Optimisation of the dryer and back coating processes for carpet manufacturing in terms of heater configuration, nozzle shape, airflow and control / adjustment

Dirk Collet (TFI), Norbert Effertz (TFI), Christian Goetz (TFI), Christian Leiritz (iSD)

Prime Proposer: Maltzahn KG Textilveredelung
Co-Ordinator, RTD Performer: Deutsches Teppich-Forschungsinstitut e.V. (TFI)
RTD Performer: Gesellschaft für intelligente Systeme & Datenanalyse bR (iSD)

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1 Abstract

Energy costs for ventilation and heating account for the largest part in running costs in carpet manufcting, so that reducing them leads to a considerable decrease of production costs.
For the realization of the project seven partners from the carpet industry as well as a dryer manufacturer started co-operating with two R&D-performers. The European Commission supported the project by 50 %.
The project aimed at the optimization of the drying process, including the improvement of the burners and air flow conditions. The air flow was therefore measured on the material surface to obtain this improvement.
Results are to serve the optimization of existing plants as well as the development of new dryer designs.
The profits of the project concerns the reduction of energy costs, the reduction of material-related plant emissions and the improvement of product quality.
In the beginning of the project detailed measurements for status determination in carpet production lines where made. At the same time a lab-scale dryer for research activities was installed. Afterwards the different parts of the dryer were optimized at the test rig and tested industrially. In a concluding task the results of the optimization were evaluated.
The results of air flow and temperature measurements at industry dryers made clear that there is a high potential of optimization. The industrial air-flow optimization was focused on the optimized setting of the exhaust gas flap valves at the different sections of the dryer and showed a significant energy saving. The newly developed nozzle box design shows a low pressure drop, an even velocity at the nozzle outlet between entrance and the end of the nozzle box as well as an airflow which is perpendicular to the carpet. For the industrial optimization of existing nozzle boxes a guiding sheet kit which can be installed in a simple way has been developed.
The research activities on the optimization of the burner results in a significant reduction of carbon monoxide and methane, realized by the installation and the optimized adjustment of a passive pre-mixing (air & gas) system. This system is based on the venturi principle
The evaluation showed that the total thermal energy reduction amounts at least 15 % by using the developed features of air flow and nozzle box optimization at existing dryers.

2 The Partnership

2.1 Partners

The project partners are divided into three groups:
1) Manufacturer of dryer (1 participant)
2) Carpet manufacturer (6 participants)
3) RTD Performer (2 participants)

at	Participant	Contact person
1	Olbrich	Mr. D. Robeling
2	Maltzahn KG	Mr. Bücker
2	HWP	Mr. Heier
2	Longlife Teppichboden	Mr. H.-J. Cleven
2	Foamtex as	Mr. B. Garde Nielesen
2	DESSAUX	Ms. E. David
2	Forbo	Ms. M. Antoin
3	Deutsches Teppich-Forschungsinstitut e.V. (TFI)	Mr. C. Goetz
3	Gesellschaft für intelligente Systeme & Datenanalyse bR (ISD)	Mr. C. Leiritz

Tab. 1: Participating Carpet Producers

The project co-ordinator is TFI. It has the following address:
Deutsches Teppich-Forschungsinstitut e.V.
Charlottenburger Allee 41
D-52068 Aachen

2.2 Information about the partners

The Olbrich company is a technological construction company in the field of mechanical engineering dryer and back-coating plants.
The Olbrich company participates in this research project to increase their know-how, which they can apply directly to the commercialisation of their products. Furthermore, they are interested in contact and co-operating with the carpet manufacturers as their potential customers.
Carpet manufacturers provide a major share in partners. The Maltzahn KG is the prime partner in this research project. The carpet manufacturers who co-operate in this research project represent the European carpet industry with respect to the produced fabric quality as well as the production machinery. The manufacturers participate in this research project to improve production conditions, resulting in a decrease of production cost (reduction of energy consumption) and an increase of the reproducibility in the production of defined fabric quality.

TFI e.V. is a private research organisation in Aachen, Germany, with a turnover of 1.5 million Euro and 25 employees which are directly involved in R&D work. The main R&D activities are research, testing and consulting in the field of floor coverings to support the interests, medium and long term strategy of the European carpet industry and business. TFI has experience with national RTD Projects and CRAFT-projects (CR-1070-91, CR-1229-91, CR-1391-91, CR-1388-91 and CR-1900-91) for years.
iSD is a small German company involved in the fields of surface metrology and finishing and building testing equipment and has a turnover of 350 kEuro. iSD has extensive experience in the area of research on a national scale, software and micro-controller development and has a staff skilled in sensor technology and flow calculations.

