Universität Stuttgart
**INSTITUT FÜR THERMODYNAMIK DER LUFT- UND RAUMFAHRT**
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Report about the

Doctoral Dissertation of Mrs. Marta Gortych, M.Sc., Eng. entitled:

# "Solidification of PCM materials in a horizontal annular space"

**Topic of the work:**

The storage of heat energy based on phase transition (solidification or melting) is a very important process, which can be utilized in many practical applications. The main advantage of this method is the relatively small size of the heat storage accumulator and a stable temperature of the phase transition. A phase change material (PCM), which is used in heat accumulators, is a substance with a high energy of transformation (latent heat) associated with storing and releasing large amounts of heat.

In this thesis, the solidification of phase change materials in a horizontal annular space has been investigated. In such a situation, the phase change process is complicated by the free convection in the liquid, surrounding the solid material. Mrs. Gortych presents in her work an experimental and theoretical study to investigate this interesting and technical very important problem.

**Contents of the thesis:**

The thesis is structured into five chapters. After an introduction into the topic, chapter 1 provides an overview about PCM properties and geometrical shapes of PCMs used in heat accumulators.

In chapter 2, the state of the art is discussed for the liquid solidification process in an annular space. First Mrs. Gortych summarizes the work on solidification and free convection in vertical annular spaces. After this, a detailed literature review is given on the

solidification process in a horizontal annular space. Here it is also shown that the present thesis adds knowledge to our present understanding in this field.

Chapter 3 presents the analytical investigations for the solidification problem in an annular space. First Mrs. Gortych explains some general basics of the solidification process, showing the conservation equations for the fluid and solid and the related boundary conditions. After this, the classical Stefan problem is discussed. Then the heat exchange at the solidification front is explained in detail. After this, Mrs. Gortych shows the development of the analytical model for the solidification in a horizontal annular enclosure and the solution for this model. For this model the heat transfer coefficients are described by cosine functions of the angle and the resulting partial differential equations are solved by using the method of separation of variables. This results finally in a strongly non-linear equation describing the dependence of the dimensionless interface position ($\tilde{\delta}$) as a function of dimensionless time ($\tau$). At the end of the chapter she shows then some results obtained by the theoretical model, e.g. the dependence of $\tilde{\delta}$ on the cooling parameter B, the Biot numbers and dimensionless time.

In chapter 4 of the thesis the experimental investigation is shown. First the used test stand and the operation is explained in detail. The experimental apparatus used for the tests has been designed and build by Mrs. Gortych. After this, the used measurement methods are described. The interface position (thickness of the ice-layer) has been measured by taking photographs of the ice layer and by using a measuring cylinder, which recorded the increase in water volume. The temperature distribution in the experimental apparatus has been measured in detail by using 24 PT 100 temperature sensors. The flow rates of water and ethylene glycol have been measured with Venturi nozzles. In chapter 4, Mrs. Gortych shows experimental results for the interface position as a function of time. Here she compares the ice-layer thickness obtained from the photographs with the one obtained from the measuring cylinder. She shows that there is a good agreement of the mean values between both methods. From the photographs also the local distribution of the ice-layer thickness as a function of the angle can be determined and is reported in this chapter. At the end of the chapter Mrs. Gortych then obtains from the measured experimental data the distribution of the average Nusselt number.

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Chapter 5 presents a comparison of the experimental data with the theoretical model. For this, the obtained heat transfer coefficients from chapter 4 have been used in the model. Overall, there is a good agreement between theoretical predictions and experimental data.

After chapter 5, the main conclusions and achievements of the work are summarizes.

**Assessment of the work:**

The work is concerned with the important process of the storage of heat energy based on phase transition, which can be utilized in many practical applications. The present doctoral dissertation shows new experimental data, which have been obtained with an experimental apparatus, which has been built by Mrs. Gortyhc. In addition, a theoretical model has been developed in order to predict the thickness of the solid layer around a cooled cylinder.

The thesis is well structured and well written. There are several small language errors, which should be corrected. In addition, it would be nice to include in the appendix a short summary of the measurement uncertainties for all used measurement methods. Also this needs to be done, before the thesis can be published. However, these modifications are mostly minor in nature.

Summarizing, I can say that this thesis is a very interesting piece of work, which will extend our knowledge in the area of solidification in horizontal enclosures.

With this work, Mrs. Marta Gortych has shown that she is very much able to work scientifically. Thus, I would like to ask the faculty to accept her thesis without any reservations and to progress the doctoral dissertation procedure, e.g with the defence of this work.
Overall, I rate the thesis as “very good”.

B. Weigand

(Prof. Dr.-Ing. habil. Bernhard Weigand)