MODERN METHODS TO RETRIEVE INNOVATIVE MATERIAL SOLUTIONS FOR TRIBOSYSTEMS

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Abstract

A numerical, tribological data collection system with 15,000 data records was developed to find materials for tribological operations. The database enables the user to search, retrieve and display information and data about the appropriate material couples in a fast and convenient way. The database is intended to be used by researchers, engineers, consultants and developers. All tribological characteristics of the listed materials are directly comparable; the data has been compiled and put into a standardized form, which covers the specific properties of nearly all tribometers used. The structure and the precisely defined formats may help guide future scientists and engineers to organise, archive and publish their tribological tests and results in a complete and comprehensive way.

1. Introduction

Each year many thousands of tribological tests are performed and published. Accessing this information for engineers and researchers can be time-consuming. Inconsistent tribological specifications hinders the validation of these data and any comparison between them. Unfortunately, material manufacturers, evaluators or testers and modellers all speak a different language. Also, they pursue different interests and philosophies. As a consequence, the readers of tribological literature are often not in the position to decide if the published tribological properties of materials and/or lubricants are suitable for a specific application.

The manufacture of high-quality products with high performance and reliability in shortened development times is crucial in today's competitive markets. Additionally, light-weight construction increases the stresses in tribosystems. Given that the failure of most components are surface initiated and that tribological performance of materials, coatings and lubricants are of considerable significance in the design of system components, design engineers need rapid access to tribological expertise and know-how. The successful engineer and consultant in this field is the one with the broadest experience of different materials. More specially, they must have an understanding of the conditions under which the materials will and will not operate.

To overcome this, a format and identified fields has been developed by the author´s organization for organising sliding, fretting and rolling friction and wear data originating from screening tests under unlubricated and boundary or mixed lubricated conditions. The information provided from the tribological database should assist material selection but not serve as a substitute for careful testing of prototype parts in typical operating environments before beginning commercial production.

2. State of the art

Previous attempts to improve the transfer of tribological knowledge to design engineers have included the development of tribological check-lists, handbooks and compilations. The application of computers in tribological testing and data acquisition is not new [1-3]. Today designers routinely use FEM methods to simulate the behaviour of components. So it is curious, that databases, which are common for mechanical, physical and chemical properties of materials, are not readily available for tribological data. This may arise from the fact, that tribological data characterise system properties that depend on many parameters and consequently there are no ”hard data“. Moreover, a philosophy to include wear quantities for mixed lubrication or/and unlubricated conditions needs to be developed [4]. In today’s practice, engineers and researchers can use a knowledge-based expert system (refer to Table I) or make a literature survey (International literature data base „Tribology Index“ via the hosts „FIZ-T“ or „STN“) in a literature database. However, a literature database search can take up to 12 to 15 weeks to complete. Table I compiles the worldwide activities regarding database and expert systems. It is interesting to note, that all projects related to tribological database were abandoned and this shows impressively the complexity of the thematic “Tribology”. Only the rule based expert systems have become operational.

Expert systems (also called knowledge-based systems) are defined as computer programs which are developed to encode expert knowledge and make it easily available to the user [5] . They comprise heuristic rules and mathematical models or specialist expertise used in the methodology of selection [6-9] .

3. Development of a database

The starting point at the author´s organization for the development of a numeric database was the observation that hundreds of single data files existed on many personal computers. These data files were mostly built-up to draw diagrams or to add the listings of results to final reports.

Examination of the data files resulted in the conclusion that not only were none of the files numerically compatible with each other, but in the same laboratory, their was an unexplainable scatter concerning the precise technical definition of the numerous formats and in the testing philosophy. This may be a mirror image of the tribology field world-wide.

The existing data including most recently published data sets are incomplete, because to the author or data originator everything was clear. More data and results were not requested from the tasks of a specific project, but these data and the information could have been collected during the tests. In the long-term view, it is to anyone other than the author nearly impossible to validate these results and they may be classified as “unusable“. Accordingly, the “wheel must be reinvented“, new tests are necessary and a loss of knowledge occurs.

