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Case Study: Improved Bit Life Utilizing Advanced Cryogenics in Drilling and Blasting

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EXECUTIVE SUMMARY

The advanced cryogenic treatment is a post-manufacturing metallurgical process that involves subjecting off-the-shelf materials to extremely low temperatures, significantly improving wear resistance and reliability. These case studies explore whether the claims of Enrich Bits & Tools benefit metals and their specific in-field application to drill bits in the blasting industry.

This paper reviews the application of the treatment to button drill bits for enhanced wear resistance in two operations. The first is a civil construction project with highly abrasive rock. To confirm the remarkable benefits of the treatment, a second case study was performed. This case study utilized measure-while-drilling technology in consistent rock characteristics to reduce variables in the field study.

Case Study 1

Conducted under a driller with 25 years of experience, the project location was chosen as the worst-case scenario for this client located on the most abrasive geology for any of the client's current operational sites, the OG Gasconade Dolomite Formation was completed over a 7-month.

A 165% increase in bit life was measured at the final borehole footage of 12,999 feet. An untreated bit from the same manufacturer resulted in 4,907 borehole feet. Resulting in 2.65× bit life.

Case Study 2

Utilizing a measure-while-drilling system in an 80-day-long study of drill bit production rates, the second case study was performed by a different client where the project owner tested drill bits treated with Enrich Bits & Tools' advanced cryogenic process. This second case study was to obtain consistent data on factors that can affect bit life such as feed pressure, rotation pressure, and the LA abrasion factor of the rock. The comparison was completed in case study 2 at the quarry property with uniform limestone and confirmed by the measure-while-drilling system. The bits were compared to the average production rates.

A detailed investigation of the production rates of the treated bits produced 48,807 borehole feet over a time frame of 208 operating hours. The untreated bits from the same manufacturer produced 31,282 borehole feet over 192 hours. The parameters of the drill were consistent throughout the test. All bits were tested in the Burlington Limestone Geologic Formation. Results showed a remarkable 1.5× bit life or 55% increase in drill bit reliability.

INTRODUCTION

Drill bits and their production rates are often closely studied in civil explosives, mining production, and quarry applications. The efficiency and lifespan of these critical tools largely depend on their wear resistance and durability. Over the years, the introduction of cryogenic treatment has been debated on whether the treatment increases the performance of drill bits by enhancing their wear resistance and overall effectiveness.

HISTORICAL INFORMATION ON CRYOGENIC TREATMENT AND ITS BENEFITS FOR METALS

Cryogenic treatment is a thermal processing technique that subjects materials to extremely low temperatures, typically below –150°C (–238°F). The process involves gradually cooling the material to cryogenic temperatures, holding it at these temperatures for an extended period, and then slowly warming it back to room temperature. This controlled cooling and warming cycle modifies the microstructure of the material, resulting in several advantageous changes for metals. "The results of CT (cryogenic treatment) is a reduction in material degradation and a possible 3-fold increase in the service life of the treated metallic material" [1]

The origins of cryogenic treatment can be traced back to the early 20th century. Its application in metallurgy began to gain prominence in the mid-20th century. Cryogenic treatment found its first notable industrial application in the aerospace industry, where it was used to improve the performance and lifespan of critical components like turbine blades and gears. [8]

BENEFITS OF ENRICH BITS & TOOLS TREATMENT FOR METALS

There are numerous benefits to metals when treated with a cryogenic process, which have been extensively studied and documented over the years. These benefits include:

Enhanced Abrasion Resistance: Cryogenically treated metals exhibit superior resistance to abrasion and wear, making them ideal for high-wear applications like drill bits. *"The increasing of the hardness and wear resistance in deep cryogenic treatment is related to the conversion of the retained austenite to martensite, more sediment and more uniform distribution of carbides." 6 maybe use this one for tool life below." [7]*

Extended Tool Life: Cryogenically treated tools, including drill bits, demonstrate a longer service life due to increased wear resistance and reduced wear rates. *"DCT (Deep Cryogenic Treatment) provides a significant improvement, up to 25%, in the wear resistance of AISI 431, which is related to the much slower evolution of the wear processes and the reduced coefficient of friction induced by the higher presence of harder microstructural phases (martensite phases and carbides)." [6]*

