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Journal of the Balkan Tribological Association is an International Journal edited by the Balkan Tribological Association for rapid scientific and other information, covering all aspects of the processes included in overall tribology, tribomechanics, tribochemistry and tribology.
The Journal is referring in Chem. Abstr. and RJCH (Russia).

Aims and Scope

The decision for editing and printing of the current journal was taken on Balkantrib'93, Sofia, October, 1993 during the Round Table discussion of the representatives of the Balkan countries: Bulgaria, Greece, Former Yugoslavian Republic of Macedonia, Romania, Turkey and Yugoslavia. The Journal of the Balkan Tribological Assosiation is dedicated to the fundamental and technological research of the third principle in nature – the contacts.
The journal will act as international focus for contacts between the specialists working in fundamental and practical areas of tribology.
The main topics and examples of the scientific areas of interest to the Journal are:

(a) overall tribology, fundamentals of friction and wear, interdisciplinary aspects of tribology;
(b) tribotechnics and tribomechanics; friction, abrasive wear, adhesion, cavitation, corrosion, computer simulation, design and calculation of tribosystems, vibration phenomena, mechanical contacts in gaseous, liquid and solid phase, technological tribological processes, coating tribology, nano- and microtribology;
(c) tribochemistry – defects in solid bodies, tribochemical emissions, triboluminescence, tribochemiluminescence, technological tribochemistry; composite materials, polymeric materials in mechanics and tribology; special materials in military and space technologies, kinetics, thermodynamics and mechanism of tribochemical processes;
(d) sealing tribology;
(e) biotribology – biological tribology, tribophysiotherapy, tribological wear, biological tribotechnology, etc.;
(f) lubrication – solid, semi-liquid lubricants, additives for oils and lubricants, surface phenomena, wear in the presence of lubricants; lubricity of fuels; boundary lubrication;
(g) ecological tribology; the role of tribology in the sustainable development of technology; tribology of manufacturing processes; of machine elements; in transportation engineering;
(h) management and organisation of the production; machinery breakdown; oil monitoring;
(j) European legislation in the field of tribotechnics and lubricating oils; tribotesting and tribosystem monitoring;
(k) educational problems in tribology, lubricating oils and fuels.

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Computer processing of tribology data

CONVERSION OF DATA INTO INFORMATION IN TRIBOLOGY RESEARCH

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ABSTRACT

Relevant and timely information is of crucial importance in scientific investigations and understanding of the phenomena should be precise and explicit. Among others, phases of scientific investigations comprise data acquisition and their structuring into database and data warehouse, followed by their analysis in order to find laws and patterns and comparison with similar data. These activities are aimed at data to become information and for information to grow into knowledge and to further use of that knowledge to formulate decisions and to anticipate future events and possibilities. However, simple analysis of information obtained from conducted research is no longer sufficient, therefore, proactive approach is needed, that is technologies, skills and tools are needed that will assist in rapid decision-making and forecasting. The paper presents architectures for data acquisition, developed databases and reporting, as well as contemporary information technologies used for tribological investigations in area of Metal–Matrix Composites – MMCs, in the light of the above observations.

Keywords: information technologies, database, software tool, data conversion, tribological investigations, tribology.

AIMS AND BACKGROUND

We live in time of dynamic, dramatic, complex and unpredictable changes, in a period which is marked by different terms as: starting from digital revolution, information age, up to third wave. Information and knowledge growth are becoming more and more essential development and economy resources. We have been living in digital technologies era for three decades now and Internet and Intranet

* For correspondence.

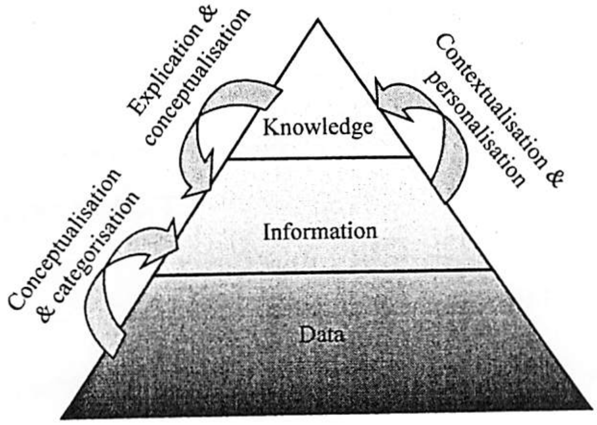

Fig. 1. Data–information – knowledge[1]

environments fundamentally change the way of communications, availability, accessibility and data/information exchange. Relevant and timely information is of crucial importance in scientific investigations and understanding of the performed event should be precise and explicit. Among other, phases of scientific investigations comprise data acquisition and their structuring into database and data warehouse, followed by their analysis in order to find laws and patterns and comparison with similar data. These activities are aimed at data to become information and for information to grow into knowledge and to further use that knowledge to formulate decisions and to anticipate future events[1] (Fig. 1).

