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PTO shaft guards: Alignment of standard quality control in testing and manufacture

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for the Health and Safety Executive

CONTRACT RESEARCH REPORT

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PTO shaft guards: Alignment of standard quality control in testing and manufacture

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The Health and Safety Executive (HSE) commissioned this research following the ISO meetings of October 1999 in Moline, Working Group 5 of which had produced a paper ISO/TC 23/SC2/WG5-N 003. This is a re-draft of ISO 5674, followed by another revision N-010', ('Tractors and machinery for agriculture and forestry guards for power take-off (PTO) drive shafts - Wear and Strength Tests') incorporating proposed changes to the Standard. These proposals included test methods and pass fail-criteria, which were derived from various sources, including practical tests, manufacturers' own research and previous projects sponsored by the HSE

This latest project was undertaken to investigate whether the proposed revisions to the current standard adequately dealt with the action of physical agents, such as UV radiation, dust and, particularly, salt on plastic guards within a Quality Controlled testing and manufacturing environment. It was also considered necessary to examine how the Standard could encompass new designs of guard, which are needed to fit shafts with an ever-increasing number of special attachments. The designers are currently limited in the way they can adapt to technical change by the way the Standard is written. It was intended to provoke discussion, attract input from experts and provide technical data, which would contribute to the process of revising the Standard.

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SUMMARY

The project was commissioned by HSE who are concerned about the safety of power take-off shafts for agricultural tractors and their guards, as defined by the Standard ISO 5674 (EN 1152 is the CEN equivalent). Deficiencies in the performance of shaft guards identified through observations in the field and commissioned research over a number of years, could be remedied by further contributions to the development of better test standards, which will, in turn, influence the design of guards.

More dynamic strength tests are advocated and methods for conducting them have been written into a revision of ISO5674. They have been designed around the test apparatus already available in test stations and the test loadings have been suggested. These suggestions however would be subject to verification and revision through a consultation process, which could best be achieved via the Working Group of TC23 SC2.
This piece of research was commissioned to support the work of the Working Group. Information was sought, about the relevance of the parts of the revised Standard, in the context of a Quality Controlled testing and manufacturing environment, which deal with the action of Physical Agents, such as UV radiation, dust and salt spray. Suggestions are also required, on the possible inclusion of new designs of guard within the scope of the Standard.
The contractor was directed to operate in conjunction with the Working Group and to prepare proposals to be presented in preparation for meetings in September 2000. Reports were submitted that proposed changes to the Standard in a format which could readily be adopted, if required.

1. INTRODUCTION

1.1 RATIONALE AND BACKGROUND

HSE has been actively involved in developing CEN and ISO standards for the testing of PTO shaftguards.
The Standard ISO 5674 has been reviewed at recent ISO meetings and HSE have taken a lead through its involvement as convenor of a working group on this subject and by commissioning research work. The work culminated in reports, which have been adopted as definitive documents and which the International representatives and experts have decided to use as a framework for their ongoing discussions and development of standards.

The main author and the person in charge of the work was P. Seward who used the facilities of Silsoe Research Institute (SRI). SRI has been involved in many of the research projects connected with this subject. P. Seward has been involved with the committees responsible for the drafting of the standards and has used the Silsoe test rigs to carry out the tests over a period of several years. S.R.I's resident Ergonomist, D. O'Neill, acted as a consultant to the project. His experience was utilised to define the Human Factors, which were considered when formulating the revised test methods. He was involved with a recent H.S.E. review of farm accidents, which gave valuable insight into defining what circumstances might conspire towards accidents occurring as a result of using PTO shafts.

Due to the acceptance of the findings of the research mentioned above and taking into account, the wishes of the people developing the Standards, it was proposed that further work be undertaken to develop the proposals.

It was decided to work with the manufacturers of the guards and other experts to investigate whether the provisions in the current standard for testing the resistance of guards to the action of physical agents:

a. are appropriate for the current designs, and

b. whether the proposals being made can be applied equally effectively, to test novel guards, which are coming onto the market.

It was also accepted that there is an overriding necessity to ensure that the proposals recognise that the Standard itself, the testing bodies and the manufacturing processes take account of Quality Control of materials and processes.

1.2 OBJECTIVES

To collate and review all recent research work on PTO shaft guards which has been done by guard manufacturers as a result of the ongoing review of this Standard, to establish work programmes and, where appropriate, involve the manufacturers, who have already pledged equipment and resources.
To research the fundamental theories upon which the tests in ISO 5674 are based, especially those tests which involve the action of physical agents such as UV radiation, dust and salt.

Aims Of The Work:

1.2.1 Information about the effects of these agents on materials currently used in the manufacture of guards will be gathered. A method for evaluating the effectiveness of the tests for the performance of the guard bearings after being sprayed with salt will be developed and a series of tests will be run on samples of guards and shafts.

1.2.3 Information will be gathered from the guard manufacturers and their suppliers of materials on the means of classification of the materials. Industry views on the how these material properties can be quality controlled to meet the conditions set out by ISO 5674 will also be sought.

1.1.3. The provisions of the proposed new ISO 5674 will be compared with developments in European standards and other ISO standards such as ISO 5673, which is also being reviewed by a working group of ISO TC23/SC4 and in collaboration with WG5 of ISO TC23/SC2. Particular attention will be paid to the need to accommodate new designs of shaftguard.

1.3 ACTIVITIES AND MONITORING

Comments in Italics are the scope and limitations:

1.3.1. Study and bring together all relevant data and papers.
Starting with the latest research in U.K. and taking into account the most recent work of the manufacturers of shaft guards and their materials suppliers.

1.3.2. With particular reference to the physical agents of UV radiation, dust and salt, study the developments identified above, and put the findings into context with the requirements of the latest version of ISO 5674; taking into account the wear, damage and hazard problems identified by recent research.
Particular attention will be given to the aspects of Quality Control in the use of materials in production and the ability of the standard to adequately evaluate the properties of the materials in the context of their long-term use. The possible effects of UV radiation will be investigated as a priority.

1.3.3. Set up tests using existing rigs and development rigs, to assess the relevance of the ‘Salt Test’.
Test rigs will be utilised and adapted to test samples of guards and shafts to assess whether there is a need to continue testing in a salty atmosphere when guard components are non-metallic. Opportunities will be taken to involve the guard manufacturers in the process and in providing samples to test, which is a good way of ensuring their support in the eventual acceptance of the work.

1.4 DELIVERABLES

From the various activities listed above there will be the following deliverables:

1.4.1 A programme of trials, which defines the relevance of tests in a salty atmosphere, will be drawn up (and carried out) in consultation with HSE. Manufacturers and members of the appropriate ISO working group of TC 23 will be consulted where appropriate.

1.4.2. An interim report to HSE will provide information for discussion at the September meeting of ISO TC23/SC2.

1.4.3. A final report will be produced, which evaluates the effectiveness of the current tests. It will discuss how the proposed revised Standard aligns with other ISO standards under review and how they and the equivalent EC standards deal with the effects of physical agents. Particular attention will be paid to the adaptability of the standards to cope with new designs of guard.

2. INVESTIGATION INTO THE IMPACT OF PHYSICAL AGENTS, PARTICULARLY UV(ULTRA VIOLET) RADIATION ON THE DURABILITY OF PLASTIC SHAFTGUARDS

This part of the research project seeks to understand the nature of the problem. It aims to highlight the ways in which polymer degradation, in general, is caused by physical agents and the effects of UV, in particular. It suggests how the information from plastics experts, the manufacturers of guards, plastic material suppliers and testing bodies can be used to formulate guidelines on the important factors to be considered when manufacturing and testing plastic guards, and must eventually be included in a future revision of ISO 5674. Proposals to ISO, based on this research, have already been made as described in Appendix 2. These findings could be used in the interim, in conjunction with the current Standard, to ensure some uniformity of interpretation until the manufacturers produce a viable test and Quality Model, appropriate for inclusion in a later review.

2.1 SUMMARY OF THE BACKGROUND AND DISCUSSION TO DATE

ISO 5674 is intended to assess the fundamental strength and durability through the strength and wear tests. Current equivalent legislation requires that account be taken of foreseeable misuse as well as normal use.

The general principles of ISO 5674 are based on the approach, that if one has an item to test, which is of complex structure, it is best to test the whole assembly rather than try to specify each separate part, or the materials themselves separately. This stands up to scrutiny very well, if the long-term behaviour of the materials is well known and if the processes which contribute to structural deterioration can be accelerated, so that the test period is condensed into a time short enough to be practicable.

It is widely acknowledged that the standard has been successful in encouraging the design of more durable guards. This may suggest that the tests already replicate the most severe working environments that a guard will encounter. However, there is still a concern that novel guards, and the use of different materials to solve design challenges may be introducing potential durability problems which cannot be identified using the current Standard alone. The concern is mainly one of Quality Control.

2.2 SCIENTIFIC DEFINITIONS OF POLYMER DEGRADATION

In order to decide on what tests and supporting Quality Control measures need to be implemented to check the original design and ensure the continued integrity of the product, it is necessary to consider the fundamental nature of the materials used in its construction. A major threat regarding the long-term integrity of the plastic materials is ‘Polymer Degradation’, which is caused by the agents given below.

Schnabel,[1] in his book ‘Polymer Degradation’, identifies the six main modes of polymer degradation:

1. Chemical
2. Thermal
3. Biologically induced
4. Mechanically initiated
5. Light induced
6. High energy radiation (not discussed further as not applicable in agriculture)

The material most often used in the manufacture of shaftguards is HDPE, i.e. High Density Polyethylene. This is a material for which there is comprehensive information on its susceptibility to the above factors.
Unfortunately, the scientific information on how the properties of the material are affected by each of the factors or agents refers to the pure forms of the polymer. This becomes complicated when additives are applied to improve certain properties or the material undergoes a manufacturing or forming process. Testing of the finished product using in-house methods or ISO 5674 can be used to check that it meets certain strength and durability criteria.