Improved Corrosion Resistance: Some materials also experience increased resistance to corrosion, which is essential in harsh operating environments. *"The possible mechanism for increase in corrosion resistance has been explained based on Scanning electron micrographs (SEM) and X-Ray diffraction (XRD) study. The morphology of the corroded surfaces of the samples was studied using Atomic force microscopy (AFM). It was found that there is 69 % improvement in corrosion resistance because of deep cryogenic treatment, further it was seen that the increase in corrosion resistance was due to the contribution of increased pearlite phase. Deep cryogenic treatment had no adverse effect on ultimate tensile strength and hardness, which are crucial properties to be considered for rebar." [3]*

Reduced Residual Stresses: Cryogenic treatment helps relieve residual stresses in metals, reducing the risk of cracking and improving dimensional stability. *"The reversed austenite even occurs DIMT behavior under large plastic deformation to further reduce the stress concentration and prevent the initiation and propagation of cracks." [5]*

Better Dimensional Stability: *"Simultaneous enhancement of ductility and strength with higher elastic modulus was obtained for cryogenically treated alloy. Lower carbon content of martensite and higher volume fraction with more uniform distribution of carbides with average diameter below 1 μm made major contributions to mechanical properties improvement" [4]* Cryogenic treatment can enhance the dimensional stability of metals, ensuring reliability in critical applications.

Increased Hardness: Cryogenic treatment significantly enhances the hardness of metals. The process promotes the transformation of retained austenite into martensite, resulting in improved wear resistance and strength. *"..after the cryogenic treatment increasing the hardness of the tool steel and causing secondary carbide precipitation. These are among the most important factors for the improvements in the service life of tool steel." [2]*

FAILURE MODE

Failure modes of production drilling are increased in the field outside of a controlled laboratory experiment. For this study, a typical button bit was implemented over a rotary bit to reduce the number of failure modes. The application of limestone quarry blasting calls for a button bit primarily. The quarry maintained the standard operating procedures during the entirety of the test. This results in the typical failure of three methods.

1. The life of the bit lasts long enough for the carbide buttons to wear flat. This is the best-case scenario for a bit failure and usually results in the target life of the bit.

2. Second, the drill steel becomes lodged into the rock due to failure of the drilling system such as the steel breaks, the air pressure being reduced clogging the necessary release of air to expel the cuttings, or the machine operations causing an irretrievable bit in the hole. This is considered a failure because the bit and the steel likely need to be replaced thus resulting in the end of the bit life production rate.
3. The third failure mode and the most common failure mode for a button bit occur when the "button rolls." This term indicates one of the carbide inserts of the drill bit becomes worn loose from the metallic host that makes up the body of the drill bit. This usually occurs well before the more abrasive-resistant carbide tooth wears flat. The less abrasive-resistant steel body of the bit is worn away by the constant particles of rock that are grinding against the face and the sides of the bit by the cuttings as they are expelled from the borehole. This wear reduces the strength of the bit's body resulting in a button cleanly breaking loose or a fracture along the edge of the bit's face. See Figures 2 & 3.

The third failure mode is the most common in the field and is the target mode for the case study at hand to test if the Enrich Bits & Tools treatment can improve bit life reliability.

MATERIALS

The Drill Bits:

For the consideration of the manufacturer of the bits and to reduce any negative projection of the manufacturer, The producer of the bits and the type will remain anonymous. It is worth mentioning the treated bits used in case studies 1 and 2 are from the same manufacturer. The untreated bits in case study 2 however were not from the same manufacturer. This adds an unwanted variable and in phase two of the study, the bits from the same manufacturer will be utilized and the report will be updated.

Case Study 1:

The Drill: Sandvik Ranger DX800 The Rock: Missouri OG Gasconade Dolomite

Casy Study 2:

The Drill: 2018 Epiroc T45
The Rock: Burlington Limestone Geologic Formation

RESULTS

Case Study 1:

In a direct comparison between treated and untreated drill bits Table 1, the untreated bit produced 4,907 borehole feet before the button roll failure of occurred (failure mode 3). The treated bit produced 12,999 borehole feet before the same failure mode occurred. See Figure 1.

Table 1. Bit life measured in borehole feet.

