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AN OVERVIEW

OF

MECHANICAL DESCALING OF STEEL WIRE ROD

Mechanical Descaling as a current-day manufacturing process for removing mill scale from steel rods includes processing by:

- Reverse Bending Deformation
- Shot-blasting
- Combinations of Reverse Bending and Blasting

The MD process can be performed by processing rod bundles:

- In-line with the wire drawing machine
- By batch, and transported to a wire drawing machine.

This presentation will focus on the MD process as accomplished by reverse bending deformation performed in-line with a wire drawing machine---the most widely used production method for mechanical descaling.

The points to be covered are:

- Basic principles of the mechanical descaling process
- Brief history of the MD process
- Current status of the MD process
- Equipment to perform the MD process
- Systems approach to successful MD

Basic Principles of the MD Process

The Mechanical Descaling process is based on the principle that steel wire rod is ductile and hot-rolled scale is brittle. When the rod is deformed, the steel bends, but the hot-rolled scale breaks and, provided the scale is there in sufficient quantity and provided the deformation is sufficient, the scale will release from the surface of the rod and fall away. The deformation mode is principally bending, but may also, importantly, include stretching deformation.

What makes Mechanical Descaling a production process is the availability of equipment that will use the foregoing principle in a controlled manner to get consistent results of scale removal without unduly affecting the properties of the wire rod being descaled.

Of the key factors affecting the Mechanical Descaling process, the amount of total wire rod deformation is one of the most important. Early on in development of MD, it was determined in laboratory development that the optimum amount of rod deformation for essentially complete scale breaking is 8%-10%. Less than 8% could result in incomplete scale breaking, leaving patches of adherent scale, and more than 10% did not accomplish any additional scale breaking, while at the same time adding an undesirable amount of work hardening to the steel. An additional undesirable effect of heavy deformation (much greater than 10%) is increased back tension on the rod line which can stretch and neck-down the rod, affecting wire drafting schedules and requiring more horsepower from the first block to pull the rod through the descaling system.

The 8-10% deformation goal is controlled by the relationship between the size of the sheaves used to do the reverse bending and the size of the rod being processed. As mentioned earlier, the added issue of rod stretching is also an important consideration. Elastic stretching can add to the effectiveness of the descaling process while excessive plastic stretching can have undesirable affects as previously noted.

As to the matter of how much reverse bending, the balance to be struck is just enough to break the scale over the entire rod surface without causing undue rod work hardening and excessive back tension.

With WILCO equipment, we have determined through development and field production tests that a three-sheave scale breaker configuration is optimum. In the three-sheave configuration, the middle sheave is at 90 degrees orientation to the entrance and exit sheaves. This results in the rod surface being bent in alternate planes, thereby covering the entire surface. The total wrap the rod sees when passing over these three sheaves is a minimum of 360 degrees and this can, through adjustment of the rod entry and tensioning guide, be increased to about 400 degrees.

More than three sheaves and more total wrap has a similar effect as more than 10% rod deformation---unnecessary rod work hardening, excessive back tension, and the requirement for more horsepower from the first block of the wire drawing machine.

So the scale breaker, although outwardly appearing as a very simple, straightforward piece of equipment, actually has very concrete design parameters that must be satisfied in order to have balanced descaling performance where the scale is broken off while not resulting in undue side effects on the rod.

Proper equipment designed in accordance with the basic principles of the scale breaking process is one key factor in accomplishing successful mechanical descaling. Another key factor is the rod quality and specifically, the nature and extent of the scale on the rod that is to be processed.

In chemical cleaning, the best hot-rolled rod is rod that has a bare minimum of scale. Rod suppliers, by controlling rod-rolling variables, particularly cooling, can minimize the

amount of scale formed during the manufacturing process to enhance acid cleaning. A typical level of scale for rod that is to be chemically cleaned would be about 0.25% by weight.

For Mechanical Descaling, a different level of scale is required. An example may help illustrate: imagine a bare length of steel rod that is coated with a layer of paint. After drying and when bending the rod, the paint might crack, but would continue to adhere to the rod surface. As this procedure of painting, drying and bending continued, the thickness of the paint layer would increase until a thickness was reached where the paint would begin "popping off". This is what happens with scale on steel rod. There is a minimum thickness of scale that is required for scale breaking. That thickness is usually best defined by a weight percent of scale present. For best Mechanical Descaling, the scale level on the rod should be at least 0.50% and the range of 0.50% to 0.75% by weight is considered good commercial standard. This is not to say that rods with scale below 0.50% or above 0.75% cannot be used---it is just that the range 0.50%-0.75% by weight is the best for consistent overall production results. Scale below 0.50% can have a tendency to not break off completely and scale above 0.75% wastes steel.

