OPTIMIZATION OF OBSTACLE WRAPPER SHAPE IN A PIPE BY GENETIC ALGORITHM

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Abstract

This paper deals with finding of an ideal cover shape for barrier in a water flow. The shape was optimized by vorticity, Reynolds number and velocity of outlet boundary.

For creating of the pipe model and simulation was used COMSOL Multiphysics and for genetic computing was used Matlab with genetic toolbox. Generated model code with postprocessing variables create fitness function, which was used to optimize the geometry of barrier cover by genetic algorithm.

Genetic algorithms proved to be effective search tool for ideal barrier cover and give optimal solutions in acceptable time. This generalized method can be purposefully applied in hydrodynamics and aerodynamics.

The results showed that from the three selected parameters of postprocessing is the Reynolds criterion the best optimization condition of objective function.

Optimized network points were joined with line segments. It is possible to calculate the barrier with less resistance in condition of curves connection of optimized barrier points.

Keywords: genetic algorithm, Comsol, construction task optimization, global optimum

1 Introduction

The basic idea of using genetic algorithm in obstacle wrapper shape optimization is the FEM solution. The creation of the object geometry and defining the areal or spatial network points, which are called finite elements. In these points are calculated the fair value of the function. In other areas appropriate value is determined by approximation. FEM allows modeling of many physical based problem (flow, heat transfer, etc.). Evolutionary algorithm [1] in our case a genetic algorithm serves as an instrument which is in a defined area able to find optimal (suboptimal) values of selected sets of parameters that minimize the specified objective function. This task is solved by combining the FEM environment COMSOL [2] and genetic algorithm running in Matlab / Simulink (Matlab) [3]. Managed object is represented by a simplified linear or nonlinear models using some form of representation or differential. equations or artificial neural networks, as usual. Physical processes are modeled using the FEM in its defined area.

2 Geometry and FEM network model

As was mentioned model will be optimized by using of genetic algorithm. Model represents a cut from the pipes in 2D dimension. Model at the same time serve as the objective function, ie. the model will be with any change (except wrapper of obstacle) used by the genetic algorithm (re-evaluated) and will assign fitness to each solution depending on the conditions that will either minimize or maximize.

In terms of computational complexity of model is better to keep it simple as much as possible, because the optimization is then more technologically feasible and less time consuming. Of course it can not as detriment of precision and accuracy of suboptimal solutions.

In addition to the physical characteristics and FEM network density affects the computational complexity of the model, not least its geometry (size, location and shape of geometric objects, etc.).

Geometry model can be divided into 3 parts:

1. geometry pipeline cutting
2. wrapper geometry constraints (to be optimized)
3. geometry of obstacle in the pipe.

