7TH BALKANTRIB'11

International Conference on Tribology

PROCEEDINGS

Editor: Prof. K.-D. BOUZAKIS

3-5 October 2011, Thessaloniki-GR

7[TH] BALKANTRIB'11

International Conference on Tribology

PROCEEDINGS

7TH BALKANTRIB'11

International Conference on Tribology

PROCEEDINGS

Editor: Prof. K.-D. BOUZAKIS

3 - 5 October 2011, Thessaloniki-GR

7th BALKANTRIB'11
International Conference on Tribology

PROCEEDINGS

ISBN 978-960-98780-6-7

Thessaloniki - Greece

Printed by

EDITIONS ZITI

18th klm Thessaloniki - Perea
P.O. Box 4171 – 570 19 Perea -Thessaloniki
Tel.: +30 2392 072.222 – Fax: +30 2392 072.229
e-mail: info@ziti.gr

www.ziti.gr

SCIENTIFIC COMMITTEE

Conference Chairmen

Prof. K.-D. Bouzakis, *Greece*
Prof. S. Mitsi, *Greece*

International Scientific Committee

Prof. G. Andreadis, *Greece*
Prof. N.N. Antonescu, *Romania*
Prof. E Assenova, *Bulgaria*
Prof. M. Babic, *Serbia*
Prof. G. Cholakov, *Bulgaria*
Prof. E. Diaconescu, *Romania*
Prof. F. Dimofte, *USA*
Prof. K. Efstathiou, *Greece*
Prof. E. Iakovou, *Greece*
Prof. S. Ivanov, *Bulgaria*
Prof. B. Ivkovic, *Serbia*
Prof. G. Haidemenopoulos, *Greece*
Prof. M. Kandeva, *Bulgaria*
Prof. Ch. Karachaliou, *Greece*
Prof. Zh. Kalitchin, *Bulgaria*
Prof. M.B. Karamis, *Turkey*
Prof. N. Manolov, *Bulgaria*
Prof. G. Mansour, *Greece*
Prof. A. Michailidis, *Greece*
Prof. N. Michailidis, *Greece*
Prof. G. Mischev, *Bulgaria*
Prof. I. Mitov, *Bulgaria*
Prof. R. Paraskevopoulou, *Greece*
Prof. D. Pavelescu, *Romania*
Prof. A. Rac, *Serbia*
Prof. V. Pojidaeva, *Bulgaria*
Prof. G. Savaidis, *Greece*
Prof. P. Seferlis, *Greece*
Prof. G. Skordaris, *Greece*
Prof. K. Stanulov, *Bulgaria*
Prof. I. Tsiafis, *Greece*
Prof. A. Tudor, *Romania*
Prof. G. E. Zaikov, *Russia*
Prof. D. Vlachos, *Greece*

ORGANIZING COMMITTEE

President:
Prof. K.-D. Bouzakis

Vice Presidents:
Prof. S. Mitsi
Prof. K. Efstathiou

Treasurers:
Prof. G. Mansour
Mr S. Kalambokidis

Secretariat:
Dipl.-Phys., MSc. O. Tacha
Mrs. E. Melliou

Members:

Prof. I. Tsiafis
Prof. G. Andreadis
Lect. R. Paraskevopoulou
Dipl.-Eng. M. Grigoriadou
Dipl.-Eng. G. Giannopoulos
Dipl.-Eng. G. Kalidaropoulos
Dr.-Eng. E. Bouzakis
Dr.-Eng. G. Maliaris
Dr.-Eng. I. Mirisidis
Dr.-Eng. G. Skordaris
Dr.-Eng. A. Tsouknidas
Dr.-Eng. E. Varitis
Dipl.-Eng. M. Batsiolas
Dipl.-Eng. S. Gerardis
Dipl.-Eng. G. Katirtzoglou
Dipl.-Eng. S. Kombogiannis
Dipl.-Eng. S. Makrimallakis
Dipl.-Eng. M. Pappa

SPONSORS

Mechanical Engineering Department,
School of Engineering,
Aristoteles University Thessaloniki

Research Committee of the
Aristoteles University Thessaloniki

Scientific Sponsor:
International Institution for Production Research (CIRP)

PREFACE

Tribology is an interdisciplinary scientific area, always in the core of research and industrial interests. Seeking opportunities for further developing and solidifying co-operations in the field of tribology, scientists from six Balkan countries, Bulgaria, FYROM, Greece, Romania, Serbia and Turkey established in 1993 the Balkan Tribological Association (BTA). BTA aims at strengthening the relations between academic institutions and companies from the member countries and instigating collaborative efforts with further countries from all over the world.

After 15 years, for second time, Greece organizes the International Conference of BTA in Thessaloniki. This significant event takes place every three years successively in the BTA member countries. The "BALKANTRIB'11" embraces the scientific fields of tribology, focused on the friction description and control as well as the wear reduction in various applications, such as of manufacturing, machines' operation, bio-engineering, etc.