Rod manufacturers are typically well aware of this desired scale level on rod for MD, but it is the wise user of rods who, when ordering material from their supplier, specify that:

1) the rod will be used for Mechanical Descaling
2) the scale level should be 0.50%-0.75% by weight.

Another aspect of rod scale that is a key factor in the MD process is the nature of the scale. Ideally, the scale will be all lustrous metallic gray, and break off leaving a silvery gray matte steel surface. In the real world, that is not always the case. Secondary scale can form during the rod manufacturing process. This results in a condition where, after primary scale is broken off, there remains a dark, sooty-appearing secondary

scale. This is an undesirable condition. The presence of secondary scale can cause serious productivity problems such as rapid die wear as well as finished wire quality problems. If the quality requirements for the wire being made by the wire manufacturer

require the removal of all secondary scale in the rod preparation process, then this has a definite effect on the type of Mechanical Descaling System chosen for rod prep. For example, this would call for an aggressive cleaning Mechanical Descaling System as compared to a lower operating cost, non-aggressive system.

One last point on rod condition that affects MD involves surface rust. Red rust on rod can usually be tolerated depending on:

- Extent of Rust --- surface vs. pitting-type
- Descaled rod quality requirements
- Finish wire quality requirements

If it is tolerable in the wire product to have some slight surface staining, then a not too heavily rusted rod can be processed through the most economical, non-aggressive MD equipment.

If the wire product is to have a clean, bright surface without any red rust staining, then a more aggressive descaler, for example a brushing-type unit would need to be used. Under any event, deep pitting-type rust should be avoided since rods with this condition are not capable of complete clean-up during descaling—in fact, even acid pickling would not be able to deal with that kind of rod surface.

So to summarize the basics of the scale breaking part of MD:

Equipment Design

- 8-10% total deformation of wire rod
- Principally bending deformation with some stretching
- 360-400 degree total sheave wrap for rod
- Balance scale breaking vs. other side effects

Rod Condition

- Scale level of 0.50% to 0.75% by weight
- Minimum secondary scale
- Minimum surface rusting

Brief History of the MD Process

Wire manufacturers have been aware of the MD process for over 50 years; however, a proper understanding of the process and commercial incentive to use it has really occurred in the last 25-30 years.

Initial interest in the MD process was associated with the manufacture of low price, low profit margin, common steel wire products with very modest quality requirements. For these types of wire products, rod preparation was considered not too critical, with low cost being the main objective. Coarse scale breaking only was considered sufficient for most applications. Equipment used for MD was, in many cases, homemade and crude with open arrangements of sheaves common including, in some cases, the use of used auto wheels as sheaves.

The process was determined to be economically viable for producing high volume wire products such as galvanized wire and Mechanical Descaling became standard practice in many operations. As a result, a need developed for better control of the MD process and this represented a business opportunity for commercially available MD equipment. Equipment suppliers responded. Included was Wire Lab Company, which was formed

33 years ago for the main business purpose of taking laboratory concepts and equipment and refining that into commercially viable, production MD equipment.

In looking at an overview of MD equipment development, the following steps occurred in the approximate order shown:

1950's Coarse Scale Breaking
Scale Residue Removal
Scale Waste Management
Aggressive Rod Processing
1990's Rod Cleaning and Coating

A review of these show that the main driving force is an increase in the level of quality of the prepared rod—quality generally defined as cleanliness and more recently defined as essentially equivalent to acid cleaned and coated rod.

Coarse Scale Breaking

We have considered scale breaking and the factors that affect it. From the standpoint of equipment, scale breaking has advanced from crude open sheave units that broadcast scale throughout the work area to compact, enclosed equipment that performs the scale breaking job while largely containing the coarse scale that is generated.

Scale Residue Removal

A properly designed scale breaker, processing rod made for MD, will break loose essentially all of the hot-rolled scale. In doing so, 80-90% of the coarse scale falls from the rod and collects in the scale breaker. The remaining 10-20% of scale, although loose, continues to cling to the rod surface. This is a fine, powdery residue that is held on the rod by electrostatic charge. If not removed, this residue will cause problems

such as contaminated lube boxes, reduced die life, rapid draw block wear, poor wire quality and an overall reduction in productivity.

The undesirable results of leaving fine scale residues on the descaled rod surface were recognized early on. Initial attempts to remove this were fairly crude, including such methods as tying wiping rags on the rod line, or looping heavy hemp rope over the rod—hardly production processes.

