THE ROLE OF UNIVERSITIES IN THE QUALIFICATION AND VERIFICATION PROCESS OF EuP REQUIREMENTS FOR TURBOMACHINES USING THE EXAMPLE OF ROTODYNAMIC PUMPS

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SUMMARY

Besides general Energy using Products (EuP) related issues concerning the qualification approaches for rotodynamic pumps this paper demonstrates a practical example how universities are able to support the work of market surveillance by providing their neutral scientific expertise as well as their infrastructure in the frame of product verification. This example based on the work achieved within a small pilot project funded by the Ministry of Environment, Climate and Energy Economics of Baden-Württemberg respectively the affiliated market surveillance authority. The small project consists of a round robin test to verify the MEI (Minimum Efficiency Index) of a single stage end suction centrifugal pump.

INTRODUCTION

Since the effects of global warming due to human caused CO_2 emissions has become more and more evident in all areas of life and all over the world governments have started diverse activities to strongly reduce the emission of greenhouse gases. Because fossil-operated power plants are currently one of the main CO_2 emitters it is obvious and plausible that saving of electrical energy in general can be an effective strategy to reduce CO_2 emissions significantly and therefore is in the focus of legislative measures of the European Commission (EC).

From several data aggregated by the Chair of Fluid Systems at Technische Universität Darmstadt [1] it is well known that approximately 35 % of the electrical power generated in Europe is needed to drive pumps, fans, compressors, and other fluid-energy machines in industrial plants as well as in public and private buildings (figure 1).

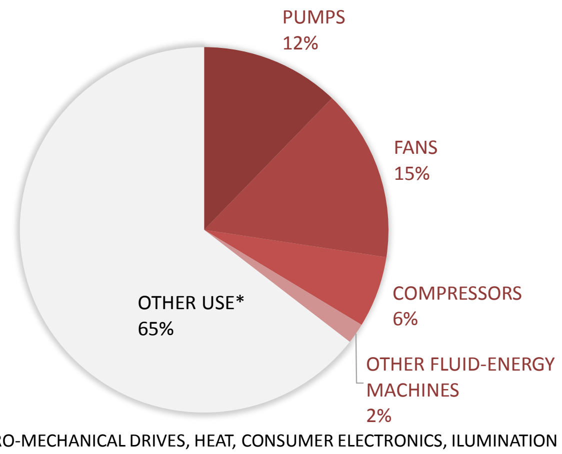

Figure 1: electrical power generated in Europe distributed to consumers

On account of these facts it is comprehensible that the European Commission focusses on this huge group of machines with the intention to improve their energy efficiency by legislating lower permissible limits becoming obligatory for all products placed on the European market.

Due to the fact that many of the fluid-energy machines produced by European manufacturers already show an appropriate energy efficiency, the potential of energy savings for such a product approach is rather limited and should always be assessed critically. It has to be taken into account that the special functional demands on fluid-energy machines, in consequence of physical reasons, in many cases affects their energy efficiencies negatively. Furthermore, the mere increase of pump efficiency above a certain limit leads to an uneconomical rise of production efforts especially for machines operating already at an appropriate high efficiency level.

From the perspective of an experienced mechanical engineer designing fluid-energy machines as well as fluid systems it is obvious and well known that much higher potentials of saving can be achieved by focusing on technical measures like:

- the use of speed variable pump drives (extend product approach),
- the optimization of the whole fluid system (system approach).

Nevertheless, the European Commission up to now mainly traces the product approach, and it is the task of the industrial stakeholders to develop and promote simply applicable methods to assess not only products but also extended products and complete systems regarding their energy efficiency. Within this task universities can support manufacturers of fluid-energy machines and fluid systems successfully in terms of a neutral institution providing independent scientific and technical expertise as well as an experimental infrastructure to carry out necessary validation tests.

EUP-RELATED WORK AT THE CHAIR OF FLUID SYSTEMS REGARDING THE QUALIFICATION OF THE ENERGY EFFICIENCIES OF CENTRIFUGAL PUMPS

The Chair of Fluid Systems has a long tradition in consulting and supporting European pump manufacturers as well as related associations like Europump in developing appropriate methods to qualify products in respect to their energy efficiencies, in order to meet the EuP requirements legislated by the European Commission.

