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Evald I. Lepp

IMPROVING THE COMPETITIVENESS OF FREE-FLOW MICRO-HPP DUE TO STRUCTURAL DESIGN AND TECHNOLOGICAL MEASURES

Master's Program Automation of design and engineering

The abstract of the Master's Thesis

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The thesis work is done at the Federal State Autonomous Educational Institution of Higher Professional Education «Siberian Federal University»

Scientific supervisor:
PhD of Engineering, assistant professor Michail. P. Golovin

Peer Reviewer:
Rinat G. Galeev, CEO "NPO" Radiosvaz", PhD of Engineering

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Master's Program Leader:

Ph.D. in engineering,
Associate Professor — Michail. P. Golovin

INTRODUCTION

The topicality of thesis. In remote areas, where there is no opportunity to fully provide the population with electricity, and the creation of a developed energy infrastructure has no economic feasibility, the prerequisites for the introduction of equipment for renewable energy sources using are revealing. Thus, the manufacturing of similar systems is actual.

A variety of equipment, compete with the object of study, are presented on the market. Now the system has a high cost and a number of difficulties in the manufacture, installation and operation as a whole. This fact reduces the competitiveness of the product on the market, so that it becomes feasible to hold actions to construction optimization.

To lower the cost it was decided to eliminate the use of the butt-end oscillator in latest versions of system. In turn, it constitute more than a half of the micro HPP cost. However, revision of methods for micro-HPP critical items making is necessary also to reduce the manufacturing cost and increase the technical level of construction.

The purpose of thesis is improvement of free-flow micro-HPP construction technical level due to structural and technological measures.

There are several **tasks** to reach this purpose:

1. Patent and technical analysis of solutions and review of mathematical models of micro-HPP efficiency;
2. Multicriteria and topological optimization of the micro-HPP components geometry;
3. Possibilities and efficiency of the rapid prototyping using for micro-HPP critical elements manufacturing analysis;
4. Tests of modernized micro-HPP.

Research methods.

1. The method of finite - element modeling in CAE environment ANSYS Workbench;
2. Analytical calculation using the functional computing packages;
3. Methods of topology optimization (iterative approximation method);
4. Full-scale experiment on samples.

Reliability of the data is determined by the selected methods for solving tasks, as well as numerical simulations and field tests.

Subject of investigation is free-flow micro-HPP with orthogonal turbine, which model is presented on figure 1.

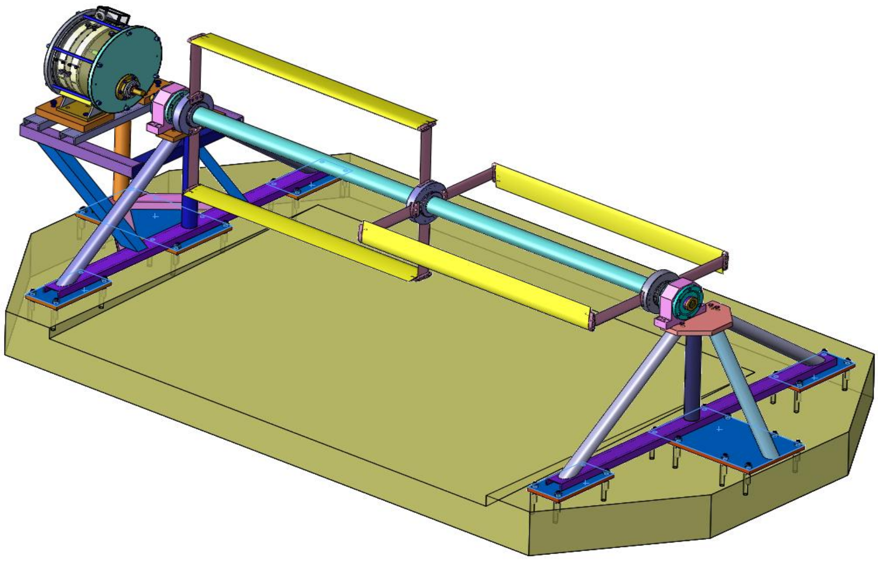

Figure 1 – Model of free-flow micro-HPP

The scientific novelty

1. Model of micro-HPP sustainability, taking into account the interaction of the turbine with the flow.

2. Model of construction elements topology optimization, using multiobjective optimization as a mechanism of elements forming for free-flow micro-HPP.

