# FINDING NEW BEST PRACTICES:
# TESTING CERAMIC GREASE TO REDUCE GREASE CONSUMPTION AND INCREASE EFFICIENCY IN EUROPEAN AND U.S. PELLET MILLS

Dipl.-Kfm. Holger Streetz
BVG Vertriebsgesellschaft AG • Alte Steinhauserstrasse 19 • 6330 Cham (Zug) • Switzerland
h.streetz@bathan.ch • phone: +49 (0)173 591 85 50 • fax: +41(0)41 740 45 29 • www.bathan.ch

_ pelletization
_ operation and maintenance
_ innovative concepts
_ efficiency
_ economical aspects

ABSTRACT: Finding new best practices in wood pellet production is often a long and frustrating journey. Besides extensive testing and costly adjustments, time is a critical factor, since tests should not interfere with production plans. However, sometimes improvements approach fast. BVG AG Switzerland proved within months that it is possible to decrease lubricant consumption in pellet mills, and therefore reduce environmental impact, while increasing lifetime of components due to improved wear protection. The key to performance improvements is a solid lubricant based on ceramic.

## 1 BASICS IN PELLETIZING

Theoretically, pelleting wood is an easy process (see Fig. 1): Shredded wooden material is conditioned and fed to a pellet mill. In the pellet mill, rollers press the material through a die, and the pressed wood is cut off on the outside (see Fig. 2). After cooling, the pellets are separated from fines, and stored or bagged. The goal is to produce wood pellets in acceptable quality with an adequate production rate at reasonable cost.

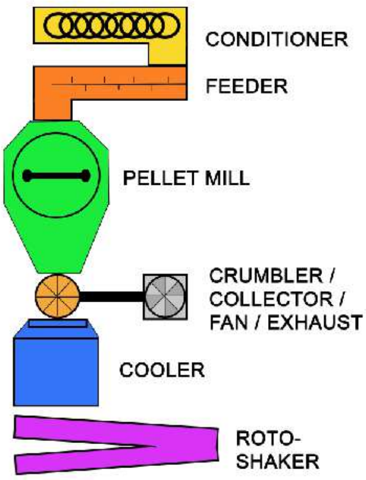


**Figure 1:** Flowchart Pelleting

All pellet mill operators are testing different lubricants to find a best practice. A best practice shows consistently superior results in comparison to those achieved with other means, and therefore describes a benchmark. Finding a best practice is an iterative process, which means that once finding the best solution, it still can evolve to become better as improvements are discovered.

This project focusses on lubricating roller bearings of pellet mills, aiming for reducing the grease consumption drastically, while remaining or improving performance.

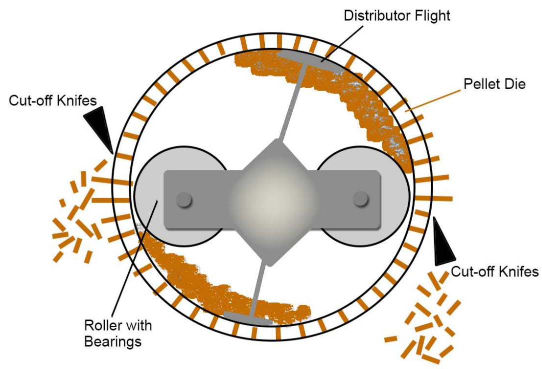


**Figure 2:** Pelleting Process

## 2 CERAMIC AS A LUBRICANT

### 2.1 Bathan Ceramic Technology Characteristics

Micro-technological materials can change chemical and physical structures of surfaces, leading to new characteristics. Ceramic particles can act as a solid lubricant. Ceramic is a group of inorganic, nonmetallic materials. Industrial ceramic is optimized for technical applications. Most important characteristics are:

- High heat-resistance (> 2000°C)
- Abrasion-resistant
- wear-resistant
- Good thermal conductivity
- Low friction coefficient
- Chemically inert

### 2.2 Boron Nitride

One essential component of the Bathan Ceramic Technology (BCT) is hexagonal Boron Nitride (BN). It has a distinct crystalline structure, and exists in two forms, α-BN and β-BN, both of which are stable compounds. While β-BN has a cubic structure and is highly abrasive, α-BN is an excellent lubricant, due to its hexagonal structure.

