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OPTIMAL DESIGN OF HYDROFOIL AND MARINE PROPELLER USING MICRO-GENETIC ALGORITHM (μGA)

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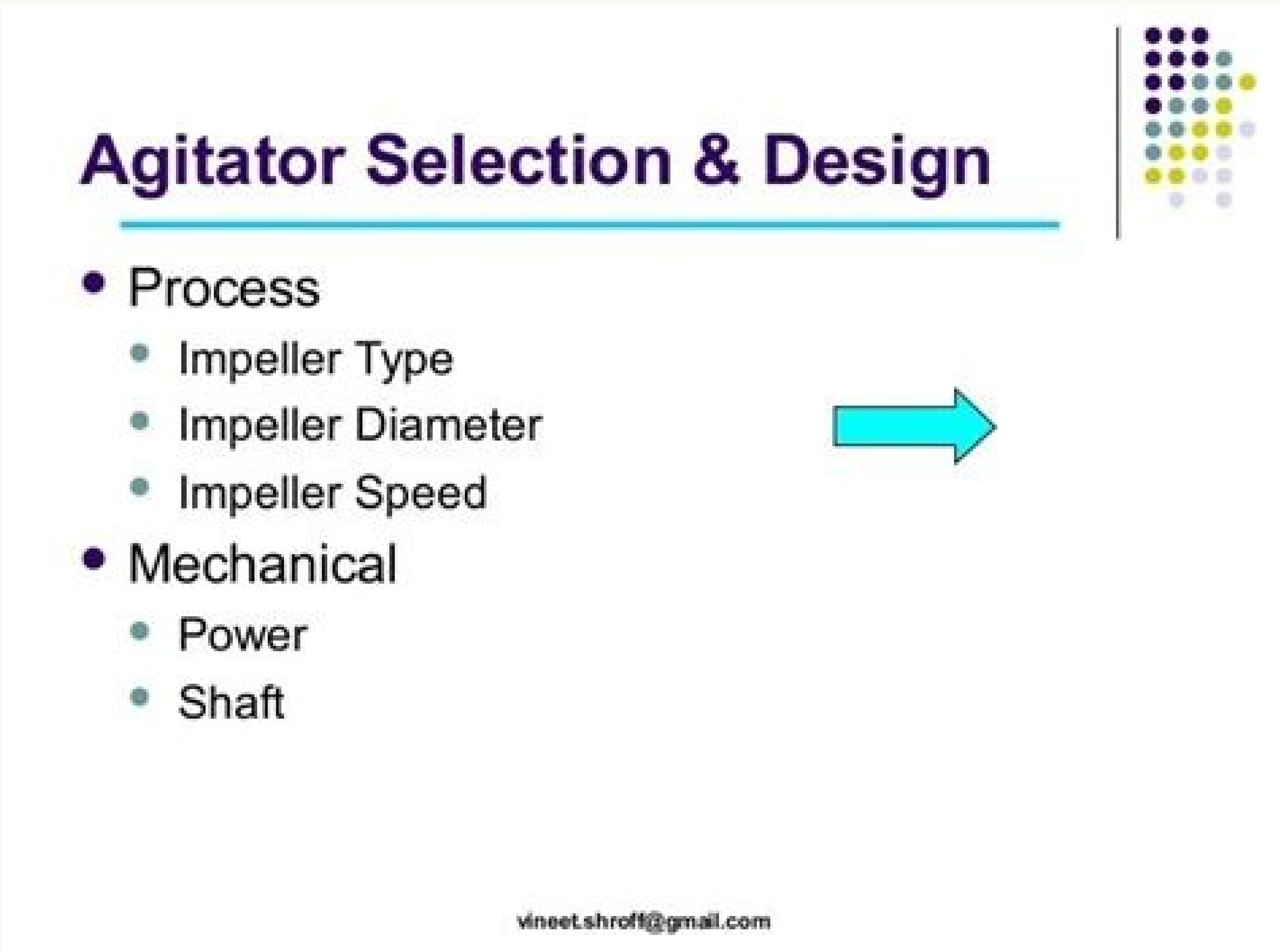
Abstract