3. Algorithm of management of topology components under the influence of operating loads.

The practical significance of thesis

Developed micro-HPP design optimization models and recommendations for the individual components construction design reduce the cost of its production and increase efficiency, thereby improving the competitiveness of the whole system.

Personal contribution of the author

1. Models of free-flow micro-HPP units optimization are designed;

2. The optimization of free-flow micro-HPP has been carried out;

3. Software for determining of micro-HPP deviation in the flow under load from a predetermined position was developed.

Place of thesis realization. "Design - engineering support of machinery production" department, Polytechnic Institute of Federal State Autonomous Educational Institution of Higher Professional Education "Siberian Federal University".

Place of International internship. Delcam plc (Birmingham, United Kingdom).

Approbation of thesis results.

Main provisions of of the thesis and its individual sections reported at:

– IX All-Russian scientific and technical conference of students and young scientists "Youth and Science", in section "Mechanical Engineering & Automation" 2013 (Krasnoyarsk - III degree diploma);

– IX All-Russian scientific and technical conference of students and young scientists "Youth and Science", in the section "Professionally Oriented Foreign Language" in 2013 (Krasnoyarsk);

– Regional Scientific and Technical Conference Master students "Special engineering education - training of modern engineering staff" in 2013 (Krasnoyarsk);

– X All-Russian scientific and technical conference of students and young scientists "Youth and Science", in the section "Information Technology: System analysis, automation and control" in 2014 (Krasnoyarsk, correspondence participation form);

– X All-Russian scientific and technical conference of students and young scientists "Youth and Science", in the section "Engineering" in 2014 (Krasnoyarsk).

Published works. Results of thesis are presented in 4 publications.

CONTENTS OF THESIS

In Introduction the topicality of the project is grounded and the purpose and tasks of the work are formulated, object and subject of research are noted, basic provisions for the defense are set.

In the first chapter of thesis an overview and analysis of similar equipment constructions and their performance are provided. A.M.Gorlov, T. Stephens, E. Sultanova, E.R. Abramowski, S.V. Gorodko, N.V. Sviridov works for the power system design optimization are considered. Calculations of vertical axis wind turbines are considered, A.I.Yakovleva. M.A.Zatuchnoy works which contain the aerodynamic distribution models for load on the blade in a continuous medium are given.

Studies that substantiate the choice of constructive solutions in the turbine design were considered, also the choice of solutions for the blade shape designing in A.M.Gorlova work is justified. Along with this justification of other design solutions is considered. The above mentioned work are followed by the conclusions:

1. A list of original parts which are present in all constructions and having the same function is compiled.
2. The analysis procedure results of individual constructive solutions, considered systems are resulted in recommendations for the free-flow micro-HPP units design.
3. Alternative critical construction details manufacturing technologies are considered and analyzed.
4. Preconditions to the mathematical model formation to optimize the construction critical parts are identified.

In the second chapter optimization is considered. First of all stepwise critical parts optimization algorithm is described (Figure 3, 4). Then the description of the models design process and turbine working process is followed. Based on it decision of optimization is performed.

The main criteria for optimization are the following parameters:

- weight;
- permissible moving construction elements.

In this work all parts for optimization are divided into two categories – with a designer beforehand certain topology and details, which geometric shape just need perceive acting on them workload adequately. Thus, in the thesis the sequence of operations in the optimization for details of different categories is changing too with application of topological and multicriteria optimization order changing. To optimize the blade with a certain topology, multiobjective optimization is initially applied, only then to find the optimal proportions the material remnants is not involved in the work are removed (Figure 3). On the other side, the landing gears under turbines don't have a particular topology. In this case, the topology optimization is used to generate structure contour on which it will be formed. As soon as parametric model on the basis of contour will be formed, multiobjective optimization process starts.

