Framework for the Comparison and Selection of Release Agent Technologies for Aluminum Extrusion

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ABSTRACT. Technical review of the industry's top six release agent technologies used in aluminum extrusion: acetylene flames, boron nitride powder, boron nitride suspensions, graphite-based suspensions, solid bar of graphite or boron nitride and water-based solutions. We intend for this review to serve as a framework for understanding the strengths and weaknesses of each release agent technology, and how each one fits into each user's business and operation goals. Each one of these technologies is radically different from the rest, from their chemical structure to their implementation in the extrusion process. This presents a true challenge for aluminum professionals because there is no 1:1 comparison they can easily make. That's why we present, in this document, a comprehensive process to compare these technologies, based on information obtained from experimental data results and user experiences from real use cases in extrusion plants.

INTRODUCTION

This work will help users in the aluminum extrusion industry to understand how different lubrication technologies used in the aluminum extrusion process work, and what are the main differences between them.

When we refer to *lubricants* used for the extrusion process we are talking about the lubrication process that takes place in the transversal face of the dummy block that is in touch with the billet. With is main function being to create a protective layer in the face of the dummy block in order to prevent "aluminum transfer" and work as a *release agent*.

In this paper the term lubricant and release agent will be used interchangeably.

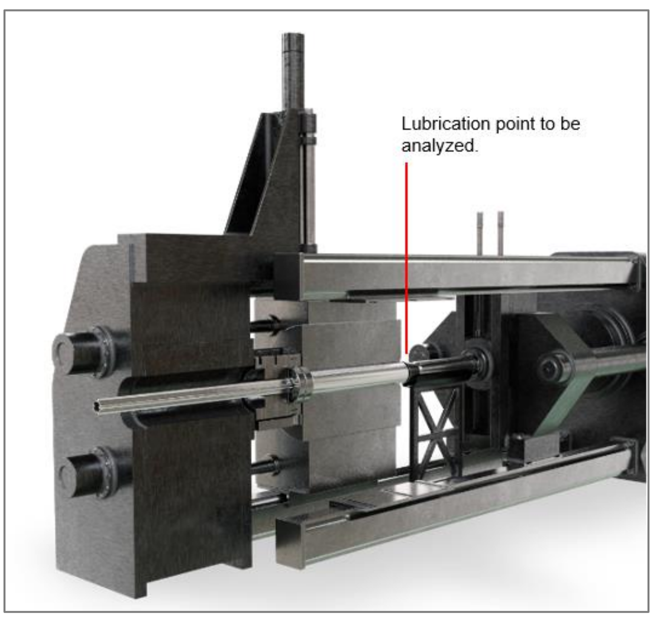

Fig. 1 Diagram showing the lubrication point to be analyzed.

The challenges present to select and compare the different products to serve as release agents between the dummy block and billet is that the existing technologies are widely different form each other. Usually in any other process you can compare datasheets of products that are pretty much the same and have only variations within certain specific properties. When you compare a grease to another grease you can understand what the differences are, such as consistency, dropping point or load carrying capacity, and one can predict the expected performance from the change. The same goes for lubricant oils and other kind of lubricants for different processes. This changes for aluminum extrusion lubricants because all the options are wildly different form each other. Their physical properties, the application method, the amount used, the type of implementation and operation that each need are all radically different. So being tasked with changing a lubricant or choosing between two or more options is quite a challenge.

Any maintenance and lubrication engineer that has had to deal with these issues there is no guideline or steps to follow to get to the right answer. That's what this paper is intending to provide, an easy-to-follow methodology and framework of reference to get to the best option for each user taling into account each one of their plant priorities and goals.

The authors of this paper are part of the R&D and Application Engineering department in a lubricant manufacturing company that has a global reach. This gives the team a unique perspective because they have visited dozens of different plants specialized in aluminum extrusion to give technical support, lubricant testing and lubrication system implementation.

It is in these visits that they have garnered the expertise and information to put together a framework to simplify the process of selection and testing of a lubricant technology.

