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ANSELMUS

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D2.9 Design description for the wire-wrapped rod bundle water experiments

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Document Summary
The document presents the experimental facility that will be used at the von Karman Institute in the frame of the ANSELMUS project. The facility previously used in PASCAL project (GA-945341) will be modified in order to host the wire wrapped fuel bundle. The geometry will consist in 7 electrically heated fuel bundles around which a wire will be twisted. This experiment will allow velocity and heat transfer characterization thanks to laser technics (PIV or PTV) and thermocouples.

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v1.0	02/10/2023		Final version

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1 Introduction

In this Work Package 2, the von Karman Institute for Fluid Dynamics is responsible of generating experimental data in a wire wrapped 7-pin configuration. For this purpose, an existing water loop designed and constructed in the frame of H2020 PASCAL project will be used to provide new data for non-deformed and deformed wire wrapped fuel bundles. The objective here is to characterize both the velocity field and the temperature field in a dedicated wire wrapped fuel bundle as well as to characterize the effect of deformation on the momentum and thermal field. This experiment will be performed in water and the data can be used to validate CFD modelling. Therefore, no similarity with the liquid metal used in the real reactor is foreseen.

This document will describe the existing parts of the experiments and foreseen new design for the wire wrapped tests.

2 Experiment and methods

In the frame of the ANSELMUS project, the von Karman Institute is responsible for a thermal-hydraulics experiment. It will consist in 7 cylindrical heating rods placed in a hexagonal section. Those rods will be heated and the thermal gradient created will be measured with several thermocouple embedded in the rod. Moreover, a laser/camera system will be set up to perform velocity measurements (PIV or PTV).

2.1 Scaling

2.2 Hydraulic loop

The hydraulic loop is presented on **Figure 1**. The working fluid is water and it flows in a semi-closed loop thanks to a pump. The pump is a multiphase vertical pump (Lowara 15SVH07F055T), allowing a maximum flow rate of $10\ m^3/h$. Orange dots arrows indicates the direction of the flow in the loop. The water is pumped from the water tank. It goes through the pump, the test section, the chiller, the flow meter and comes back to the tank. The flowrate is measured thanks to an electromagnetic flow meter (WaterMaster ABB). The fluid is cooled by the chiller (ProfiCool Genius PCGE 101) with an effective cooling capacity of $51.6\ kW$.

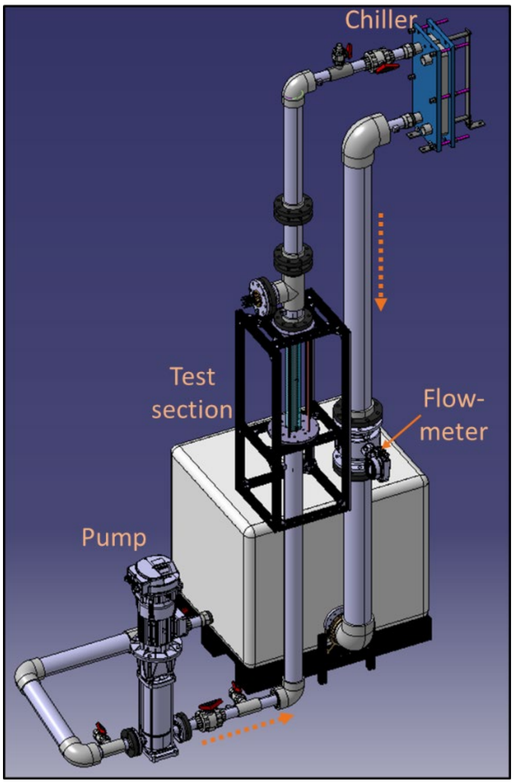

Figure 1 *Hydraulic loop*

2.3 Test section

The test section is presented on **Figure 2**. The drawing of the complete test section is presented on the right side of the figure. It consists of a 715 mm long square based quartz mounted in between two flanges. The quartz is presented on the left side of the picture. It consists of two pieces glued together. The quartz is a 69 mm x 62.1 mm rectangle on the outside and a 22 mm regular hexagonal on the inside. This difference of geometry between the inside and the outside is mainly due to the challenge of machining such long quartz pieces. The use of quartz will allow consistent optical path and will perfectly resist the heat of the heating rods placed inside.