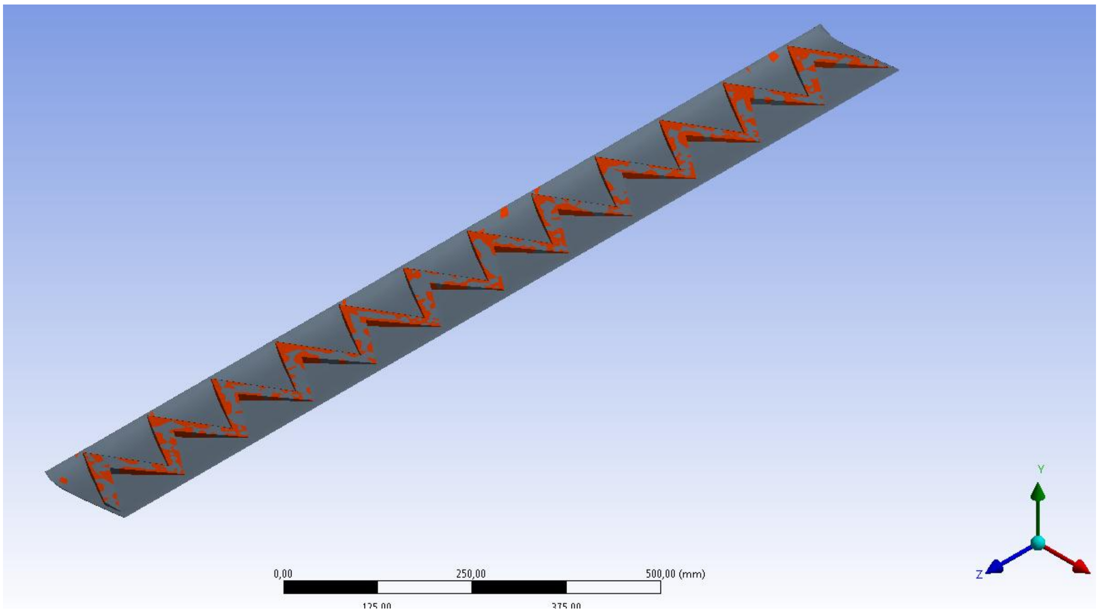

Figure 2 - Result of the blade topology optimization

For clarity of this optimization technique applying appropriateness the intermediate results of the optimization of support construction are showed in the table below.

Table 1 - Results of the geometry support construction optimization

Stage of optimization	Weight, kg	The maximum stress, MPa	Deformation, mm
The initial construction	123	3.2	0,14
Topology optimization	91	1.3	0,16
Multicriteria optiizatsiya	83	1.2	0,3

As a result of the topological and multiobjective optimizations there was a significant reduction of material inputs of construction, indicators of equal strength of almost all details have been increased.

It is noteworthy that the topological optimization without a predetermined topology generates model, focusing only on the stress value in the volume of material. Such an approach can't guarantee optimality of generated construction topology, but only the minimum mass characteristics. Preforming construction topology and finding of the optimal proportions using multiobjective optimization tools can provide a common vector for the formation of the final optimized parts geometry, which in turn in the subsequent stages of optimization can be modified with topology optimization mechanisms. Below flow charts of optimization objects with defined in advance geometry topology (Figure 3), and for constructions with only certain points of load application and fixation are presented.

