EFFECTS OF POOR TRIBOLOGICAL PRACTICES: A USER'S PERSPECTIVE©

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Editor's Note: As this article pertains to the cost factor and how it is costly as a result of "poor tribological practices", the theme of "money" ($) was carried throughout the article with "$" used in subtitles.

Poor tribological designs and poor practices are costing industry millions of dollars but while many of the resulting equipment failures and performance losses which result in higher production costs are thought to be preventable, it is unfortunate that little is apparently being done. This paper gives examples of losses industry wide and then for the power generation industry. Discussed are the causes, the costs and what can be done to minimize or even eliminate many tribological failures thereby reducing needless wastage. Action by the management and technical staff at the suppliers and users is required to increase the awareness of both the problem and of solutions. This is necessary now more than ever because of new environmental, legislative and external factors including greatly increasing international competition. Existing industries must upgrade and maximize "up-time" if they are to survive. A need for improved tribological awareness is specifically identified.

INTRODUCTION

Tribology is a word coined in the UK during the early 60's and is useful to describe the multi-disciplinary scope and inter-dependency of this field. Friction and wear as the consequences of surfaces in relative motion are not new as most in the field are likely familiar with the evidence of lubricants being used long ago by the Egyptians and of the rolling element bearings used for a statue base found in Pompeii. In addition, any industrial or even rural society that had wheeled vehicles, weaving looms, windmills, grist mills, water pumps or the like would have had some early tribologist trying to get the components to last longer or to produce more with less friction. Unfortunately, the materials available then were very limited and this would have placed severe restrictions on design improvements. This is not the case today and in fact one of the problems can be the abundance of choices so that a clear, no risk option is not available; then the tendency is often to stay with the status quo. Taking no action can be to the detriment of the facility. This does not mean to plunge on regardless but that many problems are not new and there are often very simple and inexpensive solutions available.

Great strides have been made in tribology in all walks of life whether this was in the soles of shoes or aerospace components, however, these are often taken for granted. Further, memories are often selective or old articles and equipment revered as part of the "good old days." For example, a colleague has a 1936 Lanchester, which is sought after as a classic car. However, one does indeed have to be an enthusiast to drive the vehicle because according to the owner's manual, dozens of points on the chassis have to be lubricated every 1,250 kilometers. This is not acceptable today as most vehicles have sealed for life or self-lubricating chassis bearings. In addition, passenger car engine lives are vastly improved with guarantees from the manufacturers and/or oil companies for up to 400,000 kilometers. Of course this long service can only be achieved if the oil and oil change intervals are correct. Even for technical presentations, there have been tribological improvements as early 16mm film projectors had a number of small lubrication cups for oil and small screw down fittings for grease at the reel bearings. These are of course not required today. Thankfully, such aspects of the "good old days" are gone now as will some present day technology. In fact our days will pass even faster as it had been reported that 50 percent of the items to be used in the year 2000 have not even been invented yet. This is a far cry from those at the turn of the last century who thought everything had already been invented. What this means is that tribologists, like other groups, must be receptive to new ideas and requirements if our industries are to survive in a world of global competition. Some examples of those who were a little off base on certain areas are given in Table 1 and many of you have probably heard similar statements.

It is an unfortunate situation if these are from the decision makers but tribologists can have problems with "mind sets" as well. Some examples are as follows:

- its always failed like that before so why bother now;
- thicker oil is better;
- there is no justification for using more expensive lubrication; and
- one cannot over lubricate a bearing.

In the majority of cases, all of the above are wrong.

TABLE 1 - Examples of Changing Times
"Radio has no future," Lord Kelvin 1824-1907, president of British Royal Society
"I think there is a world market for about five computers," T. Watson, chairman of IBM in 1943
"Who in the hell wants to hear actors talk," H. Warner, founder of Warner Bros., in 1913