2.2.1 How Does ISO 5674 Account For The Various Modes Of Polymer Degradation?

The test procedure we already have within the ISO 5674 Standard does expose the material of the shaftguard to some of the agents of degradation:

Chemical

During the wear test, grease will come into contact with the plastics as it would in practice. The chemicals within the dust will be in contact with most of the plastic surfaces, as will be the salt water from the brine spray.
Although water can accelerate the process of chemical decomposition, it is applied very late in the test sequence and it would not have time to affect the properties of the plastic.
Grease and dust could be injurious to the plastic but the exposure time is relatively short and the effects of other chemicals such as animal effluent, fuel oils, detergents and particularly agrochemical sprays are known to be far more injurious to HDPE (Henninger[2]). This factor is therefore only superficially addressed by ISO 5674.

Thermal

The ISO Standard does address the potential problems associated with extremes of temperature, especially the embrittlement of the materials at low temperature and the breakdown of chemical bonds, and therefore mechanical properties, which can occur due to fluctuations between ambient and 85 C.
The low (freezing to –35 C) temperature is applied only at the end in the strength tests, so it makes no contribution to the wear test. The alternation between hot and ambient temperatures does little more than find out whether the materials become too flexible, or even melt. It provides no information about the long-term durability of the plastics.

Biologically Induced

The tests in the Standard make no specific attempt to expose the plastic to this kind of attack except that they do create conditions under which microbes (and any associated chemicals they produce), could begin to affect the surface structure of the guard. The amount of time available during the test is unlikely to be enough to see any real effects from this agent.

Mechanically Initiated

This important factor involving the action of shear forces and stresses within the polymer structure which break the bonds and join with the action of other agents to accelerate the degradation of the material, is well covered within the wear tests of ISO 5674. Testing experience can testify to the failure of many guards due to this factor.

Light -Induced (mainly UV)

It has not been possible, so far to provide a test, which can be included in ISO 5674 and which will account for the effects of UV photodegradation.

The chemistry/materials technology associated with this problem is very complex. It has prevented those developing ISO 5674 from identifying specific criteria to regulate the manufacture and testing of guards made from materials which are known to be susceptible to UV damage.

UV radiation has the capability of directly breaking the bonds in polymers, and accelerating their oxidisation and that of any additives. This photodegradation has the effect of changing the structural characteristics of the material containing the polymer and therefore of the object into which it has been made (Hamid, Maadhah and Amin [3])

The manufactured item, in this case a shaft guard or part thereof, can suffer UV induced deterioration of its desirable properties such as tensile strength, toughness and elasticity. It may become brittle for instance, which is a problem for a shaft guard in particular, as it will no longer be able to withstand the shock loads for which it was designed and tested. When this embrittlement occurs, the guard may break and become detached in use, thus causing danger to the operator or bystander (e.g. see Tinker et.al. [4])

2.3 REVIEW OF THE CURRENT UV PROVISIONS IN ISO 5674

In order to acknowledge the potential problem of UV degradation, a statement was put into the current ISO 5674, which can at best be described as a warning to manufacturers to take notice of the problem and, at worst, be called a ‘get-out clause’.
It states that: **‘4.2. When the guard is made of plastic material, it is assumed to have been certified by the manufacturer to be resistant to UV-radiation’.**

This statement has probably served the purpose of drawing the manufacturers’ attention to the problem and had a positive effect on the development of modern guards. It cannot however be included in its present form in any rewrite of the standard because it is not specific enough and the phrase **‘it is assumed’** cannot be used in a Quality Controlled manufacturing and testing environment.
‘Certification for resistance to UV’ could take the simplest form of a declaration that **‘UV stabilisers had been added to the base material’**. These stabilisers can themselves weaken the structure, however, by reacting with its constituents in such a away that it is more susceptible to oxidisation, which is another way in which the material can deteriorate.

The latest thoughts are to change the clause to state that the manufacturer **‘must provide certification as to the UV resistance of the plastic materials used in manufacture’**. See Appendix 2, part 3.

It is necessary to identify an existing standard or develop a new one which will better meet the needs of the industry. Appendix 1 shows the UV-test that the German Delegation to ISO have proposed for inclusion in the forthcoming revision of the Standard.

This would be progress but there is still doubt as to whether the only Standards which seem to be remotely relevant, including the one upon which the German proposal is based, are really applicable to this kind of product, because they mainly relate to the material in an un-worked state.

Therefore, can an approval authority decide whether the evidence of certification is appropriate when:

1. The materials undergo manufacturing processes which can alter their structure and bonding and they are formed into shapes by processes which create stress concentrations which may react badly to UV?
2. New materials are being used because of developments in shaft design, such as softer ‘bellows’ type covers for wide-angle joints and their long-term durability is untried?
3. The guard manufacturers have to use materials from several suppliers, which may have slightly different constituents but a vastly different level of UV resistance?
4. The guards work in a wide range of climates and the time of exposure to UV and the actual level or strength of the radiation can vary widely?

3. QUALITY CONTROL ISSUES

The four factors mentioned at the end of section 2.3, above are actually Quality Control issues and may be associated with other forms of material degradation as well as UV. They can be verified to some extent by the application of the methods of test already given in ISO 5674, as augmented by the German proposal for UV testing. The results however will only be directly applicable to the actual guard tested and its constituent raw materials.

Provided that the guard manufacturing processes do not change and the material remains consistent, the original tests remain valid. If the material specification is altered however, it is necessary to review whether all the original properties are maintained.

A broader framework of tests and conformity checks will be needed to predict if any deviations from the original design, or working environment, invalidate the original certification. A properly researched and documented Quality System can provide this facility.

3.1 MATERIAL SELECTION AND MODIFICATION OF ITS FORMULATION OR END REQUIREMENTS

3.1.1 Original Selection

Plastics are materials, which should be regarded as being in a constant state of change. The plastic material can be exposed to many influences during its life, any of which can have a bearing on its chemical state and physical properties. The key to selecting the appropriate plastic for a particular job is to first consider what properties are needed and then the environments in which the guard is expected to work. Secondly, testing and use of standard data will define the rate at which those properties are likely to change with time.

Chemical changes will proceed at differing rates until, eventually, a stabilised state is reached. This process is depicted in Fig. 1, taken from Kulshreshthas[5] article on chemical degradation. All these factors may be pertinent to shaftguards.

To be effective, the desirable properties of the plastic must remain within acceptable limits throughout the expected life of the shaftguard. This includes storage and treatment prior to manufacture, storage and treatment prior to putting into work, and storage and treatment during and between periods of work.

3.1.2 Modifications To Specification

If the guard is subjected to more extreme conditions than originally anticipated, the expected life of the guard may have to be revised. If additives are used to inhibit undesirable chemical changes resulting from extreme conditions, there may be an adverse effect on other properties, which must, therefore, be carefully monitored and taken into consideration.

If re-cycled material is used in the manufacturing process, this may also have an adverse effect on the integrity of the guard. This may occur, for example, if re-cycled material is added to the mix (when it was not used before), or the re-cycled material is contaminated, or if the percentage of re-cycled material is changed.

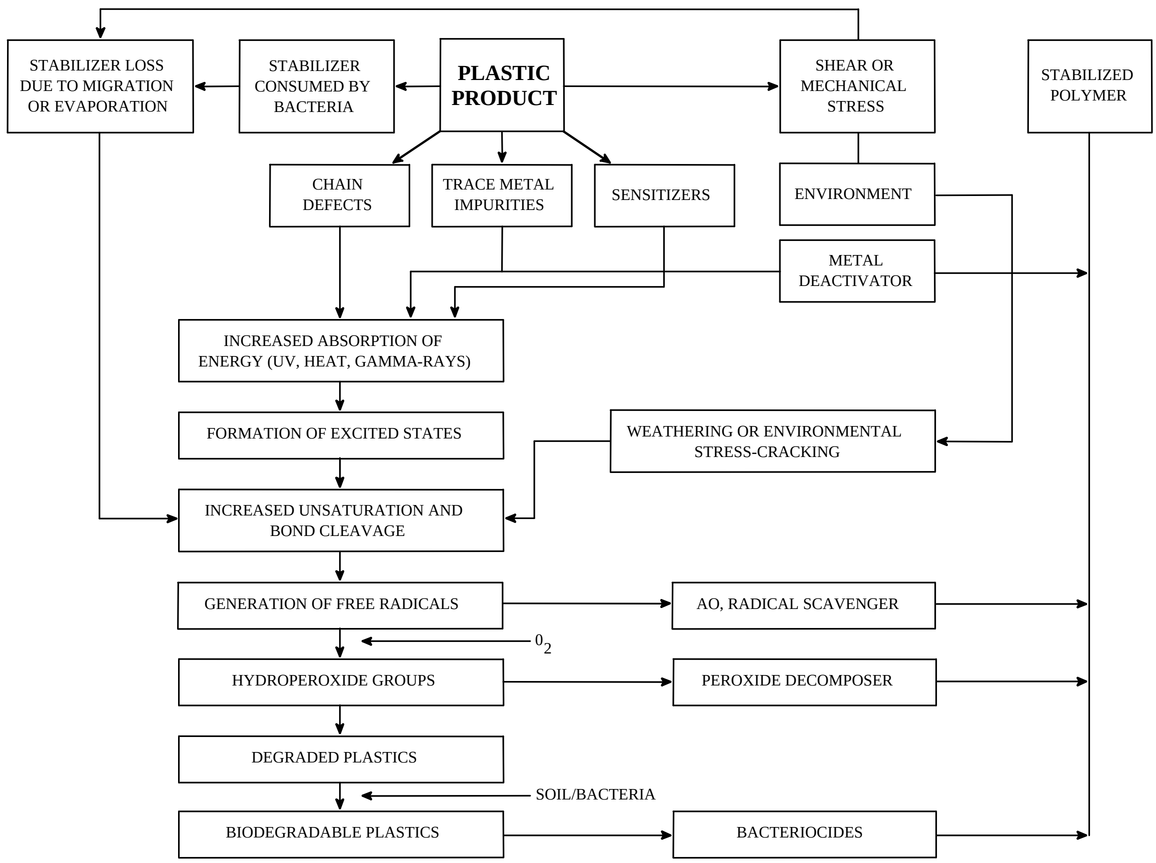


Figure 1
An overview of polymer degradation and stabilisation processes

3.2 AN ANALOGY FROM ANOTHER INDUSTRY

Kulshreshtha[5] also discusses how the knowledge of a product can be applied to the selection of materials. It shows how testing of the product can be coupled with continuous monitoring of the materials and manufacturing processes to ensure conformity of production.
He describes the ways in which polymer degradation manifests itself and mentions methods of recognising them, which are similar to those given in the German Proposal of Appendix 1. (4.1.2.4.2 and 4.1.2.4.3) but also recommends other techniques such as IR spectroscopy and alternative mechanical tests of samples.

