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Faculty of Mechanical Engineering

Conference on Mechanical Engineering Technologies and Applications

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CONTENTS

PLENARY LECTURES

1. **Stefan Wagner**
IMPROVED FAILURE DESCRIPTION IN FORMING OF AUTOMOTIVE
SHEET METAL PARTS 1
2. **Gorazd Hlebanja**
CHARACTERISTICS OF NON-INVOLUTE GEARS 9
3. **Aleksandar Veg, Emil Veg**
DEVELOPMENT OF A HAND-HELD VIBRODIAGNOSTIC
INSTRUMENT 21
4. **Milosav Ognjanović**
TECHNICAL SYSTEMS DEVELOPMENT TOWARDS TO ACTUAL
TRENDS AND METHODOLOGY IN ENGINEERING DESIGN 31

INVITED PAPERS

5. **Ljubodrag Tanovic**
INVESTIGATIONS IN DEVELOPING A NEW GENERATION OF
MACHINE TOOLSS 37
6. **Ranko Antunović, Aleksandar Veg**
ANALYSIS OF DYNAMIC BEHAVIOR OF ROTATING MACHINES 43
7. **Vojislav Miltenović, Biljana Marković, Milan Banić,
Aleksandar Miltenović**
FUTURE TECHNOLOGY AND EDUCATION OF ENGINEERS 53

Session I

MANUFACTURING TECHNOLOGIES AND ADVANCED MATERIALS

Chair: Milan Zeljković, Ljubodrag Tanović, Obrad Spaić

8. **Milan Zeljkovic, Aleksandar Zivkovic, Slobodan Tabakovic**
COMPUTER AND EXPERIMENTAL AIDED ANALYSIS OF
HIGH-SPEED SPINDLE ASSEMBLY DYNAMIC BEHAVIOR 63
9. **Dejan Jeremić, Nebojša Radić**
IMPLEMENTATION OF CARBON FIBER IN THE AUTOMOTIVE
INDUSTRY 75
10. **Obrad Spaić, Budimirka Marinović**
INFLUENCE OF WEARING DRILLS ON DRILLING AXIAL FORCE 83
11. **Obrad Spaić, Zdravko Krivokapić, Slavoljub Grče**
MODELING OF AXIAL CUTTING FORCE USING NEURAL
NETWORKS 91
12. **Milija Krašnik, Dragiša Vilotić, Leposava Šiđanin, Žarko Petrović**
EXPERIMENTAL VERIFICATION OF DIFFERENT THEORETICAL
APPROACHES FOR DEFINING FLD 99
13. **Aljoša Ivanišević, Igor Kačmarčik, Dejan Movrin,
Miroslav Plančak, Sergei Alexandrov, Dragiša Vilotić**
INFLUENCE OF FRICTION AND NUMBER OF DEFORMATION
PHASES ON FORMABILITY OF STEEL C45E 109

14.	Aleksandar Košarac, Saša Prodanović, Milan Zeljković POSSIBILITIES FOR INTERACTIVE CONTROL OF MACHINE TOOLS IN THE VIRTUAL REALITY ENVIRONMENT	117
15.	Saša Živanović, Zoran Dimić, Nikola Slavković, Dragan Milutinović, Miloš Glavonjić CONFIGURING OF VIRTUAL ROBOT FOR MACHINING AND APPLICATION IN OFF-LINE PROGRAMMING AND EDUCATION	125
16.	Zorica Djordjević, Mirko Blagojević, Saša Jovanović, Vesna Marjanović, Nenad Kostić MATERIAL TYPE INFLUENCE ON STATIC AND DYNAMIC CHARACTERISTICS OF COMPOSITE SHAFTS	133
17.	Slobodan Stojadinović, Jasmina Pekez, Nikola Bajić, Eleonora Desnica HARDENING OF AlMgSiCu ALLOYS AS A FUNCTION OF THE THERMO-MECHANICAL TREATMENT	141
18.	Zdravko Božičković, Dragoslav Dobraš, Milorad Poljašević THE INFLUENCE OF THE DEFORMATION IN THE PROCESS EXTRACTION ON QUALITY OF WIRES FOR REINFORCEMENT MESH	145
19.	Svetislav Marković, Dragoljub Veličković, Marijana Marković, Marija Popović, Jelena Milić, Ljubiša Milovanović THE ABILITIES AND PRACTICAL APPLICATIONS OF LASER CONTOURING CUTTING OF MATERIALS IN THE MAINTENANCE OF MECHANICAL SYSTEMS	153

Session II
APPLIED MECHANICS AND MECHATRONICS
Chair: Aleksandar Veg, Ranko Antunović, Nebojša Radić

20.	Nebojša Radić, Dejan Jeremić BUCKLING ANALYSIS OF DOUBLE-ORTHOTROPIC NANOPATE USING NONLOCAL ELASTICITY THEORY	161
21.	Ljupco Trajcevski, Tale Geramitchioski DYNAMIC RESPONSE SIMULATION OF PLANETARY GEAR BY NEWMARK METHOD	171
22.	Tale Geramitchioski, Ljupco Trajcevski, Vangelce Mitrevski COMPUTER SIMULATION A VIBRATION SIGNAL FOR THE GEAR FAULT DIAGNOSTICS	179
23.	Rusmir Bajrić, Ninoslav Zuber, Denijal Sprečić REVIEW OF VIBRODIAGNOSTIC METHODS FOR PLANETARY GEARBOX GEARS CONDITION MONITORING	187
24.	Ninoslav Zuber, Rusmir Bajrić REVIEW OF VIBRODIAGNOSTIC METHODS FOR ROLLER ELEMENTS BEARING CONDITION MONITORING	195
25.	Saša Nikolić MOTOR CURRENT SIGNATURE ANALYSIS TO DETECT FAULT OF INDUCTION MOTOR	205
26.	Nenad Marjanović, Biserka Isailović, Vesna Marjanović, Nenad Kostić INTEGRATED APPROACH TO STRUCTURAL OPTIMIZATION IN CAD SOFTWARE	213