Data alone are rather hardly usable. Only after they have been processed, when relevance in certain context and in specific way is given to them, they become information. Data conversion into information is relatively mechanical process and is realised using information technologies that categorise, process and storage them. Role of information is to lower uncertainty in scope of some critical area. Collection of data that has been processed and presented in a certain way, combined with experience and intuition constitutes knowledge. Information becomes knowledge when it is processed in a mind of a person. Such a knowledge again becomes information when it is transferred to other persons in a form of a text, picture or graphics. Knowledge is sustainable and unlimited resource accumulated through experience. It is embedded in persons who create, develop, enhance, use and transfer it. One of the goals of information technology and databases is to facilitate storage, documentation and transfer of experimental knowledge.

EXPERIMENTAL

The implementation of tribological principles in the database and expert systems has always been a goal of many research efforts. However, the complexity of seemingly simple interaction of two bodies, carries a number of challenges and concerns when it comes to designing tribological database or expert system. A major problem is that the data that describe the tribological phenomena are not unique and unambiguous. An example of this is that, for the same contact geometry, materials and conditions under which the contact is achieved, researchers can get different values that describe the basic tribological phenomena such as friction and wear. In addition to problems related to the origin of the data, a number of problems related to the fact that quite a number of tribological phenomena cannot be described quantitatively, and the qualitative evaluation is often subjective evaluations of researchers. Many such examples are given in the book 'Modern tribology handbook' in 'Friction and Wear Data Bank'[2]. In the aforementioned chapter is an overview of database instance for different types of tribological materials.

An example of a database for the selection of tribological optimum material for known exploitation conditions is given in the Woydt paper[3], in which the author referred to the table showing the existing database and expert systems in the world.

Database[4] and expert systems[5–9] were the subject of investigations of many authors in order to assist tribomechanical system designers, primarily in selection of materials, as a consequence of that, practical tribological recommendations, which are the result of a large number of systematised results of laboratory tests conducted by researchers all over the world.

Contact surface has a major influence on the quantity of friction wear. Therefore, tribomechanical system designers, along with the material selection, must consider the quality of the contact surface. Franklin and Dijkman[5] presented a method by which way tribological principles can be implemented in the database and expert systems for the metal materials, surface treatments and coatings selection. The authors define the database and expert system based on 9 rules (Rule design and implementation philosophy; Mechanical contact overloading; fretting rule; Excessive material transfer; Three-body abrasion; Two-body abrasion; Negligible wear; Surface fatigue; Steady state wear factor), which describe tribomechanical system and its exploitation conditions, recommends solutions in terms of material, surface treatment and coating selection.

Also, Luoa et al.[7] presented on which way preliminary selection of single or multilayer coating, coatings materials, deposition process, thickness of coatings can be done.

Potentially the interpretation of data into information is a very complex issue. It is also subject to consideration of a number of authors, and also the subject of this paper. One of many possible scenarios of conversion process of data obtained from different resources is shown in Fig. 2 (e.g. from the embedded sensors on the machines, from maintenance database, from manually input working conditions and experimental laboratory investigations) into information[10].

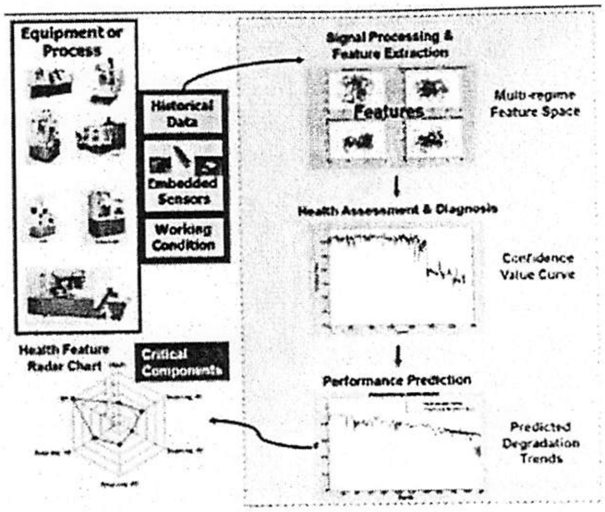

Fig. 2. Data to information conversion process[10]

Data is obtained from several resources and further transformed into multiple-regime features by selecting the appropriate computational tools for signal processing and feature extraction. In the feature space, indices are calculated by statistically detecting the deviation of the feature space from the baseline by choosing the appropriate computational tools for assessment/evaluation[10].

The starting point for developing a database into the conversion platform (Fig. 3) is the observation that the hundreds of individual 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. After examining the files can be concluded that formats of these files were not compatible with each other even at the same laboratory, and that their format depended on the subjective approach to the researchers. There is question of reliability and repeatability and results verification possibility, if the data are available only to the author.