It's a privilege for the Laboratory for Machine Tools and Manufacturing Engineering of the Aristoteles University of Thessaloniki and for the Fraunhofer Project Center Coatings in Manufacturing (PCCM) to organize the 7^{th} International Conference "BALKANTRIB'11", a unique 3-days forum, in the historical city of Thessaloniki. The participants will have the opportunity to attend lectures of their interest, in the frame of the 9^{th} "THE-A" and the 4^{th} "ICMEN" international Conferences, which take place simultaneously at the same location in Thessaloniki.

I wish all participants's a pleasant stay in Thessaloniki and a fruitful conferences' attendance.

Fraunhofer
Project Center
Coatings in Manufacturing

Prof. Dr.-Ing. habil., Dr.-Ing. E.h., Dr.h.c. K.-D. Bouzakis
Director of EEDM and PCCM
Chairman of the Organizing Committee
Thessaloniki, October 2011

ARISTOTELES UNIVERSITY OF THESSALONIKI
LABORATORY FOR MACHINE TOOLS AND MANUFACTURING ENGINEERING
MECHANICAL ENGINEERING DEPARTMENT

ACKNO LEDGMENTS

The President of the Organizing Committee would like to thank

the collaborators of
the Laboratory for Machine Tools and Manufacturing Engineering of
the Aristoteles University Thessaloniki, for their efforts in organizing
the 7th International Conference BALKANTRIB'11,

as well as
ZITI SA for all printing works.

Contents

Tribological Properties, Wear and Corrosion

Friction characteristics of plasma nitrided H11 steel
M.B.Karamıs, K.Yıldızlı and G.Carkıt Aydın 3

Noise, vibration and harshness (NVH) in automotive applications: gear rattle and the role of tribodynamics
M. De la Cruz, S. Theodossiades and H. Rahnejat 13

Corrosion behavior of materials in technological environments from oil atmospheric and vacuum distillation installations
M. Morosanu, Ov. Georgescu, N.N. Antonescu 23

Research the wear intensity of pvd coatings on steel X46Cr13
S. Dishliev; G. Mishev 31

Austenitic stainless steel type AISi316L corrosive behavior in hair shampoo medium
R.G. Ripeanu, V. Ispas, D. Ispas 41

Influence of dry sliding conditions and coating roughness on the wear of titanium nitride coatings deposited at low temperature
D. Kakas, B. Skoric, P. Terek, A. Miletić, L. Kovacević, M. Vilotic 49

Influence of Al_2O_3 particle content on the sliding wear behaviour of ZA-27 alloy composites
S. Mitrovic, M. Babic, F. Zivic, I. Bobic, D. Dzunic 59

Wear properties of shot peened surfaces of 36NiCrMo16 alloyed steels under lubricated condition
M. Babic, D. Adamovic, S. Mitrovic, F. Živic, D. Dzunic 69

Wear and corrosion behaviours of low temperature nitrided AISi 304 L austenitic stainless steel
O. Celik, H. Cimenoglu, E.S. Kayali 77

The rough chromates steel XC45 wear behaviour at dry friction and high temperature
M.-T. Popescu, N. Popa, R.-N. Dobrescu, J. Denape, C. Onescu 81

Tribological behaviour of duplex treated plastic mold steel
O. Alpaslan, M. Gunyuz, E. Atar, H. Cimenoglu 89

Studies on wear protection for humidity sensor in a sand drying plant
O.N. Ionescu, G.C. Ionescu, M. Minescu, I. Nae 95

Lubricants

Solid lubrification with powder WS_2 through self-repairing and self-replenishing. Modeling and Experimentation
I. Filip, T. Constantin 103

Viscosity of future biofuels under pressure and temperature variation
S. Drumm, A. Fatemi, L. Leonhard, H. Murrenhoff 111

Polyacrylamide – new opportunity in lubrication
A.C. Drumeanu 117

Some aspects about lubrication in the presence of nuclear radiation
O. Florea, A. Marin 125

Comparative methodes for measuring the rheological properties of fresh and used oils
A.V. Radulescu, I. Radulescu 135

Experimental researches on biodegradable lubricants with multifunctional properties
A. Tudor, M. Vlase, A. V. Radulescu, E. Bojan, E. Stepan, V. Vladut 141

Tribo-tests and Tribo-aspects in Various Applications

Influence of the machining tool wear on the tribological properties of the produced surfaces
A. Mihailidis, C. Salpistis, C. Sachanas, S. Gatsios 153

Experimental measurements for determination of frictional forces within the rod seals of hydraulic cylinders
C. Cristescu, P. Drumea, D. I. Guta, S. Anghel, M. Crudu 163

Corrosion behavior evaluation of high strength aluminum alloy
A. Mavropoulos, S. Skolianos 171

Methods of fault detection in rolling element bearings
P. Stepanic, V. Kvrgic, N. Misic, Z. Dancuo, I. Lazarevic 179

Neural predictor to analyse the efficieny of positive displacement pumps
F.Canbulut, C.Sinanoglu, M.Erkilet,Ö.Özmen 189

Experimental determination of the heat of adsorption of mineral oils on a two–disk test rig
A. Mihailidis, S. Gatsios, C. Salpistis 199

Non destructive testing in roller bearing using wavelets
I. Tsiafis, K.-D Bouzakis, A. Kaplanis, A. Karamanidis, Th. Xenos 209