2.3 Structure of the Partners Group

The consortium represents a co-operative research and development activity involving carpet producers and coaters from Denmark (Foamtex), Germany (Maltzahn, Longlife, HWP), Belgium (DESSAUX), France (Forbo) and a German producer of dryer and back-coating machines (Olbrich). This research project brings together companies from various sectors of carpet manufacture and with different standards concerning plants. The high number of participating carpet manufacturers is necessary to provide a representative group of production facilities. It is thereby guaranteed that the generated know-how to improve dryers will meet the maximum number of objectives with regard to airflow and energy consumption, especially for companies in the SME category, and will provide the basis for an application Europe-wide. The partners are not capable of running a research project of this significance and with these objectives on national level.
DESSAUX, Forbo, and Olbrich participate as non-SME's. DESSAUX and Forbo are crucial for the project's success since their plants complete the typical spectrum. The company Olbrich is important for the exploitation of the results.

3 Objectives

Drying, setting and back-coating operations represent critical stages in the production of textile floor coverings. The energy consumption in these methods of production is a vital factor affecting process quality, operating costs and environmental effects. These processes directly have a major influence on the quality of the end product and on production costs. However, for the purposes of objective reproducible machine adjustment and obtaining optimum energy economy and environmentally-friendly process control, up to now there has been a lack of basic data.
So far, machines have been controlled by empirical means. However, uncertainties and process variability show that the drying process can cause variations in fabric appearance in the longitudinal direction (end-to-end variation in the piece) and differences across the width (side-to-side variations). As a rule, the fabric is over-dried. Measurements have shown that the drying and coating processes could

be shortened which would result in savings in energy consumption, accompanied by increased production rates and enhanced quality, since it is conceivable that over-drying may be a contributory factor in the shading phenomenon in cut-pile products and in shade changes.
Up to now, a precise determination of temperature and airflow on the product surface and in the airflow channels was not possible. For the purpose of a reliable and reproducible machine setting, as well as for the determination of energy saving and environmentally conscious process control, a database is lacking. The process control is usually an empirical one, thus leading to irregularities, qualitative production variations and over-drying of the product.
The project aims at a reduction of unburned methane by optimising the burner, which results in a reduction of energy costs and easing the environmental burden. The airflow optimisation aims at an increase of the plant's output and therefore at the economical efficiency by reducing the energy consumption. Furthermore, the product quality can be improved by a more consistent drying. An optimised control of the equipment must be easy to handle, must have an easy hardware that can react flexibly to varying goods quality and control data and must regulate itself. The adjustment of conditions within the dryer will lead to a reduction of emissions, an increase of economical efficiency and the improvement of goods quality. In addition to that, the optimisation will increase the reproducibility of the drying process, which is an important aspect for small and medium-size carpet manufacturers working in this field.
In addition to the application of results from airflow optimisation of dryers in the industry, they can also be applied to other fields of the small and medium-size textile industry (e.g. technical textiles). Thus the profit of the research project can be increased even more.

4 Technical description

The project is sub-divided into nine task:
1. Status determination industrial plants
2. Installation of the test-rig
3. Labscale optimisation of the burner
4. Industrial optimisation of the burner
5. Labscale optimisation of nozzles
6. Industrial optimisation of nozzles
7. Labscale optimisation of the airflow
8. Industrial optimisation of the airflow
9. Economic evaluation

The flowchart below shows the procedure of the project:
Fig. 1: Project's flow chart
The project started with tasks one and two at the same time. Status determination at the industrial partners consisted of an extensive measuring program that was executed at the machines of the involved carpet producing companies. At the same time the design and installation of a test-rig that is based on a dryer's sub-section equipped with measuring sensors was realised.
Afterwards analogous to the industrial measuring program measurements concerning the listed components (heater, airflow, and nozzle box) were made at the test-rig. By

means of comparing the data coming from industrial machines and test rig, a concept for all listed components (heater, airflow, nozzle box) was developed that gives exact information on the optimisation degree needed for each component. Optimisation is slightly different in parts of the dryer. Considering the test results, the test rig was modified to achieve optimum results. Subsequently, a concept for the modification of the industrial dryer was drawn up. Due to specific construction of different dryers the concept can only serve as a basis for design but cannot be applied to all machines. With respect to improvement of the dryers' control systems the placements and the sensors were selected.
After having compared the specific data of the industrial dryer and the test rig, the nozzle box was calculated to find an ideal model. This model was used as source for a new design concept.
According to the exemplifying optimisation of industrial dryer, the measuring program was performed once again, with a final comparison (before/after) for the quantification of all economic and ecological effects.