In the present work, authors wanted to show information platform architecture for data conversion, developed database architecture as a one way of applying modern information technologies on an example of tribological investigations of ZA27-based metal matrix composite reinforced with Al_2O_3 particles. An attempt has been made to evaluate the dry friction and wear behaviour of ZA-27/Al_2O_3 composite over range of applied loads and sliding speeds. The unreinforced ZA-27 alloy was tested as a reference material.

DATA INTO INFORMATION CONVERSION PROCESS

On the Faculty of Engineering at the Tribology laboratory for the data into information conversion processes basic platform shown in Fig. 3 is used. The platform combines hardware and software that should provide a high level of functionality, communication and independence. The mechanisms that support this are: modelling Mechanisms (UML – Unified Modelling Language, MDA – Model Driven Architecture), Web mechanisms (universally accepted protocols and services) and virtual executive systems (JVM – Java Virtual Machine).

In case of tribological investigations, conversion process is realised by data acquisition process whose block diagram is shown in Fig. 4 (Ref. 11).

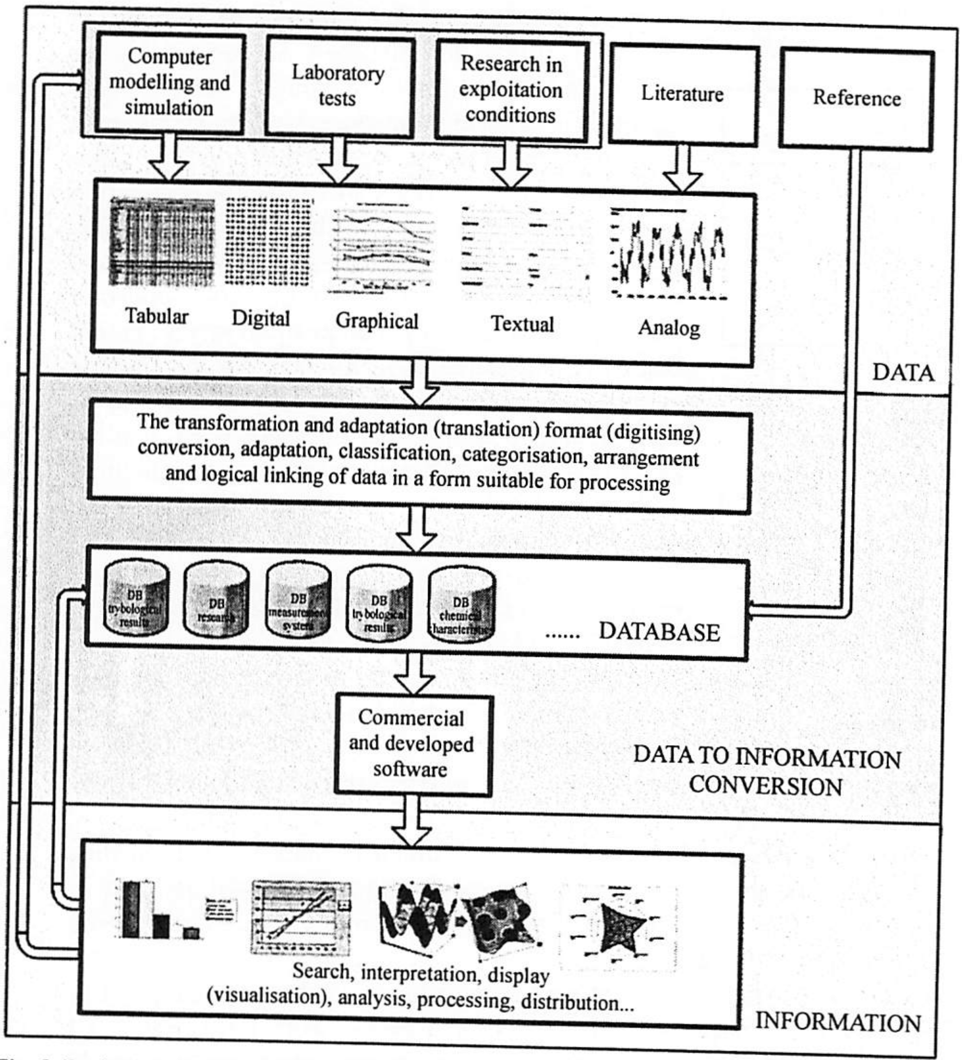

Fig. 3. Basic platform for data into information conversion process

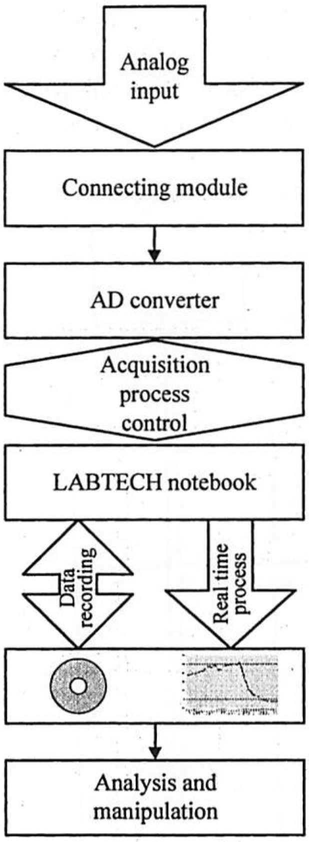

Fig. 4. Block diagram of data acquisition process[11]