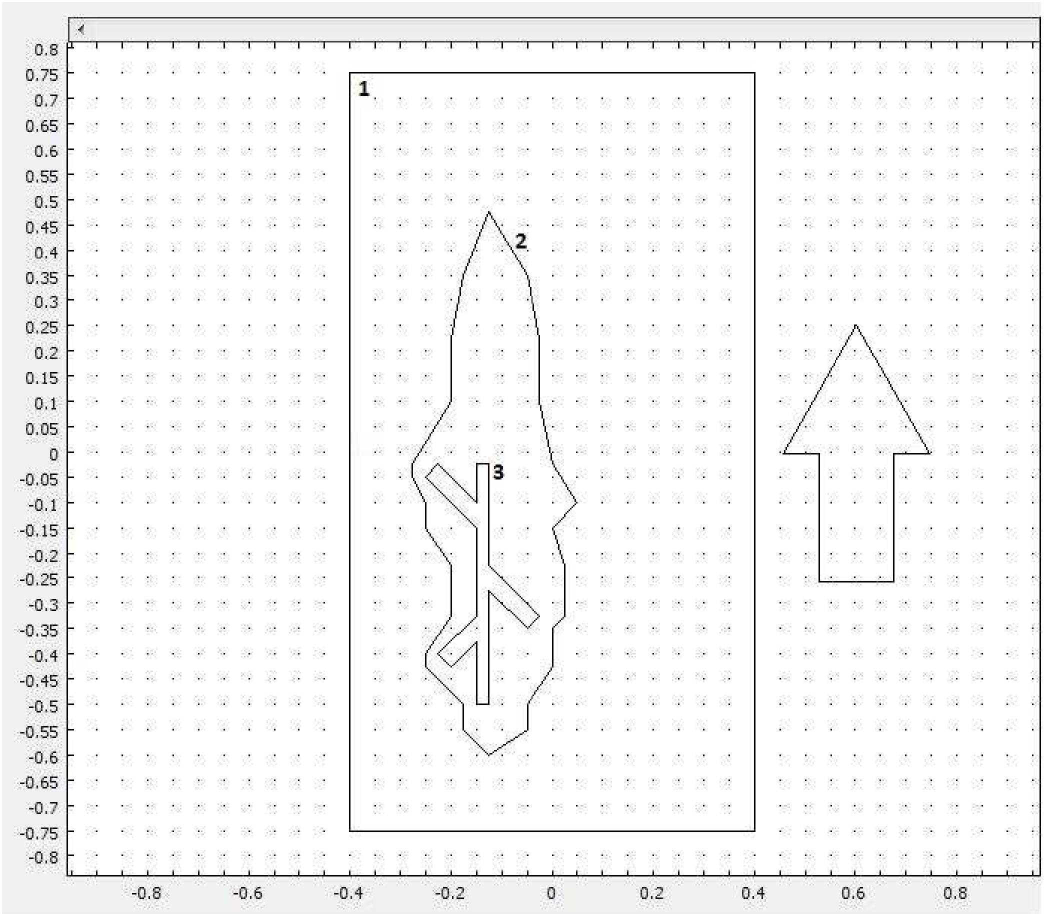

Fig.1: Picture of the model in COMSOL Multiphysics graphical editor, the arrow shows the direction of water flow

3 Geometry pipeline cutting

Dimensions of the pipe cutting has to be suitably chosen due to computational complexity and feasibility. Algorithm not converged for too long the model, for its more complex shapes or obstacles and COMSOL Multiphysics would not be able to find a solution model. The problem could be solved with more detailed parameterization space search, which avoid the extreme shape of the obstacles that are both as bad solutions. Therefore, the length of pipe cutting relatively short compared with the shell, which does not affect significantly suboptimal solution to the ideal form of wrapper constraints. The flow is in the vertical direction, bottom-up.

4 Wrapper geometry constraints

Under the wrapper geometry constraints can we understand the location coordinates of "y" points forming the container. Since the coordinates "x" will change the genetic algorithm, it makes no sense now to think about them, because their positions are only self-explanatory. The space points will move be specified in the section "Parameterization search space."

Number of points depends on the shape and complexity obstacles. It has to be large enough due to desired solution accuracy, but cannot be too high because it would increase the computational complexity (time consuming model required a large number of individuals in the population, etc.).
To ensure the model solvability in every situation, it is necessary to put points on the level of cover (each point where the edge changes direction).
Cover is larger than a barrier to the wrapper (to be able to "influence" the flow of all dimensions and not just the front cover). We set the number of points to 27.

