Hidden advantage

John Stowe investigates a little known finishing process that is widely used among the top racing powertrain producers

There is a normally "undisclosed" metal-finishing procedure that is shared by top Formula One teams, international sports car competitors, and leading competitors in NASCAR's Grand National, Busch, and Race Truck series. Astute engineers routinely specify this process to be used with all manner of engineered driveline components prior to DLC coating. The U.S. military calls out for this methodology to be applied to gearbox components used in high performance helicopters. Formula One offshore racers, WRC competitors, and competition off-road machines use this process as well.

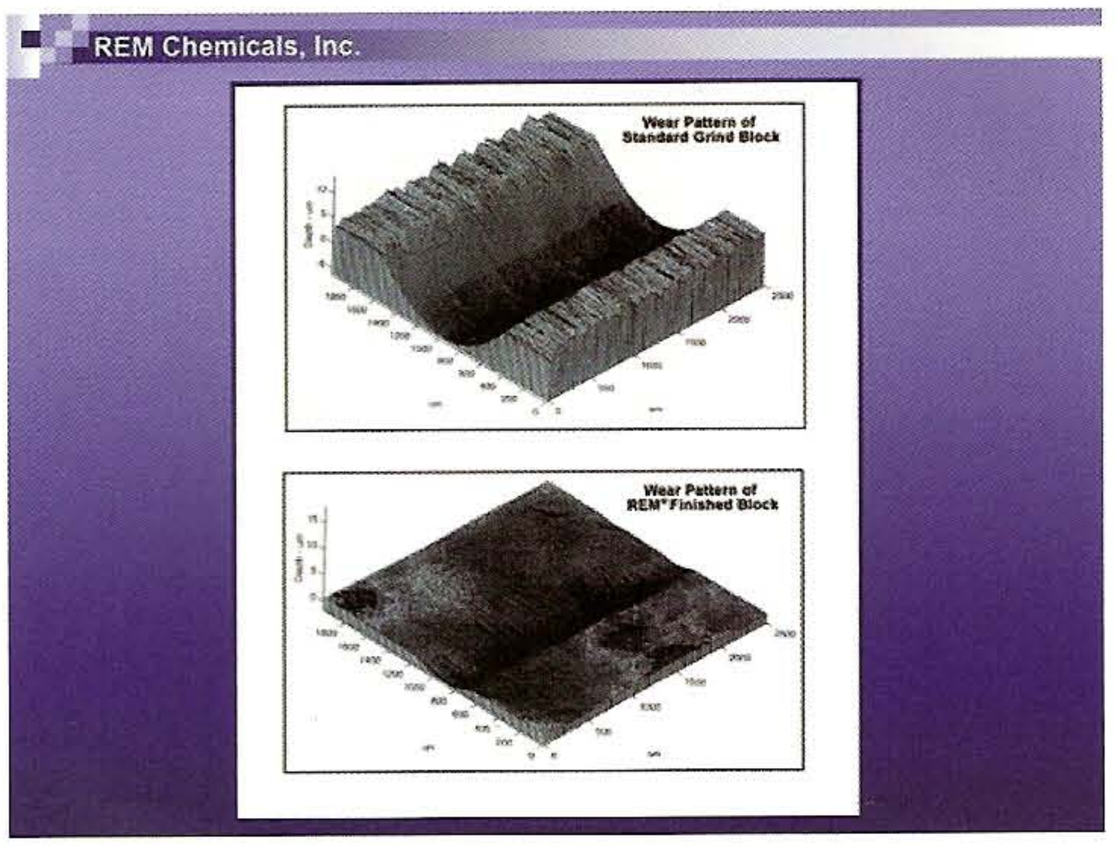
In general, when demanding applications require reduced friction, noise, and heat, combined with improved strength and wear resistance, this technology is found with increasing frequency. Yet virtually no one outside of the select group of engineering professionals that occupy these specialized industries has heard of the procedure, and even fewer still are aware that it is accessible to anyone who wishes to avail himself of it.

The process is called Isotropic Superfinishing (ISF), a relatively new, but well-established, technology used to produce ultra-fine finishes on stainless-steel, titanium, high-density carbide steel, high-alloy steels, as well as soft steels. Of course, super finishing itself is not new; conventional super finishing technologies that utilize various abrasive media have been with us for a long time, and can produce quite smooth surfaces, at least to the naked eye. The ISF method, by contrast, is largely a chemical process that is nonabrasive in nature, and as a result, confers a range of beneficial properties that go far beyond friction reduction. The company that has originated this technology is REM Chemicals, Inc, which has been involved with metallic surface treatment and cleaning since the mid-sixties.