5 Results and conclusion

To make laboratory dryer optimisation possible a lab scale dryer was designed and installed. The most important features of this dryer are listed in the following table:

feature	result
• reduction of the dryer section which is normally 3 m long to a much shorter version	⇒ reduction of the expenditure
• no chain to transport the carpet, only a simple drawer	⇒ reduction of the expenditure
• putting the whole nozzle box onto wheels to be able to roll it out of the housing	⇒ optimally accessible nozzle box
• by-passing of the nozzle boxes possible	⇒ integration of test unit for combustion chamber into the dryer unit / possibility for up-scaling of the combustion chamber
• realising the standard air-flow design of actual dryers	⇒ higher acceptance of the results by the carpet producers

Tab. 2: Most important features of the lab scale dryer

Fig. 2 shows this industrial-like and also highly flexible and accessible lab scale dryer.
Fig. 2: Complete test rig with the drawer for carpet input
The central task at the test rig was the nozzle box optimisation. The figure below (Fig. 3) illustrate the not optimised nozzle box with a chaotic and inclined exit air flow.
Fig. 3: Not optimised nozzle box at the beginning

To realise a directional airflow out of the nozzle box different ways of nozzle box conversion for existing dryers have been taken into consideration. An important aspect is a realisation with low costs. Fig. 4 shows the results from the installation of simple fittings in the nozzle box.

Fig. 4: Modified nozzle box with installed guiding sheets

As a result of this conversation also the velocity profile along the nozzle box (from the entrance to its end) got more even, which is shown in Fig. 5. Consequently also the air velocity on the carpets surface between its left and right side gets more even.

Fig. 5: Velocity profile along a nozzle box

Alternative to the improvement of existing dryer's nozzle boxes the design of a newly complete new design has been calculated. Afterwards it has been realised and tested at the lab scale dryer.

Fig. 6: Optimised nozzle box with new design

In Fig. 6 the airflow of the new designed nozzle box with the same length as the first nozzle box (2 m) is printed. For up scaling test the new nozzle box design has been lengthened to industrial size with a length of 4 m.

The project showed that different aspects of airflow are very important to the thermal energy efficiency of dryers. There is a potential of at least 15 % thermal energy savings at the typical present dryers of the carpet industry, which can be achieved by some conversions and changed settings. Based on the project's estimations this means for the European carpet industry a reduced energy consumption of 35 million kWh. For a typical SME carpet producer (2.5 million m²/a) who implements these project results, this means a saving of approximately 30 kECU/a.

This optimisation will be realised by:

- an optimisation of the nozzle boxes
- a optimised air flow
- miscellaneous

The optimisation of the nozzle boxes can be done at existing dryers as well as at new dryers. The main target of these activities is to realise airflow, which is perpendicular to the carpet surface. Nozzle boxes of existing dryers can be converted by a newly developed guiding sheet set. This can be simply installed during the routine cleanings of the nozzle boxes.

Also for new dryer designs there is a potential to improve effectively. The nozzle design for new dryers is completely innovative. Its high performance was achieved by an unusual nozzle box design. Additional to the perpendicular air flow outlet its characteristics are a low-pressure drop over the nozzles and an even distribution of pressure between the entrance and the end of the nozzle box. The results of the new nozzle box design will be used in new dryer designs of the project partner Olbrich.

Industrial airflow optimisation has been focused on the novelty of the setting of the exhaust gas flap valves at the different sections of the dryer. Concept of these settings is the consideration of different separate functional areas for heat transport and mass transport in the dryer instead of doing both at the same place in each section of the dryer. The transfer of this to various industrial dryers showed a significant thermal energy saving. This activity can be completed and improved by the installation of additional seals at the carpet entrance and outlet to the dryer. The grade of energy saving depends highly on the present standard of the dryer.

Measurements at industry showed the importance of miscellaneous activities, which should belong to routine maintenance. These are a regular and exact inspection of door seals and burner. Just small leakage at the door seals causes a relevant temperature difference between the dryer's left and right side. Faulty burner has as an effect that

- the nominal dryer temperature can not be reached,
- the temperature between the carpets left and right side differs (depending on dryer design),
- more energy will be consumed and
- there will be a much higher pollution (because of methane's green house effect).