3.2.1 A Case Study About Polymer Degradation In Milk Crates

Kulshreshthas work also contains a case study on milk crates made of HDPE, in which he looked at the theoretical processes involved in degradation and compares them to the real-life study of the crates.This case study was chosen because milk crates need to have many of the structural properties as shaft guards and are exposed to similar environmental conditions.

The model shown in Fig.2, summarises the mechanisms thyought to be operating during the service life of the crate. (ESC stands for ‘environmental stress cracking’.)

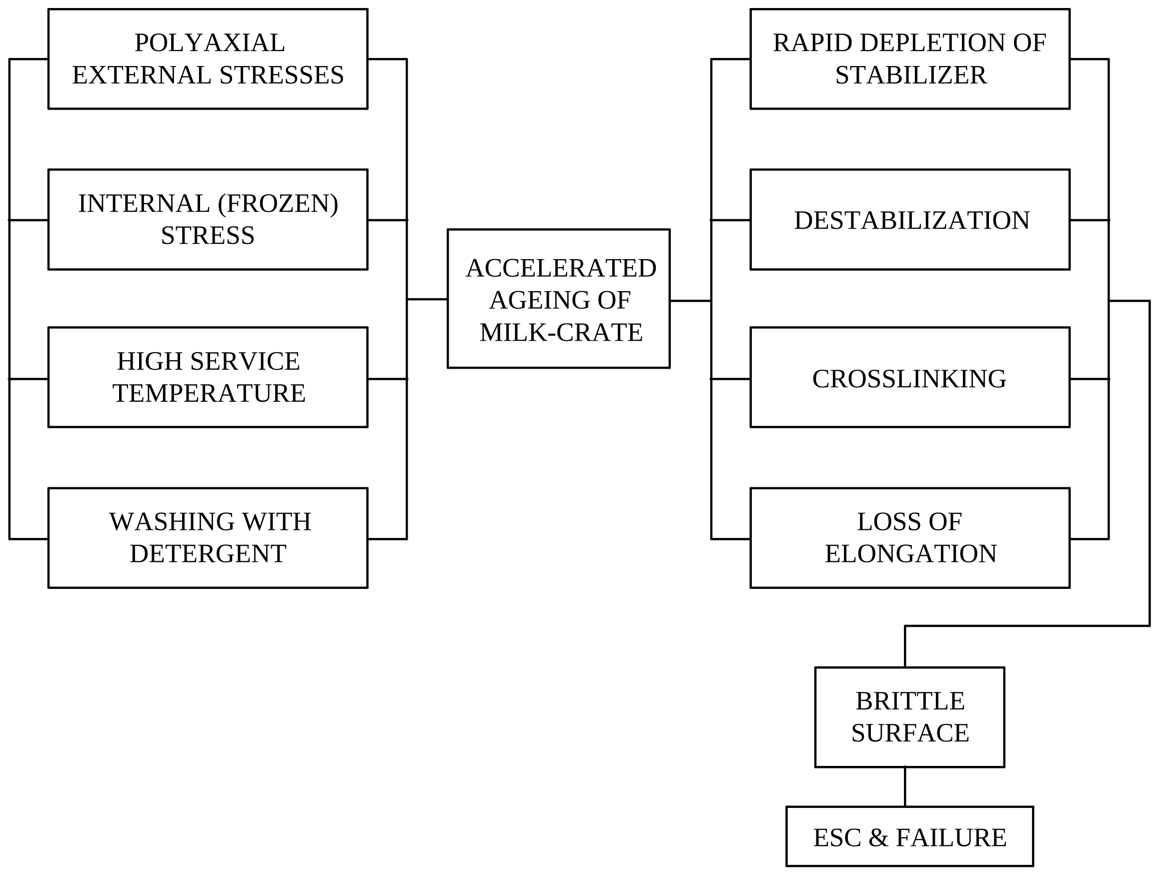


Fig. 2
A model of probable mechanisms operating during the service life of a milk crate, resulting in its' poor performance

This analysis enabled Kulshreshtha to establish the following approaches on how to improve the durability and service life of milk crates: (verbatim)

1. Since the protective agents (eg. Antioxidants, stabilisers, etc.) are consumed much more rapidly in plastics subject to dynamic stress than in plastics aged in the absence of stress, it is necessary to boost stabiliser levels in plastics or use more effective stabilisers in conjunction with mobilising additives.

2. Rapid cooling of moulded plastic leads to development of fine spherulitic structure and the lowest practical crystallinity in the material. Formation of impurity-rich, brittle spherulitic-boundaries, is prevented by rapid cooling. Low matrix crystallinity and small spherulitic sizes ensure a better acceptance of stabilisers and improve crack resistance.

3. Crack resistance of plastics can be enhanced by increasing their molecular weight and by the removal of brittle low-molecular-weight material. The resistance to failure of plastic will depend on the number of tie molecules, and this has been shown to depend on molecular weight. Low content of tie-molecules contributes to brittleness.

The knowledge obtained from such studies helps to define the important factors, which need to be considered. It helps to define what Quality Control systems need to be in place so that the manufacturer, and anyone certifying the product, can be confident that the right measures will be taken if the properties of the materials or the manufacturing processes depart from the original specification.

3.3 GUARD MANUFACTURERS AND QUALITY CONTROL

3.3.1 Materials

Discussion

The established guard manufacturers tend to take a similar approach to their products as that advocated by Kulshreshtha[5]. They combine the plastics manufacturers' information with their own testing and prefer to continue using materials that they have found to perform well.

However, technical and commercial pressures to use alternative materials, are causing concern. For instance, they may need to meet a new technical requirement or the plastic-manufacturer may have ceased to produce the product they have previously used.

Discussions with guard manufacturers and plastics producers confirm that it is becoming more difficult to guarantee the supply of materials with unchanged specification. Furthermore, the materials, which are being substituted, do come with the full portfolio of information on their properties, as did the previous materials. The plastics producers rely on bulk sales to justify their testing activities, so the relatively low volume ordered by guard manufacturers is insufficient to warrant the generation of all the test data the manufacturers require.

Kamal and Huang[6] have produced a report, 'Natural and Artificial Weathering', which embodies many of the important factors which need to be taken into account by manufacturers of plastic products which are intended to be used outdoors. Not only does it consider the chemical properties of plastics but it also discusses how laboratory testing can be combined with outdoor testing in harsh environments to build up a comprehensive set of tests. These tests, if built into a Quality System, could assist in the task of designing products and ensuring that they retain the appropriate characteristics over an appropriate life-span. The paper also contains a comprehensive list of internationally recognised standards, which could be applied directly, or in a modified form, to measure and predict the performance of the product.

Conclusions

Suitable materials information is increasingly difficult to obtain. Appendix 3 is an example of the basic information about the material properties, (in this instance, tests, probably based on the ASTM[7] set of standards) which will normally be supplied by the plastics producer. If the information is insufficient for the purposes of the guard manufacturer, he will either have to pay for more testing or do the testing himself

3.3.2 Processes

Discussion

Guard manufacturers also have to be aware that some changes in their processes, which may seem relatively routine, can have serious consequences even though the raw material has not changed. For instance, using a different moulding system and especially altering mould temperatures could have a dramatic effect on the strength of the guard. Premature degradation of the product could also be a consequence.

Conclusions

It is therefore, increasingly incumbent on the manufacturers of guards to initiate background testing and checks of their materials and processes. At the same time it is necessary for those responsible for developing Standards and those overseeing the application of those standards to be more particular about checking the Quality Control procedures of the manufacturer.

3.3.3 Overall Conclusions On Quality Control

All specification, processing and testing measures adopted by manufacturers should be contained and documented within a Quality System. ISO 9000 is the Standard used by many manufacturers worldwide. It is not the only Standard which is appropriate and manufacturers could develop or adapt their own systems but it is essential that their systems take account of the factors which may have a serious effect on the end product. Such systems should form an integral part of the certification as approved by a Notified Body or an appropriate equivalent as happens under EU regulations (Machinery Directive).

4. LEGISLATION AND STANDARDS

4.1 EC DIRECTIVES AND REQUIREMENTS FOR TEST

‘Machinery Directive’
Within the European Union (EU) there is a structure operating under the umbrella of the Machinery Directive, which governs the manufacture, supply and use of shaftguards. This structure demands that the design, development and manufacture of guards be certified via a Notified Body, who require the manufacturer of the shaftguard to have a technical file for the product. The file must contain information, which shows how the manufacturer will continue to produce the shaftguard to the specifications as confirmed by various declared tests, including those to EN1152 (the equivalent of ISO 5674). Conformity of production must be guaranteed by other documented checks, which are triggered by any deviations from the original processes. The checking system must identify potential problems and specify what action must be taken if such problems occur.
These checks are increasingly contained within Quality Systems such as ISO 9000, which is a worldwide standard. It helps the manufacturer establish ‘good practice’ in many different ways but most importantly in this case, provides data in a format which will satisfy the requirements of a Notified Body.

Pto shaftguards were identified in the EC Machinery Directive (89/392/EEC and as consolidated in DIRECTIVE 98/37/EC) Annex IV, as safety components requiring special attention because of their safety function. The Directive deals with them as follows:

TYPES OF MACHINERY AND SAFETY COMPONENTS FOR WHICH THE PROCEDURE REFERRED TO IN ARTICLE 8(2)(b) AND (c) MUST BE APPLIED

8.2. Before placing on the market, the manufacturer, or his authorised representative established in the Community shall:
(a) if the machinery is not referred to in Annex IV, draw up the file provided for in Annex V;
(b) if the machinery is referred to in Annex IV and its manufacturer does not comply, or only partly complies, with the standards referred to in Article 5(2) or if there are no such standards, submit an example of the machinery for the EC type-examination referred to in Annex VI;
(c) if the machinery is referred to in Annex IV and is manufactured in accordance with the standards referred to in Article 5(2):
- either draw up the file referred to in Annex VI and forward it to a notified body, which will acknowledge receipt of the file as soon as possible and keep it,
- submit the file referred to in Annex VI to the notified body, which will simply verify that the standards referred to in Article 5(2) have been correctly applied and will draw up a certificate of adequacy for the file,
- or submit the example of the machinery for the EC type-examination referred to in Annex VI.