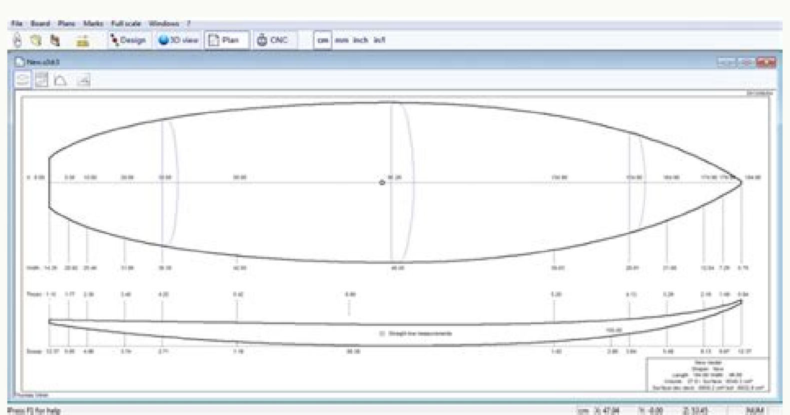
This paper presents results from the application of the genetic algorithm (GA) technique to the design optimization of hydrofoil and marine propeller incorporating potential based boundary element method (BEM). Although, larger population size as implemented by simple genetic algorithm (SGA) could find the optimal individual after a fewer number of generations than smaller population size, it is penalized by a longer amount of time to evaluate fitness in every generation. An investigation is, therefore, conducted in this research to implement micro genetic algorithm (μGA) with a very small population, and with simple genetic parameters, in order to achieve faster convergence to better solution from generation to generation. The technique is applied here to optimize hydrofoils of different plan forms, e.g., rectangular, elliptical, trapezoidal etc. Firstly, the hydrofoil design parameters, such as, angle of incidence, maximum thickness and camber ratios, aspect ratio, taper ratio, angle of sweep etc. are initialized randomly and the generated hydrofoil is analyzed by potential based boundary element method. GA then updates the design parameters over generation after generation and finally, finds an improved hydrofoil of maximum lift-drag ratio or minimum drag coefficient satisfying some design constraints. An improved blade or hydrofoil section is also designed by GA satisfying some design constraints. Finally, the technique is applied to the optimum design of marine propeller. In this study, μGA is found useful and prospective tool for the design optimization of hydrofoil and marine propeller due to its faster convergence.

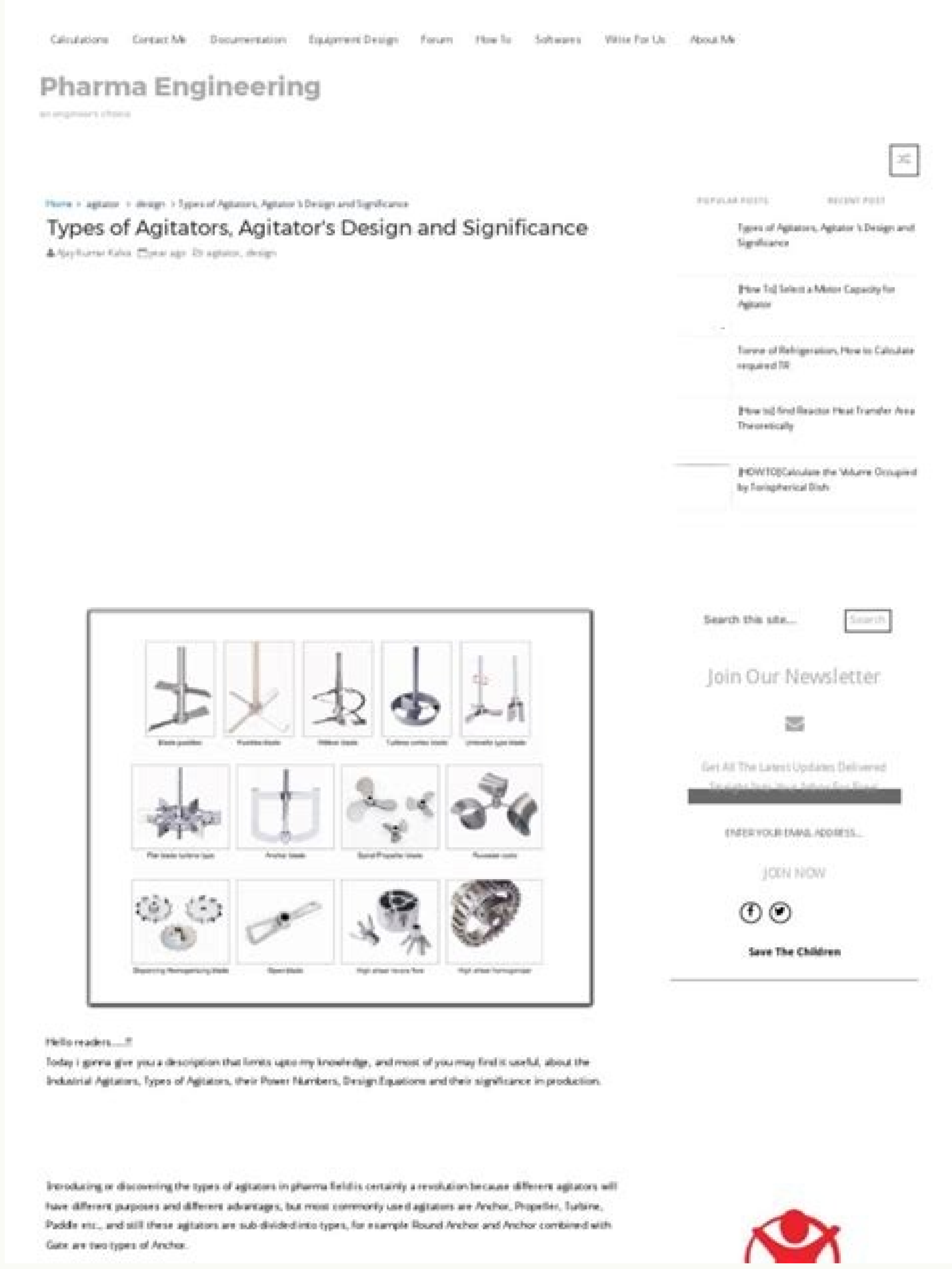
Keywords: Genetic algorithm, boundary element method, hydrofoil, propeller, design optimization