Data acquisition system must convert real practice signals, such as amplitude, level, voltage, current intensity, temperature, pressure, weight, time period, etc., which are not in a format acceptable for computer (Fig. 5). It converts them into format understandable for computer, that is, into format that can be registered in databases. Analog signals for normal and friction force are brought from the dynamometer (measuring transducer), via an amplifier to connection panel that serves as an interface between the device (tribometer) and PC. From the connection panel signals are brought to the AD converter (inverter) that was implemented as a module (card) and is located in the PC slot. One of the most important characteristics of the data acquisition system is that computer integrates them all into one compatible system. When appropriate software is added upon it, system is obtained that does not need detailed knowledge to use it. It is necessary to get acquainted with main problems in this area in order to make selection of such a system.

Collected data regardless their origin (computer modelling and simulation, laboratory testing, research in exploitation conditions and data retrieved from the literature), can be in any of the following forms: tabular, graphical, textual, digital, analog. For each of the forms programs for their processing are used (Fig. 6), which translate, classify, categorise, arrange and logically connect data into a form suitable for the database.

Database was designed to storage data obtained by data acquisition during tribological investigations and its concept (logic) scheme is illustrated in Fig. 7 as entity relationship diagram. Conceptual scheme, that is, logical frame of the model, is done using DeZign for Databases CASE tool. DeZign for Databases is software for database creating and working with them by using entity relationship diagram. Software enables easy and simple work for a user in all database development phases: database creation, documenting, program code generation, etc.

By using DeZign for Databases, logical data model is created, in a form of a graphical diagram of entity relationships. Each entity has attributes that describe it and they are linked to each other by relationships. This software tool utilises

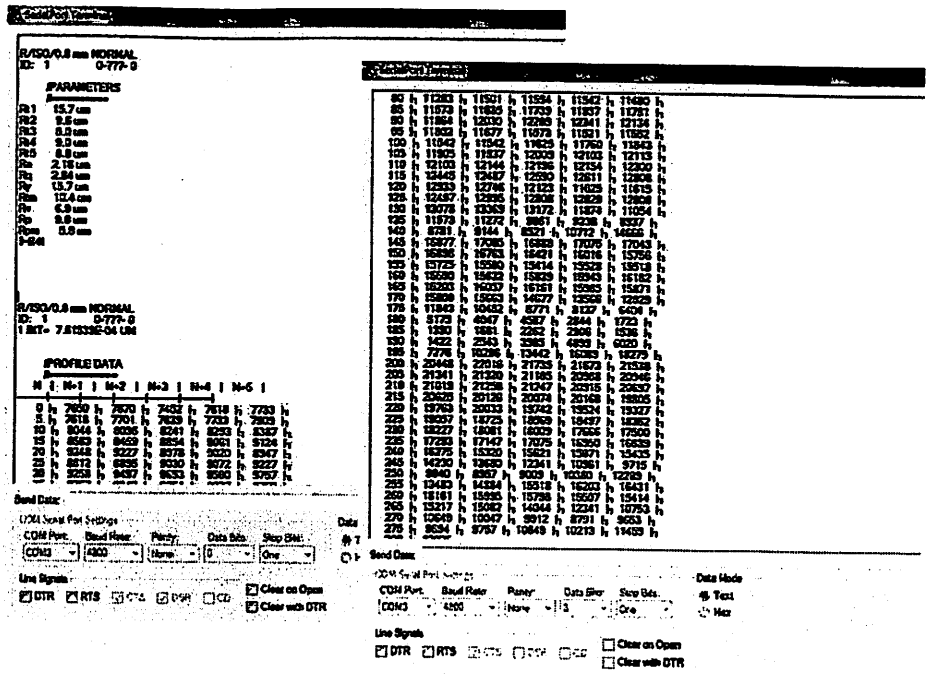

Fig. 5. An example of developed software application for acquisition surface roughness parameters from Talysurf 6 measuring device