Another aspect of miscellaneous activities consists of an optimised control system of the dryer, which should be more differentiated, more sensitive and also includes the period of cold start-up.
A further project task focuses on the optimisation of dryers with diffusion type burner. The research activities on these tasks showed a significant reduction of carbon monoxide and methane by the installation and optimised adjustment of a passive pre-mixing (air & gas) system. This system is based on the venturi principle. An alternative is active systems with a controlled air-gas-mixing unit or systems, which use compressed air.
The measured Methane reduction of the passive system is 50 % and of the active, controlled system 70 %. With regard to the higher invest cost of actively controlled systems the passive ones have to be favoured.
The break even time of optimisation activities differs between the different subjects and is extremely sensitive to the number of shifts and the general energy efficiency level of the dryer. The break-even time for nozzle box conversation with guiding sheets varies for example between less than one year and more than four years.

6 Exploitation and anticipated benefits

The exploitation of the project is divided into five exploitable results, which are listed in the table below.
The in house implementation at the projects carpet producers will done by the manufactures themselves. They will be supported by the projects dryer producer (company Olbrich) and the RTD Performers.
For the dissemination of the carpet industry relevant information the *Deutsches Teppich-Forschungsinstitut e.V.* and the *Gemeinschaft umweltfreundlicher Teppichboden e.V. (GUT)* (Association for Environmentally-Friendly Carpets) will support these activities. All carpet producers of the project are members of GUT.
Gut's main objective is to optimise the manufacturing- and recycling procedures to obtain the largest possible protection for man and environment. This means: economical use of selected raw materials, avoiding waste and turning waste into new raw material, reducing air effluents, using products that contribute to the well-being of the consumers and facilitating recycling.
The contacts of the company Olbrich as a plant producer to manufactures of wall paper, coated foils or imitation leather will result in an exploitation of the project results beyond the carpet industry.

result	exploited by
design of an improved dryer	⇒ dryer producer of the consortium supported by RTD Performer
improved air flow	⇒ carpet producer of the consortium (in house implementation) ⇒ Deutsches Teppich-Forschungsinstitut e.V.; Gesellschaft für intelligente Systeme & Datenanalyse bR
improved nozzle boxes (inside)	⇒ dryer producer of the consortium (in house implementation) ⇒ Deutsches Teppich-Forschungsinstitut e.V.; Gesellschaft für intelligente Systeme & Datenanalyse bR
improved seals	⇒ carpet producer of the consortium (in house implementation) ⇒ Deutsches Teppich-Forschungsinstitut e.V.; Gesellschaft für intelligente Systeme & Datenanalyse bR
optimised burner	⇒ Textiles and Flooring Institute GmbH ⇒ Deutsches Teppich-Forschungsinstitut e.V.; Gesellschaft für intelligente Systeme & Datenanalyse bR

Tab. 3: Projects exploitation

The magnitude of the anticipated benefits varies between the different results. If the new dryer design fulfils the extended demands of the project partner Olbrich the production costs of the nozzle boxes will be reduced in a significant way.

The break even time of optimisation of old dryers is extremely sensitive to the number of shifts and the general energy efficiency level of the dryer. The break-even time for nozzle box conversion with guiding sheets varies for example between less than one year and more than four years. The improved airflow results in an average reduction of energy consumption of at least 10 %. With regard of the opportunity to realise improved seals by the carpet producers without external help and the low invest this improvement has also a very short break even time. The optimisation of the burner with a passive premixing system has got at the investigated case a break even time of approximately four years. There is also an ecological benefit with respect to the greenhouse effect. The carbon dioxide equivalent will be reduced by more than 15 %.