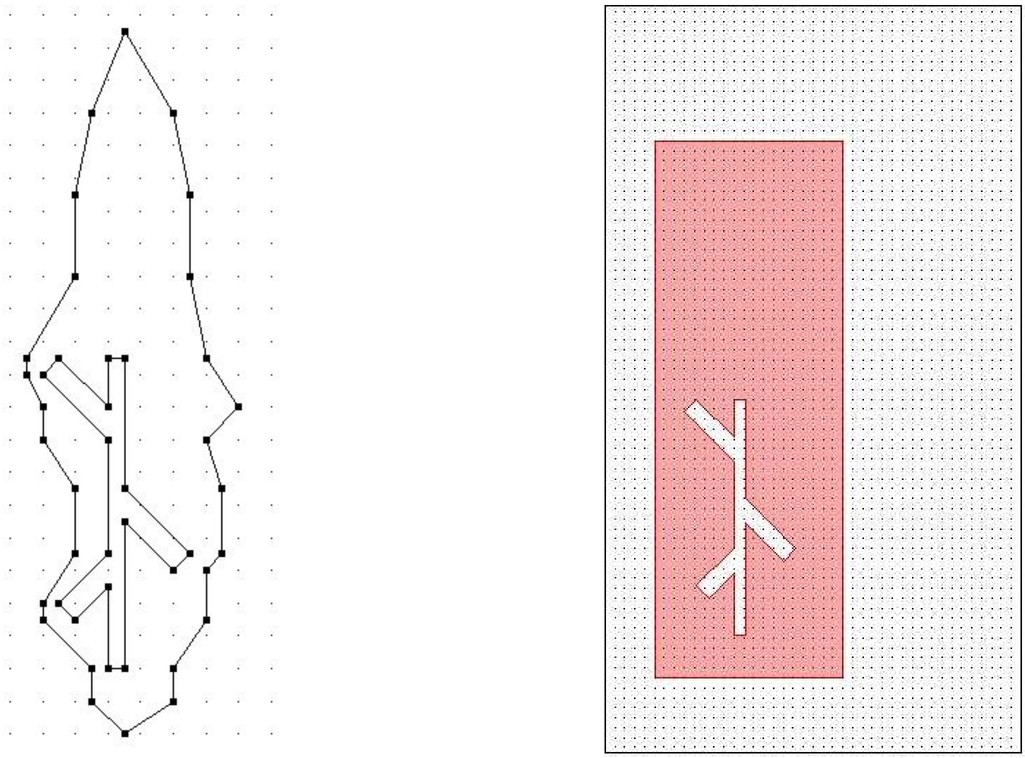

Fig.2 Cover and obstacles in draw-point mode (left), searched area – red (right)

5 FEM model of network

FEM system is very important, because physical parameters require exact outcome of a postprocessing. Too sparse network would create uncertainty and a densely network of unnecessary time-consuming solution model. Of course, everything depends on the particular physical quantity which we will evaluate to the objective function.

6 Genetic algorithm optimization

The next step is to specify the genetic algorithm, to ensure proper optimization of the ideal shape of the obstacle wrapper in the pipe. Genetic algorithm is designed to be a robust algorithm, since we do not know what condition (maximizing / minimizing postprocessing variable) in a dedicated use.
Genetic algorithm will consist of the genetic toolbox functions.

Code genetic algorithm consists of 4 main parts:

1st definition of input parameters
2nd definition of search space
3rd genetic operations
4th processing results.

Parameterization search space

To define searches of premises, means to identify possible range of coordinates "x" points, which form the border container barriers. The genetic algorithm codes to the border coordinates stored in a matrix (first row is the lower limit and the second row of the upper limit).

Processing results

In the last part of the genetic algorithm processing is carried out results. Values that are processed, there are two. The first value is the best suboptimal solution that is stored in the first position of the matrix forming the variable A. This variable is overwritten after each iteration, so at the last iteration of the first matrix is the best bird dog.
The second value is used to create a chart within the objective function. Auxiliary variable to be the best fitness stores each iteration, which depending on the number of iterations passed to the chart.

7 Results of optimization

For evaluation in the terms of used of objective function is possible to postprocess next three parameters: the Reynolds criterion, vorticity and velocity in the direction of the axis "x". The first two will be evaluated on a subdomain of the main flow velocity in the direction of the axis "x" will be assessed on the edge of the output pipe. All three postprocess variables will be minimized. Any postprocessing variable in a separate dedicated functions will create their own solution.

Reynolds number is the criterion, which is characterized as the ratio of inertia and viscous forces. Used in the basis of hydrodynamics and aerodynamics, it is possible to determine whether flow is laminar or turbulent.
Vorticity is similar to the Reynolds criterion, and basically the liquid tends to create whirls. Whirls are formed mainly in the complicated flow around obstacles. Results for the Reynolds criterion vorticity should be different because of the different interpretation of the formation of whirls.
The last postprocessing variable is velocity in the direction of the axis "x" on the output boundary flow. The lower this rate, the greater the speed of the axis "y" and thus should be laminárnejšie flow.

In the genetic algorithm optimization is necessary to repeat several times to find statistical outliers. The number of repetitions depends on the desired accuracy, in practice, optimization is usually repeated about 100 times. I repeated the optimization of each 5 times, due to the strong similarity solutions when pricipaltasks. Optimization lasted an average of 7 hours. (Dual Core processor)

Reynolds criterion

Reynolds criterion showed a good condition in the minimization of objective function. The result represents the geometry of wrapper constraints on the hydrodynamics of flow over. Cover view of the low value of the Reynolds criterion does not wrap the faith and would not significantly impede flow.