27. Vladimir Milovanović, Dragan Rakić, Miroslav Živković, Snežana Vulović, Miroslav Milutinović	
THERMO-MECHANIC ANALYSIS OF CEMENT TRANSPORT WAGON - IDENTIFICATION OF THE CAUSE OF CRACKS	221
28. Nedeljko Vukojević, Fuad Hadžikadunić	
EXPERIENCES OF APPLICATION OF VIBRATORY RESIDUAL STRESS RELIEVING METHODOLOGY ON LARGE WELDED CONSTRUCTIONS	229
29. Boris Rakić, Nikola Beloica, Danica Josifović, Lozica Ivanović, Andreja Ilić	
STRESS - STRAIN ANALYSIS OF HYDRAULIC CYLINDER AT EXCAVATOR BUCKET MECHANISM	235
30. Lozica Ivanović, Danica Josifović, Mirko Blagojević, Blaža Stojanović, Andreja Ilić	
DETERMINATION OF GEROTOR PUMP THEORETICAL FLOW	243
31. Aleksandar Nikolić, Milan Blagojević, Vladimir Milovanović, Miroslav Živković, Miroslav Milutinović	
ANALYSIS OF HEAT TRANSFER THROUGH THE BEAM SUPPORT OF THE WAGON STRUCTURE CALCULATED BY SOFTWARE PAK MULTYPHISICS	251
32. Marko Topalović, Miroslav Živković, Nenad Busarac, Snežana Vulović	
IMPROVEMENT AND INTEGRATION OF FEM SOLUTION USED FOR R&D INTO FEMAP	255

Session III

DEVELOPMENT OF PRODUCTS AND MECHANICAL SYSTEMS

Session III-1: DESIGN OF POWER TRANSMISSIONS

Chair: Miloslav Ognjanović, Siniša Kuzmanović, Dragan Milčić

33. Miloš Ristić, Milosav Ognjanović	
RELIABILITY-BASED DESIGN OF BUCKET WHEEL EXCAVATOR GEAR DRIVE UNITS	263
34. Milan Rackov, Siniša Kuzmanović, Željko Kanović, Miroslav Vereš	
SOME IRREGULARITIES WHICH MAY OCCUR DURING IMPLEMENTATION HCR GEARING	269
35. Dragan Milčić, Miroslav Mijajlović, Dragoljub Živković, Slobodan Miladinović	
CALCULATION OF LOAD CAPACITY OF AXLES AND SHAFTS ACCORDING TO DIN 743	277
36. Predrag Živković	
EXPERIMENTAL IDENTIFICATION OF FAILURE AND RELIABILITY CALCULATION OF ELEMENTARY PLANETARY GEARS POWER TRANSMISSIONS	285
37. Radoslav Tomović	
NEW APPROACH TO THE MODELING OF ROLLING BEARINGS	293
38. Dragan Milčić, Miroslav Mijajlović, Boban Anđelković, Miodrag Milčić	
SOFTWARE SYSTEM FOR CALCULATIONS OF MACHINE PARTS – PROGRAM MODULE FOR FRICTION TRANSMISSION CALCULATIONS	303

39. **Dragoslav Janošević, Nikola Petrović, Vesna Nikolić, Jovan Pavlović**
ANALYSIS OF HYDRAULIC CRAWLER TRACTORS TRANSMISSION 309
40. **Marko Miletić, Mirko Blagojević, Snežana Vulović, Ivan Miletić**
CONTACT SURFACE ANALYSIS ON CYCLOID DRIVES WITH SINGLE, DOUBLE AND TRIPLE MESHING 315
41. **Miroslav Milutinović, Milosav Ognjanović, Spasoje Trifković**
DESIGN PARAMETERS IDENTIFICATION OF AUTOMOTIVE GEARBOX BASED ON DESIRED RELIABILITY 323

Session III-2

ENGINEERING EDUCATION AND INNOVATION IN DESIGN

Chair: Vojislav Miltenović, Gorazd Hlebanja, Biljana Marković

42. **Tihomir Mačkić, Mirko Blagojević, Živko Babić**
ANALYSIS OF PARAMETERS THAT HAVE AN IMPACT ON CYCLO DRIVE EFFICIENCY 331
43. **Nenad Kostić, Mirko Blagojević, Vesna Marjanović, Zorica Đorđević, Nenad Marjanović**
INFLUENCE OF CYCLOIDAL GEAR PROFILE CORRECTION TO THE NUMBER OF CONTACTS BETWEEN THE ELEMENTS OF A CYCLOIDAL SPEED REDUCER 339
44. **Nada Bojić, Dragan Milčić**
EFFECTS OF VARIOUS PARAMETERS TO SLIDING BEARINGS 347
45. **Miroslav Živković, Miloš Janošević, Snežana Vulović, Nenad Busarac, Marko Topalović**
THERMAL ANALYSIS OF HIGH POWER REDUCTION GEARBOX 355
46. **Biljana Marković, Milan Banić**
REQUIREMENTS FOR DEVELOPING ENGINEERS EDUCATION – HOW TO PARTICIPATE IN INTERNATIONAL PROJECTS? 359
47. **Mirko Blagojević, Zorica Đorđević, Vesna Marjanović, Nenad Marjanović, Blaža Stojanović, Rodoljub Vujanac**
STRESS AND STRAIN STATE OF CYCLOID DISC 367
48. **Dejan Krstić**
IMPACT OF EURO NCAP TESTS ON BODY MODIFICATION IN AUTOMOTIVE INDUSTRY 375

