

# Proceedings of VAREHD Conference

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Vol. 14, 2008



ISSN 1844-8917

*"Stefan cel Mare" University of Suceava Publishing House*

*Suceava, 2008*

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# Contact Mechanics

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## **1. AN IMPROVED INCREMENTAL MODEL TO ANALYSE ELASTIC-PLASTIC CONCENTRATED CONTACTS – THE FINITE ELEMENT ANALYSIS AND VALIDATION**

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**pp. 1-7**

**by Marcelin BENCHEA & Spiridon CRETU**

*Department of Machine Design and Mechatronics Technical University “Gheorghe Asachi” of Iasi, ROMANIA*

**Abstract:** *To model the nonlinear strain rate dependent deformation of rolling bearing steel stressed in the elastic-plastic domain a theoretical analysis was previously developed by the authors, [1, 2, 3]. The analysis was developed in the frame of the incremental theory of plasticity by using the von Mises yield criterion and Prandtl-Reuss equations. To attain the final load of each loading cycle, the two bodies are brought into contact incrementally. Both, the new contact geometry and residual stresses distributions, are further considered as initial values for the next loading cycle, the incremental technique being reiterated.*

*A finite elements analysis model has been developed to model the nonlinear strain rate dependent deformation of rolling bearing steel stressed in the elastic-plastic domain. By considering the non-linear hardening laws of Swift, and also of Ramberg-Osgood, the model accounts for the cyclic hardening phenomena.*

*Comparisons of the computed deformed profiles, as well as of the computed residual stresses distributions, with those obtained by measurements, or numerically by using the finite elements method, reveal a very good agreement and validate the incremental analysis model.*

## **2. EXPERIMENTAL INVESTIGATION OF A DYNAMIC RUBBER CONTACT**

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**pp. 8-15**

**by F. CIUTAC<sup>1</sup>, E. DIACONESCU<sup>2</sup> & D. PINTILIE<sup>2</sup>**

<sup>1</sup>*“Bucovina” Inspectorate for Emergency Situations – Suceava, Romania*

<sup>2</sup>*Faculty of Mechanical Engineering “Stefan cel Mare” University – Suceava, Romania*

**Abstract:** *The paper presents the behaviour to dynamic contact of two rubber balls, having different radii and materials, with a glass plate, in dry condition, without lubricant. There were carried out 40 sets of experimental tests, at different forces and frequencies. It is established that at reduced loads and*

frequencies, the rubber has a linear elastic behaviour, whereas at high loads and frequencies the hysteresis increases.

### 3. THE ELASTIC NORMAL CONTACT BETWEEN REVOLUTION RUBBER BODIES

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pp. 16-21

by E. N. Diaconescu<sup>1</sup> & F. Ciutac<sup>2</sup>

<sup>1</sup>Department of Mechanical Engineering, University of Suceava, ROMANIA

<sup>2</sup>ISU – Suceava , ROMANIA

**Abstract:** The theory of mechanical rubber contacts is based either on nonlinear elasticity or on viscoelasticity. Experimental evidence shows that the former approach is more adequate. The number of works based on this approach is very limited. This paper advances a new theory based on a combined, linear plus power law, dependence of stress on strain. At low loads, the contact behaves in a Hertz fashion, whereas at high loads it becomes purely nonlinear. It is shown that the distribution of pressure remains semi-ellipsoidal and new equations are advanced for contact radius, maximum pressure and normal approach. At high loads, the equation of contact radius yields results in good agreement with existing published results.

### 4. A REFINED NUMERICAL METHOD FOR ELASTIC CONTACT PROBLEM WITH A TILTING TORQUE ON THE CONTACT AREA

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pp. 22-26

by Sergiu SPINU

Department of Mechanical Engineering, University of Suceava, ROMANIA

**Abstract:** A numerical method for elastic contact analysis valid at any loading eccentricity is refined in this paper by removing the need for an additional Newton Raphson outer loop, which was present in a previously proposed solver. Surface separation equation and pressure correction instruction are modified by adding a term linear in coordinates. Numerical simulations are performed on a circular rigid flat ended indenter with rounding radius pressed eccentrically against an elastic half-space, and the eccentricity effect upon stress state induced in the half-space is assessed.