Treated or Non-treated	Cryo Treated Bit	Non-Treated Bit	% Increase
Footage	12,999	4,907	165%

Case Study 2

At the quarry location, 17,000 feet per bit is average wear before a breakage failure (failure mode 3). This kind of sheer breakage failure occurs in the untreated bits despite which manufacturer is supplying the bits.

While a breakage failure did occur in one of the cryogenically treated bits at the typical production life, the Cryo Treated Bit 2 outperformed the Untreated Bit 1 by 1.55× or an increase of 55%. See Table 2. Combining the performance of the treated bits vs. the untreated bits, the penetration rates of the untreated bits were 163.1 ft/hour. The treated bits had a penetration rate of 234.7 ft/hour. The untreated bits' combined production rates were 69% of the performance of the treated bits.

It is important to note the increase in performance of the second treated bit was only limited by the fact the treated bit was lost in the pattern due to drilling failures described in the failure second mode and not the result of the third mode.

APPLICATION OF ENRICH BITS & TOOLS TREATMENT TO DRILL BITS

The implementation of The Enrich Bits & Tools treatment of button drill bits has yielded remarkable results. Traditional drill bits often suffer from rapid wear, leading to frequent replacements and increased operating costs. By subjecting drill bits to the Enrich Bits & Tools treatment, their wear resistance is significantly improved, resulting in;

Eliminating Downtime. In-pit transportation to restock drill bits is reduced as well as the time associated with replacing the bit. The time associated with a bit change can equate to the cost of a bit in machine availability and the labor costs associated with it.

Job hazards associated with replacing worn-out bits are reduced. While a standard operating procedure is associated with the task, human risk is associated with removing the worn-out bit and lifting and installing the new bit.

Figure 1. Untreated bit with failure at 4,907 ft (left). The treated bit with 12,999 ft (right) from the same manufacturer

Figure 2. Side view of Treated Bit 1 with breakage failure

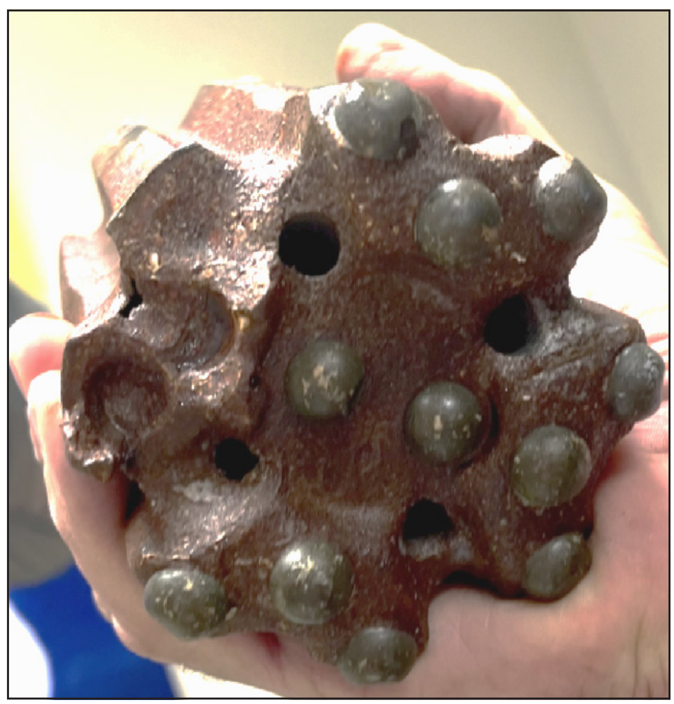

Figure 3. Face view of Treated Bit 1 with breakage failure

Table 2. Measure-while-drilling results and drilling data

Treated or Non-treated	Treated Bit 1	Treated Bit 2	Non-treated Bit 1	Non-treated Bit 2
Days in use	20	40	24	16
Footage	17,604	31,203	17,175	14,107
Holes	541	1,306	446	452
# of Blasts	5.75	6	4.5	4
Avg Drill (ft/hr)	226	230	242	250
Avg Fuel Conservation (g)	40.47	41.13	41.06	41.02
Feed Pressure (bar)	14.5	15.2	15	14.7
Rotation Pressure (bar)	46	51	48	45
Operating Hours	77.5	130.44	63.04	128.75
Burlington LA Abrasion	47.5	47.5	47.5	47.5
Burlington Formation Density (g/cc)	2.23	2.23	2.23	2.23
Comments / Failure mode:	Bit broke	Lost steel & bit	Bit broke	In use - end of bit life

Depending on the size and weight associated with a drill bit, a crane is necessary. For this case study, the risk is less of a factor.