Effectively, this means that a manufacturer or the person placing the shaftguard on the market in EU has to apply the Essential Safety Requirements (ESR) of the machinery directive to the shaftguard and submit them for certification via a Notified Body. The product can then be given the ‘CE’ mark, which allows it to be sold in all EU countries and some other countries that have adopted the same legislation for trade purposes.

4.1.1 Notified Body

A Notified Body within EU is appointed through its own national authority as being competent to carry out the function of certification and/or testing. The Notified Bodies' accreditation is usually also based on ISO 9000 principles, which helps it mesh conveniently with the Quality Systems of those manufacturers who have progressed that far.

Notified Bodies maintain consistency of interpretation with their peers from other organisations by attending meetings of 'Vertical Groups'. These groups are officially recognised by CEN and are encouraged to raise questions of interpretation, which are answered by the appropriate standing committee on the subject. The answers become official documents and part of the law.

4.1.2 ESRs, EN1152 And Other Directives

EN 1152 was generated from the current ISO 5674 to provide an official EU method of checking that shaftguards complied with several of the most important ESRs. It did not provide the full solution, however, and manufacturers still have to apply or have applied on their behalf, other checks based on fundamental guarding principles.

EN1152 (and ISO 5674) adopts the stereotype design of telescopic guard as the basis for its tests. Any guard having features not conforming to the preconceptions of the Standard may be effectively 'outlawed' unless the aspects of the design which do not conform can be dealt with using the ESRs and an appropriate alternative test.

The application of fundamental principles can raise many ambiguities and differences of opinion so it was decided within CEN (the body responsible for writing EC Standards) that it was necessary to write a Standard which would bring together all the ESRs as applied to shaftguards into one document. This policy complies with the Article 5(2) of 98/37/EC as mentioned above.

The Article 5(2) states:

2. Where a national standard transposing a harmonised standard, the reference for which has been published in the Official Journal of the European Communities, covers one or more of the essential safety requirements, machinery or safety components constructed in accordance with this standard shall be presumed to comply with the relevant essential requirements. Member States shall publish the references of national standards transposing harmonised standards.

The application of the single new Standard would mean that the certification process would be simplified and the paperwork reduced.

The Standard which emerged is at the provisional stage awaiting approval as prEN12965. It has not achieved the goal of consolidating all the ESRs in one document but has achieved 95% or so. PrEN12965 includes reference to EN1152 so compliance with EN12965 confirms compliance with EN1152.

In a similar way to prEN 12965, EN1553 provides a means under Article 5(2) for Agricultural Machines to comply directly with 98/37/EC. It contains references to shaftguards because the shaft and guard connect to the machine and it refers to EN1152 and EN12965.

For the time being the certification process still relies on EN1152, the guidelines as given by prEN12965, the interpretation of ESRs (guided by Vertical group consensus) and the recorded Quality System of the manufacturer.

4.2 TESTING AND CERTIFICATION IN THE REST OF THE WORLD

ISO (International Standards Organisation) provides a structure under which Standards can be developed, thus assisting the international trade of many products.
The Standards do not have any direct legal standing but they are often quoted, and used, within individual national legal systems, as a means of demonstrating compliance with certain safety requirements.

4.2.1 Self-Certification

The manufacturers of items such as shaftguards often apply the Standards themselves, because some national authorities allow self-certification. In the USA, for instance, self-certification has been common in the past and ASAE standards have provided the means for certification by US manufacturers and foreign importers to sell on US markets.

4.2.2 Third-Party Testing And Certification

Nowadays, there is a tendency even in the US, towards using independent witnesses or a third-party test house to apply Standards when potentially dangerous products are involved. There are at least two reasons for this, the first being that it is convenient to test to cover EC markets at the same time.The second reason is that, in the event of litigation, US courts look more favourably upon companies which have had their product scrutinised independently.
A third, and slightly cynical, view might be that involving a third party spreads the burden of responsibility and hence liability, in the event of an accident. There are also reports that the legal system in US may look beyond their own laws when attempting to prove negligence by the manufacturer. Lawyers may look at the EU regulations to establish ‘the state of the art’ and if these requirements of test or certification are more stringent, they may try to use them in court to support their case.

4.2.2 ISO As A Solution To The Incompatibility Of Different National Regulations

ISO Standards are acceptable in many countries as an alternative to the specific national norms. In the cases where they do not have such stringent requirements it has been possible to review and amend the ISO standard so that it can regain local acceptance, thus making it more widely used.
ISO 5674 was duplicated in EU by EN1152, which meant that the same tests could be carried out and certification obtained against both standards at the same time. Even so, the certification had to be done separately in EU and US.
Eventually, as the machinery directive gathered momentum, other requirements became part of the certification process. This has resulted in the situation described above where EN1152 needs EN 12965 to augment it. Over and above that, the Quality systems and Notified Bodies have their respective roles that combine to ensure continuity of production and impartiality in testing and certification.
Currently, ISO 5674 compliance cannot ensure acceptance of a shaftguard in EU.

4.2.3 Overall Conclusions On Legislation and Standards

It is intended that this project will provide valuable information so that ISO5674 can be modified to include some Quality Control requirements within it which will duplicate those imposed by the EU regulations surrounding EN 1152. Additionally, it is intended that a new ISO can be brought in to cover the same requirements as prEN12965. It is possible that the next revision of ISO 5673 may be used as an opportunity to convert it to an ‘Interface Standard’, containing all the provisions of EN12965.
The system will then be sufficiently close to EU regulations that the manufacturers will need to satisfy only one common set of criteria.
Another benefit of bringing ISO and EU in line is that the American ASAE system can adopt the ISO directly in place of its current standards, whilst, it cannot legally adopt EU regulations. This would cut down on duplication, which is usually good for everyone.

5. INVESTIGATIONS INTO THE TESTS IN A SALTY ATMOSPHERE

The tests in ISO 5674 which required the shaft and guard to be run in a salty atmosphere were originally devised when the majority of systems had ball bearings on the guards running in grooves on the steel shafts.
Problems had been encountered with rusty ball bearings, especially when left for some time without grease or when exposed to corrosive conditions without being cleaned and re-greased before use.
The salt water spray test was introduced because brine was thought to be the best catalyst to promote rust development and it was relatively easy to specify in terms of chemical constituents and concentration in water.

5.1 QUALITY CONTROL OF TESTING (GENERAL)

In re-writing the test codes recently, ISO TC23/SC2 and its Working Group 5 had to consider whether the test methods laid down in the existing Standard could guarantee uniform application of test techniques. It was also necessary to check that they could be justified in terms of their scientific correctness and relevance and their sustainability under testing protocols, which need to be 'Quality Controlled'.

5.1.1 Quality Control Of Testing (Salt Test)

It is not known exactly how the application method was developed but it seems that it was based on the spray technology used in agriculture at the time. The principle was to have a system, which utilised standard nozzles to deliver droplets of a given size and distribution into the atmosphere around the shafts, that could be easily reproduced in test chambers around the world.

There was also general agreement, although testing organisations thought that the salt spraying was, on the whole, being done effectively within the spirit of the standard, that the test methods could not easily be accredited under Quality Control regimes. It was even suggested that the simplest solution might be to remove this aspect of the test completely. The vast majority of guards on the market are now designed to have nylon (or similar material) bearings, which run in metal grooves and the metal ball bearings are now outdated.

In anticipation of a probable change to the Standard, the section of it dealing with the salt spray was split into two options: (see Appendix 2 Part 2.)

a. Allows testers to opt for no salt spraying, if the guard to be tested '**had bearings with no metallic elements'.**

b. To remain largely as it is in the current version, for the case of any **'bearings with metallic elements'**

In either case, the shaft and guard would still need to complete the requisite hours of running. This was supported by the general principle that it would not be acceptable to reduce the overall running time, because it would effectively make the Standard less rigorous than before.

5.2 TESTS AND INVESTIGATIONS INTO RUSTING AND BEARING WEAR

Questions which needed to be investigated:

1. If the shaft does rust, does it become more likely to wear the bearings (particularly in the case of nylon bearings)?

2. Even if the spray method could be specified well enough to be repeatable in a Quality Controlled test facility, could the spray penetrate the grease and dirt around the bearings?

3. If it could penetrate the barriers described above, do the materials used nowadays rust enough in the time allocated in the test?

4. If the salt test is to be retained, can it be adequately Quality Controlled or are there other methods of application which would be at least as effective but easier to control?

Manufacturers had suggested that the nylon bearings were less prone to wear than the shafts that they were running on. On the other hand, a testing organisation had speculated that rusty shafts would considerably reduce the life of bearings, which was why they thought the salt test should be retained. These different opinions made it essential that some objective information be gathered on the actual effects before any major changes to the Standard could be considered.
The research work was commissioned to address the above questions and a series of short trials was duly devised.

5.2.1 If The Shaft Does Rust, Does It Become Substantially More Likely To Wear The Bearings (Particularly In The Case Of Nylon Bearings)?

It was decided to investigate the first question using shafts which were already rusty rather than making new shafts rusty and finding that there was no problem to consider.
From shaft/guard combinations provided by manufacturers for previous research, it was possible to identify one type, of proven and popular design and size, which had the same bearings on both ends. SRI stocks of old machinery parts yielded two examples of the same shaft, which had been left in a rusty state for several years and these examples were used in the first trials.

5.2.1.1 Preliminary wear tests

Experiments
To find out more about the subject of rusting and its effect on bearing wear, it was decided to run a new bearing on a rusty shaft at the same time as one on a new, untarnished shaft.
One rusty shaft-end was paired up with a new one inside a single new guard and both ends were fitted with new nylon bearings. No grease was used at this stage as it was thought that in the 'worst case scenario' this would give a discernible amount of wear. In order to help evaluate the effect of the bearing running on a rusty shaft, pictures were taken, both before and after the runs. Temperature probes were fitted next to each bearing and a loadcell was attached to the restraining member because previous research[8] had shown that bearing problems often manifested themselves in excessive heating or restraining-member load.