Also, in many high-quality papers, a lack of information is often very apparent. With the information published, approximately only 40 data fields could be filled. This is not enough for a reader to validate the published results. When an engineer reads about the promising tribological behaviour of a tribo-couple, he can not transfer these results to solve his problem, because only the common name of the material or lubricant was published. The policy of some societies and journals exacerbates this by prohibiting the publication of trade and company names. The variety of tribological quantities and dimensions hinders additional comparison between the papers and journals.

Based on these facts it was decided, that the database “Tribocollect“ should contain only critically evaluated numerical data from the author´s organization and should focus on the following areas of application:

- comparative analysis of the tribological behaviour of materials;
- assistance for the selection of candidate materials for a specific tribological operation;
- influence of operating conditions on tribological quantities; and
- input, documentation and management of tribological results.

These areas of application lead to additional questions about the common sense, philosophy and output of such a database. For example, what will we do with the numeric wear data? Should the numeric wear data be used to predict the life-time, e.g., for dry running or boundary and mixed lubricated tribosystems? And so forth.

3.1 Definition of formats

Intense, difficult and long discussions between scientists are necessary to determine not only an internal consensus between all, but to precisely define data fields to establish a definitive terminology and to satisfy all indispensable needs, which has to be derived from the needs of more than 30 different test machines and many test procedures. The convention of the database contains no material properties, as was planned for “ACTIS“ [10,11] and is realized in “Tribolog“ [12]. The material properties are, if they were available, compiled in a separate database. The compatibility of this outcome was later checked with existing German standards DIN 50320, 50323, 50324, 51834, international standards ISO 7148 and ASTM G118-93 and running EC research projects, such as EUFRETTING or FASTE. The first assembling of all data files lead to around 300 data fields, which were standardised to 160 for version 1.0. During the development of the version 1.1, a further reduction of data fields to 150 was achieved as well as an increase of the filling grade and the consistency.

It was pointed out that designers always need to know what has been used before and what results were obtained. They want to match the needs of the application with the properties of the tribo-couple. Properties such as surface characteristics, the friction coefficient and wear behaviour were the predominant ones. Further important issues to validate the results and to obtain an identity between the data from the model tests and the application are: the application environment, geometry, lubricant, initial roughness, ambient temperature, load or pressure and surface speed.

Up to 140 attributes (Version 1.2; appeared in June 1997) can now comprehensively describe a complete tribological test. The reason, why so much information or data formats are necessary, is the fact, that a design engineer needs them for his drawings. The general contents of the numerical data collection are as follows:

- description of the operating conditions;
- test identifications;
- geometry of samples/test configurations;
- description of surfaces;
- extensive definition and information on materials, substrates, coatings and lubricants;
- test results; and
- different tribological quantities of a couple.

3.2 Working with the database

Database systems generally are only searched for materials on entered datasets and retain materials whose specifications match or exceed those requested in the filter condition. These systems will not provide recommended materials to use or identify the “best“ or “next best“ tribo-material. The main philosophy of the approach presented here is the numerical selection of candidate materials, based on a system analysis of the tribosystem and that any operating tribosystem under mixed/boundary lubricating and/or unlubricated conditions exhibit a wear rate or coefficient. The validation of the successful match or hits has to be done carefully by the tribological expert.

- Search for candidate materials

The search for candidate materials via the tribological properties of couples can be performed for versions 1.x using a commercial database software. Work with the commercial database software enables a full validation of the tribological results, but requires deep knowledge of databasing and tribology. An easier and faster way is to the computer mouse to locate two simplified menus for two common and typical queries. This was not possible in unable with the version 1.2. These menues help search for “candidate materials“ or for the “tribological behaviour of materials“.