Cost Savings: Reduced replacement frequency and improved efficiency translate into substantial cost savings for industries relying on drill bits.

Enhanced Precision: It is currently not proven in the field but testing is underway to measure if the advanced cryogenic treatment contributes to better-increased drilling accuracies due to the dimensional stability of the bit. The factors of the rock such as bedding planes likely play more of a role in the drilling accuracies. Additionally, drilling pressures and routine maintenance can impact accuracies which could also play a larger role in the accuracies of boreholes for blasting. Future tests would be to match borehole accuracy per footage to see if a correlation exists.

Environmental benefits: As the world's resources are growing more and more scarce, the pressure and need to be more efficient is essential. The consumerism driving the economics of the world today is not slowing down and the need to provide more environmentally friendly options is growing. The application of advanced cryogenics in production drilling can reduce an operation's need for bits in half. This cuts down on the carbon footprint of a single bit looking at the supply chain of transporting a bit from a smelter overseas to reducing the need for the raw iron and coal associated with its production in the first place.

CONCLUSION

The advanced cryogenic treatment from Enrich Bits & Tools has evolved from its origins in preservation to become an indispensable tool for enhancing the performance of drill bits and wear parts. By improving wear resistance and extending the lifespan of drill bits in the OG Gasconade Dolomite Formation and the Burlington Limestone Formation, cryogenic treatment has proven to be a valuable tool to reduce downtime, cut waste from expended drill bits, and increase reliability by a factor of 165% in highly abrasive rock and 55% in limestone. Cryogenic treatment has been proving beneficial to quarry operations. Continued testing in various rock masses and with alternative bit manufacturers are ongoing to enhance statistical results with the potential to reduce drilling wear costs by half.

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Challenges of Design and Fabrication of Fiber Reinforced Polymer (FRP) Flanges—A Review

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ABSTRACT

Fiber Reinforced Polymer (FRP) is an excellent material choice for a broad spectrum of corrosive fluids and, in many cases, offers the best value per dollar. FRP Flanges present the greatest design challenge of all standard piping components. The theory underlying the design of flanges is very complex. In addition, due to the nature of FRP material, proper fabrication of the flanges is as critical as the design. In this review, the challenges of making FRP flanges along with the design techniques and best practices of fabrication that will lead to a high-quality flange will be discussed.

RPS COMPOSITES

With over 45 years of experience, RPS Composites is a leading provider of composite pipe and vessel solutions for a wide range of industries, including mineral processing, chemical processing, power generation, and marine applications. Their expertise is underpinned by three flagship FRP manufacturing plants, strategically located to optimize production and delivery schedules. Committed to safety and service excellence, they deploy Field Service teams across the US, serving Fortune 100 industrial manufacturers and processors. RPS also plays a significant role in the energy transition, supporting projects related to hydrogen production, EV battery recycling, and carbon capture and storage, aligning with the growing demand for critical minerals. With a strong presence in North and South America, they have earned a reputation for the superior performance of their FRP piping, tanks, and vessels, securing major projects and offering both supply and installation services to their clients.

FIBER-REINFORCED MATERIAL VS. STEEL

In the dynamic worlds of mining and chemical industries, the choice of materials for pipes and tanks plays a key role in the success of operations. Traditionally, steel has been the go-to material for these critical components. However, in recent years, FRP has emerged as a formidable alternative. This section explores the advantages of using FRP pipes and tanks compared to steel counterparts:

1. Corrosion Resistance

One of the most significant advantages of FRP pipes and tanks in mining and chemical industries is their excellent resistance to corrosion. Chemical processes, aggressive chemicals, and high humidity levels in mines can rapidly degrade steel, leading to maintenance headaches and safety concerns. FRP, on the other hand, is resistant to corrosion, offering a longer service life.[1,2]

2. Lightweight

FRP pipes and tanks are notably lighter than their steel counterparts. This weight advantage could be beneficial, particularly in the mining industry, where the ease of transportation, installation, and reconfiguration is vital. Lighter FRP components could simplify logistics, and make handling in remote or challenging locations more manageable.[3]