Results
After one hour running in the SRI wear test cabinet, the rusty end of the shaft had been burnished by the bearing and much of the flaky oxides had been removed where the bearing had been in contact. It was evident, however, that the action of the bearing was not going to polish the shaft back to the level of surface finish of the 'new end'. It seemed likely, therefore, that the rusty end would cause more wear over a prolonged period of running.
The restraining member load was not excessive and the temperatures at the bearings were relatively normal.
There was visible evidence of wear on the contact faces of the bearing.

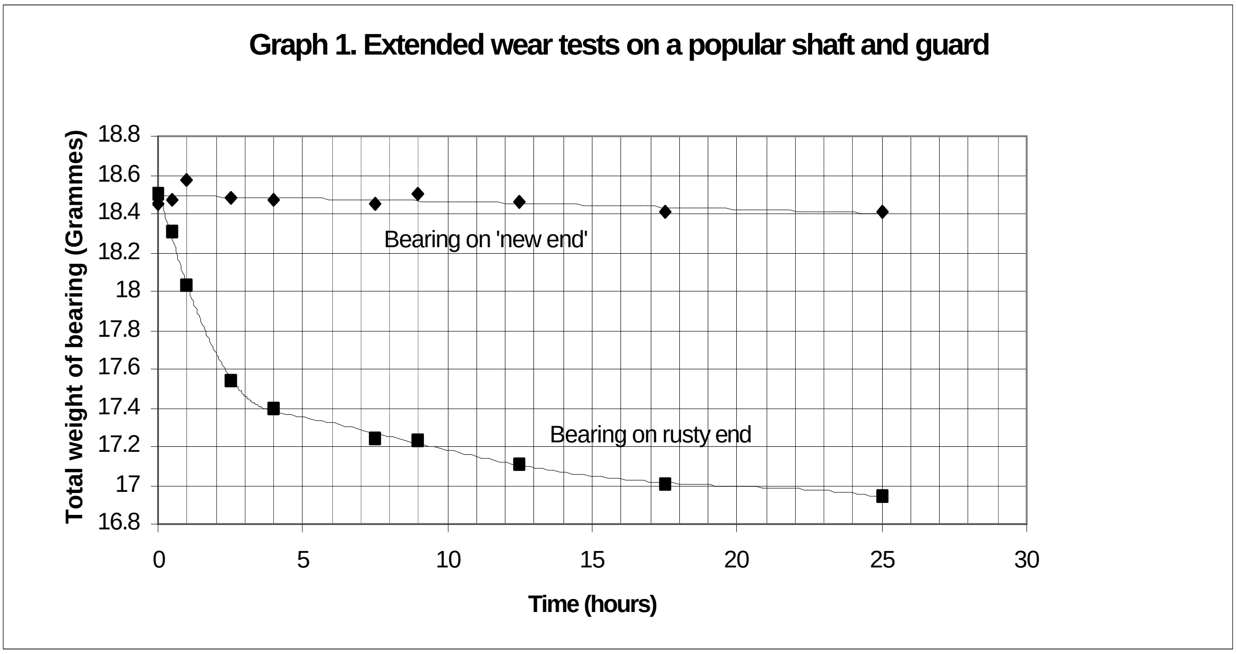
Conclusions
Under the conditions chosen for the first experiment, the indicators of wear were only visual but wear was evident on the rusty end and not on the 'new end'. To find out more, it would be necessary to run for a longer period and compare wear, by dimensional measurements and by weighing the bearings to quantify the amount of lost material. Restraining member loads and temperature would be monitored to indicate if problems arose, but not recorded.

5.2.1.2 Extended wear-tests on a popular guard and shaft combination without grease

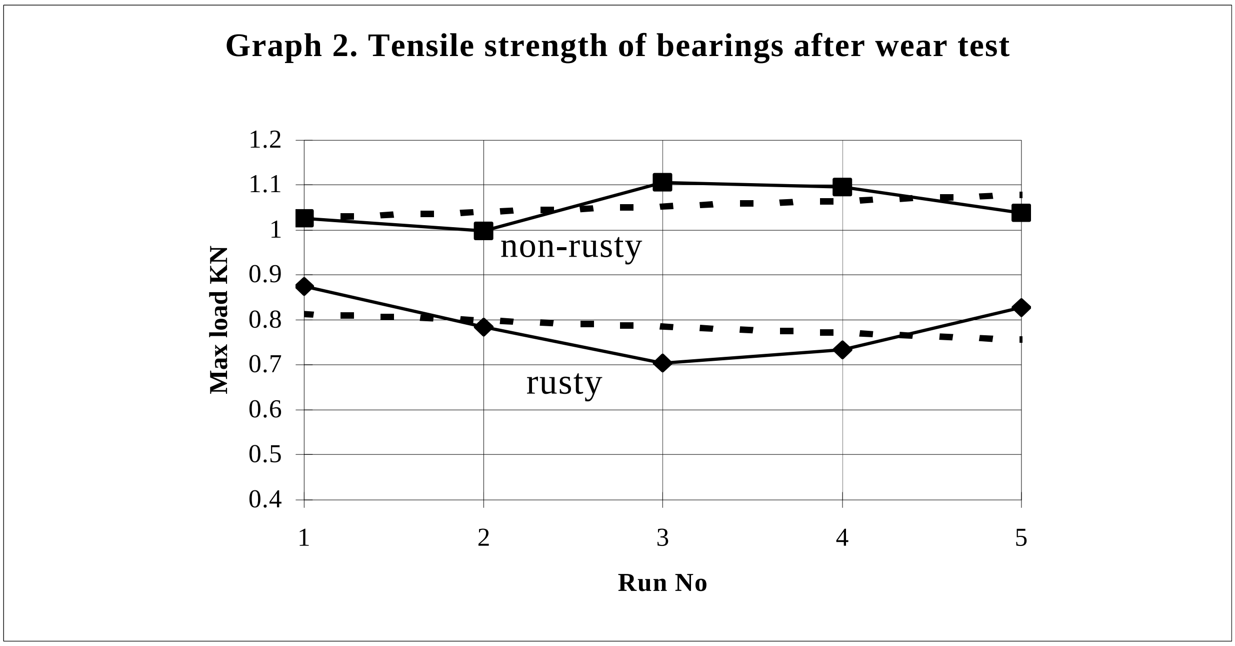
Experiments
A second rusty shaft end was paired up with the 'new' end and the new nylon bearings selected were measured and weighed. The test was run as before and interrupted, at intervals, for new dimensional measurements and weighing of the bearings. The temperature at the bearings and restraining member loads were monitored. The bearings were cleaned and dried each time before they were weighed and again, no grease was used because it would have made the weighing and measuring of the parts more difficult. It was still thought that the 'dry' bearings represented a 'worst case scenario' which would accelerate the wear process and therefore keep the running times down.
After the running tests were over, tensile strength tests at ambient temperature were carried out on the bearings in the manner of ISO 5674 to see if the bearings were weakened by the wear**.** Each bearing was tested several times to take account of any 'conditioning effects' associated with the test method.

Results
A series of runs totalling 25 hours saw the bearing on the 'new' end virtually unworn but the bearing on the rusty end wore quite quickly for the first few hours. By the end of 25 hours running, however, the rate of wear on the rusty end had diminished considerably: the bearing had reached a state of being 'bedded in ' to the profile of the shaft and was running smoothly. Dimensional measurements of the bearings were not practical because wear patterns emerged in places where the vernier callipers could not reach.

Graph1 illustrates the wear patterns as defined by loss of bearing weight versus time.



The results of the tensile tests on the bearings following the wear test are shown in Graph 2. Although there is some inevitable scatter, it can be seen that the bearing from the rusty end is unable to sustain such a high load as the less worn bearing from the non-rusty end.



Conclusions

Nylon bearings on even the most proven types of guard can wear considerably if run without grease on a rusty shaft. The example selected passed the tensile test loading of 1.0 kN from ISO 5674 when run un-greased on a 'new shaft' but failed to hold the load after being run on a rusty shaft.

5.2.1.3 The Effect Of Grease On Wear

Background

If the testing of bearing durability on a rusty shaft is to be retained in ISO 5674, it is unlikely that the wear tests will be performed in the total absence of grease.

The grease may be present from before the salt-water phase or it may be added as a permissible maintenance operation. Therefore a short trial was necessary to find out if the presence of grease significantly affected the wear patterns on rusty shafts.

Experiments

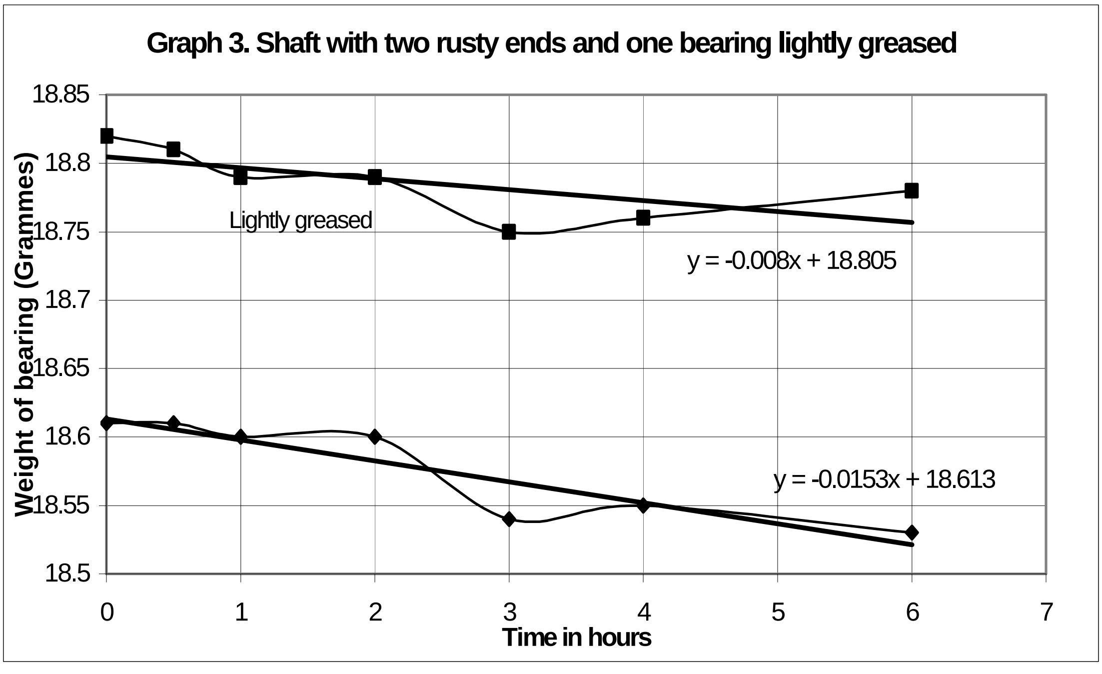
Two rusty shafts ends were selected and put together with new bearings and a guard. The assembly was run in the SRI wear test rig and the bearings were taken off at intervals and weighed as before. The tests were of short duration but sufficiently long enough to show a wear pattern which resembled that seen in 5.2.1.2 above.