About damage of the femoral head of total hip prosthesis
L. Capitanu, L.-L. Badita, D.-C. Bursuc 217

A case study of turbogenerator journal bearing failure
T. Lazović, A. Marinković, S. Marković 227

Characteri ation of titanium carbide coatings on wave bearings
F. Dimo te, N. M. Ene, K.-D. Bouzakis, M. Batsiolas, A. Asimakopoulos 235

Wheel-rail wear damage of the metro
A. Tudor, I. Tountas, N. Sandu 245

Tribological behavior of bra e bands
R.G. Ripeanu, V. Ispas, D. Ispas 255

Tribology in ballroom dance with energy consumption analysis
A. Marinkovic, A. Zunjic, D. Pejic, M. Stankovic 263

The influence of slip rate on friction coefficient during slip roll contact
B. Ivkovic, N. Marjanovic, M. Ravlic 271

Optimi ation of the deposition parameters of thic atmospheric plasma spray coatings
A. Vencl 275

ossibility of application of tribometric investigations in diagnostics tribology assemblies of vehicles
S. Peric, B. Nedic, P. Dakic 283

Tribo-mechanics

Thermal elastohydrodynamic lubrication of elliptical contacts
A. Mihailidis, K. Panagiotidis, K. Agouridas 295

Self-organi ation in tribology: the role of Synergism and selective transfer
E. Assenova, M. Kandeva 305

Friction in rectilinear **motion** mechanical systems
G. Mishev 311

Study about friction coefficient estimation in friction stir welding
M. Mijajlovic, D. Stamenkovic, D. Milcic, M. Durdanovic 323

Study of tribological coatings wear according to the law of contact interaction
M. Kandeva 331

valuation of lubrication and friction in nee oin attac ed by osteoarthritis treated with ostenil, ostenil plus, yaral forte and durolane
R. Stoilov, M. Ivanova, K. Garbeva, N. Marinova, I. Manolova, Zh. Kalitchin 337

Tribological, Mechanical and physical Characteri ation of Hydroxyapatite olycarpolactone bio-composites
A. Tsouknidas, D. Kountouras, S. Maropoulos, N. Kiratzis, N. Michalilidis 343

Multi-parametric analysis of surface roughness in high-speed turning of a high-alloyed tool steel
N.M. Va evanidis, N.A. Fountas, N.I. Galanis, I. Bounas, J. Sideris 351

The tribometamorphism A particular ind of geotribological processes in the arth s crust
E. Kozhoukharova 359

STUDY ABOUT FRICTION COEFFICIENT ESTIMATION IN FRICTION STIR WELDING

M. Mijajlovic[1], D. Stamenkovic[1], D. Milcic[1], M. Durdanovic[1]

1. Department for design and engineering, Faculty of Mechanical Engineering, University of Niš, Serbia

A STRACT

Friction Stir Welding is a solid state welding method that uses friction processes for power transformation into welding consumable state. Friction coefficient is one of dominant tribological parameters in Friction Stir Welding: its nature and value changes influence welding process, ease the application or decrease loads on the welding tool with no change in uality of weld. However, friction coefficient is not completely defined in Friction Stir Welding either theoretically or experimentally. A brief study on friction coefficient in Friction Stir Welding assumes: decomposition of the welding process, recognition of the most important parameters, application of ade uate mathematical model and validation of results. aper describes possible model for experimental estimation of friction coefficient in Friction Stir Welding and ma es parallel with theoretical connotations.

WOR S: Friction coefficient, Friction Stir Welding, Friction parameters

1. INTRODUCTION

For a long time friction coefficient was considered to be constant value and that throughout the process of friction it does not change its value. Such a view was re ected in the 19th century however, the theory that introduces the coefficient of friction as a fixed and unchanging value, for the given frictional interface has appeared. From the mid-20th century it become clear that coefficient of friction and frictional force have values that change: they depend on many factors (especially conditions in which the process of friction ta es place) and they can have extreme, even when analy ed on the same friction pair.

On the other hand, in the bra ing device is re uired that coefficient of friction has stable and often high value, while for bearings it has to be marginally low. For numerous parts in machinery it is necessary that the friction coefficient has time-stable value, with no mater on its intensity, while in some cases it is re uired that friction coefficient varies with speed or loads, etc. In other words - depending on the function and purpose of a given tribomechanical system it is necessary to set up different re uirements in terms of behavior of the friction parameters. For this reason, recognition and determination of friction parameters and the laws of their change in function of the factors on which they depend are the most important tas s from the standpoint of predicting the process of friction.

2. PARAMETERS THAT INFLUENCE FRICTION

Solving the tas of friction parameters recognition is extremely difficult even in modern times. Anyhow, first of all is necessary to get the information about the friction process: researchers often ma e different, conditionally determined, indexing of friction parameters, with an idea of simplification of the friction problem. For example, some classifies friction parameters on internal, external and combined influencing factors.

