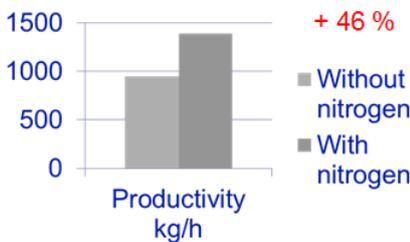
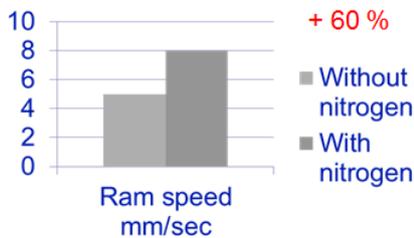
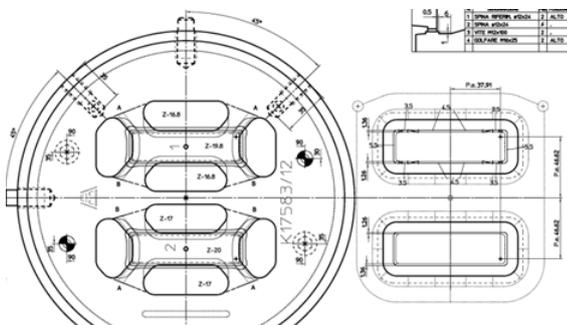


Figure 11: Increase of speed respectively productivity with liquid nitrogen of an alloy 6063



Thomas Böckler  
 Messer Group GmbH  
 Gahlingspfad 31  
 47803 Krefeld  
[thomas.boeckler@messergroup.com](mailto:thomas.boeckler@messergroup.com)

Massimo Bertolletti  
 A.t.i.e. Uno Informatica S.r.L.  
 Via Macon 30  
 Lecco, 23900 Italy  
[massimo.bertolletti@unoi.it](mailto:massimo.bertolletti@unoi.it)