Results

The rusty ends were not as pitted and rough as the one used on the previous experiments and the wear rates much lower. The overall weight losses were small and there was some scatter on the results. Trend lines fitted to the points as shown in Graph 3 predicted that the greased bearing would fail after 186 hours and the non-greased after 98 hours. These figures are based on the pattern shown in Graph 1 and relate to the same loss of weight in the bearing as that given by the tests on the un-greased bearing on the rougher rusty shaft. The bearing on the new shaft, shown in Graph 1 would have failed after 428 hours if the same principles were applied.

Conclusions

The results are not conclusive because the time taken over the test was too short. However, the principles explored, such as fitting a linear regression line to change in weight data and the testing techniques employed, could be usefully adopted by manufacturers as a means of predicting the durability of their bearings.



5.2.2 Even If The Spray Method Could Be Specified Well Enough To Be Repeatable In A Quality Controlled Test Facility, Could The Spray Penetrate The Grease And Dirt Around The Bearings?

Background Investigations

It was suggested that trials were needed to see if this did occur. However, taking into account preliminary investigations, previous experience of many tests by the author, the representatives of testing stations and manufacturers, it was overwhelmingly reported that no rusting was caused during tests.

There were no reports of nylon bearings failing the test due to wear induced by a rusty shaft, indeed, many shafts retained by SRI after testing several years ago showed little sign of rust around the bearing grooves.

Conclusions

If it is the intention of the test that rust is propagated so that the ability of the bearing to perform on a rusted shaft is evaluated, the current testing practice does not achieve it.

5.2.3 If Salt Water Could Penetrate The Barriers Described Above, Do The Materials Used Nowadays Rust Enough In The Time Allocated In The Test?

If the intention were to get salt water to reach the bearing grooves as described above, the test method would need to be changed. If however, the modern materials used in the construction of shafts was not prone to rusting then there would be little point in having the test. On the other hand, if they do rust but take more time than in the current test, it would be necessary to change the test method to encourage it.

Experiments

Shafts supplied by several different manufacturers were exposed to salt water by direct application and allowed to dry out.

Results

When dipped once in salt solution, the shafts took longer than the 46 hours given by ISO 5674, to develop significant amounts of rust. If however, they were dipped regularly, every few hours and allowed to dry out, the development of rust was accelerated.

Conclusions

Modern designs of shaft will rust but a new method would be needed in the Standard if this effect were to be achieved.

Note: The ‘salt-water application method’ was developed further and is explained, in the next section.

5.2.4 If The Salt Test Is To Be Retained, Can It Be Adequately Quality Controlled Or Are There Other Methods Of Application Which Would Be At Least As Effective But Easier To Control?

Following the above work, it was necessary to find out if there was a way to modify the current application method, which would ensure that salt-water reached the bearing grooves. At the same time it would be desirable to find out if greased shafts would rust and if the current method created the right conditions or allowed enough time for rust to develop.

Experiments (Rusting of new shafts and subsequent wear tests)
A system was developed which flooded salt water into the bearings via the grease nipples, instead of the spray system of ISO 5674.

A new shaft with new bearings and guard was selected and prepared as follows:

All surplus paint on the bearing groove was removed and the bearings and grooves degreased. The bearing and groove were lightly greased on one end, and the other left 'dry'.

The assembly was subjected to the ISO 5674 'salt test' using the salt solution specified in the standard, but, so that the 'worst-case' was represented, the bearings were saturated by injecting salt solution during the test, at very low pressure, through the grease nipples.

After the two-hour salt test, the shaft and guard were left in the cabinet for the required 46 hours.

Instead of moving on to the extended running period immediately, the bearings and shaft grooves were inspected. It was observed that there was almost no rusting and that they were still wet with salt solution. Theoretically rusting should have taken place but this was not the case and the bearing surface remained wet, suggesting that air had not been able to get to it to dry it out. Knowledge about the mechanisms of rusting suggest that it remains inhibited when air is excluded. Hence, the guard was left off and the shaft with bearing attached, allowed to sit in free air for a further 46 hours.

At the end of this period, rusting was very evident on both of the grooves.

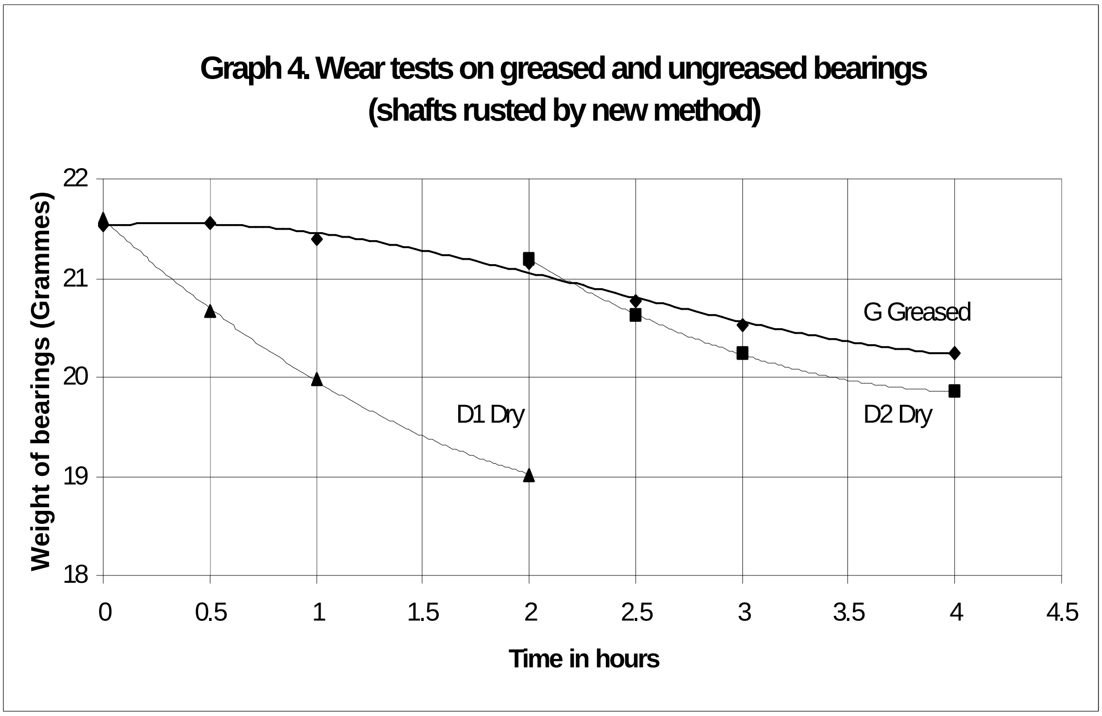
Having produced the desired effect, the bearings were weighed and both they and the guard were re-fitted. The normal running test was then started and the bearings removed at intervals to be cleaned and weighed to estimate wear. No more grease was added to the bearings during the trial.

Strength test on worn bearings
After the wear tests were completed, the three worn bearings and one new bearing were subjected to tensile strength tests at ambient temperature according to ISO 5674. The intention was to evaluate the relative strength of worn bearings against new ones using a known method.

Results

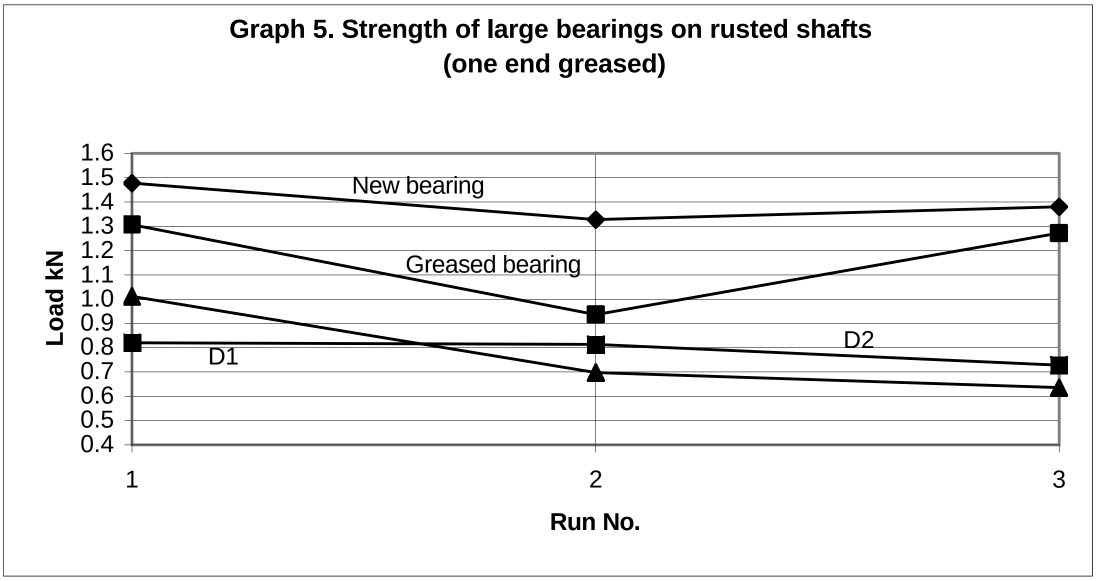
(Wear tests)
After several weighings, the 'dry' bearing was wearing faster than the one on the greased shaft so a new 'dry' bearing was fitted and the test continued. Eventually the test was terminated when the greased end bearing also showed visible signs of wear.

Graph 4 illustrates the wear patterns and it can be seen that the bearing ‘G’, which was greased initially, but not after the first weighing, wears slowly at first and then more rapidly as the grease is disappearing. Its curve begins to look more like ‘D1’ and ‘D2’ towards the end of the trial.