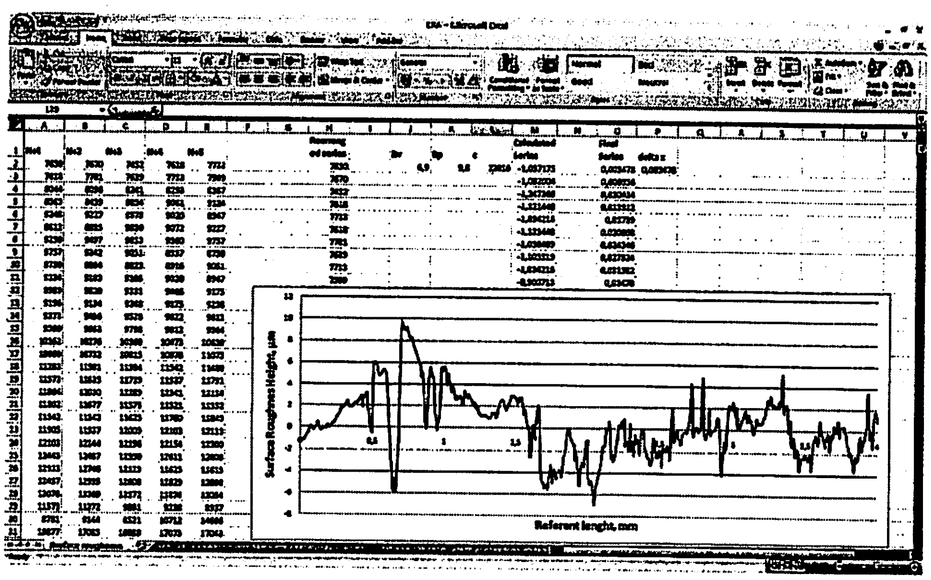

Fig. 6. An example of program application for surface roughness measured values processing and roughness profile construction

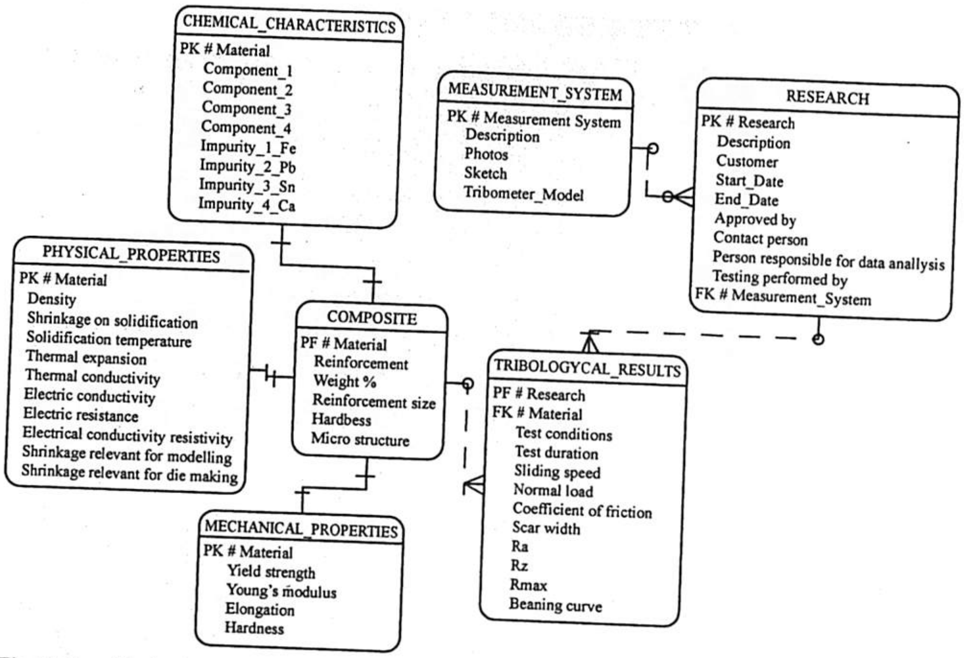

Fig. 7. Graphical views of logical schemes databases

simple technique 'show and click' to add entities into diagrams and to define their relationships. DeZign for Databases can automatically create schematic view of database from diagram of entity relationships, after they had been defined. The following database formats are supported: Oracle, InterBase, IBM DB2, MySQL, MaxDB, Paradox, MS SQL Server, MS Access, SQLAnywhere, Sybase, Informix, Pervasive, Advantage DB, DBISAM 3 and 4, FoxPro, PostgreSQL Databases are generated in MS SQL Server Express Edition, Microsoft development environment that enables very comfortable transfer to commercial versions.

The starting point for database development was a real system that is related to the investigation of the tribological characteristics of composite materials. The specimens were tested using a block-on-disc sliding wear testing machine with the contact pair geometry in accordance with ASTM G 77-83. More detailed description of the tribometer is available elsewhere[12,13]. The wear behaviour of the tested composites (block) was monitored in terms of the wear scar width – *h*. The repeatability of the results for replicate tests was found as satisfactory (variation of wear scar width was under 5%). The test block was loaded against the rotating steel disc.