IMPLICATION$ OF POOR PRACTICE$

National Studies

There are a large number of studies that have been done in various countries that highlight in dollars the costs of poor tribological practices. In Canada such a study *(1)* found that in 1982 dollars the cost per year in just seven industrial sectors was over $5 billion! Even so this did not include the steel industry and, more importantly, did not include downtime; which for the latter in the power generation industry can easily amount to $300,000 a day per unit for the cost of lost sales and/or replacement power. This is considered to be very important, especially as the size of steam turbines increase, because an outage to change one bearing can take three days. The time required being a combination of not only the repair efforts but also the hours necessary to safely bring a unit down to standstill and to allow the metal to cool. In addition if a shaft is badly damaged, this can take months or even years to get the new forging and necessary machining. Of significance as well is that while items of importance to particular sectors or countries were often documented in various other studies, it was often reported that large savings could be realized just be applying known technology or by some research. For the Canadian study, these savings were estimated to amount to 25 percent of the current losses. Experiences with electric power generation, whether it is nuclear, fossil, hydraulic or even wind power, indicates that the potential for savings is in fact much higher. This is based on the fact that in the role of providing day to day technical advice, the effort required to obtain tribological solutions can be roughly qualified as 80 percent with readily available data, 15 percent with some digging and a last 5 percent that will require research or may in fact not be solved in an appropriate time frame. While the consequences of the latter can be that the components or a plant might be scrapped, this only happens in a few instances. In the case of the author's company there is over $35 billion in fixed assets with a large portion of this in machinery and equipment, so the implications are enormous. There is no reason to suspect that the potential for tribological savings will be any less than in other industrial sectors. It is only conjecture as to why more action has not been taken when interest rates are negotiated and fought over to the last 1/4 percent but gains of 25 percent or more can be ignored. Such problems are not limited to one industry as the following examples will show.

Industry Costs

On the more generic issues of rolling element bearings, it was reported *(2)* that only 9 percent reach their fatigue limit. This is an enormous waste. It should also be noted that this is the bearing fatigue limit or design life on which much time is spent during the selection stages of equipment and for which high values can be demanded in many equipment specifications. This focus is thought to be because while it is known that there are failures that should be prevented, the stresses and $L10_h$ fatigue lives are all that can be easily quantified by a less experienced designer and in some companies, are all that can be "justified." Unfortunately, the leading causes of failures *(2)* are reported to be improper lubrication and improper mounting. See Fig. 1 from the same reference.