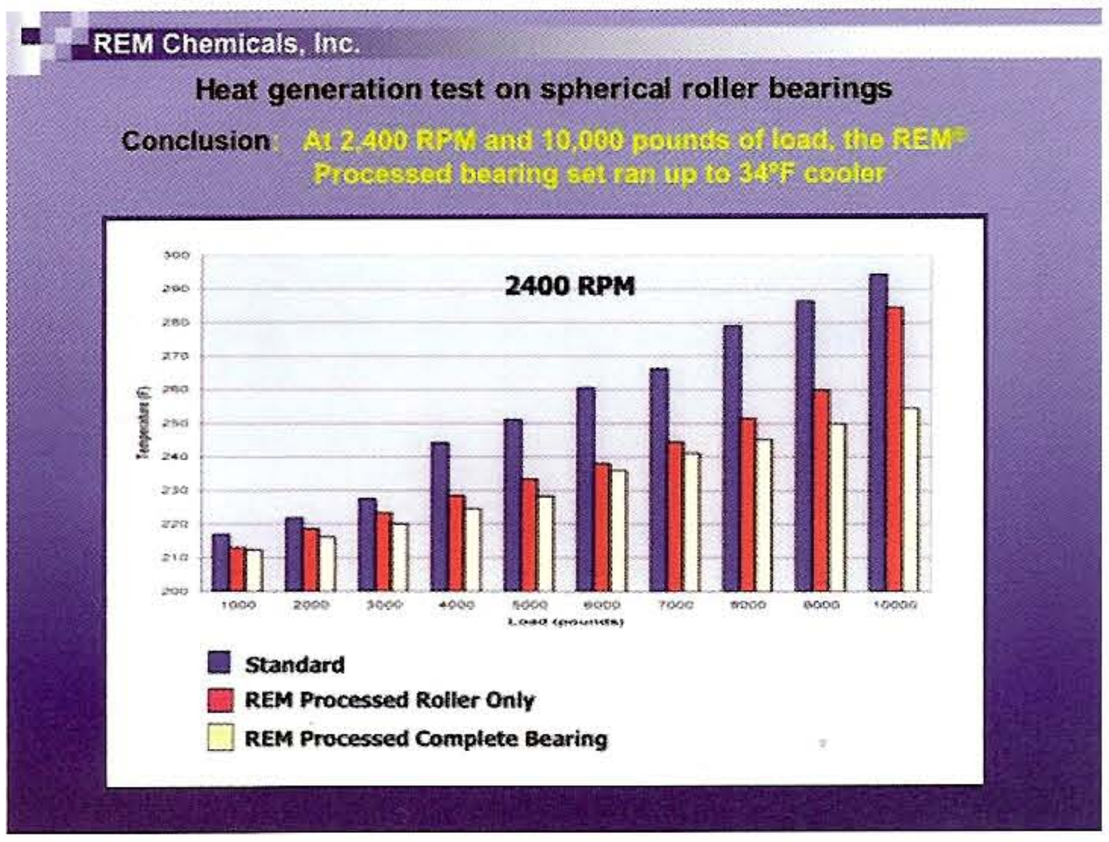
HOW THE REM PROCESS WORKS

Race Engine Technology visited one of the REM plants in Southington, Connecticut, to observe the process in person, and meet with Mark Michaud, president of REM, along with his technical staff. "The ISF process was developed through the 1980s, to some degree as a result of a fortunate accident," recounts Mr. Michaud. "Today, we finish gears, crankshafts, bearing journals, camshafts, tappets, and a wide variety of special applications for customers around the world."

In addition to the automotive industry, REM has a large group of aircraft-related, and other high-technology customers as well.



Block on Ring wearing pattern



Bearing Heat Generation Graph

"Extensive testing and analysis shows that abrasive techniques can never equal the finished characteristics of an ISF chemically treated part," explains Mr. Michaud. The reason becomes evident when a surface is viewed under high magnification. No matter how smooth appears the polished surface of, for example, a crankshaft journal it is actually riddled with a myriad of sharp, directional, peaks and valleys left by the very grinding and polishing procedures that produced it.

The peaks are referred to as "asperities", and these constitute one of the causes of friction and lubrication breakdown in mechanical systems. Each peak essentially attempts to "puncture through" the molecules that form the lubricating barrier. Because the entire face of a conventionally finished surface is populated by these tiny peaks, the actual amount of working contact surface area is relatively small. The valleys represent another problem altogether; these are, in effect, sharp "micro scratches" that can become stress risers under extreme circumstances.

Parts finished by the ISF method are finished in vibratory bowls using media that is shaped much like standard abrasive media, but here the "stones" (media) are not abrasive and are simply used to bring controlled amounts of the chemical solution into contact with the surface of the material being treated. It should be noted here that the process appears to be surprisingly "dry" during the vibratory stage; only enough solution is introduced into the vibratory bowl to wet the stones and the surface of the components being finished.

At this point, a chemical replacement reaction occurs between the solution and the parts, which results in a soft "smudge", which

"The stones are simply used to bring the chemical solution into contact with the material"

"Each cycle takes a little bit more off the peaks, and eventually creates an extraordinarily flat surface"