Internal parameters are all factors which define tribomechanical system as it is. ach one of them defines and characteri es parts of the system and the system itself and in most of the cases these parameters can not be affected changed easily (or by chance) nor does change of a single parameter stay locali ed or substantive from other parameters. Some of these parameters are the crystal structure of materials then the mechanical thermophysical chemical magnetic electrical properties etc.

he external parameters include pressure relative speed duration of the process geometry and other characteristics of the contact the state of the environment in which the friction occurs chemical composition humidity air temperature air pressure and so on. hese are therefore factors that can be predicted – measured – determined in advance – before the start of the process of friction. External parameters usually can be changed without concern on change of other external parameters what is not the case with the internal parameters .

he group of combined parameters is a result of the interaction of internal and external factors which exist or even before the start of friction or occur during the process. his includes impurities of different origin oxide lubricant moisture then coatings various contaminants and so on. his group includes very important parameter – temperature increase resulting from the heat generation in friction. hat is a factor that always occurs during the friction processes and its effects on the process and system s functionality are extremely large and can not be neglected in any analysis.

ragelskii 1 has given another classification of parameters that influence friction processes. his division is based on physics of the friction process and parameters are concerning on material of the tribo-pair elements factors of the design and working conditions factors.
owever previously mentioned classifications and groups of factors must be considered only as informational. hey only help in decomposition of the friction process and might help in local solving of the friction processes problem. If some other division or decomposition helps the problem solving every researcher is entitled to provide another explanation or decomposition of parameters that involve friction.

ut regardless of disagreements over the classifications there is a general consensus in opinions that individual action on the process of friction by any of the parameters can not be considered independently of the actions of other parameters. Even the analysis of the effects of whole groups of parameters completely independent of any other group it is also difficult or impossible to be achieved. he reason is that they are all entwined they participate in the process of friction at the same time acting in turn on each other. hat is why when examining the impact of certain factors on the coefficient and the friction force one can speak only of more or less dominant influences of one of them in the circumstances of friction.

3. FRICTION COEFFICIENT

Coefficient of friction μ on contact between two solids is defined as relation between tangential force F_t that is necessary to produce sliding condition between bodies and normal force between contact surfaces F_n

$$\mu \quad F_t / F_n. \qquad 1$$

ollowing eonardo da Vinci s supposition of basic friction principles Newton Amontons esagulies Euler and Coulomb studied friction.
omlinson 2 in 1929 developed *Molecular theory of friction* where the friction coefficient is expressed as

$$\mu \quad \frac{C_1 \cdot W \cdot n_m}{l \cdot F_n}, \qquad 2$$

where C_1 is constant W is activation energy for a pair of molecules n_m is number of molecular connections l is the distance between molecules F_n is normal force.

owden and Tabor 6 in 1930 formulated the *hesi he i i* which presents significant contribution for science of friction. Their approach is that adhesion component of friction force is the ma or part of its total value and the friction coefficient is:

$$\mu \quad \cdot\frac{\tau}{} \quad \frac{\tau_s}{} \qquad (3)$$

where C τ_s τ_0 is constant depending on material τ_s is shear strength of softer material in contact τ_0 is shear strength of membrane which covers the softer material.

ragels ii 1, 2 in 1939 formulated *M e e h i he i i*. Towards this theory, total friction force in contact area of tribomechanical system is a sum of molecular and deformable components. Friction force value depends on type of deformations contact one. eformation may be elastic or plastic depending on mechanical properties of contact bodies, normal load and surface micro-topography.
In elasto - deformable condition, in real contact one, friction coefficient can be calculated by formula:

$$\mu \quad \frac{2,4\cdot\tau_0\cdot\left(1-\nu^2\right)^{0,8}}{{}_c^{0,2}\cdot\Delta^{0,4}\cdot\ ^{0,8}}+\beta+0,2\cdot\alpha_{ef}\cdot\Delta^{0,4}\cdot\left[\frac{\cdot\left(1-\nu^2\right)}{}\right]^{0,2}. \qquad (4)$$

This complex e uation includes characteristics of friction pair (contour pressure), material features (α_e, ν,), technological parameters surface uality (Δ - micro-geometry roughness, complex parameter) and exploitation-technological parameters which include used lubricant (τ,). In plasto - deformable condition, in real contact one, friction coefficient can be calculated by formula:

$$\mu \quad \frac{\tau_0}{}+\beta+0,9\cdot\Delta^{0,5}\cdot\left(\frac{}{}\right)^{0,5} \qquad (5)$$

On the base of supposition that total friction force depends mainly on plastic deformation of surface asperities, Ludema 5 set the model:

$$\mu \quad \frac{1}{\sqrt{\ ^{-2}\ 1}} \qquad (6)$$

where is the ratio of the shear strength of surface asperities and the bul shear strength .
udins i 4 set the new model for calculating the friction coefficient and his model includes all of influence parameters: type and thic ness of surface films normal force surface texture solid solubility of paired materials presence of third bodies sliding velocity ambient temperature ambient atmosphere elasticity of the tribosystem mechanical properties of each member of the couple waviness:

$$\mu \quad \cdot\left(\sqrt{\frac{h}{s}}\ \sqrt{\frac{\sigma_h}{\sigma_s}}\ 3\cdot\sqrt{\frac{h}{s}}\right)\ \frac{1-\nu_s}{10}\cdot\left(\frac{1-}{\frac{\sigma_s}{50}}\right). \qquad (7)$$

4. PHYSICAL PHASES OF THE FSW

uring SW process speciali ed welding tool influences the material of welding plates and along the joint line creates weld. Welding tool is mostly cylindrically conically shaped tool with a shoulder with or without reservoir for the pressed material and non profiled probe that is directly involved in welding of the plates. Welding tool igure 1 consists of at least 3 active surfaces that actively involve in welding

- probe tip flat or profiled surface on the top of the welding tool and the probe itself
- probe side cylindrical or coned surface of the probe usually profiled threaded what makes this surface complex and consisted of several different surfaces the most important for weld creation
- shoulder tip the surface with the greatest area flat or coned surface bellow the shoulder of the welding tool.