From a WILCO perspective, fine scale removal modules were developed as production equipment. One concept of cleaning is with high velocity air jets and another uses a water wash/air dry-on-the-fly approach. Both methods not only remove the scale residue but also, importantly, contain it, so fine scale is not broadcast in the work area. This also makes for easier subsequent disposal.

It should be recognized that there are a number of key objectives to be met in production equipment for non-aggressive cleaning of scale residues from descaled rods. Equipment should:

- Remove the residue using industrial techniques
- Contain the removed material
- Require minimum operator attention
- Require minimum on-going maintenance
- Have operating costs less than $1/ton

There have been many attempts made at residue cleaning, but by far most fall short when judged by all of the above objectives—a limited number survive and are used today.

Scale Waste Management

The traditional broom-and-shovel approach to dealing with scale from a mechanical descaling operation is still in use today. However, in-plant environmental considerations are causing many producers to look at more mechanized approaches to scale waste handling. Motivation is two-fold, first the goal of making the plant a cleaner environment for employees and second to minimize contact of very abrasive and electrically conductive scale with other processing machinery where the scale will cause maintenance problems. Considering that a wire processing line using MD can generate several hundred pounds of scale per day, it doesn't take many lines before managing the scale generated becomes a very real consideration.

The key objectives in equipment to manage scale waste are similar to those for residue cleaning. Collection equipment should:

- Efficiently collect coarse and fine scale residues
- Contain those residues
- Require essentially no operator attention
- Require minimum on-going maintenance

WILCO equipment development efforts have resulted in a unit that will reliably accomplish these objectives. A scale collection system is available which will collect and contain coarse scale removed in a scale breaker, and scale residues removed by a cleaning module such as an Air Jet Cleaner or an Automatic Rod Brusher. The unit uses nine cartridge filters which are cleaned on an automatic preset cycle using a reverse pulse of air.

This basic piece of collection equipment can have the added feature of a built-in vacuum cleaning system added to it. This added feature provides the capability to vacuum up the work area within a 50-foot radius of the collection equipment.

There are other approaches to collecting scale, such as conveyors, endless screws and other such mechanical devices; however, experience teaches that abrasive scale will quickly take its toll on equipment with mechanical moving parts which are continuously exposed to the scale. As a result, high maintenance requirements are normal for these type units.

Aggressive Rod Processing

A considerable amount of MD is done using non-aggressive techniques for rod preparation. However, as the production goal and need has called for cleaner, brighter wires, there has been an increased need for aggressive rod cleaning techniques.

The traditional, most widely used technique has been to use steel wire brushes as a cleaning medium. More recently, the use of sanding media has entered the picture. In all cases, the purpose of aggressive cleaning is to enhance rod surface cleanliness by removing red rust or residual scale---either patches of primary scale or secondary scale.

There are a number of important objectives that should be met if aggressive cleaning equipment is to be viable in production. These are:

- Cleaning media should be readily available, standard industrial items
- Cleaning media should not “disturb” rod surface
- Equipment should be self-adjusting, minimizing operator attention
- Equipment should need a minimum of on-going maintenance
- Cleaned rod should readily pick up drawing lubricant

There have been numerous types of aggressive cleaning machinery developed to perform the cleaning task. Most have been based on brushing. Many have appeared as apparently good production solutions to aggressive cleaning; however, they haven’t stood the test of production line use, falling short in one or more of the important objectives noted above.

At WILCO, we have developed a brushing module that meets the stated objectives and at the same time requires only about three feet of line space.

The unit uses eight brushes that run perpendicular to the direction of rod travel. A brush pressure is selected and the controls maintain that pressure by automatically adjusting for brush wear. Residual brush marking is around the circumference of the rod, thereby aiding lube pick-up.

One of the most significant reasons for employing aggressive rod cleaning is that it allows the surface quality of the input rod to vary, while the processed output rod is a uniform, cleaned condition and the more consistent the rod, the more consistent the finished wire product.

Rod Cleaning and Precoating

A more recently developed area of MD rod processing is rod cleaning and precoating.

In approximately the last ten years, lubricant suppliers have made available a wide variety of precoat compounds designed specifically for MD rods, low carbon through high carbon, applied by batch processing or in-line processing.

The utility of the precoats is two-fold. First to assist and enhance lubricant pick-up and second to serve as some protection for the bare steel rod surface, supplementing the overlaying lube film.

These precoats are typically incorporated into hot water (185-195° F.), applied to the rod surface as a hot fluid and then necessarily dried before entering the ripper draft. Precoat concentrations can be from 15% up to 40%.