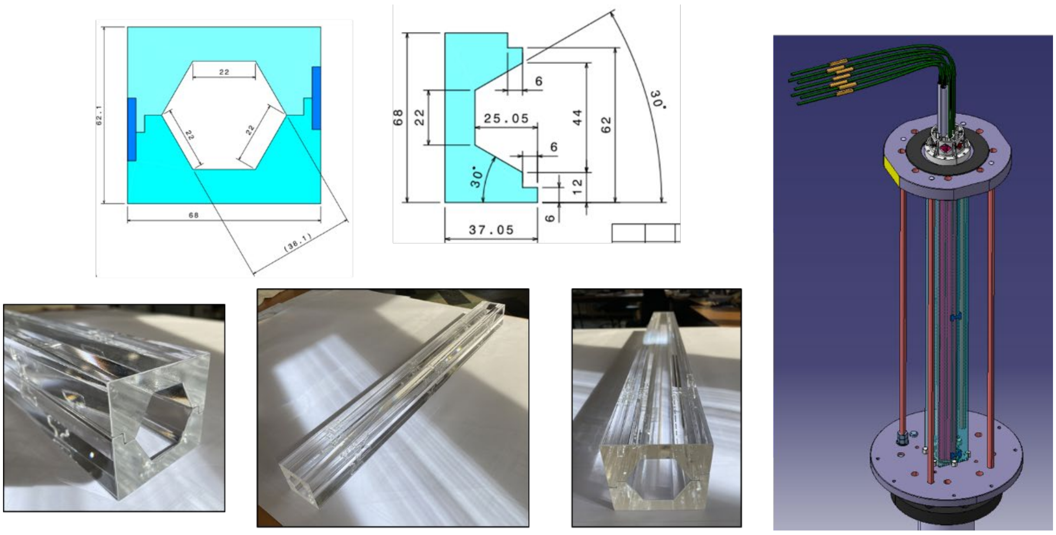

Figure 2 *Test section*

2.4 Heating rods

Inside the test section, heating rods are inserted to represent the fuel rods. They are electrically heated and their maximum power 4.25 kW each. A cut of one of those electrically heating rods is presented on **Figure 3**. They are composed of a copper wire inserted in ceramic and covered by stainless steel. The external diameter D of the rod is equal to $10\ mm$.

Figure 3 *Heating rods*

They are separated one to another by a wire of diameter $d = 2.85\ mm$ (still under consideration with the manufacturing process). The wire will be soldered to the rod and fixed at the bottom based on MYRRHA fuel assembly design.

The spatial placement of the rods and the wires is presented on **Figure 4**. The figure shows the drawing in the vertical direction along the rod and a cross section of the test section. The wire axial pitch is equal to H.

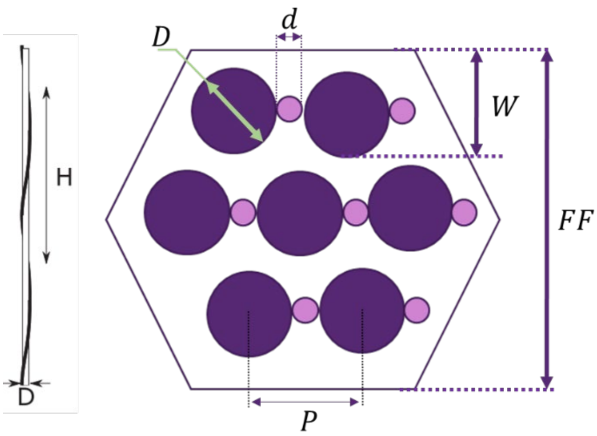

Figure 4 *Drawings of the test section*

	MYRRHA (Avg)	VKI proposal (Anselmus)	Ratio (X_MYRRHA/X_VKI)
Geometry	X Myrrha	X_VKI	
Number of pins (total)	127.00	7.00	18.14
Number of pins (heated)	127.00	7.00	18.14
Scale factor	1.00	1.53	0.65
Pin diameter **D** [mm]	6.54	10.00	0.65
Pitch-to-diamter P/D []	1.28	1.28	1.00
Pitch distance **P** [mm]	8.40	12.80	0.66
Wire diameter **d** [mm]	1.80	2.85	0.63
Wire axial pitch **H** [mm]	262.00	400.00	0.66
Axial pitch-to-Diameter H/D []	40.00	40.00	1.00
Edge distance from last pin row W [mm]	8.39	12.80	0.66
Edge distance-to-Diameter **W/D** []	1.28	1.28	1.00
Flat-to-flat distance **FF** [mm]	97.50	38.10	2.56
Heated length [mm]	650.00	778.00	0.84
Hexagonal side [mm]		22.00	
Bundle flow area A. mm2	3600.00	663.03	5.43
Wetted perimeter [mm]		414.59	
Hydraulic diameter [mm]		6.40	

Figure 5 *Rod geometry description and comparison with MYRRHA's dimension*

The main quantities are summarized in **Figure 5**. The table compares the geometrical parameter in MYRRHA reactor (on average), provided by SCK-CEN, and the VKI experimental parameters for the ANSELMUS project. The last column prints the ratio between the "MYRRHA quantity", i.e. X_MYRRHA, and the "mock-up quantity", i.e. X_VKI. To reduce the size of the experiment, the number of rods was divided by 18.14 but most of the other dimension were enlarged to create a "zoomed view". For example, the pin diameter is 0.65 times smaller in MYRRHA than in the forecasting experiment. All except, the flat to flat distance which is higher in the mockup but doesn't change the similarity itself.