**5. NUMERICAL SIMULATION OF ELASTIC FINITE LENGTH LINE CONTACT UNDER ECCENTRIC LOADING**

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**pp. 27-34**

**by Sergiu SPINU & Cornel SUCIU**

*Department of Mechanical Engineering, University of Suceava, ROMANIA*

**Abstract:** *This paper advances a numerical method for analysis of elastic finite length line contact under any eccentricity. An existing algorithm solving the elastic contact problem with centric loading is generalized to the case of eccentric loading. An additional Newton Raphson outer loop is added to the classic conjugate gradient minimization in order to iterate the tilting angle, which enters the surface separation equation. Numerical simulations are performed on finite length line contact, and the effect of eccentricity upon pressure distribution and contact area is assessed.*

**6. EXPERIMENTAL SET-UP AND PRELIMINARY RESULTS UPON A NEW TECHNIQUE TO MEASURE CONTACT PRESSURE**

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**pp. 35-42**

**by Cornel SUCIU, Emanuel DIACONESCU & Sergiu SPINU**

*Department of Mechanical Engineering, University of Suceava, ROMANIA*

**Abstract:** *Diaconescu and Glovnea [1] proposed a new technique to measure the pressure in a real contact. One of contacting surfaces is covered, prior to contact establishment, by a special gel. The contact closing removes the excess gel and, during a certain time interval, the contact pressure transforms the entrapped substance in an amorphous solid. In each point, the refractive index of this solid depends on the pressure acting during transformation. After contact opening, the reflectivity of this coating depends on the former contact pressure and it is mapped by aid of a laser profilometer and it becomes an indicator of contact pressure*

*The existing device used to load the contacts has a series of shortcomings. This paper proposes a new experimental set-up that can be used to load contacts with gel at the interface, and illustrates a few experimental results.*

# Biocontact and Biotribology

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## 7. UPON PRESSURE DISTRIBUTION ON FINGERPAD DURING GRASPING

pp. 43-55

by Ciornei FlorinaCarmen, Muscă Ilie, Irimescu Luminița, Alaci Stelian & Frunză Gheorghe

Faculty of Mechanical Engineering, Mechatronics and Management University "Stefan cel Mare" – Suceava, Romania

**Abstract:** In grasping objects, humans use the sense of touch for sensing the surface texture and discerning the shape. The surface pressure distribution of the finger pad was shown to be an essential input to the tactile systems and it depends on multiple parameters, such as geometry of the objects contacting the finger pad, magnitude and time variation of applied forces, elastic characteristics of materials, friction coefficients etc. Understanding the relationship between the shape of an indenting object and the pressure distribution on the fingerpad is essential to understanding how human perceive an object by touch. A study of pressure distribution will give an insight into the distributions of stress and strains on the mechanoreceptors. Different methods were used in modelling the fingerpad during grasping or touching. A brief review of modelling the fingerpad, both analytical, based on Hertzian contact theory, with alternatives from classical elastic to nonlinear viscoelastic models, and structural, made by finite element method, was made. Computer applications are needed in any of these models, requiring either numerical calculus or specialized FEM programs.

More convenient seem to be the analytical models, which proved to give more rapid results and involving less edge technology. The case of Hertzian contact between elastic dissimilar bodies is presented and an application is made.

## 8. EXPERIMENTAL EVIDENCE UPON CONTACT BEHAVIOR OF CARTILAGE COVERED BONE ENDS

pp. 56-62

by E. N. Diaconescu & M. Glovnea

Department of Applied Mechanics, University of Suceava, ROMANIA

**Abstract:** Contact mechanics of bioarticular elements is of great interest in biomechanics. There are many theoretical models for the mechanical behavior of the cartilage, from which the viscoelastic shows promises when the macroscopic cartilage behavior is analyzed. It is shown that the Zener model, currently used in cartilage analysis, possesses very short creep and relaxation times. Therefore, at longer static loading the cartilage behaves elastically. Experimental work carried out on the contact between a

bovine bone end and a flat glass window, by recording the dependence of contact radius on normal load. A known theory of the contacts involving thin elastic layers was used to predict the contact radius in axisymmetrical problems was applied to predict contact radius in the investigated contact. A good agreement was found at higher loads, but smaller experimental radii at low loads.