α-BN crystallizes in a layer grid comparable to graphite (see Fig. 3). The plate-like structure of the particles enables movement against each other with little energy, which makes it a solid lubricant (see Fig. 4).

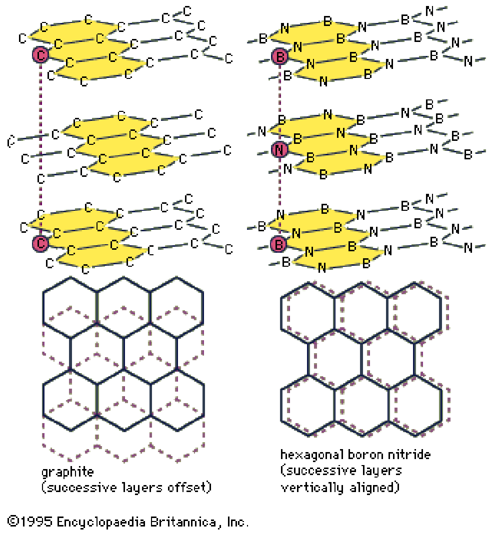


**Figure 3:** Structure of Boron Nitride and Graphite

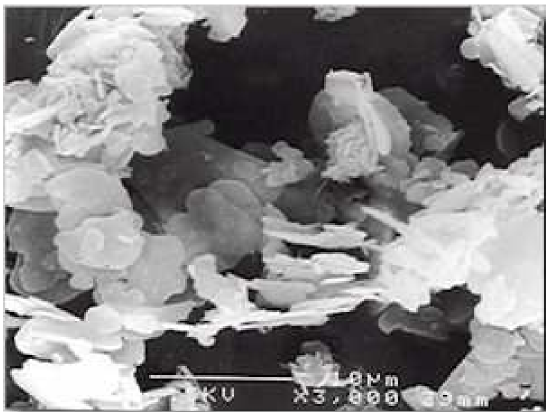

**Figure 4:** Plate-like Structure of Boron Nitride

Hexagonal boron nitride is being used increasingly because of its unique combination of properties which include a low density (2.27 g.cm$^{-3}$ theoretical density), high temperature stability (melting point near 2600°C), chemical inertness (corrosion resistance against acids and molten metals), stability in air up to 1000°C (in argon gas atmosphere up to 2200°C and in nitrogen up to 2400°C), stability to thermal shock, easy workability of hot-pressed shapes, excellent electrical insulating character as well as very high thermal conductivity. Due to its non-wetting properties it is stable to attack by molten glass, molten silicon, boron, non-oxidizing slags, molten salts (borax, cryolite) and reactive metal melts (e.g. Al, Fe, Cu, Zn). As a thermal conductor, BN ranks with stainless steel at cryogenic temperatures. [1]

Metals, coated with α-BN, have an excellent sliding and separating effect that reduces friction and wear. Lifetimes increase accordingly. In addition, oxidation process of coated surfaces decelerates. Under pressure, ductile deforming reduces wear point peaks and smoothens scallop heights with minimal loss of substance (see Fig. 5).

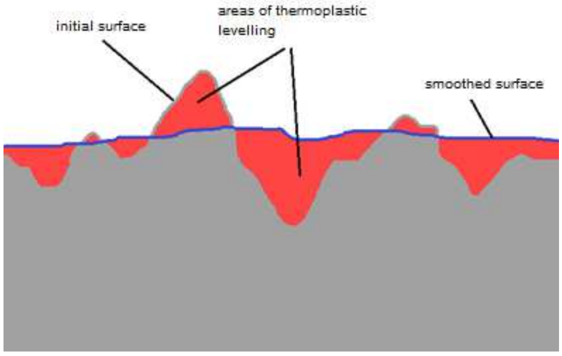


**Figure 5:** Thermoplastic Levelling

The increased load bearing capacity of the surfaces reduces wear. Friction coefficient and therefore temperature decrease significantly. Boron nitride builds a relatively soft coating on metal surfaces that wears off with mechanical attrition. Pressure forms polished surfaces (see fig. 6).