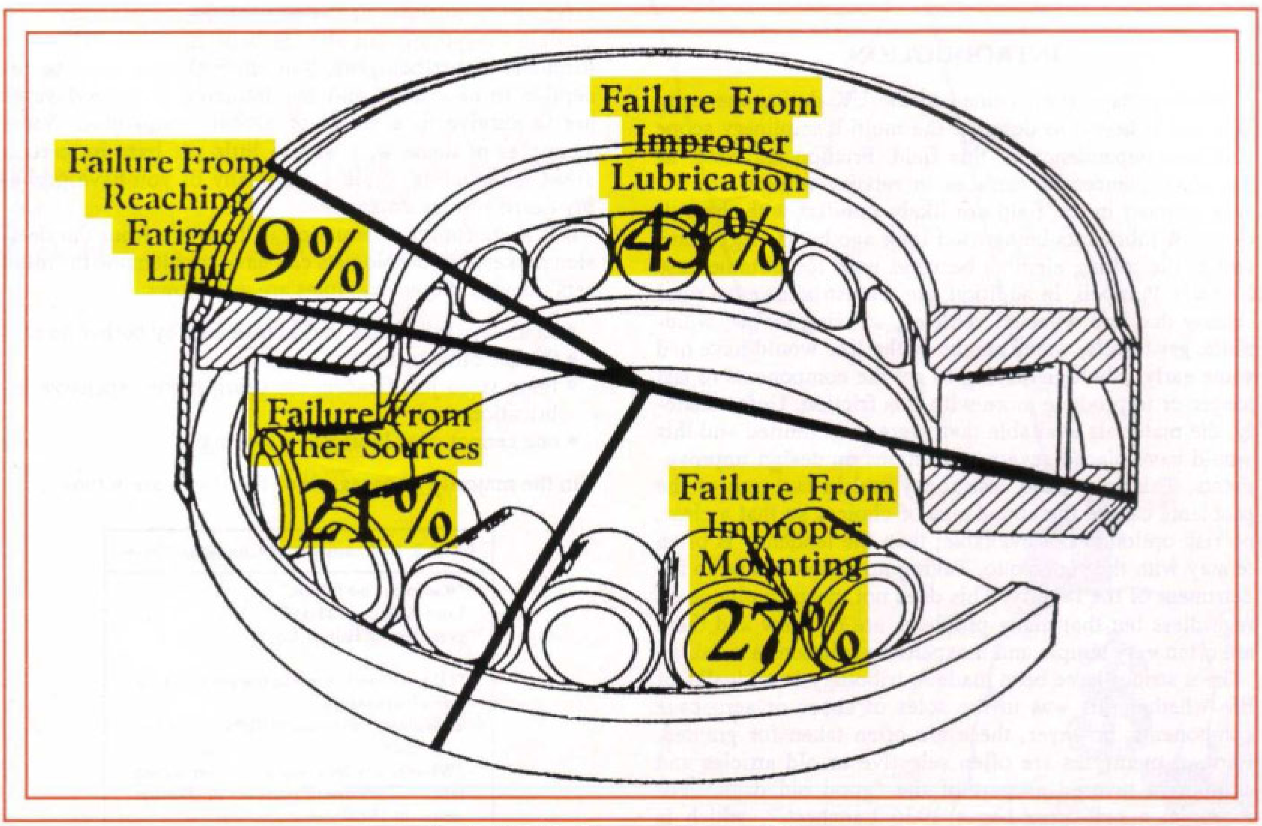

Fig. 1 - Rolling Element Bearing Failures

Apparently, little emphasis is normally given to other causes of failures at either the equipment design or the selection stages because the more readily quantified factors such as initial cost, terms of payment and nontechnical matters take precedent over life cycle costing. The optimum, if it is in fact ever achieved, is arrived at by trial and error with the error normally meaning bearing or equipment failures.

Further, contamination was shown *(3)* to cause 70-85 percent of failures and wear problems with these contaminants said to be solids, liquids or gases. These originate in the fresh lubricant, in new or repaired machines and in running equipment as either generated or ingested matter. Unfortunately, many new pieces of equipment still do not have adequate filtration equipment and lack either procedures or provision for flushing. Proper oil sampling points are usually missing as well. While major steam turbine manufacturers also now recommend oil system flushes every five years, for the equipment operators this is still the exception rather than the rule.

Power Generation Costs

Motor failures in the electric utility industries were found *(4)* to be bearing related in 41 percent of the cases, see Table 2. The main cause of these failures was design at 39.1 percent, followed by workmanship 26.8 percent, misoperation 20.4 percent and misapplication 13.7 percent.

Boiler feed pumps fared little better *(5)* with 49 percent of the failures causing outages from tribological components such as seals, journal bearings, wear rings and thrust bearings.

Similarly, bearings on boiler draft fans *(6)* were the leading cause of fan failures and were only just behind motor failures as the major case of all fan outages.

Even common power plant and factory items such as motorized valves experienced tribological related problems *(7)* as lubrication and wear were leading causes of failures. This was in 37.5 percent of the cases, see Table 3.

In general, tribological failures can be caused by any number of factors, see Table 4, most of which are outside the control of one individual or group as designers, operators and maintainers all play a role. This complicates problem solving and even if the reasons are known, preventing repeats can be difficult, especially if staff turnover is high or job rotation periods are short. Even with experienced staff but especially if there are new personnel involved, it is very important that the equipment be ergonomically sound, maintainable, provided with correct manuals, have proper operating procedures and have checks for actions built-in. As an example of the latter, it is not sufficient to just say "grease a bearing" but instead more information has to be given and procedures have to be in place to provide feedback on whether the product, intervals, amounts, etc. are correct. Fortunately, many improvements should be easy to implement and can often be easily identified by one individual or more commonly now by quality improvement teams. What is required now is action.

In the author's company, comprehensive data on actual tribological failures is difficult to obtain but recent equipment failures on pumps and motors indicate that the causes are similar to those mentioned previously. However, just as organizational systems can work against success, with proper input and the use of built-in checks, greater control can be realized and failures can be reduced.

When considering tribology, one may tend to consider only the lubricants, but there are other tribological components such as bearings, seals, wear rings and the like.