The first research work in respect to an estimation of attainable efficiencies of volute casing pumps already started in 1994 and was published in 1999 in a small booklet [2] edited by Europump.

Two years later the Chair of Fluid Systems contributed its experience and expertise to the SAVE - Study on Improving the Efficiency of Pumps [3]. Along with other investigations [4], [5] this was the basis for the first EuP activities of the European Commission regarding centrifugal pumps. It took another six years until Europump funded a research project aimed at the development of an appropriate methodology [6], [7] to determine values serving as a Minimum Efficiency Index (MEI) applicable for legislation. Parallel to this the Chair of Fluid Systems in cooperation with a Europump joint working group elaborated a proposal for a draft standard named "*Pumps - Minimum required efficiency of rotodynamic water pumps*". Although the standard was already submitted to CEN in 2008 it was only published in 2014 as preliminary European Standard prEN 16480. Unfortunately it took further 3 years until it was released as a final standard DIN EN 16480 in July 2017 [8].

On October 21st 2009 the DIRECTIVE 2009/125/EC [9] was released by the European Commission and thus the European pump manufacturers had to act and propose appropriate measures to reduce the energy consumption of all pumps focused by the EC. Based on the fundamental work of the Chair of Fluid Systems (cp. [3] to [7]) on June 25st 2012 the REGULATION (EU) No 547/2012 [10] was released by the EC. This regulation which entered into force on January 1st 2013 directed that all pumps covered by the REGULATION (EU) No 547/2012 and brought into the European market have to meet a MEI of ≥ 0.1. Furthermore, in this document it was defined that two years later on January 1st 2015 the MEI will increased to 0.4 and all relevant pumps have to be qualified for an MEI better than or equal to 0.4 in order to place them on the European market.

At the time of entry into force of the REGULATION (EU) No 547/2012, the indicative benchmark for the best available technology on the market for water pumps was a Minimum Efficiency Index (MEI) ≥ 0.7 and it was to be expected that the EC would intend to increase the MEI further to a value of 0.7 in 2017. Currently the REGULATION (EU) No 547/2012 is under revision and therefore there is a strong necessity for European pump manufacturers to propose new energy assessment approaches to the EC in order to avoid a further increase of MEI.

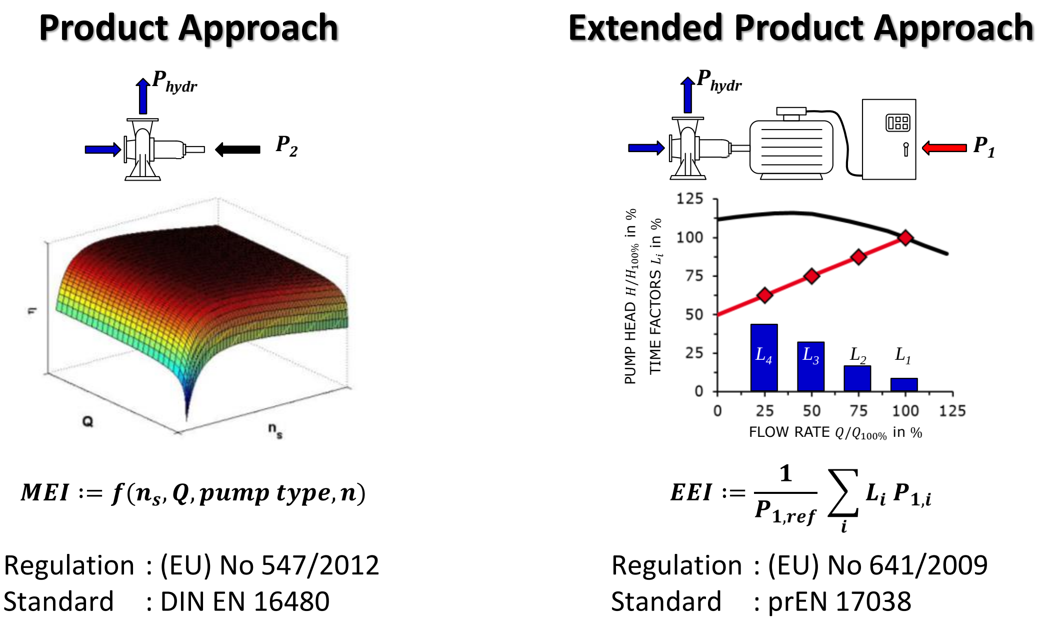

Figure 2: the principle of product and extended product approach

Because all technical experts agreed that such a scenario would demand an enormous investment in development costs for all, especially small and medium size, European pump manufacturers, yet would only lead to a slight increase of energy savings, the Europump joint working group immediately started activities to elaborate alternative methods to assess not only the energy savings of products (pumps operating at fixed speed), but also of a complete speed variable pump unit (figure 2), consisting of a pump and a speed variable electrical drive (extended product).