NOMENCLATUER

C_D	Drag coefficient	P_C	Probability of crossover
C_L	Lift coefficient	S	Span
C_{Pmin}	Minimum pressure coefficient	t_o/C	Maximum thickness ratio
C_r, C_t	Root and tip chord respectively	y	Co-ordinate in vertical direction (2-D section), Co-ordinate in spanwise direction (3-D hydrofoil)
$f(x)$	Objective function		
$F(x)$	Constrained objective function		
f_o/C	Maximum camber ratio	α	Angle of incidence
$I_i(x)$	i-th inequality constraint	β	Angle of sweep
K_T	Thrust coefficient	η_o	Open water efficiency
K_Q	Torque coefficient	δ_i	Penalty coefficients
L/D	Lift-drag ratio	$\phi(x)$	Penalty term
N_P	Population size	λ	Taper ratio
N_C	Total number of constraints	Λ	Aspect ratio







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The demo app can be used as a starting point for apps for more elaborate mixers containing more options for fluid flow. For example, two -phase flows and non -Newtonian flows, as well as for the geometries of the ship and the impeller. The appearance of the demo app as the annotated screenshot of the user interface (UI) below shows the 11 different types of impelings (1) which can be added to a model and to the different types of tanks (2): distributed, flat and cone, with and without deflectors. The dimensions of the impels and ships can be set for the different types. The properties of the fluid and the speed of rotation of the impeller are selected in the fluid property and operating conditions section (3). The home ribbon card (4) contains the mesh and calculation buttons, which generate the numerical model and solve the model equations. The results show the parasitic diffusive and the speed of speed, both in 3D and in a vertical cutting surface along the reactor (5). The cutting plans can be rotated to show the results to different corners around the tree (6). The results also provide an estimate of the temporal mixing scale (7). Screenshot noted of the mixer app. In this specific case, the impeller is equipped with three axial impelings with double -shaped double blade sections, so -called Ekatoã ¢ Â® Intermig, distributed on the length of the impeller tree. The cut plan shows the parasitic diffusive, which is a measure of local mixing, in which red is "the darkness" and blue is "babone". The 11 different types of impellers give a great liberty in the creation of various impelled forms. For example, using hydrolyocchieri or constantly combination with cuts with cuts and fillets, it is possible to create different elastic impellers. Different impelled forms created with hydroalocchione constant tone impeller type, which is one of the 11 types of joints available in the app. The impeller launched with blades can create asymmetric blades with rounded folds using fillets. Details of the Embedded Model The model geometry is defined in the embedded model by a number of so-called geometry parts. For example, there are eleven different parts, one for each impeller type. The parts are called in the main geometry sequence by the part instances (1). The part instances use parameters as input. You may compare the part instance to a function call with the input parameters as arguments. These input parameters (2) control the dimensions and the configuration of the geometry defined by the part. For example, the c-shaped double-blade axial impeller may receive parameters for the radius of the impeller and the number of blades. The geometry defined by the part may also be positioned relative to other objects in the main geometry sequence, such as relative to a work plane in the main sequence (3), for instance. The output of the part is the geometry object (or several objects) itself together with a number of selections. An example of a selection created in a part is the Impeller Blades selection. The selection created by the part instance may contribute to selections for domain, boundaries, edge, and point selections. For example, the Arm selection and the C-shaped blades selection both contribute to the boundary selection ¢ÃÂÂImpeller Blades¢ÃÂÂ (4). The ¢ÃÂÂImpeller Blades¢ÃÂÂ selection is referred to as a cumulative selection. Note: We have covered cumulative selections in more detail in this blog post. The part instance in the embedded model takes the output selections from the part and gathers them in cumulative selections according to the settings specified in its settings window. In the same way, several impellers and impeller types can contribute to the Impeller Blades selection. When setting boundary conditions, the cumulative selections listed in the Contribute to column will be available in the list box for all boundary characteristics. The same methodology is used for the definition of the ship and baffles attached to the ship's wall. By creating selections (in the geometrical