The greatest number of hits defines achieves a successful search via the quantity specific wear rate or coefficient of triboelement 1 or triboelement 2 or both as a tribocouple. This quantity is generally labels as symbol „k“ and defined in [mm^3/(Nm)]. This query implies that the previously elaborated knowledge of the tribosystem is sufficient to calculate the wear rate, which indicates the wear limit for the selection of candidate materials. Candidate materials found in this database must exhibit a lower wear rate than calculated and show a relatively close identity of the operating conditions between data file and application. The limit for the query should not be considered as sharp, because first, the calculated wear rate in the regarded tribosystem is only a roughly estimated number and second, the identified data from screening tests must not be transferable to the problem in view.

Figure 1 plots, as a general overview, the total wear rate (the sum of the wear rate of triboelement I and II) versus the coefficient of friction at test end with 8,737 hits from 11,787 data records in version 1.1. These results illustrate, that not all records fulfil the filter condition of simultaneous data content in the fields “total wear rate” and “coefficient of friction at test end“.

For the evaluation of the wear rate and other filter conditions, a special brief questionnaire was developed, that is presented in Figure 2. The questions asked in this questionnaire represent the minimum information needed about a tribosystem of an application. For many engineers, this questionnaire was their first tribological “trainee“ and they learned very quickly which tribological relevant topics in their application they had to focus on.

All tribosystems have a wear rate. The wear rate must be calculated from the wear volume, the sliding distance and the normal force of the considered tribosystem. Even if the wear rate k is adequately defined in mm^3/(Nm), determination of these three variables is still difficult. The wear volume can be determined from the maximum acceptable increase of gap, clearance or tolerance of the wearing surface area during one typical life-cycle. The sliding distance will be calculated from the life-time and an average, typical operating speed as well as with the dimensions of the components. Depending on the case, four different defined normal forces can be appropriate:

a. The normal force acting in a tribosystem could be chosen as the average or integral force during a cycle of a rotating machine element.
b. The normal force acting in a tribosystem could be chosen simply as the maximum force.
c. The normal force acting in a tribosystem could be chosen as the typical force with an 80% probability during the lifetime.
d. The normal force acting in a tribosystem could be chosen as the normal force occurring under severe wear conditions.

- Working area

From the actual experience working with “Tribocollect“, a selection of candidate materials with promising tribological behaviour could be selected several times for the following area of unlubricated and boundary or mixed lubricated applications.

- Piston ring/ cylinder liners,
- Hinge joints,
- Constant velocity joints,
- Coefficients of friction to optimise press-fits or dry sliding contacts,
- friction roller drives,
- Sliding bearings and guides,
- Cam/followers,
- Stick-slip problems, and
- Failures.

4. Summary

“Tribocollect“ is now an operational, tribological data collection which contains 15,000 data records. For version 1.4, a bilingual software is available and has been designed to search, retrieve, and display information and numeric data using two self-guiding menus. The structure and precisely defined formats may serve as a guide in the future to scientists and engineers to organise and publish their tribological tests results in a complete and comprehensive way. This data collection enables researchers, engineers, design shops and consultants to retrieve the appropriate material couples in a rapid and convenient way and to obtain reliable data about the tribological behaviour. Moreover, they have now a tool which produces innovative tribological solutions on short notice.

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List of Figure captions

Tables and Figures

Acronym	Title	Country	Type
ACTIS[10,11]	A numerical tribology information system	USA	Expert system/Database
PRECEPT[8]	Tribological principles in an expert system	NL	Expert system
ARMES[7]	Abrasion resistant materials expert system	AUS	Expert System
TRIBEX[9]	Wear expert system for unlubricated tribosystems	D	Expert system/Database
TRIBOLOG[12]	Numerical data bank (6000 data records)	F	Database
TRIBODATA[14]	Tribological behaviour of polymers (4000 data records)	D	Database
TRIBSEL	Coating selection expert system	GB	Expert system
ISIS[6]	Surface coating selection system	GB	Expert system
TRIBOCOLLECT	Numerical, tribological database (12.100 data records)	D	Database
N.N.[13]	Numerical, tribological database	CH	Database