Session IV

ENERGETICS AND THERMO - TECHNIQUE

Chair: Dušan Golubović, Mirko Dobrnjac, Buzatu Gabriel Cosmin

49. **Milan Plavšić, Zdravko Božičković, Dušan Golubović**
MATERIALS-RELATED ISSUES IN CATALYTIC AND BOILER-TURBINE PLANTS 383
50. **Miljan Savić, Biljana Marković**
ESTABLISHING ENERGY EFFICIENCY SYSTEM IN ACCORDANCE WITH THE REQUIREMENTS OF EN ISO 50001 391
51. **Vangelce Mitrevski, Tale Geramitcioski, Vladimir Mijakovski, Monika Lutovska**
RISK ASSESSMENT IN NATURAL GAS TRANSMISSION SYSTEM 399
52. **Saša Jovanović, Zorica Đorđević, Milorad Bojić, Slobodan Savić, Biljana Stepanović**
WEATHER CONDITIONS IMPACT ON ELECTRICITY CONSUMPTION 409

53.	Buzatu Gabriel Cosmin, Mircea Paul Mihai, Dinu Radu Cristian ENERGY EFFICIENCY OF A COGENERATION SYSTEM	415
54.	Šefik Bajmak ANALYSIS OF ENERGY EFFICIENCY AND ECONOMIC SEPARATED SYSTEMS WITHIN THE SUPPLY CENTRALIZED HEAT AND COOLING ENERGY	423
55.	Jela Burazer, Dragana Kalabić, Mirko Dobrnjac CALCULATION CHOICE AT THE VERTICAL PNEUMATIC TRANSPORT OF THE DUST MATERIAL	431
56.	Slobodan Stefanovic, Zivoslav Adamovic, Radoje Cvejic, Imre Kiss MATHEMATICAL MODEL OF THE SYSTEM FOR REGULATION OF ROLLING THICKNESS ON FIVE STRANDS TWIN TRAIN	435
57.	Velibor Karanović, Mitar Jocanović, Darko Knežević, Milija Krašnik DEVELOPMENT OF ELECTROHYDRAULIC ACTUATOR FOR ROBOTS	447
58.	Dragoljub Živković, Marko Mančić, Dragan Milčić SYMULATION OF A HYBRID TRIGENERATION SYSTEM DESIGNED FOR DEMANDS OF A RESIDENTIAL BUILDING	457

Session V
RENEWABLE ENERGIES AND ENVIRONMENTAL PROTECTION
Chair: Petar Gvero, Stojan Simić, Mircea Paul Mihai

59.	Srđan Vasković, Petar Gvero, Vlado Medaković, Davor Milić THE IMPORTANCE OF ANALYSIS ENERGY CHAINS BASED ON BIOMASS FOR ENERGY PRODUCTION	465
60.	Stojan Simić RECYCLABILITY-SIGNIFICANT REQUEST FOR DESIGN AND CONSTRUCTION IN THE METAL INDUSTRY	471
61.	Stojan Simić, Snježana Vujić, Omer Kovač ADEQUATE WASTEWATER MANAGEMENT SIGNIFICANT SEGMENT OF CONSERVING OF ENERGY IN REFINERIES	479
62.	Mircea Paul Mihai, Sanda Diana (Firincă) Enache, Cătălin Mihai, Sorin Abagiu, Ivan Felicia Elena Stan SMART GRIDS CONCEPT USED IN RURAL AREAS	487
63.	Dejan Krstić MANAGEMENT OF THE INNOVATIVE PROJECTS FOR CONQUEST OF MANUFACTURING SOLAR PHOTOVOLTAIC MODULE	495
64.	Roganović D., Đurović D. DETERMINATION OF HEAVY METALS IN THE BARK OF CYPRESS (CUPRESSUS SEMPERVIRENS L.) IN THE VICINITY ALUMINIUM PLANT PODGORICA (KAP) - MONTENEGRO	503
65.	Panaiteescu F.V., Panaiteescu M., Stan, L.C. ANTHROPIC IMPACT WATER QUALITY IN THE PORT MARINE MANGALIA	511
66.	Panaiteescu M., Panaiteescu F.V., Panaiteescu I.I., Panaiteescu V.A. A NEW TECHNOLOGY FOR SHIP HEAVY FUEL OIL SYSTEM	517
67.	Mina Radić, Jovana Arsić, Marija Džaleta, Svetlana Stevović IMPROVEMENT OF ENVIRONMENTAL QUALITY BY SETTING UP THE EXTERNAL VERTICAL GARDEN ON THE EXISTING BUILDING	525

Session VI
QUALITY, MANAGEMENT AND ORGANIZATION
Chair: Rade Ivanković, Slavko Arsovski, Slaviša Moljević