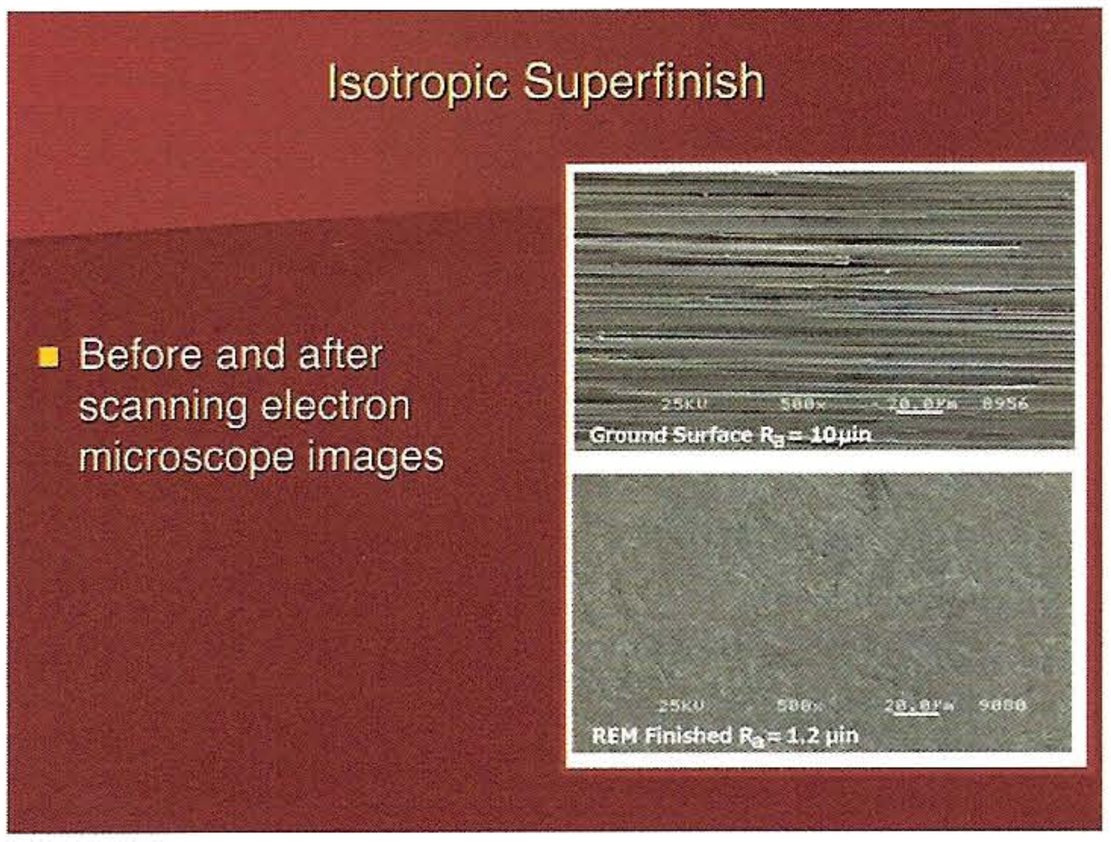
is in turn carried off by the rubbing action of the media. Each cycle of reaction and removal takes a little bit more off the peaks, and eventually creates an extraordinarily flat surface. The process is completed by the introduction of a neutralizing/ burnishing fluid, and the resulting surface has a lustrous, chrome-plated appearance, even though there is no chemical change to the component parts whatsoever.

During the RET tour of the vibratory finishing facility, I noticed the large variety of specially shaped media being used, and was told that different "media mixes" can be adapted for virtually any shape. Later on, I saw a display of ISF finished parts ranging from tiny, watch-like gears and bearings to large jet engine turbine blade hubs.

ISF CHARACTERISTICS

Parts finished by this method typically lose only about .0001" from the finished face, with a surface smoothness of less than 4 micro inches (it is possible to achieve approximately 1 micro inch). In fact, the process, and the amounts removed, can be controlled completely, and there are some customers that do not have the valleys removed entirely for their own proprietary reasons, while others finish it even further to achieve secondary benefits.

Some designers take advantage the consistency of ISF process control, and compensate for the slight amount of material removal in the manufacturing stage, which allows them to achieve the precise desired net-shape size in the final component after ISF is ▶



Electron Microscope Comparison

REM CHEMICALS, INC

REM was founded in 1965, and started life as a producer and supplier of advanced cleaning solutions, primarily for metals. In the late seventies, REM began to experiment with the combination of chemically accelerated cleaning with abrasive mass-finishing techniques, such as vibratory bowl finishing. This methodology is still highly effective, and is used with zinc and copper-based alloys for decorative finishing, and engineering applications that require very smooth surfaces.

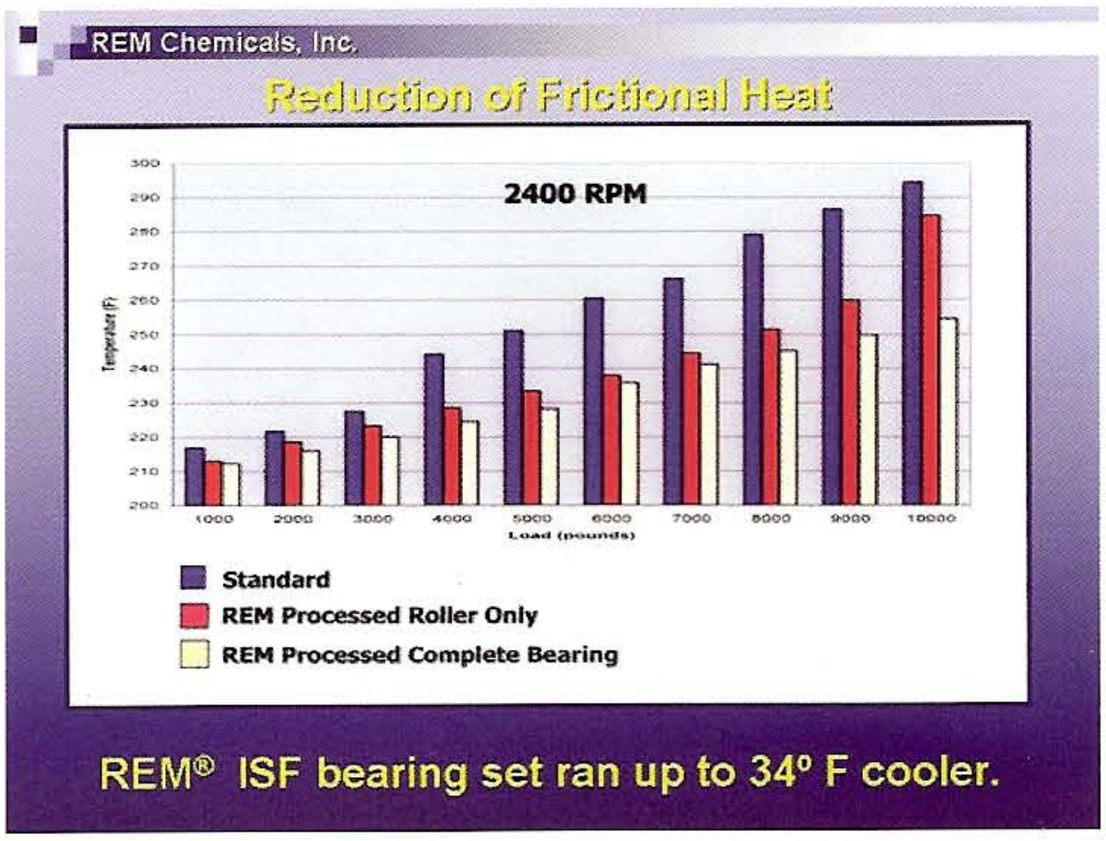
By the late eighties, REM had refined this technology to the point where it was no longer necessary to use an abrasive component at all, but just a delivery and removal system, thereby creating the Isotropic Superfinishing process for steels, nickel alloys, and titanium.