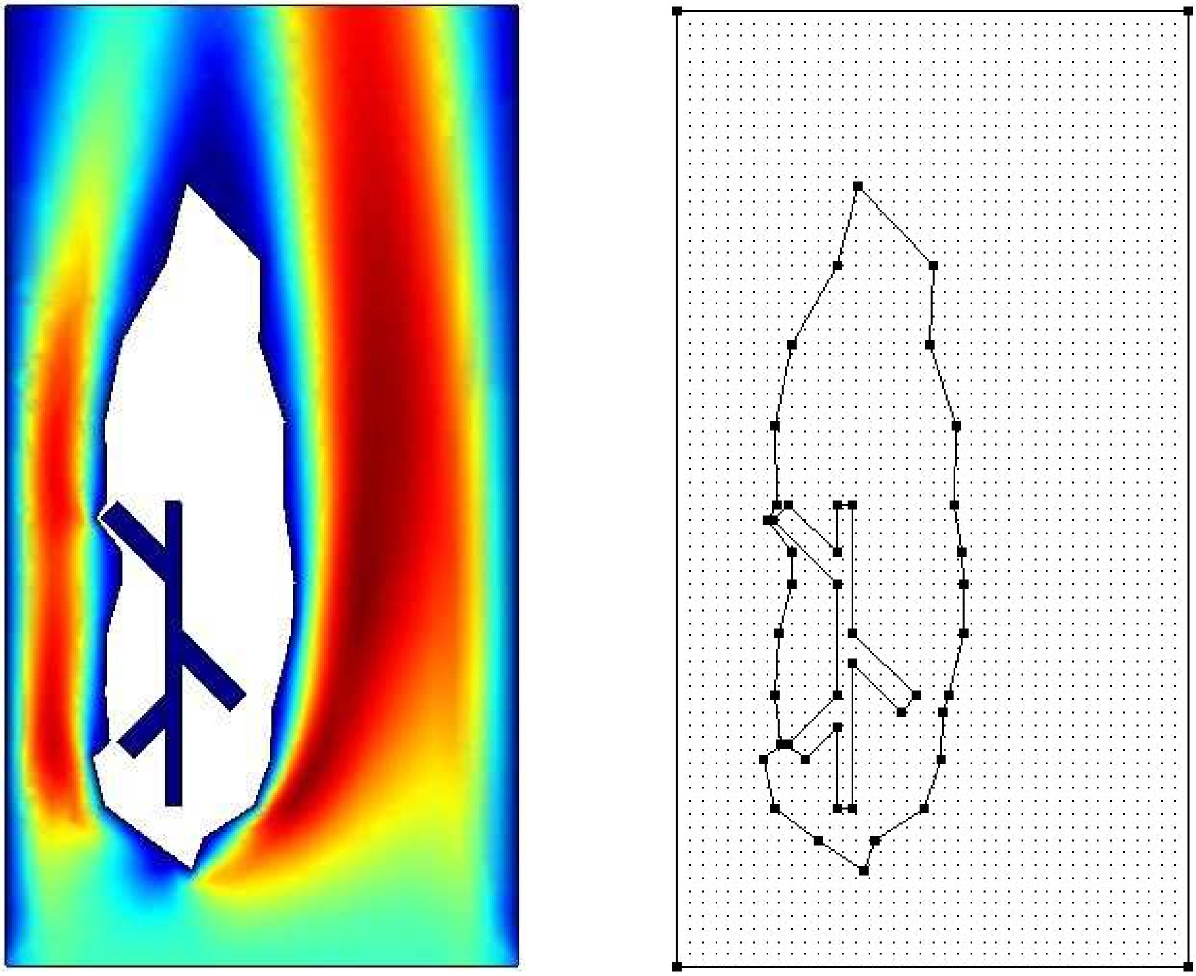

Fig. 3: Result of postprocessing mode (left) and result in a points mode (right)

Solution quality can be visually assessed. Flow around the wrapper of the obstacles (except to a few details) is continuous, without any major imperfections and follows a slightly directs the flow in the pipeline. Thus, the flow is directed, despite the asymmetric laminar barrier wrapper and significantly impede the flow hydrodynamics in the pipeline.

Vorticity

The second variable is similar to the postprocessing Reynolds criterion. The difference is that the Reynolds criterion is expressed as the ratio of velocity and kinematic viscosity, but vorticity reflects the relationship between circulating around a very small area and the contents of this area. These two variables also have different physical units, and each has very different results in terms of optimization.