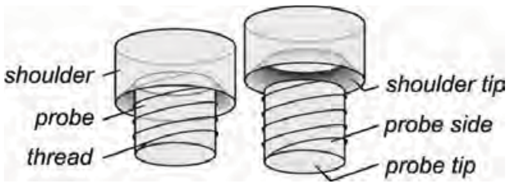


Figure 1*:* Scheme of the welding tool and active surfaces

Welding tool is positioned in the head of the machine that can provide rotating of the welding tool. In most of the cases it is the milling head and machine used for the SW is milling machine. After that welding tool is positioned above the welding plates – above the start point on the joint line igure 2 . otation of the welding tool starts and SW process begins.
SW process happens thru several phases

1. plunging phase – after positioning welding tool rotates above welding plates and slowly plunges into the material of welding plates relative movement between welding tool and welding plates is achieved due to the vertical movement of welding plates welding tool or rarely combination of both movements plunging last until welding tool reaches the maximal plunging depth what is approximately e ual to the height of welding plates.

2. first dwelling phase – there is no translational movement of welding tool or welding plates while welding tool constantly rotates this is transition phase that eases the welding process preheating of welding plates stabili ation of welding plates material after plunging phase etc.

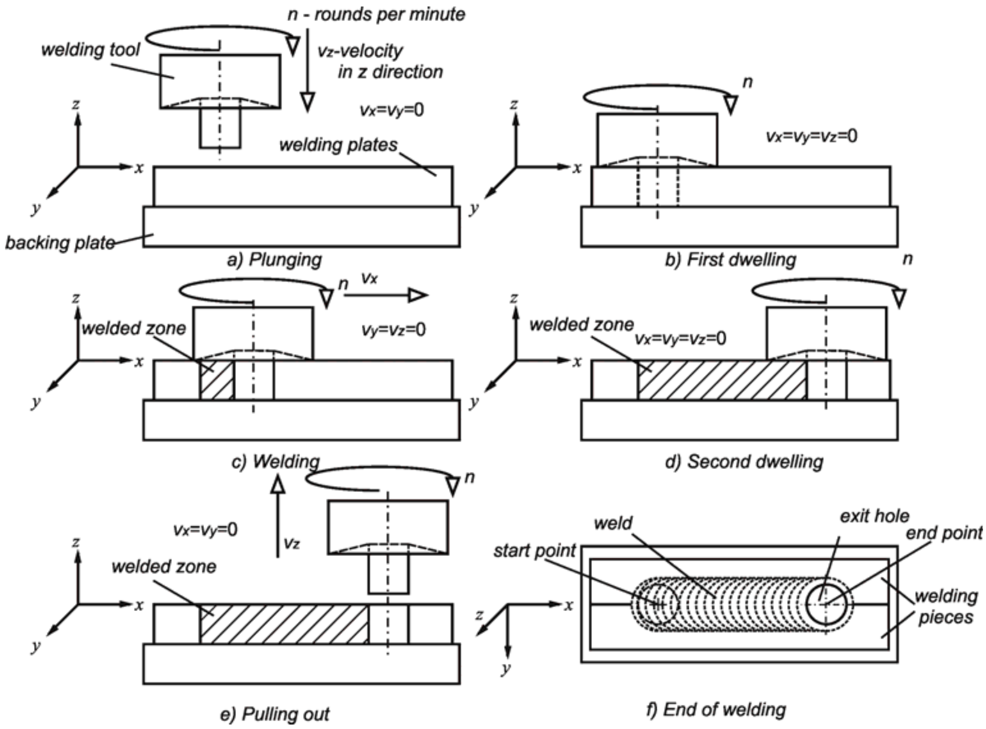
3. welding phase – welding tool is constantly rotating and moving with constant welding speed along the joint line it is relative movement since it is possible to have welding plates moving while welding tool is kept steady or welding tool is moving while plates do not or having booth – welding plates and welding tool moving the longest and the most important phase of the SW

4. second dwelling phase – similar to the first dwelling phase stabili es the welding plates after the end of welding phase

5. pulling out phase – welding tool rotates and slowly leaves the contact with the welding plates.

eside the geometrical description of the SW physical phases define and explain almost all aspects of the SW process load distribution temperature stress and strain history material flow energy consumption etc. Analysis of the friction coefficient between welding tool and welding plates during SW is bonded to the physical phases as well.