TABLE 2 - Causes of Motor Failures

Bearing related	41%
Stator related	36%
Rotor related	9%
Other	14%

TABLE 3 - Causes of Motorized Valve Failures

Mechanical damage, lubrication, loose connection, dirty contacts, broken bolts and wear	37.5%
Improper torque/limit switch settings	28.5%
Burnout/high current/TOL device not shut off or trip, motor failed or grounded	13.3%
Torque/limit switch defective, replacement, preventive maintenace	9.3%
Miscellaneous	9.0%
Breaker trip, blown fuse, defective coil	2.8%

TABLE 4 - Causes of Tribological Failures
Tribo-poor Design
Incorrect Manufacture
Wrong Installation
Improper Maintenance
Misoperation
Poor Environment
End of Life

TABLE 5 - Relationship Between Lubricant and Equipment Costs				
EQUIPMENT	LUBRICANT	QUANTITY	EQUIPMENT COST	%$
Steam Turbine-Generator (900 MW)	Steam Turbine Oil VG46	130,000 L oil	$200,000,000	0.08
	Control Fluid VG46	11,000 L FRF		0.06
Boiler Feed Pump and Motor	Steam Turbine Oil VG32	132.5 L	$400,000	0.04
Primary Heat Transport Pump Motor	Steam Turbine Oil VG32	900 L	$750,000	0.16
Service Air Compressor (screw type)	Steam Turbine Oil VG68	30 L	$110,000	0.04
Emergency Power Gas Turbine Set	Synthesized Gas Turbine Lube Oil VG 32	5760 L	$5,000,000	0.63
			average	0.17

Note: Lubricant cost is based on a manufacturers' posted price for lube oil either in bulk or drums whichever is appropriate for that piece of equipment.

Percentage cost is that of the lubricant to the equipment cost. The latter is the estimated replacement value not including engineering or installation.

Interesting though is that the lubricants in utility machinery only constitute a small portion of the equipment cost, see Table 5. It is therefore surprising as to the extent and resistance to using better lubricants when significant savings are possible. The savings can be comparable to those that can be achieved by using high efficiency motors which are being promoted to conserve electric energy. For example in one case of a 20:1 reduction ratio worm gear drive for a coal pulverizer, electrical energy savings of 8 percent were achieved just by changing lubricants.

Correct use and maintenance is essential for tribological savings and for this to be possible requires clear guidelines as to what should be checked and what actions are required. This is necessary as the best lubricant in the world will still not perform satisfactorily if it is being unnecessarily degraded in service by contamination or through the use of improper procedures. An example of this is the recommended condition monitoring *(8)* for phosphate ester fire resistant fluids used in the steam turbine control systems. In the majority of cases these fluids are tested monthly but the most important aspect is the correct action when variances are found. There also has to be continued proactive technical involvement because other factors can affect the fluids. This can be part detective work as even if the same spare parts are being ordered, there might have been substitutions by purchasing personnel or changes by the manufacturers.

Unfortunately, the greatest resistance to change can often be from the maintenance departments who, other than the customers or company owners, are the people who could benefit the most from improvements. This is not necessarily by choice as such groups can be limited by poor budgeting processes, may lack ready access to technical resources, could have no incentives for innovation and/or have restrictive organizational structures. The incentive can also be obscured because, if the costs savings go to others, rather then encouraging changes that at least will increase job satisfaction or might even help to keep a job in these competitive times, the focus is often on trying to preserve later work and hence jobs. This encourages inefficiency. That aside, a lack of awareness as to how easily beneficial changes can be made hampers tribological improvements. To show the extent of the awareness problem, during a series of presentations on lubrication and bearings to mechanical maintainers, a survey was conducted by a show of hands on the oil being used in their cars. Less than 5 percent were using a 5W30 engine oil during the winter, even though this is now the factory fill in Canada, it is likely given in most owners manuals as acceptable and this location was in an area that can experience minus 30°C nights. It is important as the use of such an oil could help minimize engine wear, 75 percent of which is reported *(9)* to occur during start-ups and warm-ups. In addition, such oils will likely qualify as an SAE/ASTM Energy Conserving II oil category, i.e. a 2.7 percent improvement in fuel economy compared to the reference oil. So in addition, there will be fuel savings. This is being pointed out because just as safety is not an eight hour job, neither is tribological awareness. In this case, the problem was apparently the impression that a 10W30 oil was better than a 5W30 oil and, after the matter was presented, the bias changed. This is of concern because these same people may not be aware of the differences between lubricants in the station and may inadvertently compromise the design function.