- | | | |
|-----|---|-----|
| 68. | Slavko Arsovski, Zora Arsovski, Miladin Stefanović
INFLUENCE OF SIZE OF ORGANIZATION AND NUMBER OF
INTEGRATED MANAGEMENT SYSTEMS (IMS) ON ORGANIZATION
OF IMS PROCESSES | 533 |
| 69. | Rade Ivanković, Zdravko Krivokapić, Đurđica Kučinar
IMPACT OF PRODUCT QUALITY ON COMPANY PROFITABILITY
BY MEANS OF EXPERT SYSTEMS | 541 |
| 70. | Biljana Marković
APPLICATION OF REQUIREMENTS OF INTERNATIONAL
STANDARD EN 9100:2009 IN AIRSPACE INDUSTRY | 549 |
| 71. | Slaviša Moljević, Dragan Rajković, Bogdan Marić,
Vlado Medaković, Slavoljub Đurđević
INTEGRATED SYSTEMS MANAGEMENT IN SMALL AND MEDIUM
ENTERPRISES | 557 |
| 72. | Ljubica Duđak
PERSONAL MANAGEMENT AND HUMAN RESOURCE
MANAGEMENT – DIFFERENCES | 567 |
| 73. | Nina Đurica, Maja Đurica, Miha Marič
THE ROLE AND USE OF INFORMATION-COMMUNICATION
TECHNOLOGY IN HIGHER EDUCATION | 577 |
| 74. | Vlado Medaković, Bogdan Marić, Slaviša Moljević, Srđan Vasković
ORGANIZATIONAL MODELS AND DEVELOPMENT GENERIC
TECHNOLOGIES FOR THE MANUFACTURING INDUSTRY | 587 |

Session VII
MAINTENANCE AND TECHNICAL DIAGNOSIS
Chair: Milan Blagojević, Radoslav Tomović, Ranko Antunović

- | | | |
|-----|--|-----|
| 75. | Andreja Ilić, Lozica Ivanović, Danica Josifović, Vukić Lazić
THE METHODOLOGY ASPECTS FOR MONITORING THE MACHINE
ELEMENTS, COMPONENTS AND SYSTEMS | 593 |
| 76. | Milan Blagojević, Miroslav Živković, Aleksandar Nikolić
THE INFLUENCE OF THE DSLR CAMERA SHUTTER COUNT ON
THE ACCURACY OF THE PHOTOGRAMMETRIC MEASUREMENTS | 601 |
| 77. | Željko Batinić, Zoran Radović, Petar Nikšić, Ranko Antunović
NEW TECHNOLOGIES AS A FUNCTION OF CONTROL OF
MECHANICAL SYSTEMS | 607 |
| 78. | Mihajlo Vujičić, Radoslav Tomović
APPLICATION OF TECHNICAL DIAGNOSTIC IN MAINTENANCE OF
GEOTECHNICAL MACHINES | 615 |
| 79. | Vojin Vukotić, Dragan Čabrilo
REENGINEERING OF MECHANICAL EQUIPMENT ON
THE BUCKET WHEEL EXCAVATOR | 623 |
| 80. | Mitar Jocanović, Velibor Karanović, Đorđe Vukelić,
Darko Knežević, Milija Krašnik
DIAGNOSTIC EQUIPMENT FOR EXAMINATION PHYSICAL AND
CHEMICAL CHARACTERISTICS OF UTTO, STOU TRACTOR OILS | 631 |
| 81. | Marko Šolaja, Vladimir Gluhović
SENSOR SYSTEM ON CHAIRLIFT „OGORJELICA 1“ | 641 |

82. Goran Orašanin, Dalibor Vlaški	
PRESSURE MANAGEMENT IN THE WATER SUPPLY SYSTEMS	647
83. Rajko Tanasijević	
IMPORTANCE OF MAINTENANCE BY MEANS OF INFORMATION SYSTEM PRODUCTION SYSTEM	655

Session VIII

STUDENT SECTION

Chair: Milija Krašnik, Srđan Vasković, Ranko Antunović

84. Zoran Radović, Željko Batinić, Nemanja Prorok, Srđan Vasković	
APPLICATION OF VIRTUAL INSTRUMENTATION IN MONITORING OF MECHANICAL SYSTEMS	663
85. Nikola Vučetić	
CONSTRUCTIONAL SOLUTION FOR INSTALLATION OF GAS (LPG) ON MOTORCYCLE	673
86. Nikola Vučetić	
END OF LIFE MOTOR VEHICLES RECYCLING	683
87. Vladimir Gojković, Ranka Gojković	
DEVELOPMENT AND PROSPECT OF NEW HYDROPOWER SYSTEM IN THE REPUBLIC OF SRPSKA	693
88. Vladimir Gluhović, Marko Šolaja	
SNOWMAKING SYSTEM ON MOUNTAIN JAHORINA	701
89. Ranka Gojković, Vladimir Gojković	
IMPLEMENTATION SOLAR AND WIND ENERGY FOR IRRIGATION OF AGRICULTURAL LAND	707
90. Marina Kondić	
APPLICATION OF INDUSTRIAL ROBOT „LIMAT RT 280-6“ IN THE PROCESS OF WELDING	715

INDEX OF AUTORS

723

PRESENTATIONS OF PARTICIPANTS



IMPROVEMENT AND INTEGRATION OF FEM SOLUTION USED FOR R&D INTO FEMAP

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Abstract: This Computer simulation and structure behavior researchers often develop their own FEM solution for testing new material models, element types or numerical procedures. Improvement and integration of user developed FEM solution into FEMAP which is state of the art pre and post-processing software has a purpose to enable researchers to focus more on their scientific investigation by reducing tedious workload that is result of inadequate UI of user developed solver. Developed methodology presented in this paper enables researchers to create analysis CAD model in FEMAP, perform FEM analysis testing new material models, element types or numerical procedures in user developed solver and view results back in FEMAP. Connection between FEMAP and user developed FEM solver is performed by automatic, programmatic customization of FEMAP and development of new features in FEM solution. These new features automate many tasks in model preparations. As a result, FEM solver looks and operates as integral part FEMAP and its functionality is greatly improved.