Analyses of the joint working group had previously shown that by the use of variable speed drives a significantly higher energy saving potential than by a simply increase of the pump efficiency to a MEI ≥ 0.7 was to be expected.

At this time the Chair of Fluid Systems once again contributed its expertise by supporting Europump in developing appropriate methods to assess the energy efficiency of extended products (speed variable pump units) by using the Energy Efficiency Index (EEI). The EEI was already implemented in 2009 by European manufactures of circulators to comply with the COMMISSION REGULATION (EC) No 641/2009 [11]. The Chair of Fluid Systems also worked on this regulation and contributed its scientific expertise regarding centrifugal pumps.

In addition to theoretical work and many statistical analyses a considerable amount of fundamental experiments had to be carried out to validate the developed semi-analytical methodologies as well as the practical applicability of the experimental qualification procedures. At the end of 2014, just before the second step of the REGULATION (EU) No 547/2012 (MEI ≥ 0.4) entered into force, the Europump funded project "*Development of a Methodology for Determination of EEI (Energy Efficiency Index) of Speed Variable Pump Units (PUs) and a Corresponding Draft Standard*" was finished. Besides internal (non-public) reports, the main results of the work were published in [12], [13], [14] and finally in the draft European Standards prEN 17038-1 [15] and prEN 17038-2 16].

After finishing the task concerning speed variable pump units (extended products) consisting of only a single pump, it was necessary to expand the semi-analytical methodologies and qualification procedures to other types of extended products consisting of more than one single pump (e.g. booster units) [17] respectively types of pumps and electrical motors (submersible pump units) showing very special functional properties affecting their energy efficiencies. In the frame of this task most of the theoretical and experimental work was also carried out at the Chair of Fluid Systems and finally edited to be integrated in a further draft European Standard prEN 17038-3 [18].

Currently the Chair of Fluid Systems is working on the development of an assessment methodology to qualify waste water pumps in respect to their energy efficiency.

THE VERIFICATION OF MEI AN EEI OF CENTRIFUGAL PUMPS: A CHALLENGE FOR MARKET SURVEILLANCE

Although it was one of the priority objectives of the developers of the above mentioned energy assessment methodologies to provide simple to use and clearly described procedures, it is important to have sufficient expert knowledge as well as a suitable infrastructure to carry out profound verification tests. During the phase of product qualification, which usually is in the responsibility of the manufacturers respectively the companies who place the products on the market, these skills should generally be available.

Another situation arises in the case of verification that means if any market participant expresses reasonable doubt concerning the declared efficiency values (MEI or EEI) and hence the market surveillance authority has to act. Furthermore, the market surveillance authority also has to carry out random tests on a regular basis. Because of the fact that the market surveillance is responsible for all issues concerning the conformity of energy using/related products it is obvious that they have to handle a great challenge, which needs a profound expert knowledge and in many cases access to complex test facilities to carry out verifications by experiments.

In Germany the market surveillance is in the responsibility of the federal states. This leads to the unfavorable situation that due to very limited personnel resources both the expertise as well as the infrastructure of the implementing authorities are currently not sufficiently skilled and experienced to meet the requirements in respect to the verification of products, especially those placed on the German market by competitors from outside the EU.

THE ROLE OF UNIVERSITIES WITHIN THE VERIFICATION PROCESS USING THE EXAMPLE OF A ROUND ROBIN TEST ON MEI MEASUREMENTS

Besides the general EuP related issues concerning the qualification approaches for centrifugal pumps, as already described in the previous chapters, the authors would like to present a practical example showing how universities may support the work of market surveillance by providing their neutral scientific and technical expertise as well as their infrastructure in the frame of product verification.