The company also has a global partnership with Rosler GmbH for the supply of mass finishing equipment. REM engineers sell and install finishing equipment manufactured by Rosler, ranging from single vibratory bowl units to fully automated turn key finishing factories. Available equipment includes shot blasting systems, vibratory finishing systems, drag finishing systems, material handling systems and waste treatment systems.

Today, REM offers a full range of surface engineering capabilities. These include testing and analysis of materials for ISF suitability, along with complete application engineering services. In addition to the already mentioned finishing systems and equipment available, REM also supplies the nonabrasive media for ISF.

Job shop work can be performed at any REM facility, or at one of its licensees, where the ISF process is FAA certified for aircraft applications. REM also has a complete line of abrasive materials and equipment that has been developed for the variety of nonferrous and decorative finishing services they offer.

REM has three locations: REM Chemicals, Inc., Southington, Connecticut, (USA), REM Chemicals, Inc., Brenham, TX, (USA), and REM Europe, Sandy, Bedfordshire, England. There are also 15 Distributors in 13 different countries, and numerous independent sales representatives worldwide.



Bearing Graph on Reduction of Friction

applied. The most obvious improvement to the component will be the reduction in friction caused by the ultra-smooth surface, but the benefits do not stop there.

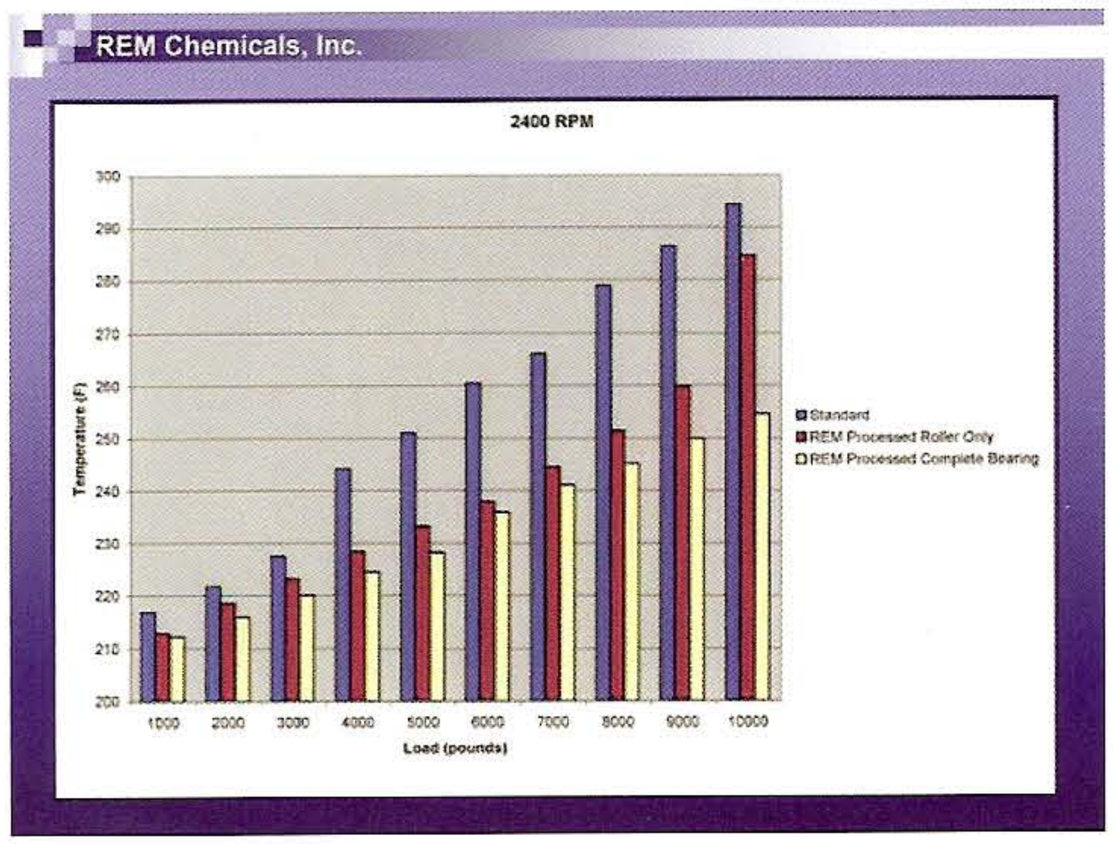
The reduction in surface roughness effectively removes the "break-in" period normally associated with mechanisms; as a result, the quantity of small metallic fines commonly dispersed in lubricants used in gearboxes and transmissions are reduced to a tiny fraction of the norm. Sealed mechanisms also last many times longer because this uncontaminated lubricant. The reduction in friction also causes a significant reduction in noise from transmissions and differentials. Finally, there is a useful increase in strength; the removal of stress risers is largely the reason for this, but on gear teeth there is the second advantage: the reduction in tooth-to-tooth sliding friction reduces secondary bending loads on the tooth as well.