Key words: computer simulation, finite element method, pre-processing, post-processing, software customization

1. INTRODUCTION

Computational methods [1] such as Finite Element Method (FEM) [2] in particular, are used for stress analysis in many fields of engineering. Wide spread of FEM means its taught on many engineering universities as well as used in many research institutes. Numerous software companies developed their FEM solutions which are widely used by many manufacturing companies. Commercial FEM solvers have good pre-processing (geometry modeling and mesh generation) as well as good post-processing (visualization of results) [3]. Downside of commercial software is no or limited access to program code which hurdle independent researchers in testing behavior of new material models, element types or numerical procedures. To have advantages of both approaches, we used combination of researcher developed FEM

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solution and commercial program used for pre- and post-processing. In this paper we described linking of our R&D FEM solver with commercial program for pre and post-processing FEMAP. Second section of this paper describes current state of implementation of R&D FEM solution in Engineering Software Lab. In the third section we described methodology used to customize FEMAP UI and create new C++ program that links our software solution with FEMAP. In the forth section of this paper we described new functionality of FEM solution integrated in FEMAP. In the conclusion we discuss benefits of new methodology.

2. CURRENT STATE OF IMPLEMENTATION OF R&D FEM SOLUTION WITH FEMAP

FEMAP is software used to create FEM models for different engineering problems [4],[5] and to display analysis results. FEMAP is solver neutral and provides comprehensive pre- and post-processing support for all of the major commercial solvers on the market, such as NX Nastran, which is built in FEMAP, and others. FEMAP can create input files for those solvers and it also can read result from their output files. To use FEMAP with unsupported solvers, such is our R&D FEM solution, users need to save analysis model into ASCII file called FEMAP Neutral (*.neu), which serves as universal data transfer interface (input and output) between FEMAP and any other program. Before analysis neutral file is generated manually by user from FEMAP and after FEM analysis R&D solver generates neutral file which is also inputted manually by user into FEMAP. FEM solver uses its own input file, which uses data from FEMAP Neutral, supplemented with data inputted by researcher needed for his specific research. Significant number of operations needed to perform FEM analysis with R&D solver is tedious work of FEM solver input file preparation and generation, manual starting of FEM analysis and loading results. We automated all these operations.

3. CUSTOMIZATION OF FEMAP USER INTERFACE

FEMAP allows users to customize its UI trough options accessible trough main program menu by choosing *Tools->Toolbars*. User can create *User Commands* which can be used for starting user's own program from FEMAP. Once created, *User Command* can be placed in main menu, some sub menu or any toolbar. In our case we want to create user command that, when clicked, starts out FEM solution.

For programmatic customization of FEMAP we used FEMAP Application programming interface (API) [6] that allows users to customize FEMAP to meet their specific needs and contains hundreds of methods that can be called from Visual Basic, VBA (Excel, Word, Access, ...), C, or C++.

To customize FEMAP we needed access to application object [6]. We developed solution that programmatically create FEMAP *User Command* and place it in FEMAP main Meny Bar by calling FEMAP API methods. Our next step was to create Windows Installer Package which unpacks FEM solution after which automatic programatic customization is performed.

4. AUTOMATION OF ANALYSIS PROCESS USING FEMAP AND R&D FEM SOLUTION

The procedure to convert FEMAP model into research solver input file begins with creation of FEMAP neutral file.

After the FEM solution is started from FEMAP, there are several actions it performs:

- attach itself to FEMAP using FEMAP API
- create FEMAP neutral file using API methods
- read data from FEMAP neutral file

Creation of R&D solver input file is a relatively straightforward process in which translator program writes data obtained from FEMAP neutral file into solver input file. Some additional analysis parameters (not present in FEMAP neutral file) can be inputted in translator. Translator can start FEM analysis, from within FEMAP, of previously generated input file. Creation of solver input file without starting analysis is used when researchers use one computer for modeling in FEMAP, and server or a cluster for FEM analysis. Batch file is generated which is used to start R&D solver, which is a console application programmed in FORTRAN, and feeds it with previously generated input file. To start batch file we used `_spawnl` method which will start analysis process and pause execution of translator segment of our FEM solution until analysis in R&D solver is finished. When analysis is finished, execution of FEM solution will continue and new pop-up dialog will be created alerting user that analysis is finished and that results are available for loading.

5. RESULTS AND DISCUSSION

Translator program, customization program and R&D solver (*pak.exe*) are all part of our FEM solution [7]. Windows Installer Package is used for FEM solution installation. Users need to start setup program and if they desire, change installation directory. Everything else is carried out automatically and users are not aware of FEMAP customization process that runs in the background. After the setup is complete users can start FEM solution called PAK from FEMAP Main Menu (Figure 1).