Complexity of the FSW process and complexity of the friction coefficient itself re uire even deeper decomposition of the FSW process and analysis of several FSW parameters that influence friction coefficient.



F . hysical phases of the FSW

. CTI E RF CE EN E ENT

If FSW is analy ed thru phases, it is important to recogni e when and how much are active surfaces engaged (AS) in the process, in a single moment of time. AS does not directly influence friction coefficient (e.g. area of the active surface), however, AS influences other parameters of the FSW (temperature, contact pressure, type of deformations, surface roughness, etc) that in great amount influence value of the friction coefficient.

Figure 3 gives a scheme of the AS during FSW. Minimal values of AS consider close to 0 engagement and maximal values of AS consider almost 100 engagement, for every of previously mentioned active surfaces.

robe tip is active surface that is fully engaged in the FSW process from the beginning of the plunging phase ( ) until the end of the second dwelling phase ( ). At the beginning of the plunging phase probe tip slides over the top surface of welding plates and there is no significant plunging into material of the welding plates. Material of the welding plates is still capable to resist influence of the contact pressure on contact between probe tip and welding plates. lunging force is rising as the plunging phase on goes and eventually plunging force will be intensive enough to produce contact pressure that will overcome resistance of the material and welding tool will penetrate into the material (in the moment of time $_s$). This intensive plunging will enable contact between probe side and material of welding plates and increase of engagement of the probe side – it will reach some value until the end of the plunging phase t_1 . It will be kept steady or slightly will decrease during first dwelling phase from t_1 to t and it will increase again during welding phase after t . When welding tool stabili es in welding phase when it reaches constant speed at the moment of t probe side will reach maximal ASE.

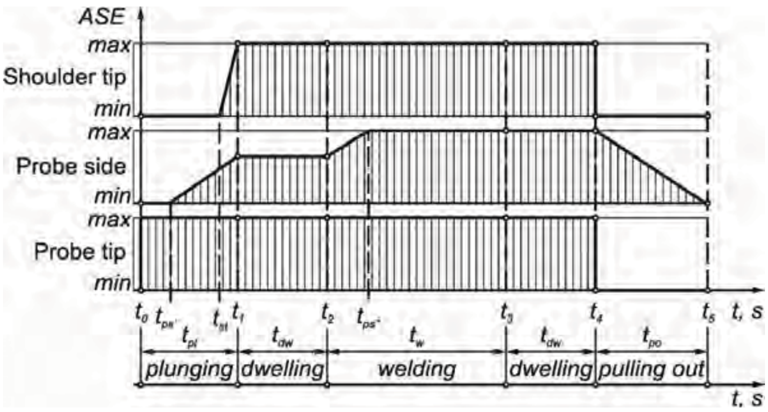


Figure Active surface engagement ASE during SW process

It will be kept relatively steady until the end of the second dwelling phase t and after will slightly decrease until the minimal value – when welding tool gets pulled out at the end of the pulling out phase t . Shoulder tip will involve in SW process when firstly touches t_t the material of welding plates that was pushed upwards while plunging phase lasted. ASE will increase to the maximum when plunging phase ends t_1 it will keep steady value until the end of the second dwelling phase t when it will drop to minimum.

. COEFFICIE T OF F ICTIO I FSW

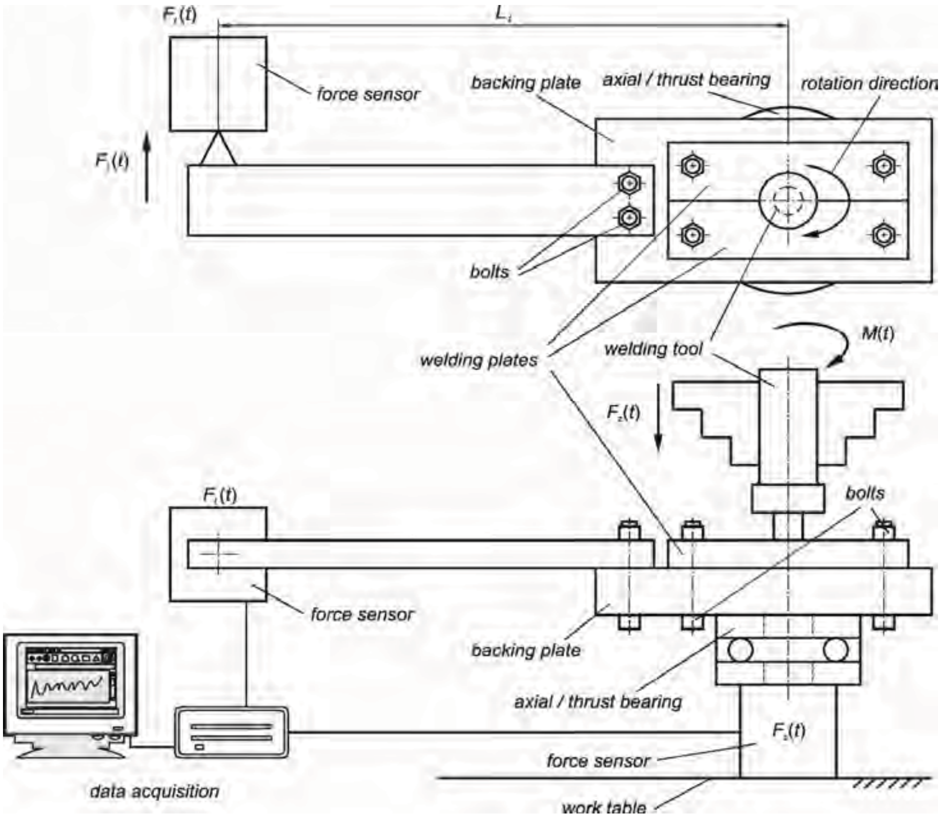
Without any doubt friction is one of the most important parameters in SW. Its dominance in this welding techni ue has motivated inventors to put the term friction in the name of the process – riction Stir Welding. owever two decades after the invention of the SW friction coefficient remains partly unknown and difficult to be explained in SW. riction was is recogni ed as somewhat important but never was the main topic of researches on SW. Numerous authors 9 10 11 have pointed out the nature of the friction in SW static kinematic and assumed for their researches that friction coefficient is constant. Values of the friction coefficient vary in these researches from μ 0 3 to μ 0 6 and they are always assumed or predicted. esearches aiming in direction of recognition and determination of the friction coefficient in SW are rare. umar et al. 7 proposed a method and conducted a set of experiments aiming to determine value of the friction coefficient in SW for different conditions loads technological parameters etc. . igure 4 shows experimental setup that umar proposed for experimental determination of friction coefficient in SW. umar has based his experiment on E uation 1 to determine friction coefficient μ t during SW it is necessary to measure tangential force F_t t and normal force F_n t F t that appear during experiment. ased on contact mechanics alin 8 proposed a dependency between tor ue M t friction coefficient μ t and normal force F t between two bodies semi-rigid punch with diameter t and an elastic half space in contact