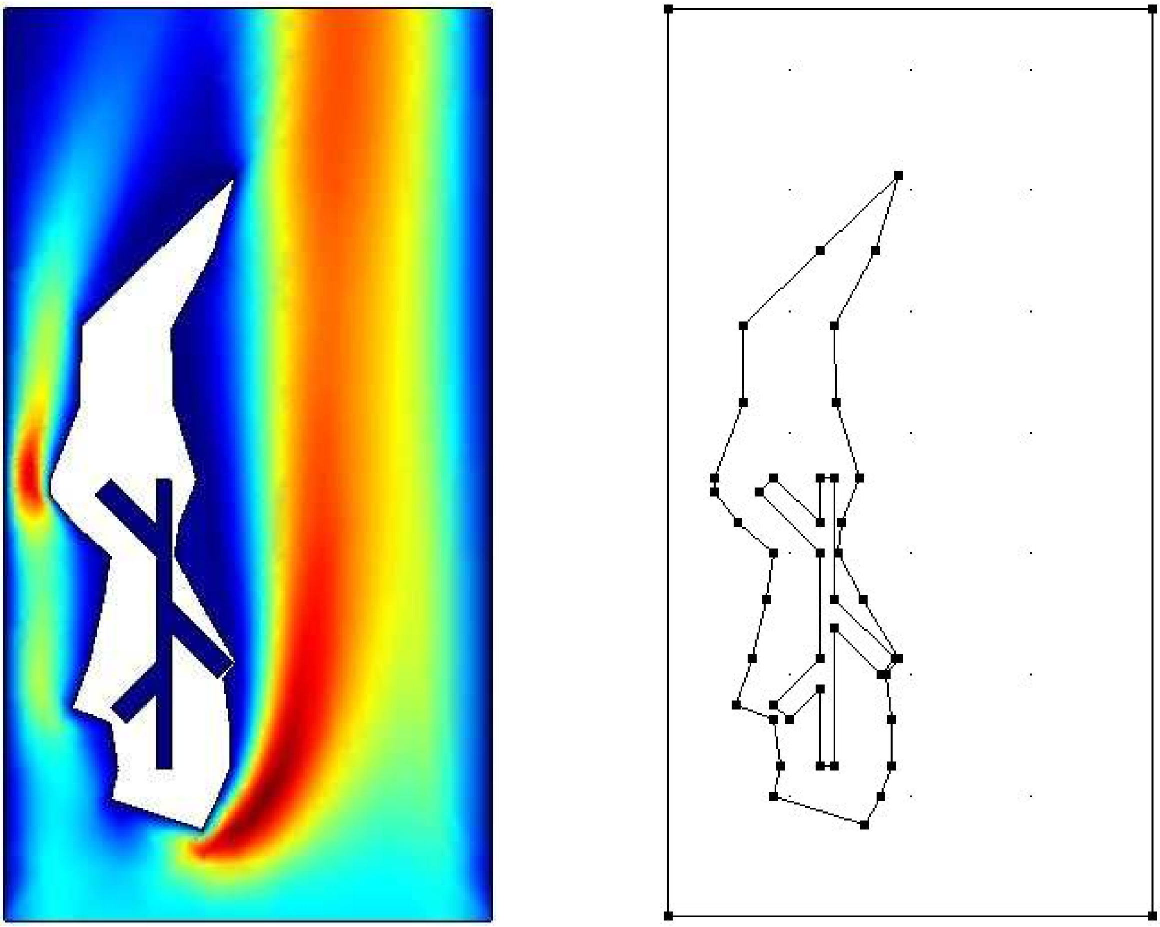

Fig. 4: Result of postprocessing mode (left) and result in a points mode (right)

In terms of optimal conditions is this solution is optimal, but from a practical point of view, its usefulness is questionable. This unusual and unexpected flow is caused by the fact, because the shape and also some points in the counting of stream flow don't participate. Despite mentioned facts solution has relatively a monolithic shape at higher speeds. The flow in this case turns slightly to the right, due to the atypical form of wrapper constraints.

Speed-axis "x"

The last variable is the speed of postprocessing-axis "x" on the edge of the output flow. This condition will be minimized, which should achieved relatively laminar flow. The results show that it succeeded in optimizing.