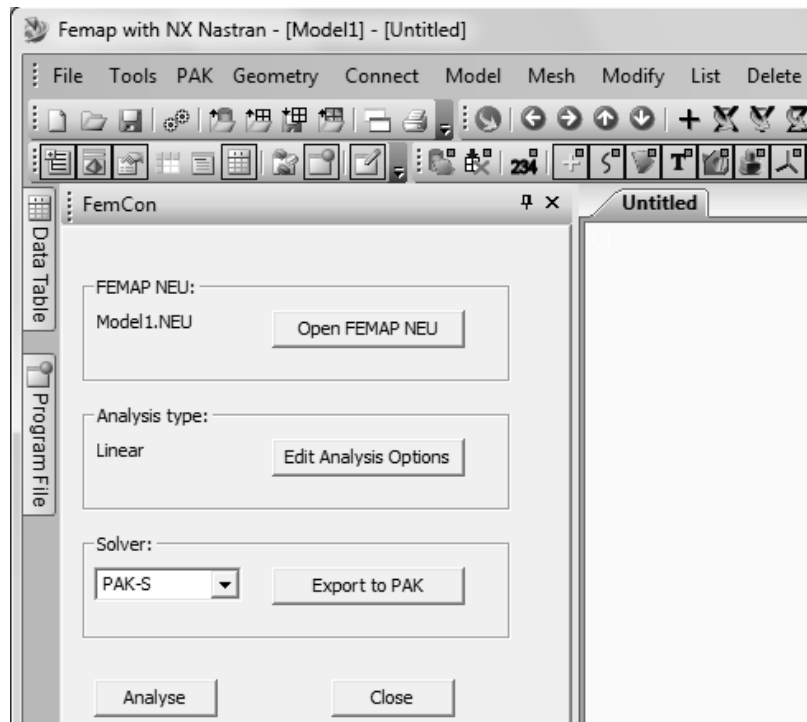


Fig.1 R&D FEM solution integrated in FEMAP

Following simple example is used to demonstrate new methodology [8]. Example shows the application of iterative arc-length method, follows the history of deformation of the structure with snap-through and snap-back effects. Circle arc having unsymmetrical supports is loaded by force (Fig. 2). Force increase causes large displacements of a structure. Material is isotropic and elastic.

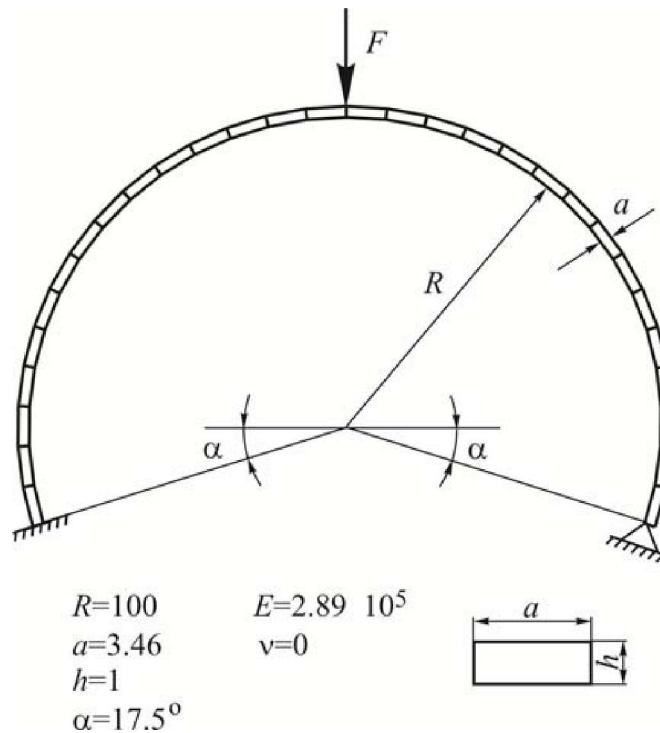


Fig.2 Arc analysis in R&D solver PAK

Modeling in FEMAP is described in FEMAP User Manual [6]. First step is definition of material with characteristics shown on Figure 2.

Young's Modulus, E is $2.89E5$

Shear Modulus, G is 0

Poisson's Ratio, ν is 0

Second step is property definition, in this case users should choose **Membrane Plane Elements** with **Thickness T1** equal 1.

Third step is geometry creation, in this case two arcs defined by their center, start and end point.

First circle arc:

Center $x: 0 ; y: 0 ; z: 0$

Start $x: 97.022 ; y: -30.951 ; z: 0$

End $x: -97.022 ; y: -30.951 ; z: 0$

Second circle arc:

Center: $x: 0 ; y: 0 ; z: 0$

Start: $x: 93.722 ; y: -29.550 ; z: 0$

End $x: -93.722 ; y: -29.550 ; z: 0$

After creation of two arcs, users need to make a surface from them.

Fourth step is mesh generation. In this step users need to set mesh size for surfaces then select surface to mesh and finally, select property defined in step 2.

Fifth step is constraints definition. Unsymmetrical supports (Fig. 2.) are modeled by constraining translation of both lowest nodes on the left side and inner lowest node on the right side in X and Y direction. Permanent constraints are set for all nodes disabling translation in Z direction and rotation in all directions.

Sixth step is definition of load. Nodal force of -1 in Y direction is set on top node. After definition of load, model is ready for analysis (Fig. 3).