The main technologies that are found on the market are the following:

- Acetylene Flame
- Boron Nitride Suspension
- Boron Nitride Powder
- Graphite Suspension
- Graphite / Boron Nitride Sticks and Blocks
- Water-based solutions.

We present a description of this technologies.[1][2]

Acetylene flames

The process involves initiating the combustion of acetylene in front of a billet, resulting in the creation of carbon black. This carbon black serves as a release agent during the extrusion process. The procedure is automated, with the flame igniting as the billet transitions from the preheating furnace to the extrusion press. While this method offers advantages such as automation and cost efficiency, it is not without significant drawbacks. The minute particle size of carbon black, approximately 100nm, poses a potential health hazard to workers who must be shielded from inhaling these loose particles. Additionally, there are concerns related to quality, as carbon black can adhere to distinct edges on extruded profiles, leading to persistent dark marks that impede the anodizing process.

The utilization of open flames for ignition introduces fire risks and the potential for interference with nearby electrical equipment. Moreover, due to limitations in the transfer of carbon black, individual billets necessitate separate coating, adding to the complexity of the process.

Boron Nitride

Boron Nitride (BN) exhibits strong adhesion at high temperatures. Coating a billet with BN ensures that the layer in contact with the dummy block adheres as well, eliminating the need for re-coating the following billet. This allows for a reduction in the frequency of billet coating, potentially reaching every third to fifth billet. An even more efficient approach could involve solely coating the dummy block, omitting the billet coating step. BN can be applied as a powder or a water-based suspension, with the prevalent method being powder application.

However, effective adhesion requires the powder to be electrically charged, achieved through finely ground particles. However, managing airborne dispersion during the spraying process can be challenging due to the fine particles floating over considerable distances. This poses an inhalation risk to operators and safety concerns. Proper storage involves a dry environment to prevent moisture absorption, and often the powder is combined with a boric oxide binder for moisture control. Spraying the powder necessitates the use of exclusively dry air or nitrogen.

Graphite suspension

Lubricants formulated with graphite necessitate the incorporation of an organic substance to amalgamate with the graphite particulates. This introduced organic component possesses flammability, igniting upon contact with the elevated temperature of the tooling's surface. The resultant emission of smoke and soot engenders the formation of blister holes in aluminum profiles. Additionally, graphite exhibits heightened electrical conductivity, thereby affording the potential to induce short-circuiting in proximate electrical equipment. Furthermore, the administration of graphite suspensions engenders disorderliness, necessitating repetitive application within each cycle—an operation confined to manual implementation.

Water based released agent

Released agents that are graphite-free, being water based the environmental impact is minimal and except this method of being flammable, keeping the operators and the press electrical equipment safe. Because of its composition of sodium-based acids and salts that are water-soluble it generates no toxic fumes and no slippery surfaces that could endanger operator’s physical integrity. Profiles also get benefits of using a water based released agent, with clean finishings, reducing scrap. The dosage method can be with manual or automatic spraying systems; the second one is more recommended, this because the dosage can be controlled and constant in every application cycle, this also will reduce the released agent consumption.

The expectation is that users will be able to use the methodology and framework established in this paper to create a more holistic process to compare solutions and share the lubricant technology that is right for their specific operating conditions, understanding these different conditions as type of alloy, speed, geometries, etc.

METHODOLOGY

The proposed framework is a simple one designed to compare different technologies that are so different form each other that it's hard to make direct comparisons.

Framework Description

This framework establishes 5 categories that we have to take into account: 1. Cost, 2. Safety & Environment, 3. Productivity & Performance**,** 4. Ease of use, 5. Supplier benefits.

Each one of these categories is composed of several parameters that we have to grade in a scale from 1 to 5, 1 being the *worst* grade and 5 the *best.* For example, if the parameter is *cost* of the product in USD per kg, then we assume that 1 is the most expensive option and 5 is the cheapest, and so on.