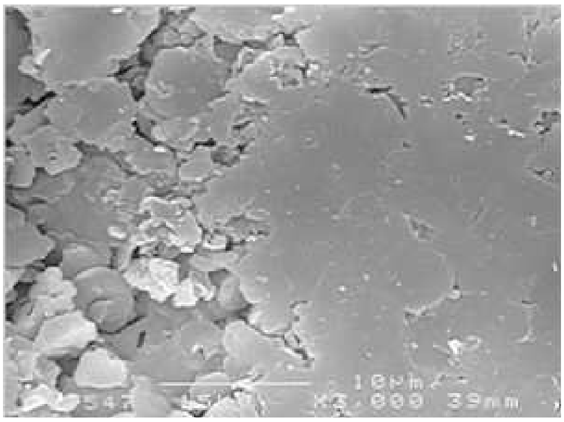

**Figure 6:** Partially Polished Surface

2.3 Boron Nitride and Other Solid Lubricants

Compared to Teflon or graphite, ceramic has a superior lubricating property temperature, a broader temperature range, and has no toxic degradation products. The small coefficient of friction of boron nitride is retained up to 900°C, whereas other solid lubricants like graphite and molybdenum disulfide are burnt away at lower temperatures (see Table 1). Therefore, positive effects of ceramic are stronger and last longer. Du Pont never recommended using Teflon as a surface modification for engines or gears. Graphite is well known as a friction modifier, but leaves residues, which are difficult to remove, and lead to layer building. [2]

**Table 1:** Comparison of Bathan Ceramic and PTFE

| | Bathan Ceramic | PTFE (Teflon) |
|---|---|---|
| Lubricating property up to | 1100 °C | 275 °C |
| Friction coefficient | 0.02 to 0.18 | 0.04 to 0.6 |
| Thermal conductivity | 40 to 60 W/mK | 0.24 W7mK |
| Max. operating temperature | 1000 °C | 270 °C |
| Melting point (degradation) | 3000 °C | 327 °C |
| Metal adherence | yes | no |
| Particle size | 0.03 to 1 µm | 0.02 to 1 µm |
| Degradation products | not toxic | partially (at 400 °C Perfluoriso-butylen) |

The 4-Ball Test measures a lubricant's extreme pressure properties and determines the relative wear preventing properties under high Hertzian contact in pure sliding or rolling motion. The test is used to determine the load carrying and wear properties of a lubricant at high test loads. The 4 Ball Test results of Bathan Ceramic Technology in comparison to a reference oil shows 20% reduction in wear, and a 33% lower friction coefficient. Gutlast and torque are higher than with reference oil and molybdenum disulfide (see Table 2).

**Table 2:** Comparison of Gutlast and Torque

| | Gear oil | Bathan Ceramic Technology | Molybdenum disulfide |
|---|---|---|---|
| Gutlast in N | 5600 | 9072 | 6800 |
| Torque in N/m | 29 | 35 | 27 |

An analysis at the Forschungsstelle für Zahnräder und Getriebebau (FZG), Technical University Munich, shows up to 9% less power losses, and up to 2.5% lower steady state temperatures (see Fig. 7, 8 and Table 3). The aim of the investigation was the evaluation of the frictional behavior of two different lubricants in the FZG back-to-back testing rig, and were carried out according to the FVA research project no. 345 "Efficiency Test". [3]