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**9. PRELIMINARY EXPERIMENTAL MEASUREMENT OF BIOARTICULAR FRICTION**

pp. 63-68

**by Emanuel Diaconescu, Marilena Glovnea, Cornel Suciu & Brândușa Bejinariu**

*Department of Applied Mechanics, University of Suceava – Suceava, Romania*

**Abstract:** *The articular human joints wear out by cartilage failure which leads to drastic friction increase and impediment of current activities. A modern procedure to overcome this deficiency is the reconstruction of ill articulation, essentially by cartilage replacement. The main problem is to evaluate the efficiency of this procedure. This paper presents a method of friction force measurement in rabbit knee joints and comparative friction results between a normal and a repaired joint. It is found that friction is higher and the clearance is smaller in the repaired joint with respect to the normal articulation. This result is supported by topography measurements on mating articular surfaces in both, normal and repaired joint.*

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**10. UNE METHODE D’EVALUATION DE L’ETAT DES CONTRAINTES POUR UN CONTACT HERTZIENNE; APPLICATION AU CONTACT DENTAIRE EMAIL - POLYMERE**

pp. 69-74

**by Luminita IRIMESCU, Florina CIORNEI, Stelian ALACI, Delia CERLINCA & Gheorghe FRUNZA**

*Génie Mécanique, Université de Suceava, rue Universitatii, no.13, 720225 Suceava, Roumanie*

**Abstract:** *L’objectif de ce travail est l’évaluation d’état des contraintes à l’interface d’un contact élastique sphère-sphère en condition de chargement normale. Dans le cas du contact entre deux solides soumis à une force normale, les déplacements élastiques de la surface lié aux différences élastiques des matériaux induit une traction tangentielle  $q$ , qui a été calculé pour trois cas : glissement total, adhérence totale et glissement partiel ou microglissement, Hills, [1].*

*L’état global des contraintes à l’interface du contact a été obtenu en sommant les contraintes induites à la fois par cette traction tangentielle et la charge normale. Ensuite, la contrainte équivalente d’Huber-Mises-Hencky a été calculée numériquement pour le couple de matériaux email - polymère.*

**11. TEST RIG FOR FINGER CONTACT STUDY**

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pp. 75-79

by Ilie MUSCA, Florina Carmen CIORNEI & Remus PRODAN

*Faculty of Mechanical Engineering Mechatronics and Management University "Stefan cel Mare" – Suceava, Romania*

**Abstract:** *The study of finger contact occurring during manual grasp is significant for shape optimization. The paper presents the test rig and the subsequent method concerning the study of contact between the fingertip and a glass flat surface, with simultaneous measurements of contact area, global normal force and relative displacement.*

**12. IMPACT OF A RIGID SPHERE ON A HIGHLY COMPRESSIBLE POROUS LAYER IMBIBED WITH A NEWTONIAN LIQUID**

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pp. 80-85

by Mircea D. PASCOVICI, Victor-Gabriel MARIAN & Cristian S. POPESCU

*Department of Machine Elements and Tribology University Politehnica of Bucharest-ROMANIA*

**Abstract:** *Very often, in nature as in technique, the process of liquid flow takes place inside a highly compressible porous layer (HCPL). In these processes, the elastic forces of the solid phase of the porous layer are negligible in comparison with the hydrodynamic forces. Such processes were named in 2001 ex-poro-hydrodynamic (XPHD). Recently, a study of the impact process in XPHD conditions was performed, for circular and rectangular aligned plates. The impact of a rigid sphere on a HPCL, in XPHD conditions, is analyzed in the present paper.*

**13. ANALYSIS OF THE TRIBOLOGICAL ROLE OF LIPID MULTILAYERS IN BIOLOGICAL LUBRIFICATION**

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pp. 86-95

by A-M. TRUNFIO<sup>1,2</sup>, Y.BERTHIER<sup>1</sup>, M.-H. MEURISSE<sup>1</sup>, J.-P. RIEU<sup>2</sup>

<sup>1</sup>*Laboratoire de Mécanique des Contacts et des Structures, Institut National des Sciences Appliquées de Lyon, CNRS UMR, 5259, France*

<sup>2</sup>*F69621 Laboratoire de Physique de la Matière Condensée et Nanostructures (LPMCN) Université Lyon 1; CNRS, UMR 5586, Domaine Scientifique de la Doua, F-69622 Villeurbanne cedex; France*