$$M(t) \;\; \frac{1}{3}\cdot\mu(t)\cdot F\;(t)\cdot\;(t). \qquad 8$$

Since tor ue M ( ) can be estimated as a product of tangential force ( ) and distance from rotation axis to the point where the tangential force is measured , transformed uation 9 gives value of experimental friction coefficient μ ( ):

$$\mu(\ )\quad \frac{3\cdot M(\ )}{(\ )\cdot\ (\ )}\quad \frac{3\cdot\ \ (\ )\cdot}{(\ )\cdot\ (\ )}\qquad \le\ \le\ . \qquad (9)$$

iameter of the punch ( ) is ta ing values from (diameter of the welding tool s probe) to (diameter of the welding tool s shoulder), depending on the AS and FSW phase.



F Scheme of a system for experimental determination of friction coefficient during FSW process

. I C ION N CONC ION

Values of friction coefficient determined by the uation 9 are giving better loo to the real conditions of friction in FSW than approximate values predicted as constant during complete phases of FSW. Moreover, uation 9 gives a possibility to have values of friction coefficient during FSW μ 1, what is not the case with other researches. Still, umar s model is having some imperfections:

1) xperimental set shown in Figure 3 can be used only during plunging and first dwelling phases since there is no possibility to enable movement of the tool along the oint line (what

happens during welding phase and measuring ade uate forces. Application of tor ue sensor mounted on the welding tool will make monitoring system capable to continue monitoring but results collected by this system are uestionable tor ue is not e ual to the friction momentum while first setup provides this e uality .

2 Value of friction coefficient has to be considered as a mean value. Analy ing the ASE it is clear that active surfaces of the welding tool differently influence the SW during process. or example from to $_s$ only probe tip is involved in SW process from $_s$ to $_s$ probe tip and partially probe side from $_s$ probe tip partially probe side and partially shoulder tip. Contact between welding tool and material of the plates changes and it results in change of contact pressure contact area temperature friction etc. It is necessary to recogni e friction coefficient for every active surface probe tip μ probe side μ_s shoulder tip μ_s and determine values during SW process.

3 riction coefficient is considered to be static without concern on kinematic characteristics of the process.

. EFE E CES

1. ragelskii I. V. and I. E. Coefficients of riction Mashgi Moscow 1962 .

2. ragelskii I. V obychin M. N ombalov V. S. riction and Wear Calculation Methods. ranslated from ussian by N Standen Pergamon Press xford 1982.

3. . A. omlinson A Molecular heory of riction Philosophical Maga ine Series 7 Vol. 7 No. 46. une 1929 pp. 905-939.

4. udinski riction in machine design Symposium on ribological Modeling for Mechanical esigners San rancisco SA May 1990.

5. .C udema riction Wear ubrication a extbook in ribology the niversity of Michigan Ann Arbor C C Press Inc. 1996 IS N 0-8493-2685-0.

6. owden .P. and abor . riction – An Introduction to ribology Anchor Press oubleday eprinted 1982 rieger Publishing Co. Malabar 1973.

7. umar . alyan C. aias Satish V. Srivatsan . S. An Investigation of riction uring riction Stir Welding of Metallic Materials Materials and Manufacturing Processes 24 4 438 445 2009.