CONTRIBUTING FACTOR$

Tribology is a "new" term and covers a very wide field with the associated poorly defined responsibilities so it can be overlooked by mechanical, chemical and metallurgical work units. In addition, there is friction that can unfortunately arise between salaried and hourly paid staff. Consequently, in many plants, it is expected that such simple matters as the use of better lubricants and the use of oil analysis as part of proactive maintenance often falls between the responsibilities for the various work units.

Consequently, it will not be possible to get the full cost savings said to be associated with proactive (predictive) versus breakdown maintenance or even preventative maintenance. The key, however, is the better use of resources and this can be remembered by changing an old adage to the following: *if you know it ain't broke, don't fix it.* Fortunately, in spite of obstacles tribological improvements are occurring. For example, while a proper oil analysis program is considered essential to optimizing maintenance and reducing the consequences of equipment failures, the greatest boost to more use could be the growing environmental and cost restrictions on the disposal of used fluids. For the correct disposal of even standard products that are not badly degraded, the costs can be as much as that for new oil. In addition, there are the drums and containers that normally also have to be sent off site for disposal. Consequently, if the tests show that the fluid is still in good condition, use can be extended and as a result the fluid does not have to be wasted. There are also such added benefits as the following:

- safer as no action by operators or maintenance personnel is required;
- no chance of the wrong oil being used or the equipment started dry;
- no chance of overfilling or having spills when moving drums of new and used fluid; and
- other tests on the oil can also warn of equipment or component damage such as bearing problems.

All of the above have cost implications as money can be consumed very quickly in the case of spills and/or injury. This is important as rather than having to associate cost benefits with an equipment failure that may not occur, it is often easier to put an economic value on the previously mentioned events or to accept the costs of the prevention of injury to personnel or to environment as having other than only financial implications. The result can be that oil testing programs or the like which are necessary to the tribologist and plant technical staff are more likely to be put in place. While the driving force is other than equipment monitoring, all the benefits can still be gained by piggy backing on these programs.

In the past, it was suspected that tribological innovation has been focused on "high technology" problems such as aerospace equipment or the increased loading and downsizing demands on the existing products in the automotive industry. On the other hand, the majority of utility tribological problems are thought to be the day to day items. These were not given the required attention because they are often mundane and with a small dollar value so that the user and supplier interest is low as well. However, the problems can be very important to the plant because equipment that is out of service for any reason, large or small, is not available to generate product. What is now new to the tribologist and should be welcomed are driving forces such as the environment, occupational safety, cost effectiveness and any relevant aspects of external programs. The last item is being noted because in the case of the author's company there is a commitment to conserve electrical energy where possible and $3 billion dollars to the year 2000 has been budgeted. Implementation will be through a number of programs which, are expected to encourage the use of tribological products such as better lubricants, mechanical seals, bearings and the like.

$UMMARY

Tribological losses amount to billions of dollars and studies have shown that because of tribological components, equipment is failing at an alarming rate. Also while a significant number of these losses are thought to be easily preventable, there has apparently been a lack of will or focus to rectify the situation.

Acceptance of the status quo is changing in the industrial sector as environmental, legislative and other external forces are now acting which will necessitate tribological improvements. Examples include waste reduction and energy conservation. These will be beneficial and increased equipment "up-time" will help to improve plant economics and hopefully to reduce plant closures.

Because of the changing work place and the need of improved equipment efficiencies, the 90's are expected to be the decade of the tribologist. Tribological work will also involve many more disciplines on a day to day basis.

However, for changes to be successful it will require a concerted tribological effort at the design stage and throughout the life of the equipment. This life cycle approach also requires a commitment to obtaining the correct equipment in the first place but also to training, optimizing maintenance, increasing awareness and fostering tribological innovation.

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