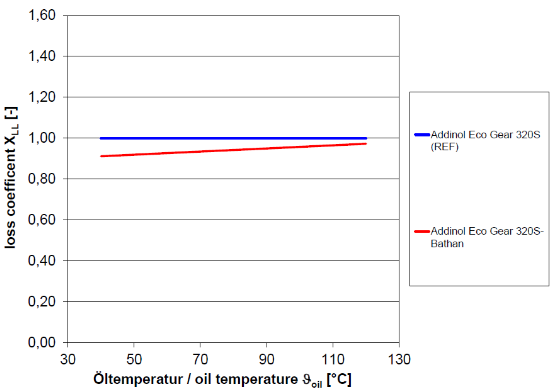


**Figure 7:** Power Loss Coefficient

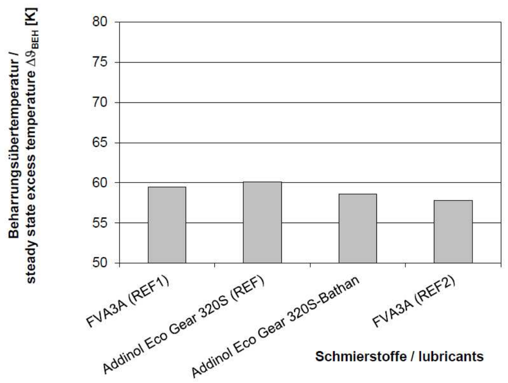


**Figure 8:** Steady State Temperatures

**Table 3:** Oil Comparison

| Oil | 40 °C | | | $R_{40}$ | 120 °C | | | $R_{120}$ | $\Delta\vartheta$ | $W_V$ | $\Sigma$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | $X_{LO}$ | $X_{LL}$ | $X_{LG}$ | | $X_{LO}$ | $X_{LL}$ | $X_{LG}$ | | | | |
| Addinol Eco Gear 320S-Bathan | 1 | 1 | 2 | 1 | 2 | 1 | 2 | 2 | 1 | 1 | 5 |
| Addinol Eco Gear 320S (REF) | 1 | 2 | 1 | 1 | 1 | 2 | 1 | 1 | 2 | 2 | 6 |

The ranking is based on the criteria $X_{LO}$, $X_{LL}$, $X_{LG}$ loss coefficient at 40 °C and 120 °C oil temperature, $\Delta\vartheta_{BEH}$ steady state excess temperature, and $W_V$ cumulated loss energy during the efficiency test.

For gear boxes in practice with a wide range of operating conditions the oils can be sorted according to the ranking sum $\Sigma$ from the order in the appraised categories. For two compared oils the minimum ranking sum $\Sigma$ is 4 for an optimum oil, the maximum is 8 for an oil with highest losses in all categories. The ranking shows the result: slightly better frictional behavior for Addinol Eco Gear 320 S-Bathan with the sum of $\Sigma = 5$ compared to Addinol Eco Gear 320 S (REF) with the sum of $\Sigma = 6$.

## 3 APPLICATIONS OF BATHAN CERAMIC

Typical boron nitride uses are electronic parts (heat sinks, substrates, coil forms, prototypes), boron doping wafers in silicon semiconductor processing, vacuum melting crucibles, CVD crucibles, microcircuit packaging, sputtering targets, high precision sealing, brazing and metallizing fixtures, microwave tubes, horizontal caster break rings, low friction seals, plasma arc insulators, high temperature furnace fixtures and supports. [4]

Bathan Ceramic Technology is used in several applications in different industries.

### 3.1 Pellet Mills

Bathan ceramic grease is used in pellet mills since 2012. First test was conducted on three 400 hp Andritz 26LM pellet mills, several conveyors, and three 250 hp shredders, processing clean industrial waste. Since then BVG AG conducted tests adding to >70000 operating hours.

### 3.2 Other Applications

There exist several applications for the Bathan Ceramic Technology, and many of them were tested. In the shipping industry, Bathan ceramic lubricants are used to inhibit corrosion, and increase wear protection with anchor windlass, mooring and towing winches, guide bar and follower. In cement plants, ceramic greases prolong greasing intervals, decrease wear, and reduce operating temperatures of ventilator bearings (homogenization silo, heat exchanger, kiln, and cooling fans), kiln bearing, cooling chain, and gears, e.g. for filter cake transportation. In combustion engines, the ceramic particles improve sealing, therefore lowering oil consumption. Additionally, increasing compression improves combustion and lowers exhaust values, especially soot. In gears, Bathan ceramic reduces wear, and increases efficiency. Current applications are construction machines, buses, cars, and heavy-duty trucks. The technology has been tested on engine test benches, too. In rail industry, the ceramic minimizes vibrations, prolongs greasing intervals, and reduces wear: jibs of rail cranes, and switches.

## 4 REDUCING GREASE CONSUMPTION

### 4.1 Theory

Under mechanical pressure, the ceramic particles build a polished coating on metal surfaces, providing improved wear protection. The new surface has a lower friction coefficient, improves the thermal conduction, and increases the load-bearing capacities. Thus, demand for lubrication should decrease.

Additionally, due to improved sealing, lower lubricant supply should not lead to contamination of bearings with dust, feed or other pollutants.