Surface pitting from local break-down on gear teeth is virtually eliminated. One Formula One team found that it was able to reduce the size of its gearbox and internal components by 40 percent, and eliminate its respective oil cooler entirely after it began to use ISF. Similar improvements were made in the camshaft gear train as well;

"Surface pitting from local break-down on gear teeth is virtually eliminated"

indeed, virtually their entire power and driveline is now ISF-treated.

Highly stressed, lightweight gearboxes such as those used in helicopter rotor drives are kept on strict component lifetime schedules; these units are rebuilt on a regular basis with full inspection of all of the interior components. Gears are inspected completely and replaced as needed on each rebuild. The US Army found that even already-used helicopter gears that were treated with the ISF process had their useful service life increased to well beyond the expected lifespan for a brand new gear without ISF.



Bearing Load graph

CASCADING IMPROVEMENTS

Once engineers become aware of this technology, they can begin to design with it in mind, rather than to use it as an "add on" process. The surface smoothness developed by ISF results in much more useful metal-to-metal contact bearing area, and as already mentioned, this allows for much smaller moving components. Moreover, the lubricant film experiences less disruption from the improved contact area. This means that a gearbox housing using the smaller gears made possible by ISF can be made much smaller and lighter than its original counterpart as well; support structures that locate the housing can have less mass, since it represents reduced strain on the entire structure of the chassis that it resides within.

It is well known that machining causes subsurface damage to mechanical components, and it is a common practice to shot-peen highly loaded pieces and then finish-grind the working surface(s). This shot-peening puts the surface material of the component in compression, which neutralizes the tiny stress risers that exist on and just below the surface of the base material. Of course, a bit of the material's ultimate strength is sacrificed because the compressive surface is in opposition to the tensile strength of the material underneath. Using isotropic superfinishing to polish below the thin layer of subsurface damage eliminates potential stress risers without compromising component strength whatsoever. In the future, shotpeening may become an unnecessary operation for many kinds of moving parts.

MAKING THE CASE FOR ISF

The independent tests and technical papers about the process are impressive and convincing. Indeed, it appears most of racing's top insiders don't need to be convinced – they already are. What is not generally known is that the service is available for anyone who wishes to use it, and the cost is not prohibitive. "In the US, it typically costs about $350 to treat a Hewland "Mark" series gearbox at REM," reports Michael Frechette, the North American sales manager.

Despite this in-house capacity, only about 10 percent of the isotropic superfinishing performed around the globe is done directly at REM. "The majority of the work, approximately 90 percent, is produced in proprietary, in-house installations that REM has provided for larger customers and licensed suppliers."

These customers include an impressive list of primary manufacturers, gearbox specialists, and major race teams. In 2005, virtually the entire Star Mazda racing series was populated by