How each parameter is grade is a subjective process and in can vary from plant to plant and user to user. For the results that are going to be discussed in the following sections the process was a mix between qualitative analysis based on the team expertise and experience and other parameters were graded based on hard data from test reports and product quotations. This evaluation will be recorded in *Table 1* where each column is a lubricant option, and the rows describe each parameter. In Table 1 each parameter is assigned to each one of the main categories to avoid any kind of confusion. For example, parameters 2.1, 2.2, 2.3 and 2.4 are assigned to Category 2 – Safety & Envinroment.

The parameters can be graded using several methods:

- Test reports where the performance of two technologies is being analyzed can provide data regarding the performance and the quantities that need to be used.
- Failure Modes and Effects Analysis (FMEA) can be made to assess the risk of the option regarding several of the parameters.
- Looking at the SDS of the products being analyzed can also result in important data such as fire hazards and environmental toxicity.
- Direct quotations from the suppliers can also be of use, to look at the price and the technical service that they're offering.

There isn't a unique or correct way to evaluate these parameters, but just taking the time to answer simple questions about these subjects can clarify the main differences between the technologies and give invaluable information to align each of the options to the plant's goals and priorities.

Table 1. Parameters to evaluate.

Category	Parameters for evaluation (1 worst - 5 best)	Option 1	Option 2
1	1.1 Lubricant Cost ($/kg) (1 Highest cost, 5 Lowest Cost)	-	-
	1.2 Lubricant consumption quantity (1 Highest Consumption, 5 Lowest Consumption)	-	-
2	2.1 Safety (Fire Hazard Risk) (1 Highest Risk, 5 Lowest Risk)	-	-
	2.2 Worker Health (Injurie risk and Long Term affectations) (1 Highest Risk, 5 Lowest Risk)	-	-
	2.3 Environment (COV Emissions)	-	-
	2.4 Work area cleanliness	-	-
3	3.1 Productivity (Release performance, Dummy protection)	-	-
	3.2 Finished product quality (Error probability)	-	-
	3.3 Tooling protection (Hot shear)	-	-
4	4.1 Ease of use	-	-
	4.2 Application method cost (1 Highest cost, 5 Lowest Cost)	-	-
	4.3Lubrication points	-	-
5	5.1 Technical service	-	-
	5.2 Logistics	-	-

After evaluating the parameters, a score is given to each category. This score is gotten from the sum of the points in each of categories' specific parameters and dividing by the highest number of points that a specific category can get. For example, if there are three parameters within a specific category then the highest number of points will be 15. This operation is described in Eq.1 and will give as a result a number from 0 to 1 for each category in each of the lubricant options. This summary will be recorded in *Table 2* where each lubricant option will have a grade for each one of the main categories.

$$Category\ grade\ number = \frac{\sum_{i=1}^{n} Parameter\ i}{n * 5} \tag{1}$$

n = Number of parameters in each category

Table 2. Summary of points awarded to each category.

Categories	Option 1	Option 2
Category 1 - Cost	-	-
Category 2 - Safety & Environment	-	-
Category 3 - Productivity & Performance	-	-
Category 4 - Ease of use	-	-
Category 5 - Supplier Benefits	-	-

Afterwards, we must establish a priority to each category in order to have a weighted evaluation that aligns to the user's goals. The priority for each category can go from 0% to 100% but the sum of the priorities of the five categories has to give 100%. For example, if we want an equal distribution of priorities each one must have a 20% assigned to it. This will be recorded on *table 3*.

Table 3. Priority given to each category.

Categories	Priority
Category 1 - Cost	20%
Category 2 - Safety & Environment	20%
Category 3 - Productivity & Performance	20%
Category 4 - Ease of use	20%
Category 5 - Supplier Benefits	20%

To finish the process, we have to get the *final weighted evaluation* for each lubricant option. For this, Table 4 will be used. For each lubricant option we have to multiply each *category grade number* in table 2 by it's respective *category priority* found in table 3. Then, this result will be added to the result with the rest of the results from the multiplication in the other categories. This is described in Eq. 2.

$$\begin{aligned} &Final\ weighted\ evaluation \\ &\quad = (Category\ 1\ grade\ number * Category\ 1\ priority) + \cdots + (Category\ 5\ grade\ number \\ &\quad * Category\ 5\ priority) \end{aligned} \tag{2}$$

This will give as a result the *Final weighted evaluation* for each lubricant option and will be recorded in *Table 4 Final lubricant evaluation*, where the user will be able to see a final score which indicates which option is the best for the priorities defined by them.