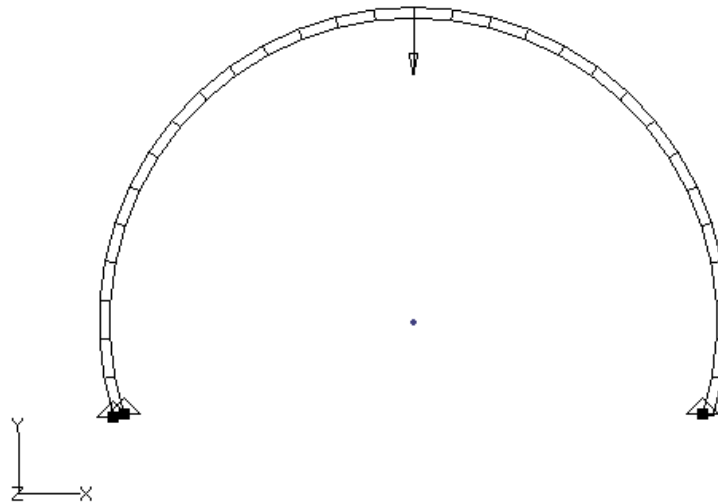


Fig.3 Model in FEMAP ready for analysis

Researchers can start translator program by clicking on a "PAK" option that is added in FEMAP Main Menu (Fig. 1). When started, translator attaches itself to top leftmost panel of FEMAP (Fig. 1). Now researchers need to set up analysis parameters by clicking on button **Edit Analysis Options** (Fig. 1). First parameter is **Analysis type**; in this case **Total Lagrangiane** (Fig. 4).

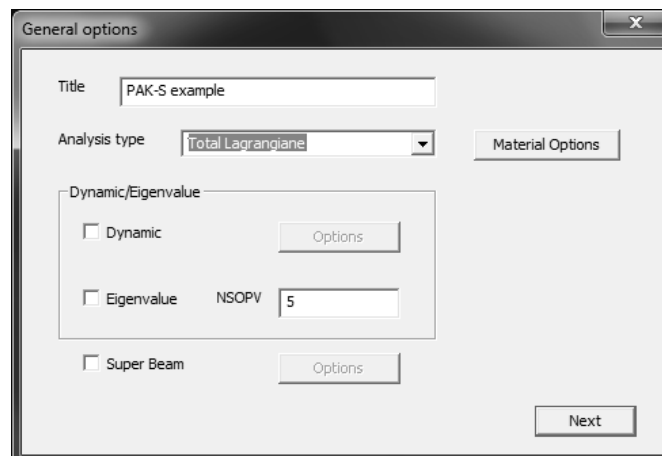


Fig.4 Translator dialog for selecting analysis type

In the next dialog researchers need to define number of steps (in this case 180) and time step increment of 1 (Fig. 5).

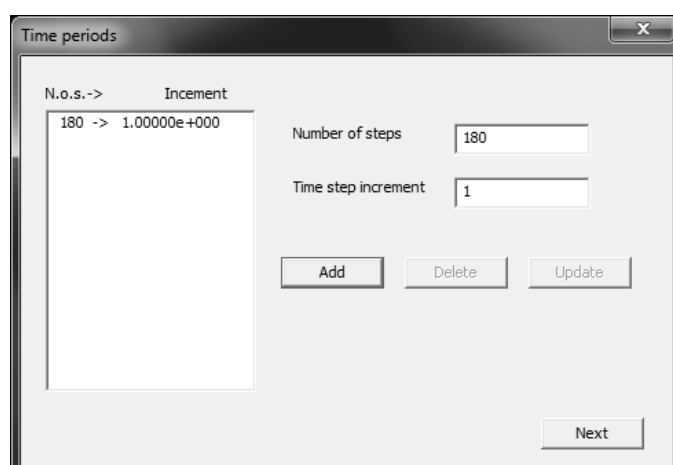


Fig.5 Translator dialog for selecting time periods

Next step is set up of **Iteration method (Arc length + full Newton)** and data for automatic load stepping (Fig. 6)

Node Number: 47

Direction: 2 (2 represents y direction)

Value: -1 (initial displacement)

AG :2 (coefficient of increase of displacement)

DS: 2 (coefficient of arc length increase)

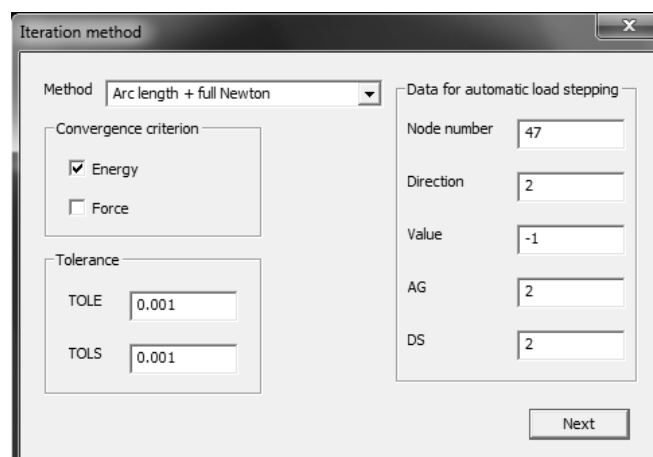


Fig.6 Translator dialog for selecting iteration options and automatic load stepping

After researchers have entered all necessary data, they can start FEM analysis by clicking **Analyze** button (Fig. 1). This action starts analysis in R&D solver PAK, and when the analysis is finished users can load analysis results (Fig. 7).

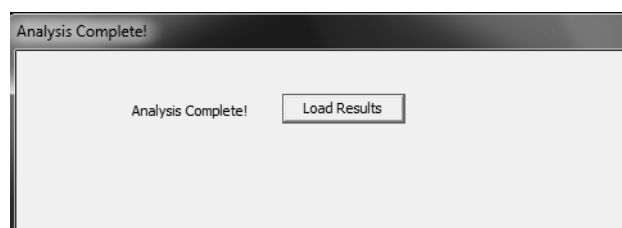


Fig.7 Analysis Complete dialog

When researchers click on **Load Results** button (Fig. 7). results are loaded into FEMAP and translator (Fig. 1) is closed. In order to view values of interest, such as stress or displacement, users need to select option from FEMAP Menu *View->Select* [6]. In *View Select* dialog users can select *Deform* and *Contour* as style and click on *Deformed and Contour Data...* button which opens dialog *Select PostProcessing Data* in which users need to select what data to display. For example, selection of *Solid Von Mises Stress* and click on *OK* button on this and previous dialog gives stress values displayed on deformed shape (Fig. 8).