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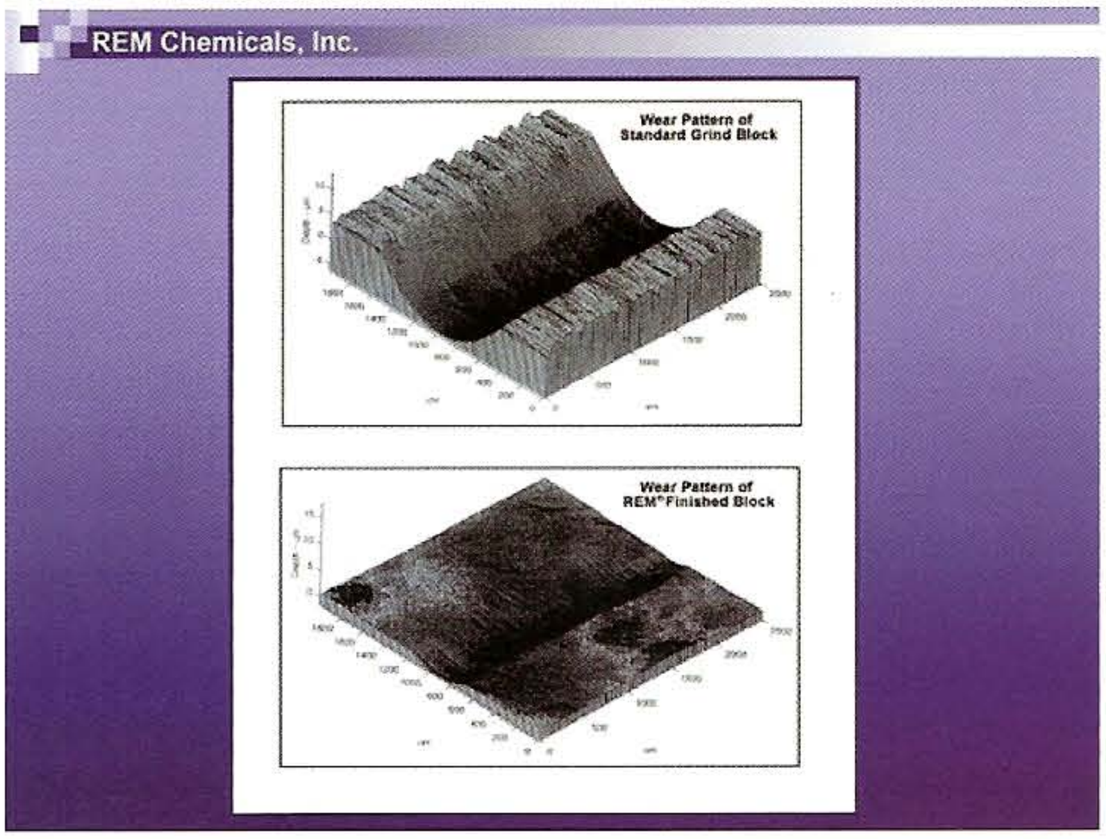


Block on Ring wearing pattern

gearboxes that had been REM treated. Not one of these gearboxes experienced a gear-related failure. The teams were also impressed by how little wear was experienced in these components, and every one of them elected to continue with REM finished gearboxes.

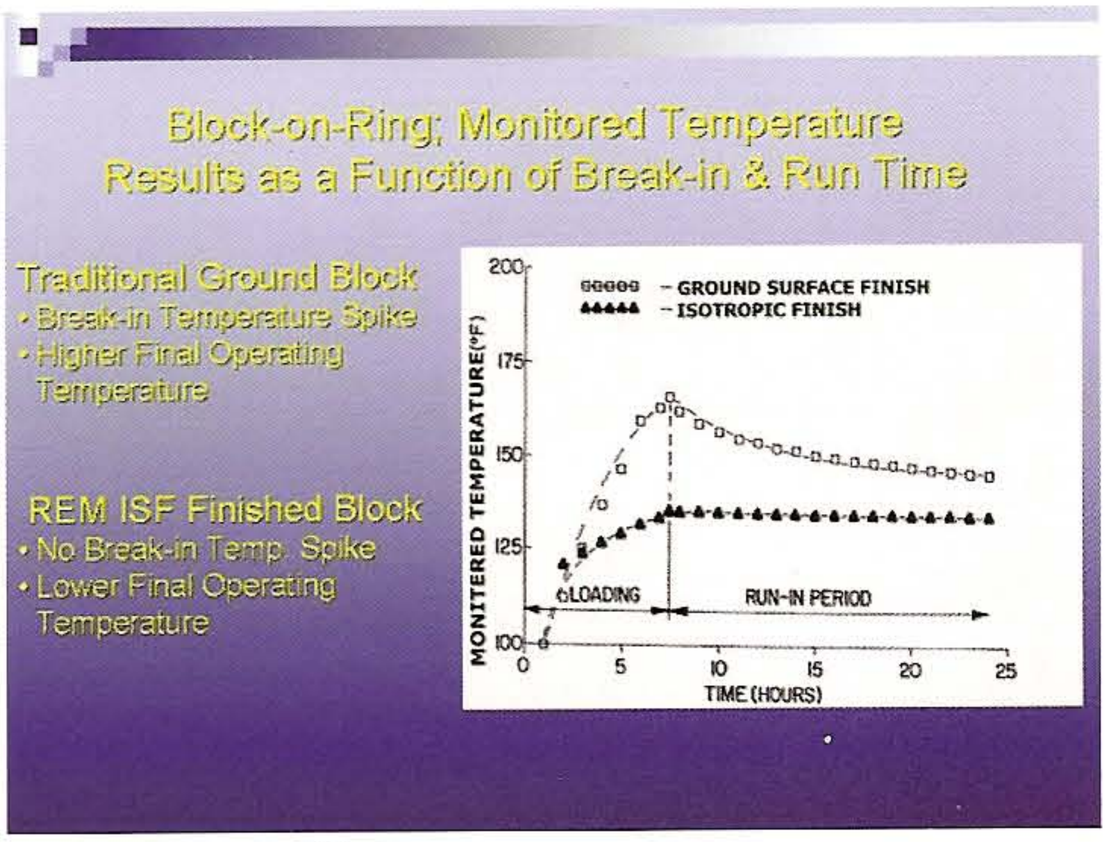
Taylor Race Engineering, arguably the most experienced Hewland service provider in the USA, now stocks ISF treated gears. "No one wants to be at a disadvantage," explains Craig Taylor, who noted that the increased gear durability more than covers the cost of the service. Customers of Xtrac can get ISF-finished components as well; this is the "Extrac Extrem" service that the company offers.