Table I: World-wide activities on tribological databases and expert systems

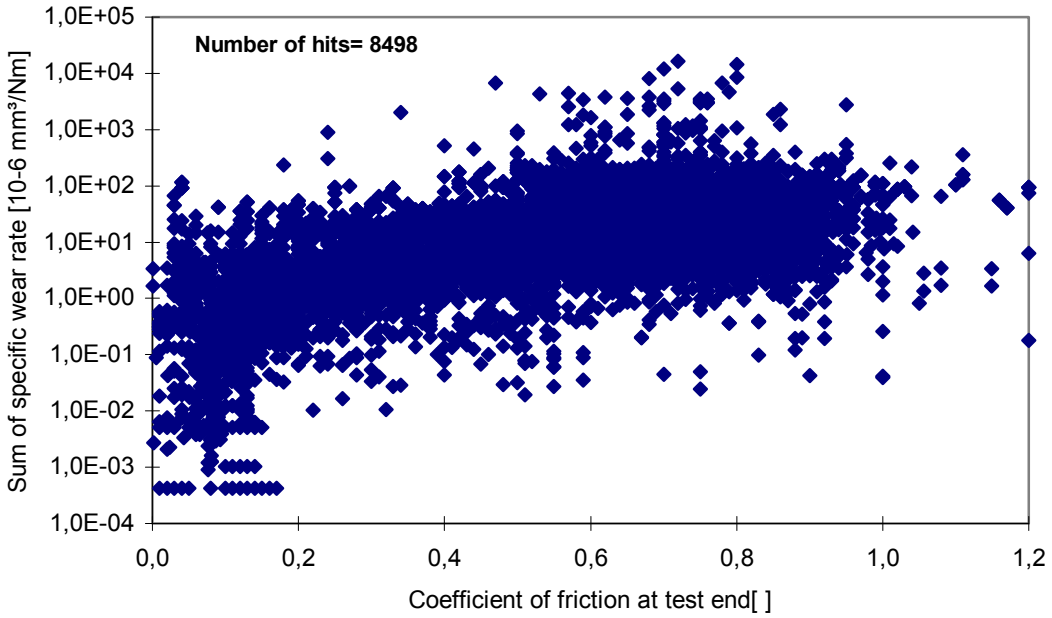

Figure 1: Plot of the hits from the filter condition „total wear rate“ versus „coefficient of friction“ found in Tribocollect

BAM QUESTIONNAIRE ON OPERATING CONDITIONS

Please fill in fields numbered 01 to 25, respectively mark what is applicable!

	name of tribosystems [1]	01	
structure of the tribosystem	tribocomponents [2]	element 1	element 2
	name	02	03
	dimensions	04	05
	material	06	07
	roughness	08 C.L.A.= µm R_z= µm	09 C.L.A.= µm R_z= µm
		interfacial medium	surrounding atmosphere
	name	10	11
	state of aggregation	12 ☐ solid ☐ liquid ☐ gaseous	13 ☐ liquid ☐ gaseous
	lubrication mode	14 ☐ unlubricated ☐ fluid lubrication ☐ gaseous lubrication ☐ mixed lubrication ☐ boundary lubrication	
operating variables	type of motion	15 ☐ sliding ☐ rolling ☐ drilling ☐ impact	
		16 ☐ continuous ☐ intermittent ☐ repetitive	17 ☐ oscillating oscillating frequency: Hz
	normal force N	18	
	pressure N/mm²	19a (geometric)	19b (Hertzian)
	velocity m/s	20a min. 20b average	20c max.
	temperature of operation °C	21a min. 21b typical	21c max.
	duration of operation h	22	
trib. characteristics	coefficient of friction	23a min.	23b max.
	allowable wear length µm	24a (element 1)	24b (element 2)
	allowable wear volume mm³	25a (element 1)	25b (element 2)

1) According to the German Standard DIN 50320 and DIN 50323 a tribosystem consists of element 1 (e.g. bearing shell), element 2 (e.g. shaft), interfacial medium (e.g. lubricant) and surrounding atmosphere (e.g. air).

2) If possible, please attach a sketch or a foto showing the areas in which wear occurs.