This example is based on the work achieved within a small pilot project funded by the Ministry of Environment, Climate and Power Economics of Baden-Württemberg respectively the affiliated market surveillance authority. The project consists of a round robin test to verify the MEI of a single stage end suction centrifugal pump that was taken directly from the market and provided by the market surveillance authority of Baden-Württemberg.

The MEI is the currently valid figure to qualify rotodynamic water pumps concerning their energy consumption and has to show a value ≥ 0.4. Besides the Chair of Fluid Systems three further university institutes, all with appropriate expertise in hydraulic turbomachinery, were involved in the round robin test (figure 3).

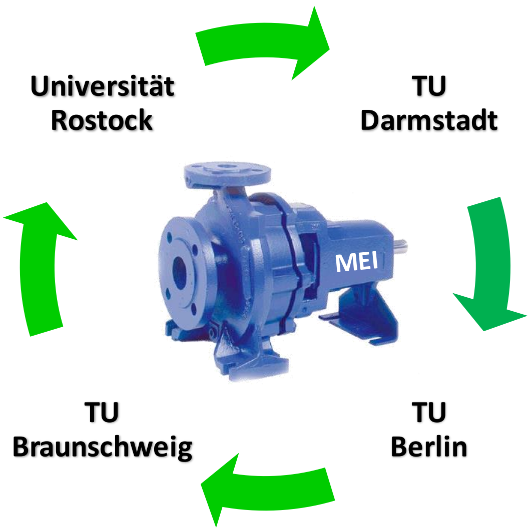

Figure 3: universities involved in the round robin test on MEI measurements

The round robin test was coordinated by the Chair of Fluid Systems and accompanied by a working group consisting of representatives of several market surveillance authorities.

Main objectives of the pilot project

1. Validation of test procedure:
   - Gain general practical experience by involving universities in conducting tests to implement respectively support market surveillance authorities,
   - Discover possible effects on test results which may arise from unclear descriptions and/or false interpretation of documents by testing staff.
2. Demonstration and on-site observation of test procedure:
   - Provide the project participants with the opportunity to visit the labs of the four involved universities and personally attend a MEI measurement,
   - Provide representatives especially of the market surveillance authorities with the opportunity to discuss all experimental aspects concerning MEI testing.

3. Validation of test results:
   - Direct comparison of the measurement results gained by the four universities,
   - Discussion and explanation of acceptable deviations due to measurement tolerances etc.,
   - Discussion of possible unacceptable deviations and clarification of their causes.

Preliminary agreements with the university partners

At the official kick-off meeting which took place in Darmstadt all project relevant documents serving as basis for MEI measurements had been provided to all university partners. Furthermore a timeline had been agreed upon the partners which determined date and duration of the test period for each university. To assure independent and neutral results no additional information or experiences from the numerous MEI tests already carried out at Technische Universität Darmstadt were given to the partners. Furthermore the partners were advised not to exchange any results with each other until the end of the project. With regard to a possible influence of the operating time of the pump, at Technische Universität Darmstadt the pump was tested twice, once at project start and once at project end. All other university partners tested the pump only once. The test object was a single stage end suction volute casing pump manufactured by the KSB AG with a nominal power input of 7.5 kW. To avoid any possible effects of corrosion on the measurement results due to downtimes the pump was made of stainless steel.

Results

- All measurement results were merged and processed for comparison and presentation by Technische Universität Darmstadt;
- The results were discussed extensively at the final meeting at Technische Universität Darmstadt;
- In consideration of the allowable tolerance of 5 %, defined in the related regulation respectively standard, all tests conducted at the university labs could verify the efficiency declaration which is stated by the pump manufacturer respectively given on the name plate of the pump;
- Final result: according to the measurement results of all four universities the pump passes the verification.

Assessment of the pilot project

The opportunity to visit the labs of the four universities was used intensively by the members of the market surveillance authorities. Many technical conversations, focused on the measurement process as well as the equipment and facilities, were held on-site and at the final meeting. The participating market surveillance authorities valued the project rather positively and very helpful for their work. A possible support of market surveillance in terms of verification tests conducted by university labs was explicitly not excluded. Finally, it may be concluded that the conducted pilot project "*Round Robin Test on MEI Measurements*" was a very suitable opportunity to give market surveillance authorities a detailed insight into scientifically based and highly qualified working methods of university labs in general and a descriptive demonstration of the special requirements in respect to MEI verification tests in particular.

ACKNOWLEDGEMENT

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