While racing is inherently an innovative engineering field, engineers can suddenly become quite conservative if failure is considered a possibility, and lives could be on the line. Repeated testing and verification is needed to verify that there will be dependable performance from any new product. Over time, REM has gained the ▶

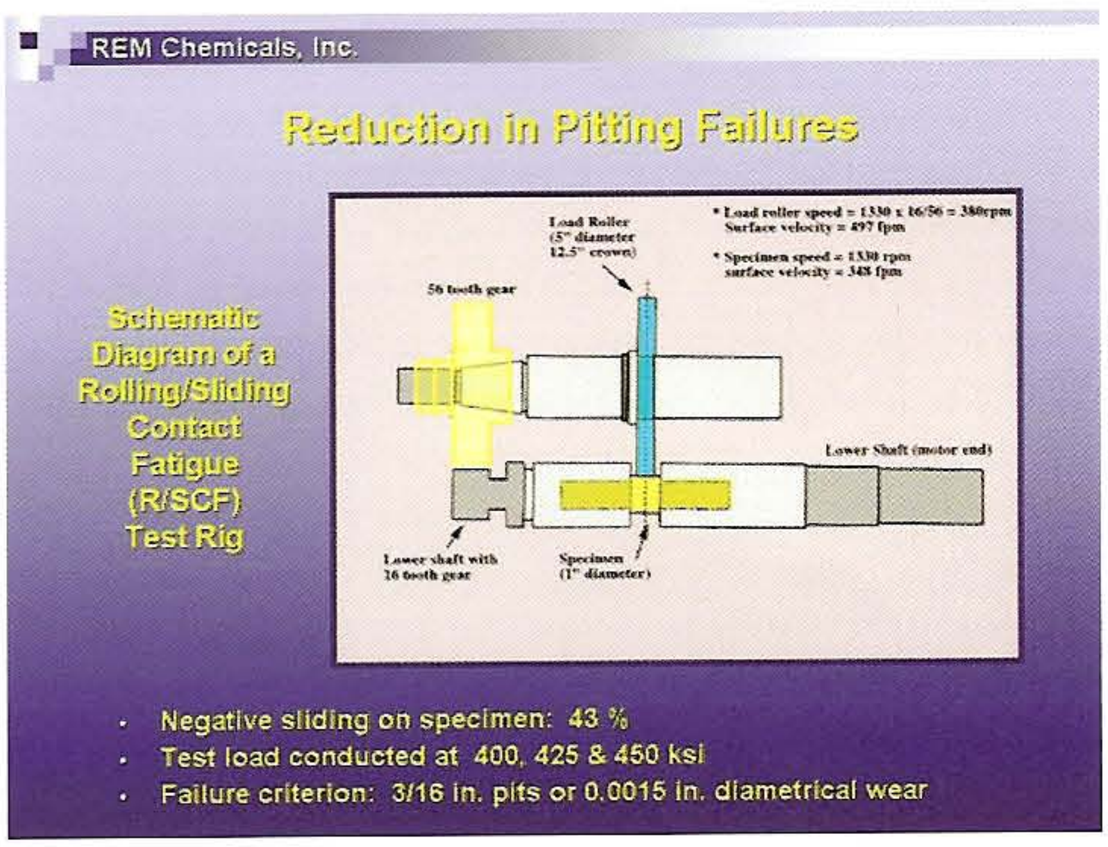
THE ULTIMATE COMPONENT

As stated elsewhere, ISF does not change the chemistry, hardness, basic material strength, or heat-treat condition of the affected component. This means that it is possible to combine this technology with other processes such as DLC (diamond-like carbon) coatings. Indeed, during this year's Engine Expo 2006 in Stuttgart, the author took an informal poll of all of the DLC and vapor deposition hard-coat specialists. Every one of them was well aware of the ISF process, and considered it to be the best possible preparation for their subsequent addition.

As an example, an "ultimate" crankshaft would be processed conventionally up through nitriding and grinding (it might be recommended to add .0002" to the journal bearings to compensate for superfinishing, but later processing might automatically compensate for this). Then, after REM superfinishing, a vapor-deposited DLC coating would be applied. It is quite possible that the normal peening would not have to be a part of this package; properly done, the stress risers should have been removed during superfinishing. As a bonus, the crank throws and webs would be also quite smooth, allowing them to throw off their oil more efficiently, thus reducing the parasitic losses during operation.



Ring on Block Temperature Chart



Rolling sliding contact fatigue

acceptance of these professionals through independent outside tests, technical reports, and the favorable experience this group has with ISF, all of which have served to reinforce the value of the process, and put to rest any concerns such as those below:

1. Part hardness is not affected by the ISF process, which is water-based, and carried out at room temperature. Therefore there is no tempering or heat-treating effect to components like gears and cams.

"The non-abrasive ceramic media used in the process has virtually an indefinite lifetime"

"ISF was found to be by far the most effective single treatment"

2. Likewise, there is no hydrogen entitlement as result of the process. In fact, the procedure produces a slightly oxidizing environment, and hydrogen is not generated; the process is metallurgically safe.

3. There is also no detrimental effect on component geometry. Material removed from gear teeth is uniform in profile, and is typically 1/10000 of an inch. The ISF Process has been certified for use on DIN 2 (AGMA Q 13) quality gears.

4. The technology does not involve hazardous materials or environmentally difficult procedures. Very little waste material is generated by ISF procedures, and what waste there is, is considered non-hazardous in most areas. (Of course, local regulations should always be consulted when setting up a facility.)

5. Costs are moderate; very little chemical material is actually consumed. The non-abrasive ceramic media used in the process has virtually an indefinite lifetime, and can be used for thousands of hours.