The test blocks (6.35×15.75×10.16 mm) were prepared from ZA27 alloy reinforced with 3, 5 and 10 wt. % Al_2O_3 particles, while basic ZA27 alloy was used as a referent material. The counter face (disc of 35 mm diameter and 6.35 mm thickness) was made of EN: HS 18-1-1-5 tool steel of 62HRC hardness. The values of surface roughness were measured on the prepared samples before testing. Measuring of surface roughness was done on Talysurf 6 device. The tests were performed in dry sliding conditions at sliding speeds (0.25 – 1m/s) and applied loads (20–80 N). Each experiment was repeated 5 times. Test duration for all tested samples was 60 min.

All the above characteristics of the test material and data related to the testing conditions must be adequately presented, in the database, the description of which follows later in this paper, and thus researchers and engineers can easily get information on tribological results acquisition method.

Database CHEMICAL_PROPERTIES contains data on material chemical composition, mainly concerning alloys used in investigations, that is, percentage composition of aluminium, copper, zinc and magnesium, as well as maximum share of impurities such as iron, cadmium, lead and tin. Database MECHANICAL_PROPERTIES contains data related to mechanical characteristics of used materials such as: tensile strength (MPa), elasticity modulus (GPa), elongation (%), hardness (HB). Database PHYSICAL_PROPERTIES comprises data on tested materials such as: density (g/cm^3) at 20°C, shrinkage during hardening (%), hardening temperature (°C), specific heat (J/kg K) at 24-92°C, thermal emission (m/m K) at 20–100°C, thermal conductivity (W/m K) at 24°C, electrical conductivity (%) IACS, electrical conductivity resistivity (μΩ cm) at 20°C, shrinkage relevant for modelling (mm/m) and shrinkage relevant for die making (mm/m). This database enables comparison and comparative commenting on materials according to their physical properties. Database COMPOSITE contains data related to type of reinforcements, mass share, particles size, hardness, as well as microstructure photograph. Databases MEASUREMENT_SYSTEM and RESEARCH contains basic data about created measurement system for investigations, its structure and elements, scheme and photography of the measurement system; investigation description, client description, beginning date, and end date, who approved test, who performed test, who realised analysis, etc. These are all data related only to the investigation itself. Database TEST_RESULTS contains data about conditions and results of tribological investigations: test conditions (with or without lubrication), contact duration (min), sliding speed (m/s), normal force (daN), friction coefficient, width of the wear scar (mm), arithmetical mean roughness of a surface, R_a, mean asperities height, R_z, maximum asperities height, R_{max}, bearing curve of a profile. Previously described databases with defined logical structure and interrelationships are suitable for analysis of tribological characteristics according to different criteria.

Previously presented database including reference database described in Ref. 14 together with developed software represent an integrated system.

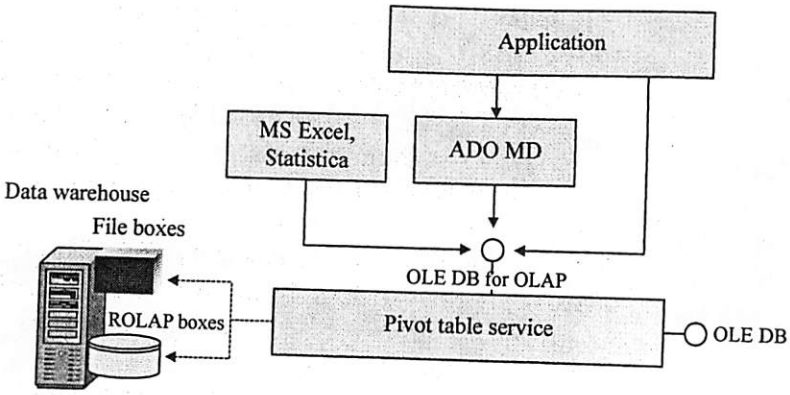

Fig. 8. Access to OLAP cube

The structure of designed database allows data mining. The term, data mining is in literature mainly related to support process to conclusions and decision-making, with application of certain statistical techniques on transactional data (note: data created by data acquisition can be considered as transactional data) in order to deliver foreseeable trends and rules. Data mining is precise mathematical area (SQL Server supports certain techniques in this area comprised by Query), but in any case it does not comprise all analytical purposes for which data warehouse is used. Analysis of data organised in OLAP (On-line Analytical Processing) cube can be done using PivotTable (dynamic table with integrated data from some database) service that enables data access to OLAP Cube. Two ways of data access in OLAP Cubes is shown in Fig. 8, using software tools Microsoft Excel and Statistica (as tools with main role being data analysis) or by creating custom user application through the so-called ADO (ActiveX Data Objects) mechanism.