### 4.2 Field Tests

Since 2012 BVG AG conducted several field tests, adding to more than 70,000 operating hours. Bathan Ceramic Grease has been applied in roller bearings and shafts of pellet mills that process waste and wood from different pellet mill manufacturers. The tests include Andritz, CPM, Salmatec, and Sprout ranging from 800 kg to 6 tons production capacity. Lubrication systems include automated and non-automated systems from manufacturers such as Dropsa and Woerner. The roller bearings tested are from the following manufacturers: SKF, FAG Schaeffler, Timken, CPM Europe, Salmatec, Graf, and others. Dies mainly used are Andritz, Salmatec, and CPM Europe.

**Table 4:** Project Partners and Manufactures (excerpt)

| Company | Manufacturer | Product |
|---|---|---|
| Greenwood Energy, USA | Andritz | Plastic |
| Binderholz, Germany | CPM | Wood |
| Pfeifer, Czech Republic | CPM | Wood |
| Forest Energy, USA | Andritz | Wood |
| Arbor Pellet, USA | | Wood |
| Tschopp, Switzerland | CPM | Wood |
| Maine Woods, USA | Sprout Matador | Wood |
| Olympus Pellet, USA | Sprout | Wood |
| Marth Wood, USA | Andritz | Wood |
| Curran Renewables, USA | Andritz | Wood |
| MAK Holz, Austria | CPM | Wood |
| Haas, Czech Republic | Salmatec | Wood |
| Schmidt Energie, Austria | CPM | Wood |
| Hasslacher, Austria | CPM | Wood |
| Bioenergy Point, Serbia | CPM | Wood |
| Glechner, Austria | | Wood |
| Braunschweiler, Switzerland | CPM | Wood |
| Dorr Biomassehof, Germany | CPM | Wood |
| ZM Technik für Holz, Switzerland | | Wood |

For all tests, BVG AG provided a 25kg keg of Bathan KF 7 / 60M ceramic grease, and attended the trial on site. Prior to starting the test, the regular timer of the (automated) lubrication system was recorded, incl. grease consumption in gram per hour (e.g. 250 g/h). Before initiation it was made sure the automated lubrication system can be set higher than 999 seconds for the pellet mill in test (fourth digit can be unlocked by technician). Regularly, using Bathan KF grease started with roller bearing change. Lubrication pipes were clean or polluted with previous grease. It made no difference to the results, since the run-in period of the ceramic lubricant cleared all areas from the previous lubricant. The tests were conducted with new, refurbished and used sets of rollers and bearings. New roller bearings were filled with Bathan KF grease to ensure prompt coating of surfaces with ceramic. BVG AG either provided some tubes for pre-filling the bearings or material was taken directly from the 25kg keg. The grease keg was plugged to the (automated) lubricating system, and after checking all parameters, pellet mills were started. Knowing the regular temperatures for operation, prolongation of the timer interval or reduction of grease supply started when operating temperatures dropped over a period of 1 to 3 hours or with not reaching regular operating temperatures at all. Monitoring of operating temperature was a key variable.

While testing, production output, operating temperatures, power consumption, greasing interval, and grease consumption were recorded for evaluation. The same data were made available for the time before using Bathan KF 7 / 60M ceramic grease for comparison. The tests were followed by an evaluation and presentation of results to the project partner as well as discussion of implementation of ceramic greases to all pellet mills. Expansion of tests included using Bathan KF 7 / 60M ceramic grease on main shafts, shredders, and conveyors.

## 5 RESULTS AND CONCLUSIONS

### 5.1 Results from Testing Ceramic Grease in Pellet Mills

Greenwood Energy tested four different greases in 2012 in their Andritz 26LM pellet mills. The objective was to directly compare the lowest add-on rate for each grease in order to maintain bearing temperatures at current levels. Add-on rates were gradually reduced until the bearing temperatures started to increase. With Bathan KF 7 / 60M ceramic grease the automatic lubrication system grease add-on rates were reduced by 95% compared to the calcium sulfonate based grease. The automatic lubrication system normally applies grease every 360 seconds with the base case grease. The grease count was increased to every 600 seconds with the Lithium and Aluminum complex greases. While using the Bathan KF7 / 60M ceramic grease, the interval was slowly increased to 6800 seconds between grease applications with no increase in bearing temperatures. In fact, average temperature shows a 1.134% decline from 192.12 °F with regular grease to an average of 189.9 °F with Bathan ceramic grease. Additionally, the frequency of manual greasing of conveyors and shredders was reduced to one fourth of the current lubrication schedule, saving maintenance hours and reducing equipment down time.