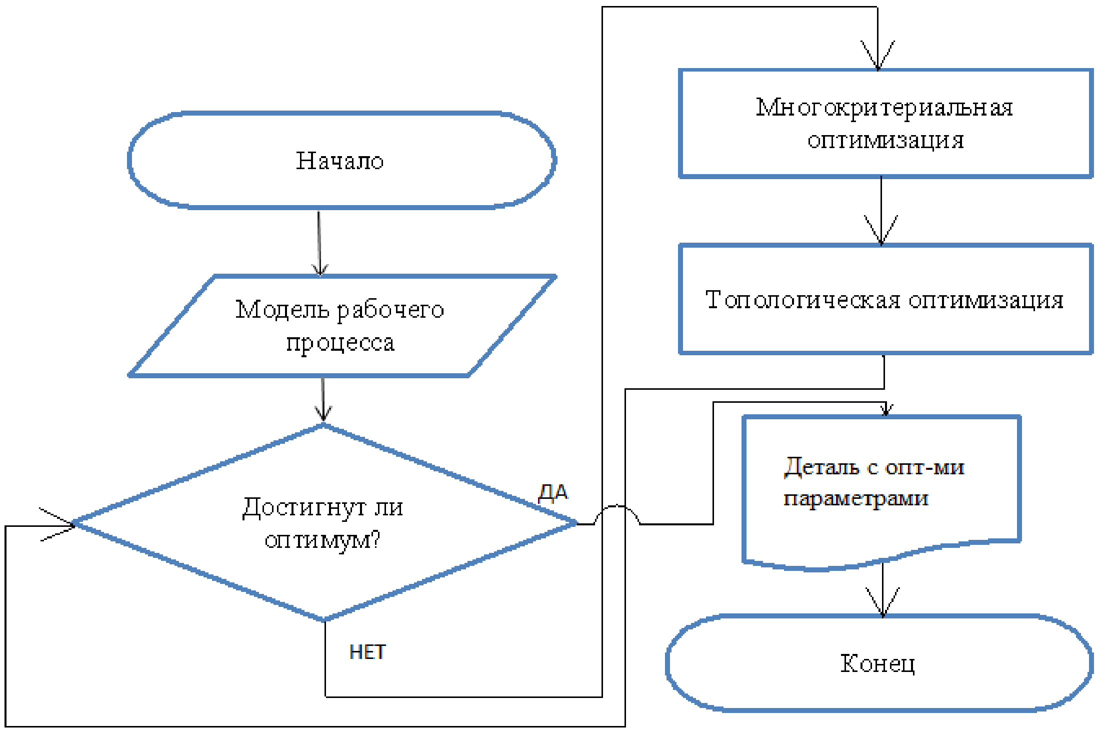

Figure 3 - Consistency of detail geometry optimization tools application with predetermined topology

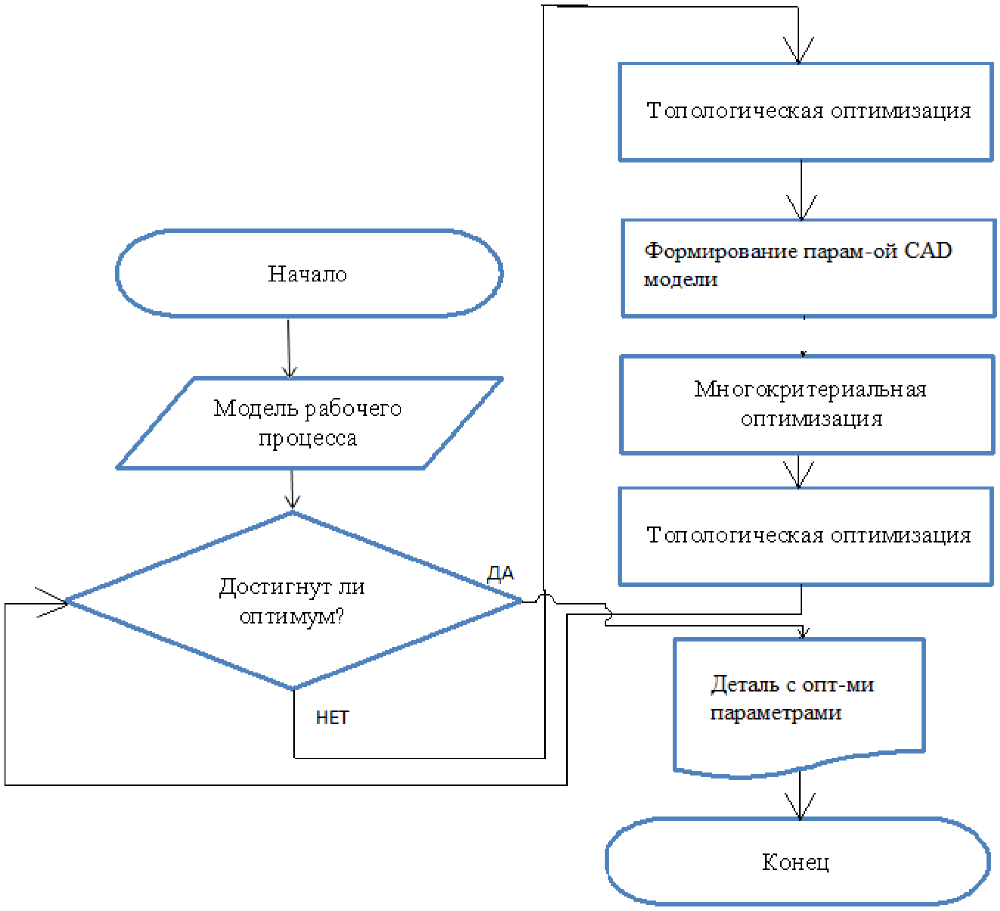

Figure 4 - The algorithm for generating the geometry in a given domain with followed multiobjective optimization