Analysis of data organised in OLAP cubes in Excel and Statistica is done by creation of the so-called pivot tables. Software packages MS Excel and Statistica enable analysis by using additional tools which are part of this software. User is provided with the possibility to directly do report printing for specified time interval, for selected level of details and dimensions distribution.

Pivot table represents dynamic table with integrated data from some database. It is used for tabular representation of number of data types/dimensions. It enables for resulting data to be presented in any selected level of details. Pivot Table Wizard in MS Excel and Statistica is used to create pivot tables.

Reporting is the last and crucial step of long and complex process of collecting, storing, transforming and manipulating data. Report creating represents presentational layer of working with databases, a layer that leads to generation of knowledge from data. Figure 9 (Ref. 15) shows data on wear scar width in time

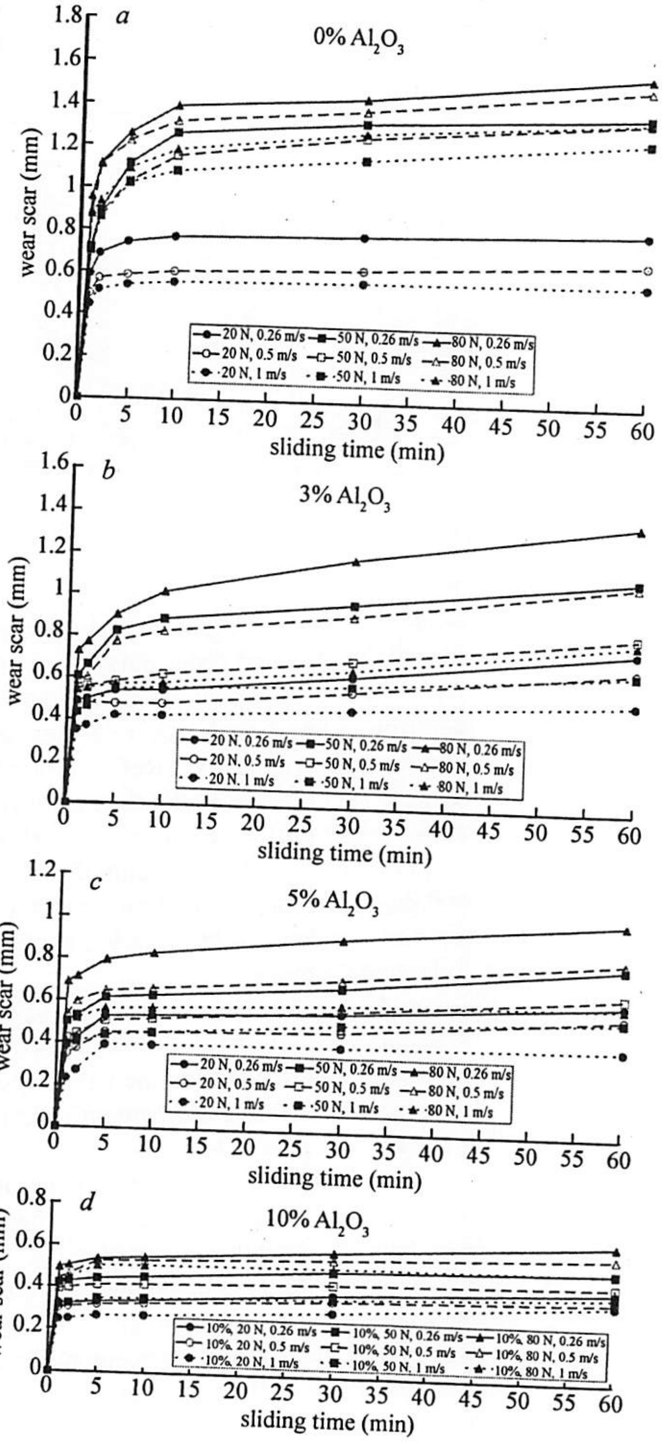

Fig. 9. Wear curves of: ZA-27 matrix alloy (*a*); MMC 3% Al_2O_3 (*b*); MMC 5% Al_2O_3 (*c*); MMC 10% Al_2O_3 (Ref. 11) (*d*)

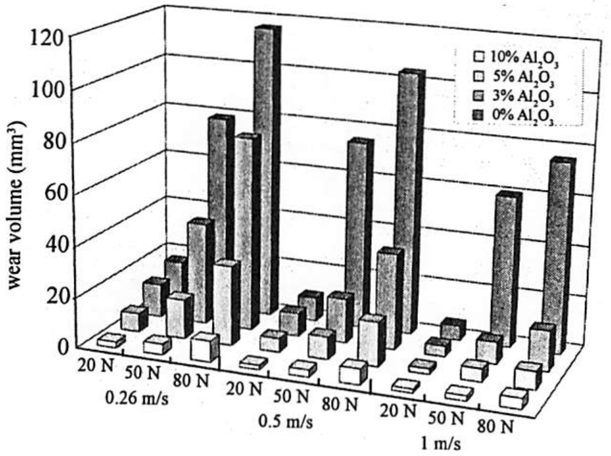

Fig. 10. Wear volume of tested materials at different applied loads and sliding speed[11]

