Abstract: In order to extract the part from the mould without altering the part dimensions, it is necessary to have a layer of lubricant. To do this, the lubricant must also preserve its basic features, even after having contact with molten metal. One of the components of the lubricant is burning at the melting temperature of the metal, leaving residues on the surface of the mould or on the cast part. The substances most commonly used as lubricants are: graphite, aluminium oxide, talc, fats, oils and waxes. Under the combined action of the speed, temperature and pressure, the injected metal tends to adhere on the mould surface. This tendency is just avoided by the lubricant layer applied on the mould surface. The lubricant has also an important role, namely to help the flow of the molten metal through the mould. In the case of absence of the lubricant, due own viscosity, the molten metal tends to slow the flow, to cool prematurely, amplifying thereby the slowing of the flow, reaching finally to not achieve the full filling of all cavities.

Key words: mould, lubricants, lubricating, aluminium casting, mould injection.

1. INTRODUCTION

The injection of aluminium is the most quick and economic technological process used to produce finished parts, with a high finishing degree and a good dimensional accuracy. These conditions are determined mainly by elevated cost of the equipment (presses for injection), of the moulds; factors that determine high depreciation costs, which are becoming competitive with the growth of the number of manufactured finished parts.

The experience has shown that the possession of injection equipment with the most advanced technology, the possession of a mould (Fig. 1) designed and manufactured to high parameters are not sufficient to produce parts with a high quality, in a high production rate. These conditions are fulfilled only with an adequate lubrication of the mould.

Fig. 1. The injection of aluminium: a - feeding of the casting cylinder; b - the first phase of injection; c - the second and third phase of injection; d - opening of mould and extraction of the cast part
The lubricant must obey the following conditions:

- to allow the extraction of part from the mould cavity;
- to prevent the welding of the injected material on the mould surface, to prevent the metallization;
- to lubricate all mobile elements of mould;
- to help the filling of all mould cavities.

The layer of lubricant prevents the metallization between the cast aluminium and mould, which are subject to a pressure of 60-100 MPa. In the extraction moment of the part from mould, the cast part should not be subjected to an effort greater than the hot mechanical strength, otherwise deformations may occur. The initial effort is also reduced by the positive action of the pressure of the gas produced from the decomposition of lubricant. This is one more reason justifying the need for lubrication, even incomplete, on the mould surface after the aluminium injection.

The dynamic aspect of lubrication is that which will be verified during the extraction phase of the cast part, when the part should slide on the generating surface of the mould.

The productivity of the injection process is related to the correct extraction of the cast part, so to the effectiveness of the lubricant.

2. THE ROLE OF LUBRICANT IN MOULD COOLING

The large majority of the lubricants are applied on the active surface of the mould in the form of a water suspension, spread on the mould cavity in the form of a jet. In contact with the mould, the water from the suspension is evaporated.

Figure 2 presents the variation curves of mould temperature, with and without lubricant.

In the process of evaporation, 1 cm$^3$ of water absorbs 0.619 kcal from mould. The vector of lubricating suspension, during the spraying, is the compressed air, so the lubricant jet is composed of compressed air and drops of fine emulsion. The compressed air contributes to cooling the mould. The amount of heat removed by the compressed air is not quantifiable because the suspension/compressed air ratio is not fixed (it may vary depending on needs).

However, in order to estimate the quantity of the removed heat, the following assumptions can be made:

- suspension / air ratio: 1:600;
- contact temperature of the air: 100°C;
- specific heat of the air: 0.30 kcal/m$^3$/1°C.

Fig. 2. Variation of the mould temperature, with and without lubricant: 1 - Mould temperature; 2 - mould temperature at time $t^\prime$ without spraying; 3 - Boiling temperature of the suspension; 4 - Mould temperature at time $t^\prime\prime$ with lubrication.
We assume 1 litre of suspension will spread on the mould surface. Considering that an air volume of 600 litres will be used, we get a quantity of removed heat by:

\[ 100 \times 0.30 \times 0.6 = 18 \text{ kcal} \] (1)

After the evaporation of the water, the following heat will be removed:

\[ 18 + (1000 \times 0.619) = 637 \text{ kcal} \] (2)

Relation (2) defines the heat quantity developed during the injection and cooling until the extraction temperature of 3.5 kg of aluminium alloy.

The percentage of active suspension varies depending on the spraying direction of the jet, on the mould geometry and temperature of mould cavities. It is estimated that 20 - 40% of suspension applied on the mould will not contribute to cooling the mould. Some other factors may contribute to the mould cooling (Fig. 3), but the evaporation of water from lubricant has a significant role.

The main phenomena that occur during the interaction of the injected metal with the lubricant layer are shown in figure 4.

During the injection in the mould, the aluminium reaches at temperature of 650-750°C. At this temperature a strong damage of the lubricant layer takes place. Figure 5 presents the decomposition of the lubricant layer.

At the end of the injection, only a very little percentage of lubricant from the original layer remains. This percentage largely depends on the lubricant composition and on temperature. These residues are designed to ensure the static and dynamic lubrication necessary for extracting the part in good conditions.