It should be noted that the resulting contour parameterization process is done manually. As part of this work was not tasked to automate the process of correct recognition of obtained volume. This problem is a potential area for further research.

In the third chapter an overview of the alternative options for the production of original features number, which currently require considerable effort, is done.

The technology of rapid prototyping, which can significantly reduce the production costs of such critical details like turbine blade and spacers processing is considered. Additionally the technology of stamping blade with a subsequent diffusion welding application is considered.

Manufacturing techniques overview limited by the indicative prices for the production of parts within the small-scale production. Question of the technological process development is not considered.

Below is a comparative table, which shows the timescales and costs for manufacture of one blade. Manufacturing cost calculated using the average prices in the Russian Federation.

Table 2 - Comparative characteristics of micro-HPP turbine blades production technologies

Part	The current cost of manufacturing, f.rub.	3D-printing, f.rub.	Stamping with diffusion welding, f.rub.
micro-HPP turbine blade	28	4	33

Thus, analyzing Table 2 we can see that the cost of manufacturing blades using rapid prototyping technology, within the small-scale production, is significantly lower.

In the fourth chapter the process of the preparation and conduction of field experiment are described. The main purpose of the experiment is a clear confirmation of the reliability of developed numerical and analytical models used to describe and optimize critical details of micro-HPP. In particular, this experiment addressed the issue of the blade structural strength after optimization and viability of design recommendations, composed in the first chapter of this work.

Before system diving into water, the blade has been previously tested for static deflection. The blade loading value was equivalent to the force applied to the mathematical model of loading.

CONCLUSION

1. Based on the created micro-HHP stability model, taking into account the interaction of turbine with flow were formed optimization models for individual critical details and assemblies of structure;
2. With the help of composed optimization model with a preliminary shaping details and subsequent multiobjective optimization were obtained overall models for lateral supports and base of micro-HPP;
3. Designed optimization model control algorithm allows detailed vary the optimization criteria such as weight, the maximum allowable displacement of selected items during the process, etc.;
4. Model of construction optimization can significantly reduce the massive construction characteristics while increasing indicators of equal strength elements and to form an optimal topology in individual elements for which, in the future, models were designed.
5. Recommendations for the design and micro-HPP critical detail production technology were proposed. A key detail – turbine blade – has been considered more detail. The most affordable and economical methods of manufacturing were analyzed and an alternative blade manufacturing technology was offered. Thus, there was significantly reduced blade manufacturing cost using three-dimensional printing, which improves the competitiveness of all construction.

MAIN PROVISIONS OF THESIS ARE PUBLISHED IN THE FOLLOWING PAPERS:

1. **Lepp E.I.** Modeling of micro-HPP turbine construction sustainability // Collected materials of IX All-Russian scientific and technical conference of students and young scientists "Youth and Science" section of "Science: System analysis, automation and control": Krasnoyarsk, 2013.

2. **Lepp E.I.** Reduction of the materials consumption of the micro-HPP blade with the use of topology optimization of its geometry // Collected materials of regional scientific and technical conference Master students' Special engineering education - training of modern engineering staff "Krasnoyarsk, 2013.

3. **Lepp E.I.**, Vonog V.V. Modeling of the micro-HPP turbine construction / / Collected materials of IX All-Russian scientific and technical conference of students and young scientists "Youth and Science", section "Professionally-oriented foreign language" Krasnoyarsk, 2013.

4. **Lepp E.I.** Application of topology optimization to generate optimal beam structure / / Collected materials of X All-Russian scientific and technical conference of students and young scientists "Youth and Science" section of "Engineering" Krasnoyarsk, 2014.