Contact
Name :
Company :
Department :
Address :
Phone No. :

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Figure 2: Brief questionnaire on the structure and operating conditions of a tribosystem

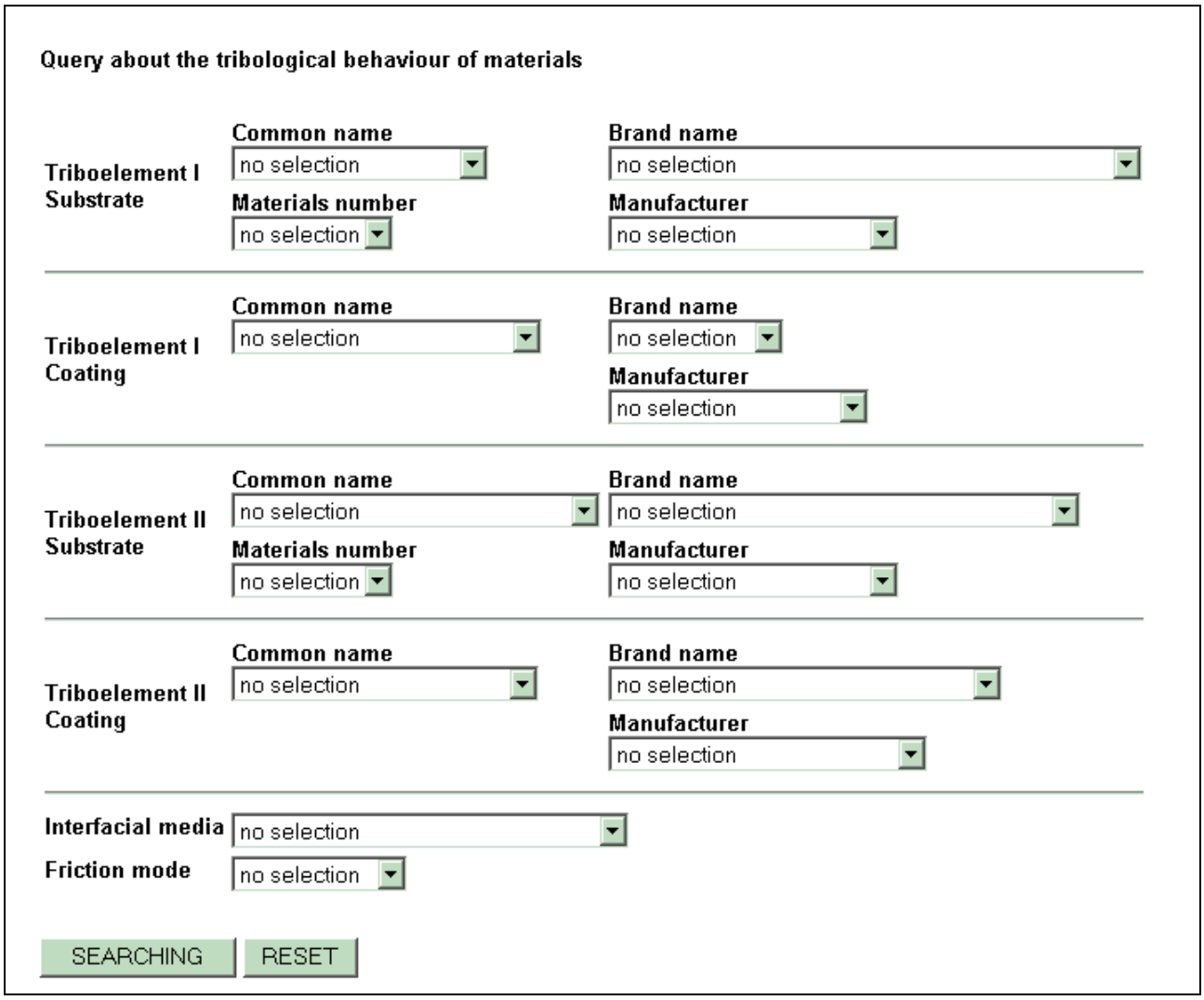

Figure 3: Example of a menu to retrieve data about the tribological behaviour of a materials couple