However, three non-dimensional quantities were kept the same to unsure the similarity between both cases: the pitch to diameter ratio (P/D), the axial pitch to diameter ratio (H/D) and edge distance to diameter ratio (W/D).

2.5 Acquisition system

The acquisition system will be composed of thermocouples and differential pressure measurements to characterize the thermodynamic state of the fluid during the test, a PIV system for velocity measurement and thermocouples in the rods for heat transfer characterization.

2.5.1 Initial boundary condition measurement

The fluid characterization during the test will be performed by several triplet of thermocouple (type K) placed in the fluid. The evolution of the mean of each triplet will be registered during the tests to characterize the fluid and the evolution of its thermodynamic state during the test. Moreover, Valydine pressure transducers will be used to measure the total pressure in the test section inlet and the difference of pressure between inlet and outlet. We consider the inlet as the bottom of the quartz, and the outlet the top of it.

A flow meter placed in the descending branch (see **Figure 1**) will be used to measure the mass flow in the volumetric flow in the test section during tests.

Those quantities will be measured using a National Instrument acquisition system and will be recorded at a low frequency (under 1 Hz of acquisition frequency).

2.5.2 Velocity measurement

The velocity alongside the rod will be measured with a PIV or PTV system in function of the measured of liquid and the density of particles inside it. In the framework of PASCAL project, PTV measurements with data consolidation technics showed interesting results for measurement in between rods where the density of particle is too low and reflection too strong to do PIV. The discussion concerning the use of the velocity measurement algorithm to use (PIV or PTV) is still ongoing.

2.5.3 Heat exchange characterization

The characterization of heat exchange between the flowing water and the rod will be calculated thanks to temperature measurement. The thermocouples are placed in the rods as presented on **Figure 6** It consists on machining 0.45 mm of depth in the stainless steel of the rods to place shielded type K thermocouples of 0.25 mm of diameter**.** Then a thin layer of glue will be applied to protect the tip of the thermocouple but also to place it as close as possible of the water to have the most reduced thermal bias due to the glue. The thermocouple will be placed as presented on the **Figure 6** and will permit to obtain temperature characterization at the same location of the PIV/PTV velocity measurement. There will be 3 vertical locations for the temperature measurement location, allowing the calculation of a gradient in the vertical direction.

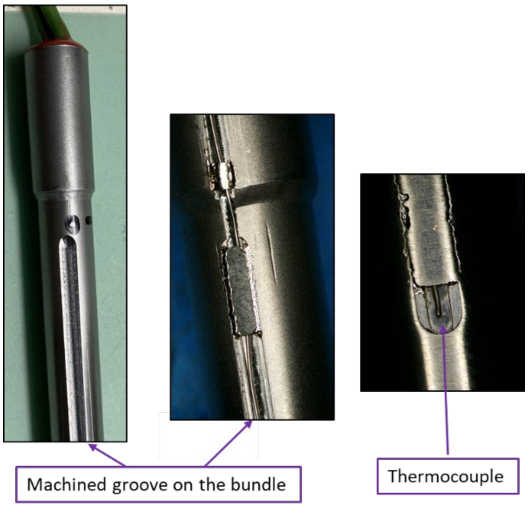

***Figure 6** Thermocouple insertion in the rod*

The thermocouple will be connected to an AMETEK EX1401 temperature conditioner and re-calibrated in order to obtain a predicted uncertainty under $\pm 0.2°C$ with a confidence level of 97.5%.

3 Conclusion

In this document the ANSELMUS experiments was presented. It will consist in a 7 rods' experiments in a wire wrapped configuration. For this experiment, a geometrical similarity is considered. Then, the pitch to diameter ratio, the axial pitch to diameter ratio and edge to diameter distance are conserved between the real reactor and the experiment.

Each rod is electrically heated with thermocouples embedded in the outer surface of the cladding. They will allow heat transfer characterization between the fluid and the rod. This will be coupled with PIV (or PTV) measurement around the location of the temperature measurements to have a complete thermohydraulic characterization in this complex geometry.

The first results for the non-deformed case are foreseen for beginning of 2024.