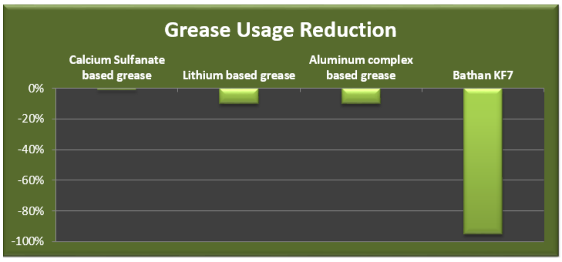


**Figure 9:** Test Results for four different greases at Greenwood Energy (Green Bay, USA)

Additionally, power consumption was measured. Starting with an average 242.7 A with regular grease, Bathan KF 7 / 60M ceramic grease proved to reduce power consumption by 9.13% to an average power consumption of 220.53 A.


**Figure 10:** Grease and Power Consumption Reduction at Greenwood Energy (Green Bay, USA)

At Pfeifer in Trhanov, the test started in September 2013 with a grease consumption of 200 g/h, supplied by an automated lubrication system. Usage of Bathan ceramic grease allowed a reduction to 10.8 g/h. Meanwhile lifetime of roller bearings was increased from an average of 800 operating hours to 2,000 operating hours (see fig. 11).

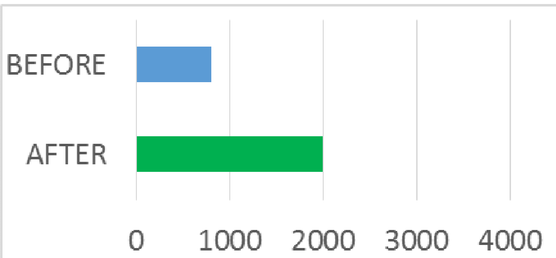


**Figure 11:** Bearing Lifetime Pfeifer (Trhanov, Czech Republic)

The test at Binderholz started in January 2014. Timer interval of the automated lubrication system using regular grease was 500 seconds (8 minutes 20 seconds). With Bathan KF 7 / 60M grease, timer was gradually increased to 9,000 seconds (150 minutes), resulting in a decrease in grease consumption of 94.4%. The average lifetime of roller bearings at Binderholz was 1,000 operating hours. The lifetime with Bathan ceramic grease increased by factor 3 to 3,000 operating hours.

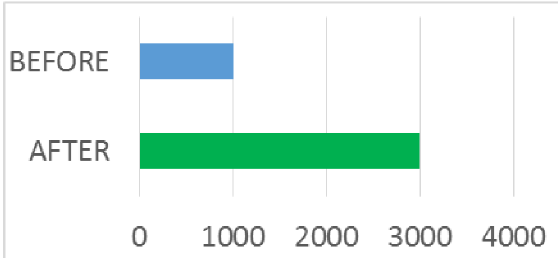


**Figure 12:** Bearing Lifetime Binderholz (Kösching, Germany)

Tschopp AG started testing in May 2014. The initial situation at Tschopp was a timer for the automated lubrication system (Dropsa) of 335 seconds, and an average lifetime of 1,000 operating hours for roller bearings. Test took place in one of three CPM pellet mills. Using Bathan KF 7 / 60M ceramic grease lead to a timer for the automated lubrication system of 6,720 seconds (95% reduction in grease consumption), and a prolongation of lifetime of roller bearings to 4,000 operating hours. Temperatures dropped drastically from a range of 110 to 120 °C to 85 to 95°C; so that grease consumption was further reduced, (a certain temperature level is needed to maintain good quality of wood pellets, enabling the **lignite** to **coat**).