7 Photographs, Illustration

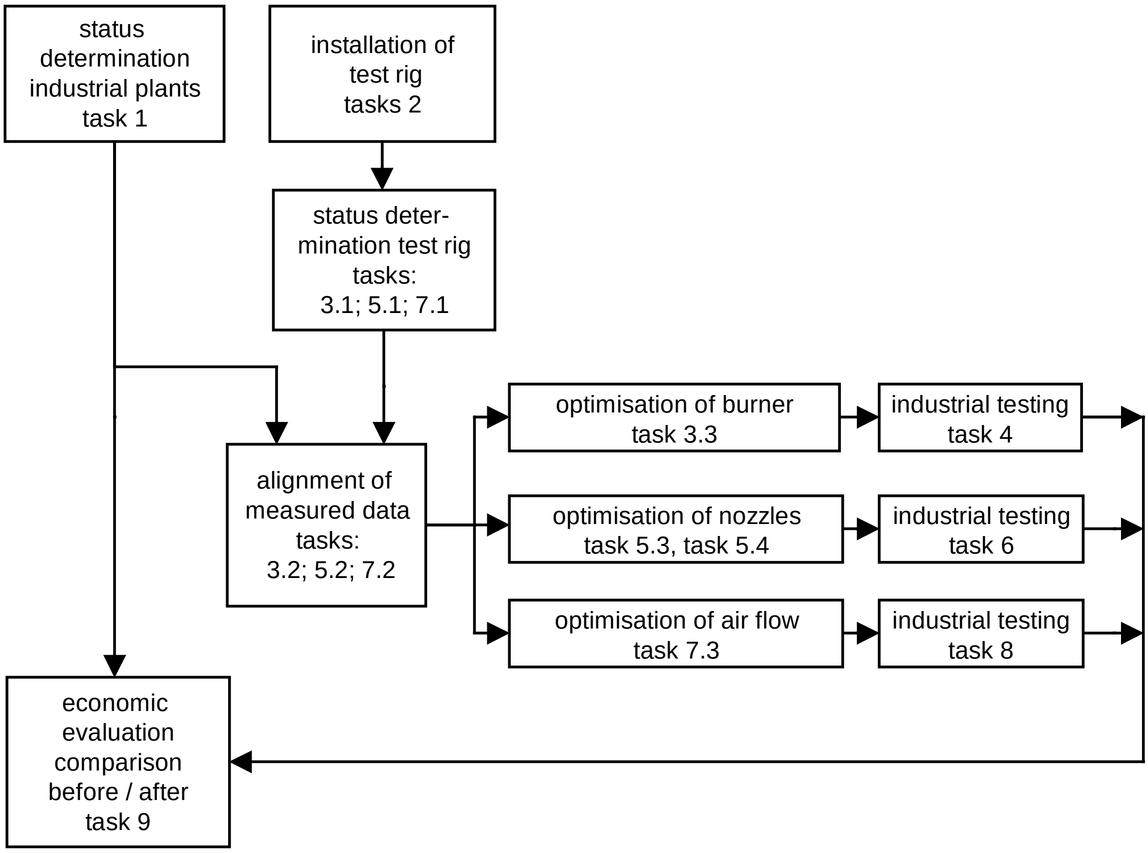

Fig. 1: Project's flow chart

Fig. 2: Complete test rig with the drawer for carpet input

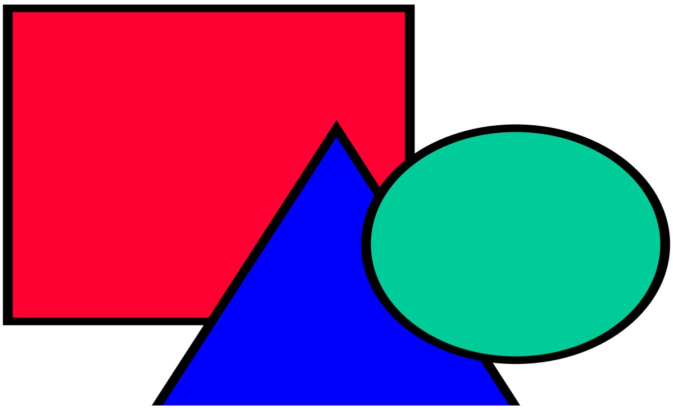

Fig. 3: Not optimised nozzle box at the beginning