Table 4. Final lubricant evaluation.

	Option 1	Option 2
Final weighted lubricant evaluation	-	-

Parameter description

In this section the parameters to be evaluated in *Table 1* will be listed and explained in order to facilitate the process. The proposed framework can be adapted, and the parameters changed if the user/reader sees it fit. There are fourteen proposed parameters across five main categories.

1.1 Lubricant Cost ($/kg)

This is a straightforward parameter. What's the cost of lubricant for each kg to be bought.

This information is important, but it shouldn't the only thing we look at given that each lubricant technology is so radically different from each other. It should be evaluated from 1 being the most expensive option to 5 the cheapest.

1.2 Lubricant consumption quantity

This parameter is also easy to understand but nevertheless should be ultimately evaluated within the plant by the team responsible for the application system or lubrication equipment. Each technology has general consumption rates but each aluminum extrusion process for each individual plant have operating conditions that have to be accounted for. It should be evaluated form 1 as the highest consumption option to 5 the lowest consumption option.

2.1 *Safety (Fire Hazard Risk) (1 Highest Risk, 5 Lowest Risk)*

This is crucial parameter within the aluminum extrusion process and the answer is inherent to each technology. Just by reviewing the SDS for each product we can find out if a product is flammable or not. This fire hazard risk is really important and can have critical effects for the operation of the plant and safety of the employees.

2.2 *Worker Health (Injurie risk and long-Term affectations) (1 Highest Risk, 5 Lowest Risk)*

The risk for workers getting injured or have long-term affectation can be estimated using the FMEA methodology and is one the main points to be evaluated. The main differences can be found between technologies that have manual application or an automated solution, and the impact can be from low level burns to fatal accidents. This usually isn't considered by the people making the decision of which lubricant to use but it can have a huge impact, given that a single incident can have costs that equal or surpass the cost of the lubricant for a whole year and is accompanied by fines and subsequent audits.

2.3 *Environment (VOC Emissions)*

This usually isn't and straightforward parameter that is usually considered but the use of these lubricants has an impact on the environment, specifically the release of VOC (Volatile Organic Compounds) usually present in hydrocarbons and the other subproducts that can be released from the combustion of the lubricant when it happens (Acetylene flame and Boron nitride or graphite Stick and block options are the main generators).

2.4 *Work area cleanliness*

This might seem as a simple parameter but it shouldn't be ignored. The workspace can have a huge impact on worker productivity and is usually interwoven with the 2.2 Worker Health parameter given that it can be one of the main causes for accidents.

3.1 *Productivity (Release performance, Dummy protection)*

Productivity and performance have to be validated within the process. Usually, a test run of 2 to 3 hours can be enough to validate that the lubricant works. The main property to evaluate is that the lubricant has to prevent any aluminum transfer from the *billet* to the *Dummy Block.* Usually this is the minimum requirement for a product to be considered and if product doesn't work it shouldn't even be considered for the analysis. In Interlub we rank most technologies at 5 with the caveats that it depends on the implementation of said technology, but we make and exception on products that have to be applied manually because they are more susceptible to human error.

3.2 *Finished product quality (Error probability)*

In this point what's being evaluated is the probability that the finished product it going to have a quality problem that can be attributed to the lubricant. The main issue that can be taken into account is the one referred as *blisters* or *bubbles*. In normal operation there shouldn't be any quality issues attributed to the lubricant but a misapplication or an excess in product can have adverse effects. The highest probability of the error should be evaluated as 1 and the lowest as 5.

3.3 *Tooling protection (Hot shear)*

This parameter refers to the protection that the lubricant can have on part of the tooling, specifically the hot shears but the user can interpret this information how they see fit. When the lubricant is applied on the Hot Shears it can prevent aluminum accumulation on them helping prologue their service life and diminish operation error.