**Abstract:** *The aim of this work is to identify the role of the lipid multilayers in controlling and reducing frictional forces between the biomimetic cartilage surfaces. We have incorporated the effect of lipid multilayers in a realistic ex-vivo model capable of reproducing the mechanical and physicochemical*



characteristics of the entire tribological triplet of the synovial joint. This model reconstitutes the properties of the articular cartilage using a manufactured convex lens in soft HEMA and of the lipid multilayers of the synovial fluid structure using nanophysics techniques. A home-made tribometer was used to measure the tangential force at constant load (friction coefficient); changes in the lipid structure were observed in-situ after long period of friction with fluorescence microscopy. The results of this work show that the DPPC lipid multilayers generated friction coefficients that were small (0.002) and comparable to that found between cartilage surfaces. This low friction stems from the localisation of sliding accommodation in the layer of physiological solution trapped between the two lipid bilayers. These results suggest that the tribological role of the lipid bilayers is mainly physicochemical: it consists of trapping thin layers of physiological solution capable of localising sliding, making it possible to obtain a very low friction coefficient. The results show that the destruction of lipidic multilayers by oxidation (case of DOPC multilayers) and the variation of mechanical properties by the reduction of pH increase the friction coefficient.

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#### 14. TRIBOLOGY LOADING CAPACITY OF UHMWPE FROM TOTAL JOINT REPLACEMENTS

pp. 96-108

by Andrei TUDOR, Georgiana BOSOI & Felix PARVU

*Polytechnic University of Bucharest, Romania*

**Abstract:** *The wear rate of ultra-high molecular polyethylene (UHMWPE) total joint prosthesis is known to be influenced by various factors such as material and design. However, it is not known if these factors affect the size or morphology of the wear particles. It is known that the molecular chain structure at the articulating surface of UHMWPE undergoes a re-organization process due to strain accumulation caused by surface traction. A theoretical model of wear particle that is based of intimate conical asperity interactions is proposed to account for the observed differences in sliding and rolling wear. Cyclic plastic strain accumulation is identified as the common cause for wear debris generation in sliding and rolling joints, as examples hip and knee replacements. In the case of acetabular cup wear (sliding velocity), the scale of plastic deformation is limited to the sites of intimate conical-asperity contacts and the wear is defined by a critical strain criterion. In the case of tibial component wear (rolling velocity), however, plastic deformation spreads into the subsurface to the site of macro-asperity contact, and material can be removed by subsurface cracking and delamination. In both cases, the wear rate is strongly affected by the ultimate tensile strength and breaking elongation of UHMWPE material.*

# Mems Tribology

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## 15. RESEARCH PROBLEMS IN MEMS ELECTRICAL CONTACTS

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pp. 109-113

by Cristina Ciornei

*Department of Mechanical Engineering Stefan cel Mare University, Suceava, Romania*

**Abstract:** *In recent years, micro-electro-mechanical systems (MEMS) cover a wide range of applications for sensors, actuators and general control modules. The paper attempts to perform a summary of the main research problems in the electric contacts entering the MEMS.*

## 16. PRELIMINARY EXPERIMENTAL RESEARCH ON ELECTRIC CONTACT RESISTANCE

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pp. 114-121

by Cristina Ciornei, Emanuel Diaconescu & Dorel Pintilie

*Department of Mechanical Engineering Stefan cel Mare University, Suceava, Romania*

**Abstract:** *An important parameter in MEMS design is the electrical contact resistance. This depends on the material conductivity, on the geometry of the contacting surfaces, on the applied load and on the current through the contact. Some research works suggest the possibility of a different behaviour at micro and nano scale than at macroscale. This paper aims to measure the electrical contact resistance of a gold micro contact from a mobile phone, under variable load and current, using an oscilloscope for the visualization and data acquisition.*

## 17. ROLLING FRICTION IN THE MECHATRONIC MICROSYSTEMS

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pp. 122-126

by Dumitru N. Olaru & Ciprian Stamate

*Machine Elements and Mechatronics Department Technical University "Gheorghe Asachi" Iasi, Romania*

**Abstract:** *To determine the friction coefficient in micro rolling systems the authors developed a new microtribometer with a rotating disc by 3 micro balls. The angular position of the rotating disc is monitored by a camera and friction coefficient was determined as a function of the angular acceleration of the rotating disc.*