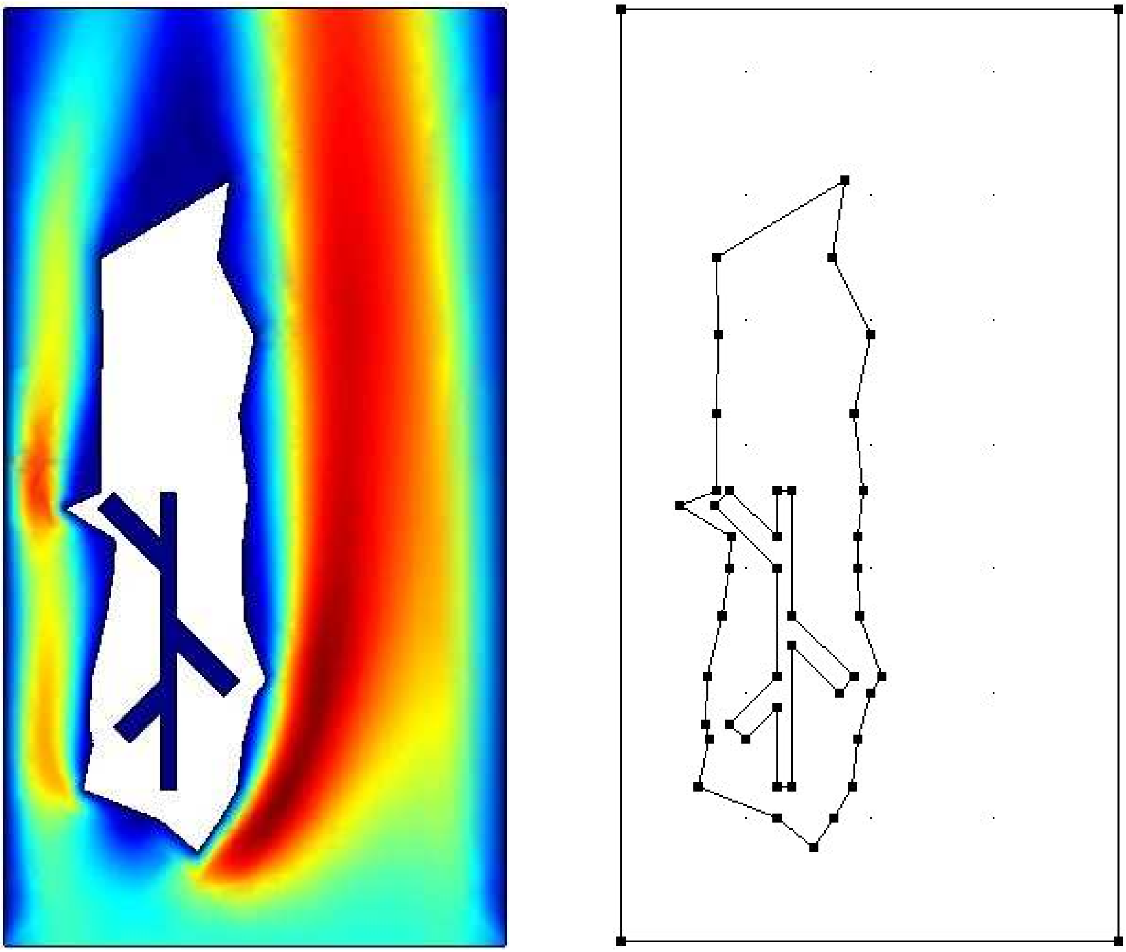

Fig. 5: Result of postprocessing mode (left) and result in a points mode (right)

The genetic algorithm is trying to place obstacles in the rectangular-shaped container with a hydrodynamically shaped front. It also contains slight imperfections that could be removed by increasing the number of cycles, but in principle this is a suboptimal solution and it is sufficient. The flow is laminar over the first case in particular in the direction of the axis "x", which is due to the minimizing of the speed in this direction.

Conclusion

The aim of this contribution was to show the possibility of mentioned optimization approach - Evolutionary algorithms with process models based on a finite element method. In our case we used software products Comsol and Matlab / Simulink, which are compatible software. This connection is an alternative to "conventional" approach, which uses different types of models of controlled objects (mostly concentrating parameters) in the form of linearized models (transfer functions, state models), nonlinear models (nelin. differential / differential equations, various types of non-linear. models , neural models). The proposed approach optimizes the chosen parameters of the system from the perspective of the whole geometry, respectively. It can also propose the optimal controller parameters by modeling the system under consideration in the whole area of working conditions. The main disadvantage of this approach is the large computational complexity. For more complex applications can be computational times on a single computer (PC) is in the tens to hundreds of hours. For this reason. The cluster computing can solve this problem.

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