# ENERGY SAVINGS THROUGH THE USE OF BIOMIMETIC ARCHITECTURES 

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#### Abstract

Absorbers in solar collectors are used to collect the heat from sunlight for heating and hot water production. The use of solar energy will continue to increase in the future due to the rising cost of fossil fuels such as oil and gas. The aim of this work is to optimize the pipework system in the absorber plate of a solar thermal collector in relation to uniform flow and a lower decrease in pressure for modern solar heating systems inspired by nature. The other parts of the collector like housing, insulation, and the transparent cover should be the same as in common flat plate collectors using the existing production equipment and maintaining the production line. It is essential to tag the problems of common solar panels and to define the parameters meaningful for the fluid mechanics evaluation.

The evaluation of different natural channel structures should help to find a suitable network with good characteristics in utilization and flow resistance. The chosen examples will be presented, simulated, and analyzed with appropriate software to demonstrate their flow characteristic. The resulting new pipework model will be integrated in the existing pipework design of the absorber to obtain the first bionic-optimized pipework design. [8]


## 1. INTRODUCTION

The degree of efficiency in removing heat from the collector is an important factor to improve the amount of energy which can be used from sunlight. This efficiency is calculated as the ratio of usable energy in sunlight and the energy input which is needed to remove the heat gained by the solar collector. An optimization of the flow structure should result in a reduction of the pressure loss. This leads to a reduction of the energy loss.

In nature, resources like water and minerals are the essential condition for subsistence. Once resources are extracted from their environment they have to be distributed throughout all the parts of the organism to supply each cell. The best way in nature to do so, is to fill the body with a network of tubes. This network is called the vascular system. The aim of this system is a lower flow deflection, which leads to lower pressure losses.

We were searching for different natural channel structures and tried to highlight the characteristics of the individual examples. We want to abstract the most promising features of our models from the plant and animal life and to use for our new design. We decided to take a
closer look at the leaf vein structure, the vein structure of insect wings and the vascular systems in animals. [8]

## 2. LAYOUT DESIGN

To detect the initial state, a model of the existing absorber was made. With the help of this simulation meaningful values were generated. The parameter of the model and the simulation corresponds to the standard test values of thermal solar collectors. These settings are also used in conventional solar systems and for comparative purposes in all other simulations.


Fig. 1: Simulation of original harp absorber [8]
The simulation of the reference collector shows us a pressure loss of 240794 Pa from inlet to outlet. This is our reference value we want to improve with our new pipework structure. We can see that the new structure should deliver an improvement in the high back pressure areas as well as to reduce the occurrence of turbulence and counter flow by alleviating branching.

The connection was optimized following the example of leaf vein structures and the venation in insect wings to achieve this.


Fig. 2: Abstraction of natural models [1, 2, 3, 4, 5, 6, 7]
To use the advantage of branching structures we decided to integrate another section in our pipework design. This section is a kind of bifurcation which could be found in many of our models from flora and fauna. [8]

The main function of the piping system in our application is to exchange the heat of sun radiation into our fluid. The different diameters of pipework structure result from the model of vascular systems and are adapted to the pipe diameter of conventional solar energy systems. This optimization could substantially reduce the region of high back pressure.

By including these sections we get our first biomimetic optimized model of a pipework structure.


Fig. 4: Simulation of optimized absorber [8]
The simulation shows a reduction of negative pressures, and a complete avoidance of secondary flows. The result of this simulation is a pressure drop of 202204 Pa from inlet to outlet which means an improvement in pressure drop of 28590 Pa. We can expect an improvement in pressure drop by about $16 \%$ when using the new pipework structure. [8]

## 3. APPLICATION \& RESULTS

In order to demonstrate the improvement of the optimization under real conditions we decided to build a prototype. The copper pipes are cut and shaped and connected by brazing to the desired pipework structure. The reference model is an absorber of a conventional collector which could be taken from current production.


Fig. 5: Photography of reference absorber and optimized absorber [8]
We created a hydraulic measuring arrangement which includes a flow control, a pressure measurement, and an irrigation pump for the circulation of the medium to prove the simulation results. This arrangement corresponds to a conventional solar system. We have performed the measurements at defined flow and read out the differential pressure.

The results of our final measurement are shown in the following chart.


Fig. 6: Plot of the results of the final differential pressure measurement [8]
The result of our measurement shows us the expected reduction in the pressure loss of about $15 \%$ due to the optimization of the channel structure. These results confirm our initial assumptions and the performed simulations.

## 4. CONCLUSION

Ramifying structures are a common phenomenon in many transport systems and there are similarities between vascular systems in leaves, insect wings, and mammals. Mechanical demands, transport constraints and possibly other aspects are interlinked and form a complex pattern. There is usually more than one constructional solution to a problem and the identification of a certain function is therefore often not trivial. The outcome of the simulations shows that geometry of flow structure influences flow behaviour. By employing a ramified structure we can achieve a minor flow redirection. This leads to a minor leakage of pressure and flow losses.

With this type of pipework structure, nature provides us a solution for a wide range of engineering problems regarding utilization, flow resistance and pressure distribution. These solutions only have to be adapted to the respective problem. As shown in our example, even small changes lead to measurable improvements. This application can be seen as a first step in the optimization of biomimetic solar energy systems. [8]

## 5. REFERENCES

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