*Experimental investigations were realized with the micro balls having the diameter of 1.97 mm and normal load of 8.7 mN. The friction coefficient between the steel micro balls and the glass disc was experimentally obtained both in dry and water condensed conditions.*

## Friction and Wear

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### 18. TEST RIG FOR SELF-LOCKING STUDY

pp. 127-137

by Stelian ALACI, Florina Carmen CIORNEI, Luminița IRIMESCU & Delia Aurora CERLINĂ

*Faculty of Mechanical Engineering, Mechatronics and Management University "Stefan cel Mare" – Suceava, Romania*

**Abstract:** *Self-locking is a phenomenon that occurs both in lower pairs and higher pairs, and especially in cam mechanisms. It is defined as the phenomenon of impossible motion of a mechanism despite the value of motor forces or moments. This phenomenon occurs due to friction forces from kinematic pairs, depending directly on normal forces from mechanism pairs. The pressure distribution has a shape directly related to the shape of the filleted curve of the bearing, always being greater at the edges of the bearing and therefore named "edge effect". Another important parameter for proper working of a cylindrical pair is correct length implementation. A kinematical pair is more efficient as the locking angle is greater. Two different situations are observed: in the first case the self-locking angle depends on the geometry of the pair and on the mechanism's position; in the second case, the self-locking angle depends only on the dry friction coefficient.*

*The aim of the paper is to present a rig designed to determine the self-blocking angle from a prismatic pair.*

### 19. METROLOGIE THERMIQUE DU CONTACT PAR PYROMETRIE BISPECTRALE

pp. 138-143

by M. Siroux, J. Thevenet & B. Desmet

*Laboratoire de Mécanique Énergétique – Université de Valenciennes et du Hainaut – Cambrésis, Le Mont Houy 59313 Valenciennes Cedex 9, France*

**Abstract:** *Un pyromètre bichromatique à fibre optique a été développé afin de caractériser le comportement thermique d'un disque de frein pendant le freinage. Le pyromètre est composé de deux détecteurs HgCdTe équipés de filtres passe-bandes et d'une fibre optique en verre fluoré. Ce pyromètre permet la mesure de la température de surface du disque de frein dans la gamme 200-800 °C avec un temps réponse de l'ordre de 8 μs. Le pyromètre a été étalonné à l'aide d'un corps noir cavité. Des essais ont été effectués sur un banc de freinage pour différents types de freinages : freinage de maintien et freinage d'arrêt, permettant ainsi l'obtention de la température de surface sur un disque de frein.*

**20. A NEW PIN DISC MICROTRIBOMETER**

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**pp. 144-149**

**by Ciprian Stamate, & Dumitru N. Olaru**

*Machine Elements and Mechatronics Department Technical University "Gheorghe Asachi" Iasi, Romania*

**Abstract:** *To investigate the sliding friction in microsystems a new pin disc microtribometer having the normal load between 5 mN to 150 mN has been realized. Experimental investigations was realized in order to determine the friction coefficient between a steel spherical surface and steel, glass or silicon plane surface. The new pin-disc microtribometer was attached to a CSM Microtribometer and friction forces with magnitude of 1- 10 mN have been experimentally determined.*

**21. A THERMOMECHANICAL WEAR MODEL FOR THE METRO WHEEL IN THE RAIL CONTACT**

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**pp. 150-158**

**by Andrei TUDOR<sup>1</sup>, Elias TOUNTAS<sup>2</sup> & Nicolae SANDU<sup>3</sup>**

<sup>1</sup>*Polytechnic University of Bucharest, Romania*

<sup>2</sup>*Attiko Metro A.E. Athena, Greece*

<sup>3</sup>*Romanian Authority of Rail Way, Bucharest, Romania*

**Abstract:** *Tribological phenomena in the wheel – rail contact of metro wagon defines the durability of wheel and rail. The contact pressure and friction temperature change the strength of rail material and wheel material. The correlation of material and operation parameters defines the wear maps. The dimensionless Von Mises parameter is used to limit the elastic deformation for a hertzian contact of wheel and rail. Dimensionless contact pressure loading capacity is obtained by to overlap the thermal and elastic normal and adhesion stresses.*

