SHORT REPORT

Title

'Development of a radiation-adaptive awning fabric with increased translucency in conjunction with increased anti-glare and thermal protection properties for vertical awnings on non-residential buildings'

Background / Starting Point

Awnings are wind-resistant and dirt-repellent, however these benefits result in disadvantages in terms of adjustability. The properties of 'light transmission' and 'degree of shading' as well as 'outward view' are essential for use. These properties depend on the fabric structure and cannot be changed.
A high level of translucency reduces the need for artificial light and increases the inflow of heat. Although these effects are beneficial in winter, they are unwelcome in summer. In order to resolve this trade-off, awnings should be able to respond to varying degrees of sunlight intensity by changing translucency.

Aim of the Research Project

1. Requirement specifications
As a basis for material selection, the criteria of 'light transmission', 'degree of shading' and 'quality of outward view' were defined for the uncoated fabric. These parameters were verified by measuring suitable fabrics prior to glazing and the target values were defined for the coated fabric when subjected to maximum sunlight intensity.

2. Material selection
Yarn and base fabric
- Yarn materials: polyethylene terephthalate (PET) monofilament yarn and polyester staple fibre yarn of various thread fineness
- Fabric type: leno fabric, produced using EasyLeno® technology
- Fabric density: constant warp density, variable weft density
- Opening degree: between 3% and 40%
- Colour: warp threads are black, weft threads are black, white or translucent

3. Fabric characterisation
The following physical textile qualities of the fabric are determined prior to and after coating: area mass, thickness, warp and weft thickness, maximum tensile strength, maximum tensile elongation, translucency
For the selection of the solvent for fabric modification, the 'layers' (processing aids for weaving) were chemically examined. The PET surfaces were hydrophobic due to the presence of fluorinated processing agents.

4. Modification of the fabric surface
Under mild conditions, the ester groups of the PET are not able to undergo reactions that allow a covalent bond between a partner and the fabric surface. In order to prevent damage to the filaments, no physical methods for surface functionalisation were applied. Coating the fabric with water-soluble polyamines seemed appropriate.

5. Production of nanoparticles with integrated photochromic colouring agents
Microspheres of a defined size were produced via the radical suspension polymerisation of methyl methacrylate (MMA), which were added to the commercially available phototropic colouring agents. As the colouring agents were soluble in MMA, the poly(methyl methacrylate) microspheres (PMMA) also exhibited phototropic properties.

6. Bonding of nanoparticles with the modified fabric surface
Following successful attempts to form covalent bonds between silane-modified glass spheres and the amine-functionalised fabrics, suspensions of phototropic PMMA microspheres were applied to this fabric. The polyamine layer was interlaced with polymers that contained oxirane. These interlinked the polyamines and fixed the PMMA spheres to the fabric surface.

7. Simulation of the visual and thermal effects of various fabric variants
- Definition of relevant simulation parameters
- Consideration of key material values
- Derivation and modelling of a parameter model for integration in a building model including control and switching conditions
- Dynamic simulation to demonstrate the functionality and operation of the radiation-adaptive sunshade as well as energy effects over the course of a year

8. Development of an awning test bench
- Definition of a measurement concept for assessing the degree of shading, energy transmission, translucency and transparency
- Experiment setup for functional models (standard 1:1) for measurements of thermal comfort, energy and radiation balance
- Experiment setup for functional models (standard DIN A4) for measurements of the influence of sunlight intensity, UV proportion, colouring agent quantity and fabric structure

9. Measurement of the visual and thermal effects of awnings in front of a window
- Comparative raster measurement via glazing (3 steps): outside, inside without shade and inside with shade
- Thermal measurement parameters (outside): short-wave radiation, thermal radiation strength, ambient temperature
- Thermal measurement parameters (inside): thermal comfort according to ISO 7730, temperature stratification, air balance
- Visual measurement parameters: illuminance; translucency

10. Evaluation of the measurement results
- Effect of UV portion and colouring agent concentration on colour change
- Effect of coating on translucency
- Radiation dependency of light transmission and reduction factor
- Duration of forward and back reactions (decay behaviour depending on colouring agent concentration)

11. Examination of suitability for use
- Abrasion resistance: assessment of the adhesion of the coating both visually and by ascertaining the loss of mass; staple fibre yarn in the weft supports the adhesion of the nanoparticles
- Crease recovery angle measurement, crease angle between 30% and 80%
- Tear resistance using the trapezoid method: very good durability, tear resistance approx. 55 N in the warp direction and approx. 100 N in the weft direction

12. Selection of joining techniques for production
- Joining using seams and ultrasonic welding, determine machine parameters according to material values
- Suitability test for ultrasonic welding for processing thermoplastic materials
- Assess seam quality

Conclusion

The aim of the project was to develop an awning with a coating, which changes the transmission and absorption properties depending on the radiation intensity of the sun. In this connection, the transmission of the visible portion of radiation is constrained by means of continuously increasing absorption such that a maximum luminance is not exceeded and the outward view is still ensured.

The functionalisation of difficult-to-modify PET fabrics with nanoparticles, which previously received modification with photochromic colouring agents, was successful and can be reproduced. The modification of PET fabrics with photochromic colouring agents via thin film layers was also successful.
The influence of the most significant effect variables ‘light transmission’ and ‘degree of shading’ could be demonstrated. The degree of influence did not yet reach the magnitude required in practice and formulated in the research proposal (approx. 50% achieved thus far).
The findings open up two possible options for further investigation.
1. Lamination of the PET fabric ‘Ettlin β35’ with the phototropic polymer
2. Further development of the phototropic polymer as film

Key data

Short title: Radiation-adaptive textile sunshade (SatS)

Researchers / Project Management:

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Total costs: €395,399.20

Federal subsidy: €276,319.36

Project duration: 24 months

IMAGES / FIGURES

Image 1: 1_Projektskizze.jpg
Solar and anti-glare protection targets for vertical awnings

Image 2: 2_grosser_Messstand_Aussenansicht.png
Floor plan and interior view for the assembly of the large testing facility

Image 3: 3_grosser_Messstand_Aussenansicht.png
Exterior view of the large testing facility with sun simulator

Image 4: 4_kleiner_Messstand.png
Exterior view of the small testing facility with sun simulator and UV lamp

Image 5: 5_strahlungsabhängige_Farbveränderung.png
Change of colour of the coated fabric depending on radiation intensity and the colour agent quantity

Image 6: 6_Lichttransmission_Gewebe_und_Folie.png
Change of light transmission (τ_v) depending on radiation intensity

Image 7: 7_Verschattungsgrad_Gewebe_und_Folie.png
Change of degree of shading (reduction factor F_c) depending on radiation intensity