4.1 *Ease of use*

With this parameter *ease of use* should be understood as everything that surrounds the main process of using the lubricant such as: How easy is it to clean? Does it need to be pre-processed to be used? Does it cause line plugging? Among other points to consider. Evaluate 1 the easiest to use, 5 the hardest to use.

4.2 *Application method cost (1 Highest cost, 5 Lowest Cost)*

This parameter can be one of the main differences between technologies. How much investment a plant must make to implement a lubrication system for each technology. This can be a tricky subject because even though the acetylene flame can be easy to implement or the use of graphite sticks doesn't need any investment to use, they can't be use in other parts of the process and require extra lubricants or other kind of equipment and the suspension-based technologies might be more expensive up front but can have multiple uses within the process.

4.3 *Lubrication points*

This might not be the main focus, but it shouldn't be ignored. How many uses can the lubricant have within the process. Even though a solution can be cheaper it could have limited functionality.

5.1 *Technical service*

This and the following parameter are not directly related to the lubricant per se, but it can have some weight when making the decision of which product or solution to invest in. Is there any extra value that the provider is adding to their solution such as technical services, installations, consulting?

5.2 *Logistics*

This parameter is to evaluate is there are any specific logistic problem or advantage that a supplier can provide. A common problem could be prolonged delivery times derived from importation processes.

RESULTS AND DISCUSION

As a part of the development of the framework presented in this technical paper, the team of researchers and application engineers at Interlub created a *review of the six main technologies* discussed in the *introduction:* Interforge KI-C is an Interlub product and is going to be analyzed as a water-based solution to compare, Acetylene Flame, Boron Nitride Suspensions, Boron Nitride Power, Graphite Suspensions, Graphite / Boron Nitride Sticks and Blocks.

Parameter Evaluation

The first step for the analysis was to evaluate each of the parameters, the is a summary on Table 5.

Table 5. Interlub parameter evaluation of main technologies.

Category	Parameters for evaluation (1 worst - 5 best)	Interforge KI-C Water Based Solution	Acetylene Flame	Boron Nitride Suspension	Boron Nitride Powder	Graphite Suspension	Graphite / Boron Nitride Sticks and Blocks
1	1.1 Lubricant Cost ($/kg) (1 Highest cost, 5 Lowest Cost)	3	5	2	1	3	4
	1.2 Lubricant consumption quantity (1 Highest Consumption, 5 Lowest Consumption)	5	5	4	3	4	1
2	2.1 Safety (Fire Hazard Risk) (1 Highest Risk, 5 Lowest Risk)	5	1	5	5	5	2
	2.2 Worker Health (Injurie risk and Long Term affectations) (1 Highest Risk, 5 Lowest Risk)	5	1	3	3	2	1
	2.3 Environment (COV Emissions)	4	1	4	5	4	2
	2.4 Work area cleanliness	5	1	3	4	3	2
3	3.1 Productivity (Release performance, Dummy protection)	5	5	5	5	5	3
	3.2 Finished product quality (Error probability)	5	5	3	5	5	1
	3.3 Tooling protection (Hot shear)	4	1	3	1	5	1
4	4.1 Ease of use	5	2	2	2	2	1
	4.2 Application method cost (1 Highest cost, 5 Lowest Cost)	3	4	3	1	3	5
	4.3Lubrication points	5	2	5	2	4	2
5	5.1 Technical service	0	0	0	0	0	0
	5.2 Logistics	0	0	0	0	0	0

The summary of the results is presented in Table 6 with a prioritization that is established on Table 7 in which an equal priority is given to categories 1, 2, 3 and 4 with 0% priority given to Category 5 – Supplier Benefits and subsequently the final weighted results were calculated and presented on Table 8.

Table 6. Interlub's summary of points awarded to each category.