*The thermomechanical wear model of wheel is defined by the fatigue strength of wheel material at the rolling parameters. The effects of adhesion, longitudinal creepage and rolling velocity about the contact pressure loading capacity and the friction fatigue are analyzed.*

# Lubricants

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## 22. EXPERIMENTAL DETERMINATION OF MAXIMUM INTERMOLECULAR FORCE

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pp. 159-165

by Zegrean Vlad, Diaconescu Emanuel & Trandafir Marius

Department of Applied Mechanics University "Stefan cel Mare" – Suceava, Romania

**Abstract:** Some experimental results show that in the vicinity of a wall the lubricant rheology changes. A series of theoretical studies try to explain the behavior of the lubricant in thin films by means of molecule-wall interaction potential, a general theory of viscosity equation and a molecular theory. In order to use this approach it is needed to know the minimum intermolecular potential which can be determined by measuring the maximum intermolecular force. This paper presents two test rigs for measuring the maximum intermolecular force either in the lubricant bulk or in thin films. A series of measurements are made on two lubricants at different temperatures. The results are compared to previous measured values and theoretical predictions.

## 23. EQUIPMENT FOR FLUID FLAMMABILITY TESTS ON HOT SURFACES AND SOME RESULTS

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pp. 166-176

by Lorena Deleanu<sup>1</sup>, Dragoş Buzoianu<sup>2</sup>, Tom Savu<sup>3</sup> Minodora Rîpă<sup>1</sup>, Ştefan Crăciunoiu<sup>2</sup> & Iustin Antomoianu<sup>3</sup>

<sup>1</sup>LubriTEST - Laboratory for Testing Technical Fluid University Dunarea de Jos of Galati – Galati, Romania

<sup>2</sup>ICTCM – Bucharest, Romania

<sup>3</sup>DOLSAT SA – Bucharest, Romania

**Abstract:** Technical fluids have to be evaluated not only for their performances as load capacity, durability, but also for their potential risk including ignition. Based on a solid documentation that has pointing out the significance of testing the fluid flammability, the authors designed an original equipment capable of fulfilling the requirements imposed by SR EN ISO 20823:2004 Petroleum and related products. Determination of the flammability characteristics of fluids in contact with hot surfaces. The paper also presents some results on determining the flammability characteristics of fluid when dropping it on a hot surface.

# Hydrodynamic Lubrication

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## 24. A SIMPLIFIED SOLUTION OF STEADY-STATE REYNOLDS EQUATION FOR WORN JOURNAL BEARINGS

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pp. 177-188

by Ing. Maria Brandusa Ilie and Prof. Traian Cicone

University POLITEHNICA of Bucharest, Spl. Independentei 313, Bucharest 060042, ROMANIA

**Abstract:** *Journal bearings operating over a great number of years and submitted to frequent starts and stops can be affected by the cumulative effect of wear. In some previous studies it was shown that, in some cases, wear has no significant negative effects or, apparently surprisingly, can be quite beneficial. This was shown based on complex TEHD models with numerical solutions. However, using such complex models that require high computational resources and long CPU time it is very difficult to perform parametric analyses. The objective of the present work is to develop a simplified solution for Reynolds equation for full film journal bearings affected by wear. The model is applied to isothermal, steady-state, 360° journal, but it can be easily adapted to partial journal bearings. The model allows for quick results with acceptable accuracy. The results are obtained numerically, based on simple integration of a 2nd order differential equation. Comparisons with similar results obtained by Fillon and co-workers 0 are very encouraging, showing very small differences with an important gain in CPU time.*

## 25. ANALYTICAL CALCULATION MODEL OF HYDRODYNAMIC PARAMETRES OF SLIDER BEARINGS

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pp. 189-194

by Mihail IONESCU

Department of Mechanical Engineering, Stefan cel Mare University- Suceava, Romania

**Abstract:** *The calculation of the functional parameters of hydrodynamic slider bearings involves the solution of the system consisting of the differential equations of pressure and of the thermal balance equation, to which other equations are added, depending on the desired degree of precision. The present paper proposes a quantitative calculation of slider bearings, using the analytical solutions of energy equation and of the Reynolds differential equation. The model consists in the transformation of the axial bearing pad into a journal bearing bush.*

*The validation consists in comparing the pad's hydrodynamic parameters, calculated by means of numerical methods, with those of the proposed journal bearing, calculated analytically.*