(Strength tests)

The strength test revealed the new bearing as the strongest, followed by the greased bearing and, finally, the two dry bearings were the weakest, as shown in Graph 5.



Conclusions
(Wear test)

It is possible that even if salt water penetrates to the bearing surface during a conventional salt test, that rusting will not take place during the 46-hour period if air is not allowed to dry-out the salt solution. The intention of the test to reproduce the effect of leaving a bearing for a period of time un-greased, therefore, will not be realised.

If the bearing surface is dried in free air rust could form, even if grease had been originally applied. Rusting will cause wear on bearings with residual grease as well as 'dry' ones.

Attempts to induce rusting on shafts have lead to more investigations into the effectiveness of the current standard in actually achieving this.

(Strength tests)

Although the strength test is an inexact way of assessing the long-term durability of bearings, it does show, how wear may weaken bearings and that they do not need many hours running, to fail at a level near, or below, the failure mark given by ISO 5674.

5.2.4.2 Development Of Salt Water Application Methods, Which Are Easier To Quality Control And Apply The Salt Water Where It Is Most Effective

Alternative methods for the application of salt solution to the shafts have been tried with a view to being able to specify a method, which can be justified in a 'Quality' environment. Based on the 'Trickle' method described above and involving more opportunity for the treated shaft to dry out, proposals have been made by the UK delegation to ISO and included in Appendix 2.

Fig. 3 Photograph of a simple method for the application of salt solution

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Useful internet websites:

STANDARDS	*ASTM;*www.astm.org*. and* www.normas.com *BSI; www.bsonline.techindex.co.uk*
PLASTIC MATERIALS	*RAPRA;* http://search.rapra.net/publications *Plastic USA;* www.plasticsusa.com
TESTING	*Sub-Tropical Testing Services;* www.sub-tropical.com

APPENDIX 1

German Proposal Submitted to ISO for Inclusion in Next Version of ISO 5674

U.V. Test for plastic Shaftguards:

General Test conditions
Guard
4.1.1 The guard shall be taken from production and be within the tolerances shown on production drawings.

4.1.2 When the guard is made of plastic material, it must be certified by the manufacturer to be resistant to UV-radiation to the following standard or an appropriate, internationally recognised equivalent of at least equal stringency.

4.1.2.1 Methods of exposure to laboratory light sources

4.1.2.1.1 Test specimen, quantity according to ISO 4892-1.

Sample sections of plastic guard components,min 1 piece of each material used

4.1.2.2 Test conditions according to ISO-4892-2

4.1.2.2.1 Black-panel temperature: 65° ± 3° C

4.1.2.2.2 Relative humidity: 65 ± 5%

4.1.2.2.3 Spray cycle

18 ± 0,5 min wet
102 ± 0,5 min dry

4.1.2.2.4 Relative spectral irradiance (table1, method A)

UV-radiation: 505 Watt/m^2

4.1.2.3 Test time: 1000 hrs

4.1.2.4 Test Report / Results

4.1.2.4.1 Description of specimen and method of test

4.1.2.4.2 Color test

grey scale according to ISO 105-A02: min 3

4.1.2.4.3 Mechanical test

no cracks by checking with magnification of 100 times,

manual bending test without visual cracks

APPENDIX 2

ISO TC23 SC2 WG5 N011

Proposals from UK

1. UK Proposals to include a wider range of PTO Shaft Guard designs within the scope of ISO 5674.

The current standard was written to deal with the safety issues surrounding the type of guard, which was the most common at the time of its conception.

The type of guard in question is the one, which is attached to the revolving pto-shaft via bearings at each end and is telescopic. The bearings used to be predominantly metal ball-bearings but have largely evolved to the plastic type over recent years.

The industry concerned with the supply of guards for pto-shafts has been under pressure to find better solutions in order to protect the user more effectively and to accommodate special shafts. These have been developed to enable wide-angle articulation and close-coupling for example but there are many other special uses as well.

As an International Standard, ISO 5674 should provide the necessary test methods to enable the evaluation of any guard, which is developed to have the function of providing protection from contact with a revolving pto-shaft.

This proposal seeks to use the existing standard as the basis for testing as many different types of guard as possible by amending its text and adding informative annexes. Testing and research have already resulted in a proposal for a new layout for the Standard in ISO/TC/ 23/SC2/WG5, N010. The following proposals are presented as revisions to that document rather than the original Standard because the general content of the revision is already widely supported.

Definitions of guard types:
This proposal modifies and clarifies the definition of guard types under the following categories:

Bearing-type(both rotating and non-rotating)

Non Rotating
The generic guard described by the Standard is attached to the shaft via bearings. It is also telescopic to allow the telescoping of the inner shaft when turning or lifting and it has to be prevented from rotating with the shaft by restraining devices at each end.

Rotating guards
It is not possible now, to apply the standard to guards, which rotate with the shaft and stop when in contact with a person or object. Although separate legislation under the European Machinery Directive prevents the sale of that type of guard in Europe, they still represent about 50% of the sales in USA. Provisions made in the revised standard to accommodate this types will promote the use of this standard in the USA but will not affect the European situation.

Cover-type Guards
This name is intended to describe complete guards or parts of guards, which are not directly connected to the shaft but they may have supporting devices inside, which have intermittent contact with the rotating parts. They do not usually have restraining devices of the type needed for 'bearing -type' conventional guards so these need not be tested. The internal devices, which may contact the rotating shaft, their attachment means and the system for telescoping of the guard, must be evaluated however.

In order to encompass these guards within the scope of the Standard, the following alterations to the existing text are proposed:
(Highlights are for the specific references but other text and numbering in these sections could also be different.)

3.5
Rotating PTO drive-shaft guard:

PTO drive-shaft guard attached to the shaft by bearings, which can rotate with the shaft except when it comes into contact with some other object.

3.6
Cover-type drive shaft guards:
PTO driveshaft guard (or part thereof) which is not connected to the pto drive-shaft by bearings.

6 Tests for all types of guard

6.1 General

The tests are intended to ensure that the guard can protect anyone coming into contact with it and that, under foreseeable circumstances, it can withstand wear-and-tear and mistreatment which may be caused by external forces and agents and from contact with the rotating shaft within.

It is intended that the wear and strength tests given below are used to reveal any weaknesses in the design or materials of the particular guard being tested.

The tests described are for the most common types of guard in current use but the tests may be applied to derivatives of these guards which may have been designed to accommodate a special type of shaft or attachment.

They may also be used to test novel designs of shaftguard where the methods of test may be modified provided there is no reduction in the severity of the test. In such cases, certain sections of the test may also be omitted if the particular test is irrelevant to the design of guard. (See guidance notes)

After each test, note and record the condition of the guard, with particular reference to any fractures, permanent deformation or detachment of components which could pose a threat to the safety of an operator or bystander or contribute to the deterioration of the guard, thus eve ntually becoming dangerous.

Then

6.2.3 When operating in the test sequence described below, the shaft shall be rotated. Whilst rotating, it shall be extended to its maximum length, for 1 min of each 5 min cycle, and held at its minimum length for the other 4 minutes.

Maximum and Minimum lengths:

For guards attached to the shaft by bearings the definitions are the same as for 'extended length' and 'closed length' above but for cover-type guards are defined as:

i. Minimum length.The minimum distance, which can be measured along the outside of the guard, when held at the 'closed length' and bent through 90 degrees.

Ii Maximum length The maximum distance, which can be measured along the outside of the guard when held at the 'extended length' and bent through 90 degrees.

Stationary guards and cover-type guards shall be fixed using their proper fixing systems.

6.3 Strength tests

6.3.1 Dynamic radial loading tests at ambient temperature

The guarded driveshaft shall be subjected to a radial loading test at ambient temperature.

To avoid excessive vibration, the wooden beam described below may be supported by a 20 mm thick rubber backing of approximately A/20 Shore hardness (see figure 1 in ISO 5674-1:1992). When applying the load, care shall be taken to ensure that no impact load is applied

6.3.1.1 Test over joints

Rotate the PTO driveshaft and, using a smooth flat 100 mm wide wooden beam, apply a direct force of 500 N to the guard over the centre of the articulation of the universal joint, for 60s as shown in Figure 1. The force shall be applied perpendicular to the PTO driveshaft.

If the guard or method of attachment of the guard to the shaft is not identical at each end, then test both ends.

6.3.1.2 Test on tubes

6.3.1.2.1 For guards attached to the shaft by bearings:

Support the guarded PTO driveshaft in a horizontal, straight line by its usual end connections, extended to the maximum length recommended by the manufacturer.

Rotate the PTO driveshaft and apply a direct vertical load of 500N for 60s at right angles to the shaft guard at its midpoint, using the device described above.

6.3.1.2.2 For cover-type guards:
Support the guarded PTO driveshaft in a horizontal, straight line by its usual end connections. To ensure that the guard is not stretched in such a way that the weight of the test beam keeps the cover clear of the rotating shaft artificially:

Starting from the closed position, extend the guard to its extended length and find the position where the internal parts of the guard come nearest to the shaft or touch it. Set the guard length to this position. Rotate the PTO driveshaft and apply a direct vertical load of 500N for 60s, at right angles to the shaft guard at that point followed by another loading at a point midway between that point and one end.

Record any damage to the guard or its end connections and make note of any excessive vibration.

6.3.2 Axial loading test at ambient temperature

6.3.2.1 For guards attached to the shaft by bearings only:

6.3.2.1.1 With the PTO driveshaft and guard stationary, apply an axial force of 250 N between the cone and the tube in both directions. The force shall be gradually applied and then held for a minimum of 60 s. If the cones, or method of attaching them to the tubes, are not the same, each cone end shall be tested.

6.3.2.1.2 With the PTO driveshaft and guard stationary, apply an axial force between the guard and the PTO driveshaft in each directions in turn. The force shall be:

a) 2.5kN if the inner diameter of the outer guard tube, D is less than or equal to 80mm.
b) If the diameter D is more than 80mm, the load shall be determined by the formula F=Dx0.027,
F being the axial force in kN up to a maximum of 3.5kN and
the diameter D being in mm..

The force shall be applied on the PTO shaft while the guard is held stationary.