The WILCO offering in precoaters is a combination cleaner and precoater module that works in-line with a WILCO Scale Breaker and/or a WILCO Rod Brusher. Descaled rod is washed of scale residues with the hot precoating fluid that is constantly recirculated. The recirculating fluid is continuously cleaned of the scale residues by a magnetic filter. The exiting rod is instantly dried using a specially engineered air-operated, drying nozzle. Rod line speed can be as much as 800 fpm but more typically is usually 300-400 fpm.

Current Status of the MD Process

As previously shown, the evolution of the MD process has been generally according to the following steps:

1950's	Coarse Scale Breaking
	Scale Residue Removal
	Scale Waste Management
	Aggressive Rod Processing
1990's	Rod Cleaning and Coating

Currently, a wire producer can use scale breaking and only some of these additional process steps, or all of them collectively, to satisfy the rod preparation requirements of the application. There are clearly many choices that a wire producer has when selecting MD equipment---both technical and economic (cost of machinery).

MD equipment decision is, in the main, driven by the quality requirements for the wire being manufactured. The following listing illustrates many of the variety of wire products being made in which the MD process is used for rod preparation. Increased wire quality requirements typically call for MD systems that are increasingly aggressive and/or sophisticated---and the more sophisticated the MD system, the more the cost per ton of rod processed and the more costly the equipment.

Bale tie wire	Stitching wire
Barbed wire	Threaded rod wire
Chain link fence	Chain wire
Field fence	Steel wool wire
Lawn & garden fence	Screen wire
Stick electrode wire	CO2 welding wire
Tie wire	Collated nail wire
Cold heading quality wire	Mechanical spring wire
Rivet wire	Bedding & seating wire
Bulk nail wire	Lacing wire
Welded mesh	Hose reinforcement wire
Wire reinforcing forms	Plating quality wire
Coat hanger wire	Music wire
Galvanized wire	Steel cord wire
Staple wire	Rope wire
Tire bead wire	Piano wire

In reviewing this listing, a significant fact becomes obvious. The MD process has evolved to the point where just about any kind of wire can be produced using the MD process. It would, however, be an over simplification to imply that the correct MD equipment choice is the only factor assuring wire production success. There are many other variables in the wire drawing process that contribute to and have an influence on the production success. These will be considered later.

Equipment to Perform the MD Process

So, we have seen how the evolution of the MD equipment allows the user a broad equipment choice ranging from very basic to fairly sophisticated equipment. Further perspective on this range of choices can be obtained by reviewing the various WILCO systems.

All WILCO systems use the same scale breaker and, in a very limited number of applications, the scale breaker is used as a stand-alone module, however as previously noted, this is not recommended practice since scale residue should be removed from rod after breaking.

The current WILCO family of mechanical descalers includes the following:

- Model 920 Air Jet Descaling System
- Model 1030 Water Jet Descaling System
- Model 1060 Mechanical Descaling/Precoating System
- Model 1250 Automatic Brush Descaling System
- Model 1750 Automatic Brush Descaling/Precoating System

Each system is designed to process low through high carbon rods, .218 inch (5.5mm) diameter through .500 inch (12.7mm) diameter. The operating characteristics and capabilities of each of these systems is as follows:

Model 920 Air Jet Descaling System

This most basic system cleans scale residues from the descaled rod using an air jet cleaner module. The air jet cleaner uses compressed air directed through two specially engineered tubular air nozzles to strip away scale residues while at the same time creating a vacuum at the entrance and exit of the unit so that none of the air/scale mixture can escape to the work area. The residues removed are captured in a reusable filter.

The unit is a non-aggressive mechanical descaler requiring about six feet of line space and can process dry rod of moderate quality at a cost-per-ton of steel processed of well under $1/ton.

Model 1030 Water Jet Descaling System

The Water Jet Descaler does a very similar job as the Air Jet Descaler except that the unit is capable of processing rod which is wet from outdoor storage. Scale residue is removed from the descaled rod by a combination of high-volume water wash and compressed air drying. The water system is a recirculating closed loop and scale is continually removed from the cleaning water by a magnetic filter. Rod drying is accomplished with a special tubular nozzle that completely surrounds the rod surface with high-velocity compressed air jets. This descaler will process rod for just under $1/ton.

Model 1060 Mechanical Descaler with Precoating

The Model 1060 is designed for use by wire manufacturers who need a mechanical descaling system that will descale, clean and apply a precoat to rod for use in producing higher surface quality wire products, or more difficult-to-process materials such as high carbon, or longer multiple draft practices.