Categories	Interforge KI-C Water Based Solution	Acetylene Flame	Boron Nitride Suspension	Boron Nitride Powder	Graphite Suspension	Graphite / Boron Nitride Sticks and Blocks
Category 1 - Cost	0.80	1.00	0.60	0.40	0.70	0.50
Category 2 - Safety & Environment	0.95	0.20	0.75	0.85	0.70	0.35
Category 3 - Productivity & Performance	0.93	0.73	0.73	0.73	1.00	0.33
Category 4 - Ease of use	0.87	0.53	0.67	0.33	0.60	0.53
Category 5 - Supplier Benefits	0.00	0.00	0.00	0.00	0.00	0.00

Table 7. Prioritization of categories from Interlub's Analysis.

Categories	Priority
Category 1 - Cost	25%
Category 2 - Safety & Environment	25%
Category 3 - Productivity & Performance	25%
Category 4 - Ease of use	25%
Category 5 - Supplier Benefits	0%

Table 8. Final weighted results from Interlub's Analysis.

	Interforge KI-C Water Based Solution	Acetylene Flame	Boron Nitride Suspension	Boron Nitride Powder	Graphite Suspension	Graphite / Boron Nitride Sticks and Blocks
Final weighted lubricant evaluation	88.75	61.67	68.75	57.92	75.00	42.92

Annotations on non-evident results of the parameter evaluation

Notes on parameter 2.2 - Graphite / Boron Nitride Sticks and Blocks use is highly dangerous.

Notes on parameter 3.2 - The nitride suspension uses other compounds to get a stable suspension that can generate the *blisters*. Graphite / Boron Nitride Sticks and Blocks is poorly qualified because it can cause quality problems if applied poorly or in excess.

Notes on parameter 4.1 - Acetylene Flame and Boron Nitride cannot be used in other lubrication points and you have to use a second product.

Notes on parameter 4.1 - Interforge KI-C doesn't need previous agitation, uses a low atomizing force and is easy to clean.

Notes on parameter 4.1 - Boron nitride has a clogging effect.

Notes on parameter 4.2 - Acetylene flame has an elevated complexity of the system to apply.

Notes on parameter 1.2 - Suspension of boron nitride and graphite tend to be more viscous and need to apply more per application.

Notes on parameter 1.2 - Nitride powder results in higher consumption and loss of material.

Notes on parameter 1.2 - Interforge KI C uses on average 10 g to 15 g per application.

Notes on parameter 4.3 - Graphite suspension cannot be applied in hot shear at the exit of the furnace because it can foul the aluminum body.

CONCLUSION

The results presented from Interlub's analysis of the main lubrication technologies used as a release agent on the aluminum extrusion process say that Interforge KI-C is the best rated solution given the parameters looked at with an equal prioritization. This is a *general review* that isn't considering a specific process or operating conditions of a plant and should be understood as an analysis of the main properties of the technologies.

The information and rating presented in table 5 will give an insight about the general properties of the products and each user can give them the weight the see fit according to their priorities and operation goals.

This framework is intended to be used to get an holistic understanding of how a lubrication technology will impact if implemented in a process.

REFERENCES

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[2] Information on https://castool.com/wp-content/uploads/2018/08/Improved-Lubrication-LMA-2017.pdf

ANNEX 1 – TABLE 1

Category	Parameters for evaluation (1 worst - 5 best)	Option 1	Option 2
1	1.1 Lubricant Cost ($/kg) (1 Highest cost, 5 Lowest Cost)	-	-
	1.2 Lubricant consumption quantity (1 Highest Consumption, 5 Lowest Consumption)	-	-
2	2.1 Safety (Fire Hazard Risk) (1 Highest Risk, 5 Lowest Risk)	-	-
	2.2 Worker Health (Injurie risk and Long Term affectations) (1 Highest Risk, 5 Lowest Risk)	-	-
	2.3 Environment (COV Emissions)	-	-
	2.4 Work area cleanliness	-	-
3	3.1 Productivity (Release performance, Dummy protection)	-	-
	3.2 Finished product quality (Error probability)	-	-
	3.3 Tooling protection (Hot shear)	-	-
4	4.1 Ease of use	-	-
	4.2 Application method cost (1 Highest cost, 5 Lowest Cost)	-	-
	4.3Lubrication points	-	-
5	5.1 Technical service	-	-
	5.2 Logistics	-	-