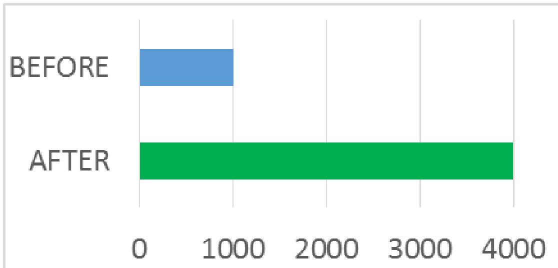


**Figure 13:** Bearing Lifetime Tschopp (Butisholz, Switzerland)

Table 5 shows an overview of the results from tests in Europe and the United States of America. All projects reached approx. 95% reduction in grease consumption, many projects resulted in temperature decreases, and prolonged lifetimes of roller bearings.

**Table 5:** Results Grease Consumption

| Company | Comment |
|---|---|
| Greenwood Energy, USA | -95% grease; -9% electricity; lower temp. |
| Binderholz, Germany | -94,4% grease; 2'000 hrs lifetime; lower temp. |
| Pfeifer, Czech Republic | -94,6% grease; >2'000 hrs lifetime; lower temp. |
| Forest Energy, USA | up to -98.4% grease; lower temp. |
| Arbor Pellet, USA | -98% grease; lower temp. |
| Tschopp, Switzerland | -95% grease; >6'000 hrs lifetime of bearing |
| Maine Woods, USA | > -95% grease; lower temp. |
| Olympus Pellet, USA | -95% grease; lower temp. |
| Marth Wood, USA | -95% grease, lower temp. |
| Curran Renewables, USA | -95% grease; lower temp. |
| MAK Holz, Austria | -95% grease; increased lifetime of components |
| Haas, Czech Republic | -95% grease |
| Schmidt Energie, Austria | -95% grease, increased lifetime of components |
| Hasslacher, Austria | -95% grease; doubled lifetime of components |
| Bioenergy Point, Serbia | -94% grease |
| Glechner, Austria | -95% grease; increased lifetime of components |
| Braunschweiler, Switzerland | -95% grease; increased lifetime of components |
| Dorr Biomassehof, Germany | -95% grease; increased lifetime of components |
| ZM Technik für Holz, Switzerland | Service company for pellet manufacturers |

### 5.2 Conclusions from Testing Ceramic Lubricants

Ceramic solid lubricants are well known, and characteristics are superior to other solid lubricants such as graphite or molybdenum disulfide. Using ceramic lubricants in pellet mills for wood and other feed material is advantageous: Reducing wear and prolonging lifetime of components while decreasing amount of lubricants used for production, and lowering environmental impact of operating supplies.

Positive effects of ceramic lubricants have been observed in several other applications before, but were never tested under such harsh conditions as in pellet mills. However, tests show that the solid ceramic lubricants are able to absorb shocks, build a protective layer, and improve overall performance.

Tests included many different types of feed (waste-to-energy, hard wood and soft wood), as well as different pellet mill manufacturers and original equipment manufacturers. Therefore, findings are backed with enough evidence to that it is proven with sufficient certainty that using ceramic lubricants improve performance of pellet mills.

## 6 REFERENCES


[1] A. Lipp, K. A. Schwetz and K. Hunold, Hexagonal boron nitride: fabrication, properties and applications, Journal of the European Ceramic Society (1989), pag. 3-9.

[2] http://accuratus.com/boron.html

[3] A. Doelschel, Vergleichende Beurteilung des Einflusses von Schmierstoffen auf den Wirkungsgrad bei Zahradgetrieben, FVA Forschungsheft Nr. 664 (2002).

[4] S. Alkoy, Crystallization, behavior and characterization of turbostratic boron nitride, Istanbul Technical University (July 1994).


## 10 BVG AG BRAND AND PROJECT PARTNERS


The Author would like to thank the following companies for their cooperation:

Binderholz Deutschland GmbH (Kösching, Germany), Curran Renewables (Massena, USA), Glechner Ges.mb.H (Mattighofen, Austria), Greenwood Energy (Green Bay, USA), Haas Holzindustrie s.r.o. (Chanovice, Czech Republic), Hasslacher Holzindustrie (Preding, Austria), MAK Holz GmbH (Haimburg, Austria), Pfeifer Holz GmbH & CO. KG (Kundl, Austria / Trahnov, Czech Republic), Sägewerk Schwaiger GmbH & Co. KG (Hengersberg, Germany), Schmidt Energie (Aspang, Austria), Tschopp AG (Butisholz, Switzerland), ZM-Technik für Holz AG (Mühledorf, Switzerland).