6. The process is robust, repeatable, and does not require unusual specialty skills for operators. REM licensees and their customers are protected by extensive patents, which cover all facets of ISF processes and equipment.

Rolling sliding contact fatigue results

The broad acceptance for demanding military applications has played a part in this course recognition as well. AMPTIAC Quarterly, published by the Advanced Materials and Process Technology Information Analysis Center (as sponsored by the Department of Defense), reported extensively on ISF treated gears in an article from an issue in 2003. This article compared ISF with other surface finishing methodologies, as well as Vapor Deposition Coatings (VDC). While all of these methods were found to be effective, ISF was found to be by far the most effective single treatment, resulting in an average 300 percent lifespan improvement of the gears tested. Of course, VDC can be combined with ISF to create an "ultimate" component (see Sidebar: The Ultimate Components).

THE TECHNOLOGY BEHIND ISOTROPIC SUPERFINISHING

An isotropic surface is one where the surface characteristics are non-directional; viewed from any direction the surface characteristics would be the same. A non-isotropic superfinished surface has directional characteristics that are a byproduct of the process that created it. For example, under a microscope, a conventionally superfinished valve stem looks like a series of very fine axial rings going up and down its entire length. As in the case of many round, ground, components, these fine grinding lines are at right angles to the motion of the part when it is in operation, as it moves back and forth (or up-and-down) in a valve guide, accelerating the wear of both pieces.

Having extolled the value of a flat surface, the truth is that ISF produces a flatter, but not completely flat, surface. Within that one microinch finish, there is even, gentle, multidirectional texturing in contrast to the sharp peaks and valleys that result from grinding and other abrasive-method superfinishing. This small amount of texturing appears to be just enough to prevent scuffing, and allow for proper oil retention, without unduly disturbing the lubrication film the way conventional superfinishing asperities do.

A graphic example of this was noted in a letter from J&J racing in Bally, Pennsylvania. J&J racing runs a vintage Tyrrell Formula One car, and they had had all of the gears, including the ring and pinion, treated with the ISF process. While on the track, the gearbox failed and became unable to shift. Upon teardown, it was discovered that, due to an oil leak, there was less than one cup of oil left. A number of roller bearings had spun in their cases, and all of them were burned, with their rollers flattened from the lack of lubrication. The gears and R&P, however, were completely undamaged.

Normally, in an apparatus such as a gearbox, it is the sliding contact parts, like gears, that fail first, and the rolling mechanisms, such as ball and roller bearings, that tend to survive. This reversal of normal failure events illustrates just how good the anti-scuffing and oil retention properties of an isotropic surface can be when it is superfinished properly.

It should be noted that not all media will produce the correct level of micro-texturing. The nonabrasive ceramic media that REM uses is the result of significant development work. Other media material such as plastics, appear to leave the surface without enough texture for good anti-scuffing characteristics, and this has been confirmed in tests.

OTHER APPLICATIONS

Besides the obvious benefits to gears, differentials, camshafts, crankshafts, valves, and tappets, there are other reasons to use the REM process. The smooth and shiny surface allows fluid to flow much more readily along its face. High performance applications such as turbine blades are already being treated by ISF to achieve the superior flow characteristics that result from low disruption of the airstream; the improved strength of these components that results from the elimination of potential micro stress risers is an important secondary benefit, especially since these components are designed with factors of safety that often approach zero at maximum load conditions.

In racing cars, splined shafts, rotating wheel hubs, and other driveline components are obvious candidates for the procedure. Inlet valves that have been super finished this way not only have less friction with the valve guide, but the smooth surface on the back of the valve face appears help to prevent de-atomization of fuel, as well as reduce inlet airflow disruption.

Yet another place where the process is particularly useful is in applications where lubricants cannot be filtered, cooled, recirculated, or replenished easily. The reduction in lubrication-borne fines and particles is crucial under these conditions, as is the reduction in heat. Wheel bearings, spindles, and rack-and-pinion mechanisms come to mind as candidates for isotropic superfinishing.

It doesn't stop here; if current trends continue, the pressure to create lighter and more efficient vehicles will eventually force this technology into the machines that we use every day, not just high-performance and specialty vehicles. ■

"The smooth and shiny surface allows fluid to flow much more readily along its face"

REM Chemicals, Inc.

Summary of STBF Results

	Mean (ksi)	Std. Dev. (ksi)
Baseline	207	15
ISF	219	13

- Two Gears Per Test
- Total of 24 Teeth Per Test

Single tooth bending fatigue

ISOTROPIC SUPERFINISH

"The best kept secret in the industry giving the world's top gear manufacturers that extra edge!"

WHERE PERFORMANCE COUNTS!

Whether it's a race to save a life, a race to build a dream or a race to the finish line, time and performance count most. To deliver speed and reliability gear manufacturers alike, know that there has to be a difference.

The difference is ISOTROPIC SUPERFINISH. ISF® removes surface burrs left by manufacturing and leaves gears with a mirror-like finish that delivers you the performance you need plus:

- Less friction and wear
- Lower operating temperatures
- Quieter operation
- Better scuffing resistance
- Improved contact fatigue resistance
- Improved bending fatigue resistance
- Reduced lubrication maintenance
- Reduces rotational torque
- No metallurgical degradation
- No geometrical degradation
- Increased time between maintenance

For more information about ISF visit us at www.remchem.com

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