8. alin .A. Contact Problems he legacy of .A. alin Series Solid Mechanics and Its Applications Vol. 155 riginal ussian edition published by Nauka Moscow ussia 1953 1980 2008 IV 318 p. ardcover IS N 978-1-4020-9042-4.

9. Schmidt attel and Wert An analytical model for the heat generation in riction Stir Welding Modeling Simul. Mater. Sci. Eng. 12 No 1 p. 143-157 2004.

10. handkar M han A and eynolds A P 2003 Sci. echnol. Weld. oining 8 165–74.

11. Colegrove P.A. Sherclif . . 3- imensional C modelling of flow round a threated friction stir welding tool profile . Mater. Process. ech. v.169 p.320-327 2005.

12. Mijajlović M Milčić Stamenković, D, Živković A Mathematical Model for enerated eat Estimation uring Plunging Phase of SW Process ransactions of amena aculty of Mechanical Engineering and Naval Architecture agreb Croatia V-1 2011 April 2011 pp 39 - 54 ISSN 1333-1124 C 621.791.1.

13. AN VIĆ M MI A VIĆ M MI ČIĆ S AMEN VIĆ eat eneration uring riction Stir Welding Process ribology in Industry no. 1-2 2009 Serbia ragujevac aculty of Mechanical Engineering ragujevac May 2009 ournal vol. 31 pp. 8-14 no. 1-2 ISSN 0354-8996.

Authors’ Index

Adamovic ., 69
Agouridas ., 295
Alpaslan O., 89
Anghel S., 163
Antonescu N.N., 23
Asima opoulos A., 235
Assenova ., 305
Atar ., 89

abic M., 59, 69
adita L.-L., 217
atsiolas M., 235
obic I., 59
o an ., 141
ounas I., 351
ou a is .- , 209, 235
ursuc .-C., 217

Canbulut F., 189
Capitanu L., 217
Car ıt Aydın ., 3
Celi O., 77
Cimenoglu H., 77, 89
Constantin T., 103
Cristescu C., 163
Crudu M., 163

a ic ., 283
ancuo Z., 179
e la Cru M., 13
enape ., 81
imofte F., 235
ishliev S., 31
obrescu R.-N., 81
rumea ., 163
rumeanu A.C., 117
rumm S., 111
urdanovic M., 323
unic ., 59, 69

ne N. M., 235
r ilet M., 189

Fatemi A., 111
Filip I., 103
Florea O., 125
Fountas N.A., 351

alanis N.I., 351
arbeva ., 337
atsios S., 153, 199
eorgescu Ov., 23
unyu M., 89
uta . I., 163

Ionescu .C., 95
Ionescu O.N., 95
Ispas ., 255, 41
Ispas V., 255, 41
Ivanova M., 337
Iv ovic ., 271

a as ., 49
alitchin Zh., 337
andeva M., 305, 331
aplanis A., 209
aramanidis A., 209
aramıs M. ., 3
ayali .S., 77
irat is N., 343
ountouras ., 343
ovacević L., 49
o hou harova ., 359
vrgic V., 179

La arevic I., 179
La ović T., 227
Leonhard L., 111

Manolova I., 337
Marin A., 125
Marin ović A., 227, 263
Marinova N., 337
Mar anovic N., 271
Mar ović S., 227
Maropoulos S., 343
Mavropoulos A., 171
Michalilidis N., 343
Mihailidis A., 153, 199, 295
Mi a lovic M., 323
Milcic ., 323
Miletić A., 49
Minescu M., 95
Mishev ., 31
Mishev ., 311

Misic N., 179
Mitrovic S., 59, 69
Morosanu M., 23
Murrenhof H., 111

Nae I., 95
Nedic ., 283

Onescu C., 81
men ., 189

anagiotidis ., 295
e ic ., 263
eric S., 283
opa N., 81
opescu M.-T., 81
Radulescu A. V., 141, 135
Radulescu I., 135
Rahne at H., 13
Ravlic M., 271
Ripeanu R. ., 41, 255

Sachanas C., 153
Salpistis C., 153, 199
Sandu N., 245
Sideris ., 351
Sinanoglu C., 189
S olianos S., 171
S oric ., 49
Stamen ovic ., 323
Stan ovic M., 263
Stepan ., 141
Stepanic ., 179
Stoilov R., 337

Tere ., 49
Theodossiades S., 13
Tountas I., 245
Tsiafis I., 209
Tsou nidas A., 343
Tudor A., 141, 245

Vaxevanidis N.M., 351
Vencl A., 275
Vilotic M., 49
Vladut V., 141
Vlase M., 141

Xenos Th., 209

ıldı lı ., 3

Zivic F., 59
Živic F., 69
Zun ic A., 263

LABORATORY FOR MACHINE TOOLS & MANUFACTURING ENGINEERING

MECHANICAL ENGINEERING DEPARTMENT, ARISTOTELES UNIVERSITY THESSALONIKI

Director: Prof. Dr.-Ing. habil., Dr.-Ing. E.h., Dr.h.c. K.-D. Bouzakis
541 24 Thessaloniki, Greece
Tel.: +30 2310 996079, Fax: +30 2310 996059,
e-mail: bouzakis@eng.auth.gr

ISBN 978-960-98780-6-7