![Fig. 4. Interaction of the injected metal with the layer of lubricant](image)

3. THE SEPARATION FUNCTION OF THE LUBRICANT LAYER

The separation of aluminium from mould steel is due to the amorphous layer of oxide produced by chemical reactions taking place at the level of lubricant layer, thereby preventing the direct contact between the two materials. At high temperatures of over 700°C, the aluminium acts as a powerful "solvent", with a strong dissociation tendency of iron steel of the mould, in accordance with the reaction formula:

\[ \text{Fe} + 3\text{Al} = \text{FeAl}_3 \] (3)

In the absence of "the barrier" made by the layer of lubricant, the aluminium will interact with iron from mould, resulting a so-called "welding" of the two components, generating the phenomenon of metallization on the mould surface, an extremely harmful phenomenon in the extraction of the cast parts. The layer of amorphous oxide has a very important effect of thermal insulator, because of its low heat conductivity. The low heat conductivity locks the heat exchange between the molten aluminium and the mould, causing a delay of the solidification. Thus it is favoured the filling of all mould cavities.

![Fig. 3. Factors contributing to the evaporation of water from the lubricating suspension](image)
Figure 6 presents the evolution of the suspension drops from the application of the jet until the formation of the lubricant layer and that of the amorphous oxide.

The evolution of suspension drops during the jet projection includes the following phases:

- the drops of emulsion are projected to the mould, with a speed proportional to the pressure of compressed air (Fig. 6.a);
- due to the Leidenfrost effect, the drop fails to moisten the mould surface (Fig. 6.b);
- the active components of the lubricant, in contact with the surface of the hot mould, join in chemical reactions with mould steel (Fig. 6.c);
- the chemical reactions produce an amorphous oxide inert in relation to the aluminium (Fig. 6.d);
- the development of the lubricant layer, after the drop comes of to moisten the mould, stopping the Leidenfrost phenomenon. The drop warms (Fig. 6.e), the water is evaporated, only the lubricant remains on the mould surface;
- with the progressive evaporation of the water, the storage of active elements on the mould surface continues (Fig. 6.f). A layer of amorphous oxide and a layer of lubricant are produced in this way.

Figure 7 presents the Leidenfrost effect in case of drops.

A drop of liquid in contact with the hot surface will soon produce a layer of steam. They will have an effect of air pillow preventing, for a short time, the contact between the hot surface and the drop, the latter giving the impression that the drop "dances" on the warm surface. Thereby it slows and delays the heating of the drop. The Leidenfrost phenomenon has a harmful effect on the capability of mould lubrication.

4. CONCLUSIONS

We can say that a good lubrication is the key of achieving high-quality products. The lubricants have a complex role, the methods for obtaining the desired effects not always converge to the same direction. The intrinsic qualities of the products must be tolerated on the basis of a good knowledge of the physical and chemical processes and implementation of lubrication substances.

For these reasons, the manufacturers have studied and put up various complex formulae, sophisticated techniques for application, so as to meet the requirements of various classes of lubricants. Since there are no magic solutions, generally valid, in the case of carrying out complex lubrications, the user must pay a special attention to the selection of the lubricant and of the application techniques: dilution, quality, local or global deposition, uniform distribution, drying through blowing out with compressed air.
Most cases involve the art of making compromises between the choices of lubricant with a higher quality and recommended for that application, the cost, as well as the available equipment and installations.

A wrong choice can diminish the quality of a whole batch of products. The negative effects of lubricants can be minimized, can be brought between acceptable limits, but can not be entirely eliminated.

The advantages of lubricating the mould cavity open a new field of research, despite the lack of a bibliography, the lack of experience in the field representing a relatively new procedure.
5. REFERENCES


**LUBRIFIEREA CAVITĂȚILOR MATRIȚELOR**

Rezumat: Pentru a putea extrage piesele din matrițe, fără a deteriora dimensiunile piesei, este necesară existența unei pelicule de lubrifiant. Pentru aceasta, lubrifiantul trebuie să ș-și conserve caracteristicile de bază, chiar și după contactul cu metalul lichid. O parte din componentele lubrifiantului, la temperatura metalului lichid se ard, lăsând reziduuri pe suprafața matriței sau a piesei turnate. Substanțele cel mai frecvent folosite ca lubrifianti sunt: grăfitul, oxizi de aluminiu, talt, grăsimi, uleiuri și ceruri. Sub acțiunea combinată a vitezei, temperaturii și presiunii, metalul injectat are tendința de a se suda pe suprafața matriței, tendință contracarată tocmai de pelicula de lărgi de lubrifiant de pe suprafața matriței. De asemenea, lubrifiantul are un rol important, acela de a favoriza curgerea metalului lichid prin matriță. În cazul lipsiei lubrifiantului, datorită proprietății vâscozității, metalul topit are tendință să-și încetinească curgerea, să se răcească prematur, amplificându-se astfel încetinirea curgerii, ajunându-se ca în final să nu se realizeze umplerea integrală a tuturor cavitaților.

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