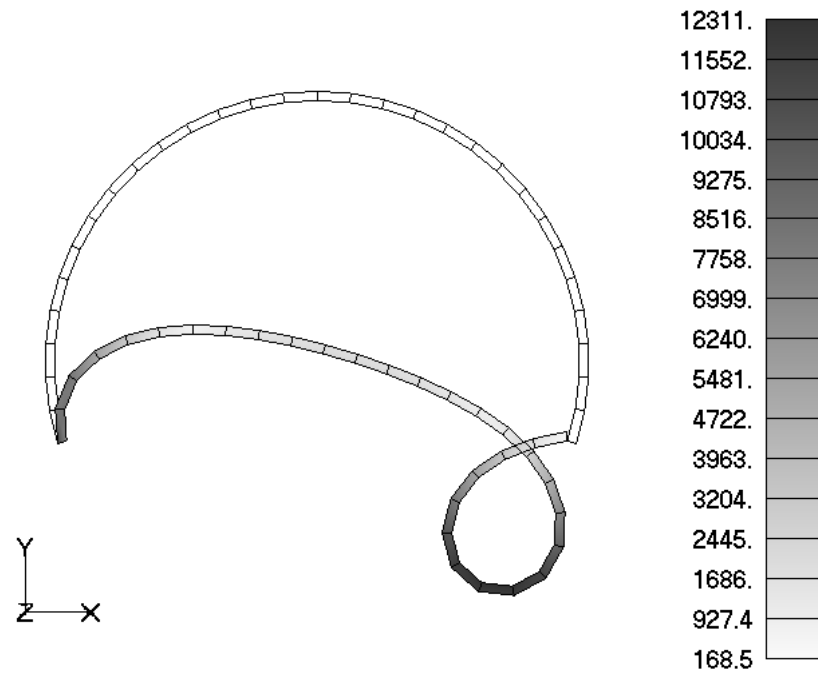


Fig.8 Analysis results: Solid Von Misses Stress

View Select dialog can be used to plot XY charts as well. if users want to export chart data they can use *List->Output->XY Plot* which will write data in specified *.rtf file. From that file data can be copied into Excel. Excel charts showing displacement of the node at which the force acts is shown on Figure 9 and Figure 10.

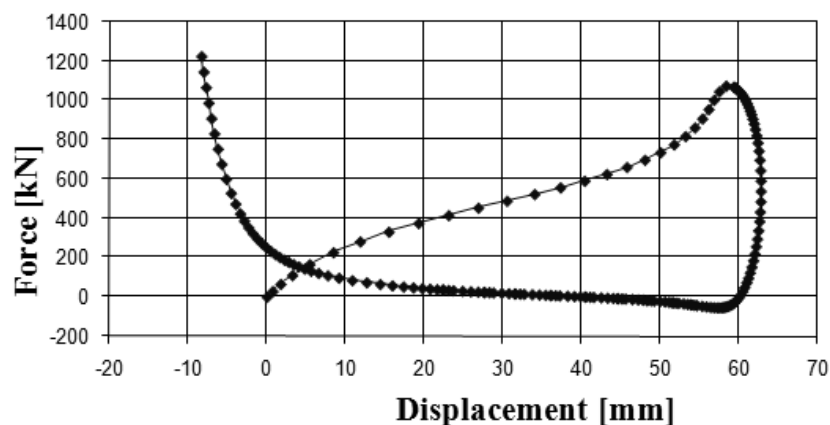


Fig.9 Displacement in X direction of the node at which the force acts

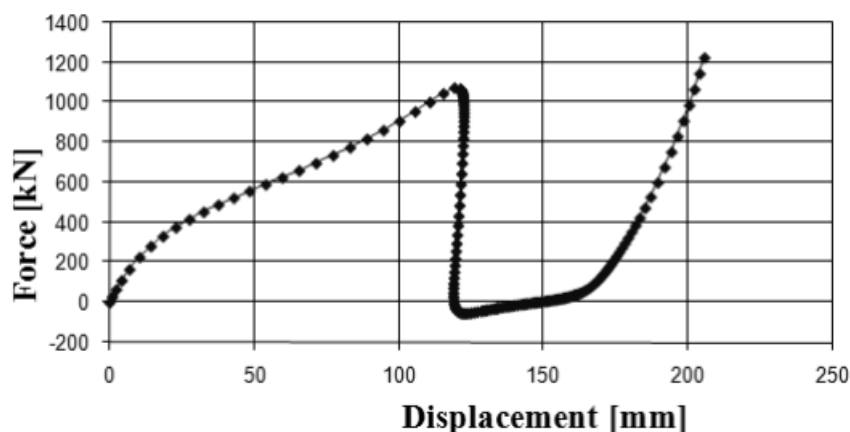


Fig.10 Displacement in Y direction of the node at which the force acts

6. CONCLUSION

R&D FEM solution PAK offers researchers opportunity to work on development of FEM program, to test their new material models, element types or numerical procedures. In this paper we described how we connected pre- and post-processing program FEMAP with PAK. Automatic generation of solver input file as well as automation of entire FEM analysis process is described. Implementation of new translator significantly reduced tedious workload that hurdles researchers in their research giving them more time to do actual research.

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