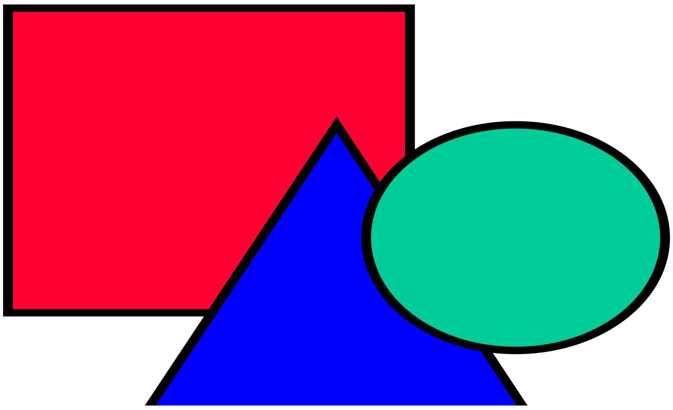

Fig. 4: Modified nozzle box with installed guiding sheets

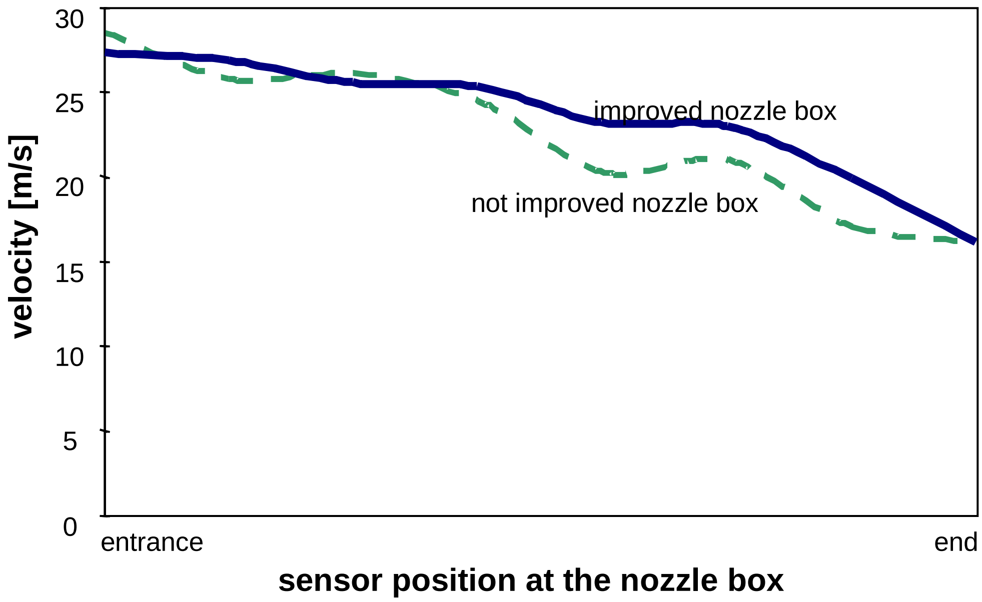

Fig. 5: Velocity profile along a nozzle box

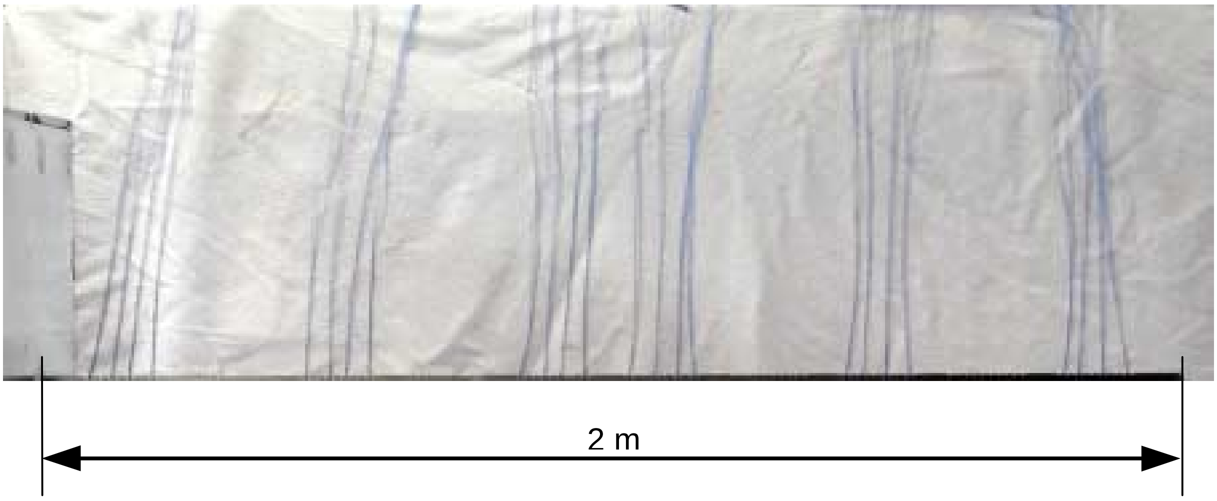

Fig. 6: Optimised nozzle box with new design