(wear curves) as diagrams, and comparative histogram view of wear of tested materials, obtained from database in MS Excel, is given in Fig. 10 (Ref. 15). By using software tool Statistica, data from databases is used for 3D view and determination of analytical relations (using regression function) with high correlation factor. Figure 11 (Ref. 15) illustrates report of tribological investigations realised in Statistica, and it shows multidimensional relationships between wear, mass weight of the reinforcements, sliding speed, and normal load.

From the tribological point of view, acquisition and data storage in databases and the application of modern information technology allow researchers and engineers comfortable information access, and assistance in solving some of the following problems:

- Analysis of the effect of various parameters on tribological performance: Tribological performance of a tested composite material is not one of its intrinsic properties, but depends on the whole system, including parameters from counterpart, base material, reinforcement, contact conditions and environment and many other specific parameters.
- Estimation of wear rate: In general, it is considered that the wear rate monitoring is one of the most important factors for selection, production and implementation of composite material.
- Accessibility, systematisation and use of literature: Composite material may be produced by different methods, different base material, different type, size and hardness of reinforcement, and the composites are tested under various conditions (different contact configurations, application conditions, running environments, counterparts, etc.). Even for a same kind of composite material, in different papers, test results present great difference.

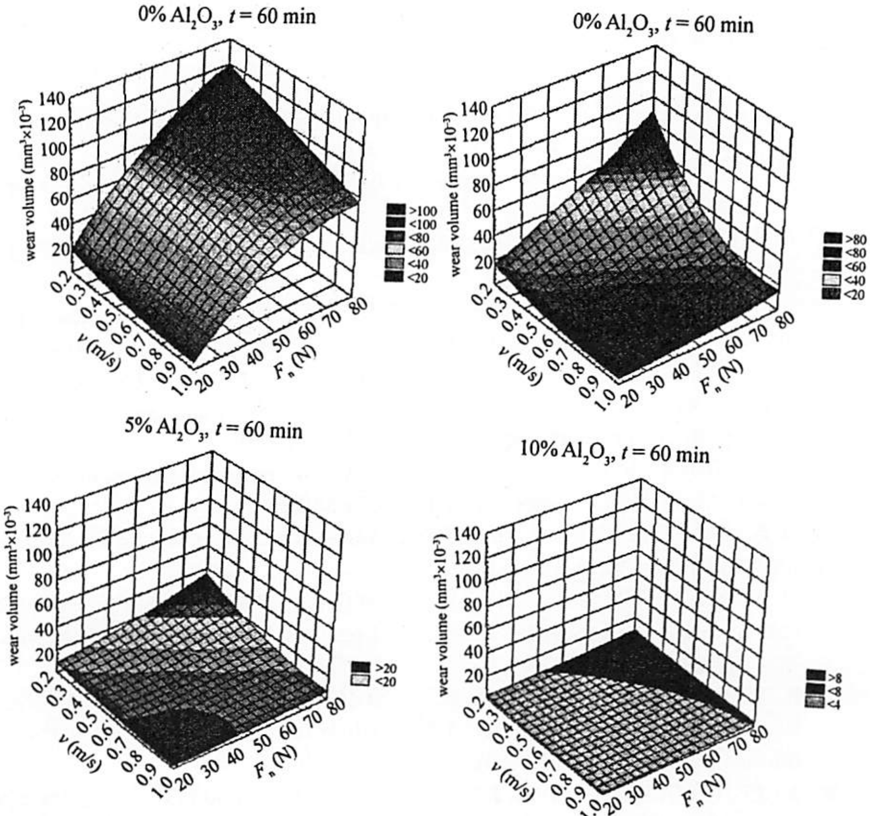

Fig. 11. Relationships between wear scar width and normal load and sliding speed, for different mass weight of the reinforcements[11]

CONCLUSIONS

The presented platform with developed database and software applications allows: documenting of all research phases (research) and sorting collected literature (references), improving the communication process and finding new ways to make good ideas and approaches, in a sea of information, that could assist in the right way to those who need them, finding new methods for formalising knowledge and experience and so on.

This paper presents an example of data acquisition process from tribological investigation of metal–matrix composite material, with ZA-27 alloy as a base material reinforced with Al_2O_3 particles, under different contact conditions. The implementation of modern information technology allows availability and an adequate tribological results presentation, regardless of whether they are the result of laboratory tests or review of literature. Also, presented system could be very successfully applied to all other tribological tests regardless of the research type (with or without lubrication), contact geometry, materials and contact conditions.

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