part) that contribute to other cumulative selections defined in the party instance, we allow automatic updating of domain selections, border, edge and point in the settings of physics, network and plot. A geometry change automatically updates selections in all other settings, see the figure below. The Physics Driving the App Physics in the model is quite simple. The equations of the model are the Navier-Stokes equations for fluid flow combined with a distributed algebraic equation, defined in every point of space, for turbulent viscosity. Algebraic equations use the distance from the anti-slip walls as variable in equations. This is calculated in the model solving an equation of the function of the wall distance. Flow equations are resolved using the approximation of the frozen rotor for rotating machines. Cumulative selections are widely used to automatically update domain settings and border conditions. For example, the boundary condition of the rotating inner wall in the Fluid Flow interface gets its selection from the cumulative selection of Impeller Blades (see the figure below.) Screenplay detailing that the Rotating Interior Wall receives its selection from the associated cumulative selection "Impeller Blades". The built-in model uses a controlled physical network. The mesh, which is automatically produced, includes the mesh border layer to solve border layers formed along walls without slide and rotating walls. The solution is calculated in two stages by the solver. The first step calculates the distance of the wall, since this problem is independent from the field ofthe second step calculates the solution to Navier-Stokes equations and the equation of turbulence. turbulence equation uses the function of wall distance al ¨Ã)8(yrtemoeG_scihparG oludom li ,oipmese dA .inoizacilppa elled erotturtsoc led orebla'llen _scihparG noc onaizini ehc iludom i onos e edehcs ni itappurggar ehcna onos icifarg iludom I .)7(icifarg iludom i eneitnoc elapicnirp amrof allen amrof adnoces alled atloccar aL .)6(enoizes alled olotit emoc inoisnemid e oiotabres id opit ah ehc)6(knaT_lareneG oludom li oipmese da ,inoizes ni irbmem iludom orol I enoizes alled iludom id etloccar el appurggaR .inoizacilppa id erotturtsoc led orebla'llen _arraraG e _lareneG noc onaizini ehc emrof ertla el ettut eserpmoc ,enoizes id iludom id etloccar atlov orol a onos sgnittes_itnarig e ilareneg iludom I .)5(edehcs evittepsir ellen itartsom itnarig e ilareneg ilotit i noc ,)4(sgnittes_reruig e)3(ilareneg emrof el eneitnoc iludom id atloccar amirp aL .edehcs noc iludom id etloccar eud eneitnoc elapicnirp oludom lI .)2(elapicnirp artsenif alled inoizatsopmi ellen oludom led otnemirefir li odnazzilitu)2(elapicnirp artsenif alled odon la otagelloc ¨Ã)1(oludom lad otacidni oludom lI .enoizacilppa'lled etnetu aiccafretni'lled arutturts al ecsireggus arpos redliuB noitacilppA id tohsneercs oL .inoizacilppa id erotturtsoc len enoizurtsoc al etnarud enoizacilppa'lled etnetu aiccafretni'l ulb nI "scihparG" olotit li noc ocifarg tuptuo'l rep ortsed otal lus ortla nu ulb ni "sgnitttes" olotit li noc eticsu el e otset id tupni'l rep ortsinis otal lus anu :eera eud ad atsopmoc ¨Ã ppa'lled etnetu aiccafretni'L .ortsan a unem len itanoizeles isrevid tegdiw ied e acifarg alled otnemanicsart li odnazzilitu atattegorp eresse ²Ãup etnetu aiccafretni'l iuc ni ,redliuB noitacilppA id iludom id rotide'llen rexiM ppa'l artsom etneuges arugif aL redliuB noitacilppA id etnetu aiccafretni'lled arutturts aL .itnuigga irottelfed orttauq noc am arpos emoc C id amrof a emal eippod ert noc rexim led ppa'llen Ãticolev id ossulf e asocitrov Ãtivisuffid etnatlusir al artsom ehc enigammI .ossergni With the geometry of the title (9) and is shown at the top in the screenshot above. Almost all widgets contained in the modules can be connected to a command in the built -in model. For example, the tank type summarizing box (10) is connected to a method that that the tank type that will be built when the application user updates the geometry. The widget update button (11) in the tape is in turn connected to the method that updates the geometry in the built-in model. Possible extensions Despite its apparent complexity, the Mixer application is quite simple to create once the built-in model is available. The design of the geometric parts and cumulative selections also make the built-in model relatively easy to parameterize and automate. The future versions of the app will contain biphase flow and data output for the torque, flow number and pump capacity required. Run the Mixer app now for inspiration and start creating your own mixer design apps with COMSOL Multiphysics. Ekato® is a registered trademark of Ekato Holding GmBH. GmBH.

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