If the method of attachment of the guard to the shaft is not the same at each end, each end shall be tested.

6.3.2.2 For cover-type guards:
Using the normal fixings for the guard, exert a tensile stretching force of 3.5kN, followed by a compressive force of 3.5kN to the complete guard.

Then

6.4 Dynamic end loading of the bearings.
For guards attached to the shaft by bearings only:

6.5 Tests at sub-zero temperatures for guards with plastic loadbearing components.

6.5.1 Impact test at sub-zero temperatures

6.5.1.1 Support the PTO driveshaft and guard in a horizontal straight line by their normal end connections, extended to the maximum length recommended by the manufacturer for bearing type guards and for cover-type, as described in 6.3.1.2.2

6.5.1.2 Maintain the PTO driveshaft and guard at -35oC for 1 h.

6.5.1.3 With the PTO driveshaft and guard at -35oC, strike three blows as follows:

a) One on the guard over the centre of articulation of the universal joint when in line with the PTO driveshaft (the position of the end yoke being such that the face of the yoke is parallel to the contact face - see figure 2);
b) One at the midpoint of the overlap of the tubes (bearing type only).or over the supporting device nearest the centre of the shaft for cover-type.
c) One midway along on one of the tubes for bearing-type and mid-way between the point in b) and one end of the guard for cover-type.

The blows shall be struck by using a pendulum so that the impact energy is 98J. The contact face shall be flat and have a diameter of 50 mm (see figure 2).

6.6 Axial loading test at sub-zero temperatures

6.6.1 For guards attached to the shaft by bearings:

6.6.1.1 Lower the temperature to -35oC and maintain the PTO driveshaft and guard at that temperature for 1 h.

6.6.1.2 With the PTO driveshaft and guard stationary and at -35oC, apply an axial force between the guard and the PTO driveshaft in both directions. The force shall be calculated as in 6.3.2.

6.6.2. **For cover-type guards:**

6.6.2.1 Extend the guard to its maximum length and immerse in potable water for 60s. Close and hold at its minimum length and allow to drain by tipping at a 60 Deg angle for 60s before placing in freezer at - 35 Deg C for 1 hour

6.6.2.2 Remove from freezer and connect to tensile test rig via its proper connections and stretch out to its maximum length. Record the load required

6.6.2.3 Record any damage to guard and fixtures.

6.7 Restraining system test at ambient temperature.
For guards attached to the shaft by bearings only:

2. UK Proposal to amend the sections of ISO 5674 which deal with the application of Salt Water as a corrosion accelerator.

The current standard has a section in the wear test, which requires salt water to be sprayed on to the shaft guard before the last section of the running tests.

Recent research has established that the primary reason for doing this was to establish whether the old ball bearing type guards would fail if rust got into the bearing systems.

A secondary reason for applying salt water might have been that it is known that salt spray is used to induce artificial weathering on plastics. It could be argued that by spraying the whole guard, one would be also subjecting the plastic material to a recognised harsh environment. This would however not be of value because the application takes place too late in the test sequence to have any effect.

Thirdly, one national test station suggested that the salt spray test also subjected the metal restraining systems to a corrosive atmosphere.

There is a problem with the test method because the definitions of how to apply the spray can not be described in a Quality System. The instructions in the standard are for a system, which is for field spraying which requires the nozzles to be moving and to have an overlap to provide an even distribution. Test bodies have been using their discretion and applying the spray within the spirit of the standard. They know that the salt water does not penetrate modern guards, which are fully greased, and that modern nylon bearings are not as affected by corrosion as the old ball-type.

It is not acceptable to revise a Standard and include test methods which are of questionable value and not properly controllable.

One solution is to make the salt test optional for guards without metallic elements in their bearings, this has already been proposed in Document N010.

However, further study has been made of the problem, taking account of the opinion of one test authority that, corrosion of the shaft grooves causes rapid wearing of the new-type nylon bearings. Recent tests have shown that nylon bearings will wear rapidly when run without grease on a rusty shaft. This would be an extreme situation in the field but the current test does wear the bearings even when they are well greased throughout so, the combination of a rusty shaft and poorly greased bearings might cause a failure.

It has also been shown that even when salt water is applied directly that corrosion will not take place during the 5674s’ 46 hour resting period if the bearings remain wet. They will remain wet if the guards are left in place and, especially, if left in an enclosed cabinet.

The conclusion is that the test is not capable of achieving its intended aim so it would not work for nylon bearings either.

In view of the above findings, it seems that there must be a change in the standard. Either exclude the salt test completely or introduces a version which has the possibility of inducing the actions originally proposed by the Standard.

Trials have shown that it is possible to apply salt water to the bearing grooves and induce corrosion by a different method, which is proposed below. It describes a system of applying the salt, which does not need a complicated apparatus and specifies a method of drying which will allow rust to form. It also proposes that the salt application take place before the bearings or shaft, have any grease applied, which would inhibit the formation of rust.

Testing and research have already resulted in a proposal for a new layout for the Standard in ISO/TC/ 23/SC2/WG5, N010. The following proposals are presented as revisions to that document rather than the original Standard because the general content of the revision is already widely supported.

In order to rationalise the inclusion of salt water application and corrosion within the scope of the Standard, the following alterations to the existing N010 text are proposed:

(Highlights are for the specific references but other text and numbering in these sections could also be different.)

5 Test equipment

5.1 General

5.1.1 The wear test equipment shall consist of a cabinet capable of holding the PTO driveshaft and rotating the PTO driveshaft at a frequency of 1000 rev/min. The equipment shall be such that it can be used for all PTO driveshafts as specified in ISO 5673. The size and shape of the cabinet shall be such that an even distribution of dust is ensured.

6.2 Wear tests

6.2.1 Bearing corrosion test:

(If the guard has bearings running in contact with the PTO-shaft)

This test must be carried out with a shaft and bearings which have had all paint removed and been completely degreased at all points where the bearings locate. The shaft with the bearing in place, but with the rest of the guard removed, shall be supported horizontally and stationary, and salt water applied to all bearings for the first five minutes of every hour for 48 hours then left to dry in free air.

The salt water may be applied by spraying, flooding or any other suitable method provided- that it flows over all the metallic parts of the bearing system at some stage during the five minutes. It may be necessary to rotate the shaft during the process to ensure good coverage but this should only be done very slowly so as not to throw the liquid off.

After the salt-water application phase, the shaft, with bearings attached, should be left to dry in free air for a further 48 hours before re-assembly, greasing as defined by the manufacturer.

3. UK Proposals to include more specific requirements about the Quality Control of materials used in the manufacture of PTO Shaft Guards within the scope of ISO 5674, with particular emphasis on their UV stability.

Plastics have become the most popular materials in the construction of guards because of their relatively low cost, their manufacturing properties and their general ability to withstand the relatively harsh conditions found in agriculture.

Surveys have suggested that the properties, which make them popular, do not necessarily last with the passage of time and do not always remain consistent if the manufacturing technique is modified or if the base material is altered.

Some manufacturers have done a lot of background research into the consistency of manufacture and particularly the ability of their guard components to withstand the damaging effects of UV radiation. They know their normal materials well and have confidence in them.

There is a problem however when the manufacturer wants to change his material supplier, his manufacturing technique or to introduce a new material with properties to suit a particular requirement. This could be to respond to the need for technical advancement or improved safety for instance. In these cases, his original guard has been tested and his knowledge about the materials used in its construction may be on record. The test authority however has no record of this information and no system in place to check it.

The tendency nowadays is for test Standards to link in with systems, which can be audited, which would have measures in place to flag-up any deviations from the production systems.

To aid the development of such Quality systems, it is necessary to indicate any supplementary tests or actions, and what certification should be provided by the manufacturer to give a particular Standard proper credence.

Such matters can be aided by the inclusion of tests like the one proposed by Germany in the N010 document which is before WG5 now. This test may well give confidence in the materials used when supplemented by adequate background research and a rigorous inspection regime.

As an alternative to the certification of guard components to UV resistance, it could be possible to propose a weathering process, which could be carried out on the guard prior to its testing under 5674.

Both alternatives are included in the proposal below.

In order to include measures to promote the improvement of guard with respect to UV tolerance within the scope of the Standard, the following alterations to the existing text are proposed:

4. General Test conditions

4.1 Guard

4.1.1 The guard shall be taken from production and be within the tolerances shown on production drawings.

4.1.2.1 When the guard is made of plastic material, the manufacturer must show evidence of how he has certified its resistance to UV-radiation to an appropriate standard (See Appendix?), and how his Quality Control systems can ensure that the design and materials will continue to meet the specification.

Alternatively, the UV requirements may be satisfied if the following wear and strength tests are carried out using a guard, which has previously been weathered using an appropriate Standard

Also

Appendix (Number to be decided)

Typical Quality control document:

Model and type of guard:

Production Drawing codes:

Inspection Process documentation:

Material Specification:

Cone
Tubes
Collar
Etc.

TO BE CONTINUED WHEN RESEARCH COMPLETE

APPENDIX 3

HDPE High Density Polyethylene

A = amorphous – Cr – crystalline – C = clear – E – excellent – G = good – P = poor –
O = opaque – T = translucent – R = Rockwell – S = Shore

STRUCTURE:	Cr
SPECIFIC DENSITY:	0.95
WATER ABSORBTION RATE (%):	0.01
ELONGATION (%):	10
TENSILE STRENGTH (psi):	4550
COMPRESSION STRENGTH (psi):	2900
FLEXURAL STRENGTH (psi):	5800
FLEXURAL MODULUS (psi):	120000
IMPACT (izod ft. lbs/in):	NB
HARDNESS:	SD65
FABRICATION	
- BONDING:	P
ULTRASONIC WELDING:	P
- MACHINING:	G
DEFLECTION TEMEPERATURE (deg. F)	
- @ 66 psi:	176
- - @ 264 psi:	131
UTILIZATION TEMPERATURE (deg. F)	
- min:	-180
- max:	248
MELTING POINT (deg. F):	266
COEFFICIENT OF EXPANSION:	0.00007
ARC RESISTANCE:	180
DIELECTRIC STRENGTH (kV/mm):	22
TRANSPARENCY:	T
UV RESISTANCE:	P
CHEMICAL RESISTANCE	
- ACIDS:	G
- ALKALIS:	E
- SOLVENTS:	E

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