After scale breaking, rod cleaning is done using a cleaning/precoating solution at 185-195° F. This simultaneously cleans and coats the rod. The recirculating solution is continually cleaned of scale residues with a magnetic filter. Drying of the rod is accomplished with a special tubular air nozzle which removes excess precoat and instantly dries the coating on the rod.

The Model 1060 will descale and prepare a ton of rod for $3.50-$4.50/ton.

Model 1250 Automatic Brush Descaling System

The Model 1250 is an aggressive mechanical descaling system which, after scale breaking, cleans the rod surface using eight steel wire brushes. The aggressive cleaning of the brushes permits use of input rod of varying surface quality, while yielding consistent, uniform cleaned exit rod.

The brushing module is completely automatic, having unique controls in which the operator selects one of three pre-programmed brush pressures (low, medium or high) based on the rod condition to be cleaned. Then, the PLC-based controls monitor the brushing operation and automatically adjust brush pressure to maintain the desired brush pressure selection. In addition to cleaning the rod, the unique design of the equipment results in residual brush marks which are circumferential to the rod and therefore aid lubricant pick-up.

The entire system is very compact requiring less than six feet of line space.

The Automatic Brush Descaling System will process a ton of rod for about $3-4 a ton of rod processed.

Model 1750 Automatic Brush Descaling System with Precoating

The Model 1750 combines reverse bend descaling, automatic rod brushing, along with cleaning and lubricant precoating to produce a mechanically descaled rod for the most demanding wire drawing applications. This system is typically used for applications requiring a high degree of surface cleanliness and with, for example, difficult-to-draw material such as high carbon. The entire system is quite compact requiring only 108 inches or 9 feet of line space.

The Model 1750 will mechanically prepare rod at a cost well below $10/ton.

Systems' Approach to Successful MD

Up to this point, we have reviewed the technical aspects of mechanical descaling and the features and capabilities of the broad range of MD equipment available to perform

the rod preparation process. Also noted was the significance of having the proper rod including the right amount of hot-rolled scale and a minimum of surface rust and secondary scale.

Although equipment and rod are both key contributors to the success of the MD process, they are by no means the entire answer. The right equipment processing the right kind of rod is only the start.

Many other variables enter into the overall process of manufacturing steel wire and each, in its own way, has an effect on the success of the process---success as defined as the right wire quality and optimum productivity. As a consequence, a systems' approach when introducing or using the mechanical descaling process for manufacturing steel wire is highly recommended to get optimum results.

Among the other variables that affect the wire drawing process are:

- Lubrication
- Use of wire drawing aids
- Drawing die geometry
- Use of pressure dies
- Die box cooling
- Draw block cooling
- Drafting schedule
- Drawing speed

The entire wire drawing process needs to be viewed as an interrelated set of variables, all of which, as a whole, represent a “system”.

It is important that the wire manufacturer recognizes this and causes an overall analysis of these points, causing the question to be asked “Why do we do it that way?” All too often, the answer is “because we’ve always done it that way”. This is especially true when a manufacturer is faced with a changeover from acid cleaned and coated rod to mechanically descaled rod.

The shortcut answer to that changeover is “get a good mechanical descaler and put it in line and away we go.” That, unfortunately, is a recipe for many problems.

The studied answer to the question of changeover is to review the variables, analyzing each individually, improving each as the need is identified. Experience shows that leads to a highly successful changeover.

An actual industrial experience serves to illustrate the point. A Midwest wire manufacturer was using cleaning and coating as a method for rod preparation. The local environmental authorities declared the facility to be totally out of compliance and that there were two choices, the first being to put it in compliance at an expense of about $250,000.00, or the second to shut it down. The choice was to shut it down and completely switch the operation to mechanical descaling.

Initially, there were many problems associated with the changeover and productivity suffered; however, an aggressive Plant Manager continued to urge his people to analyze the wire drawing process variables and upgrade each as they identified areas for improvement. As a result of this continuing analysis, review, and improvement process, a little more than a half year into the changeover, improvements made in all of the interrelated wire drawing variables had the net result of a 25% increase in

productivity when using mechanically descaled rod as compared to when using cleaned and coated rod. It was the Plant Manager's conclusion that when they were using cleaning and coating, that rod preparation process masked many other deficiencies while still providing a reasonable, but not outstanding, productivity. When the changeover to mechanically prepared rods occurred, it created a production environment where they had to analyze and review all the key factors of the wire drawing process. This analysis and the subsequent improvements resulted in the 25% increase in productivity.

So, it is highly recommended that when incorporating or using the MD process, that a systems' overview be taken. Such a self-analysis can, at times, be painful, but experience shows that the end result is to assure the success of the MD process and ultimately, the successful production of wire, which we have to remember is what this is all about.