SUSTAINABLE, FUNCTIONAL HYBRID AIR FILTER DESIGN

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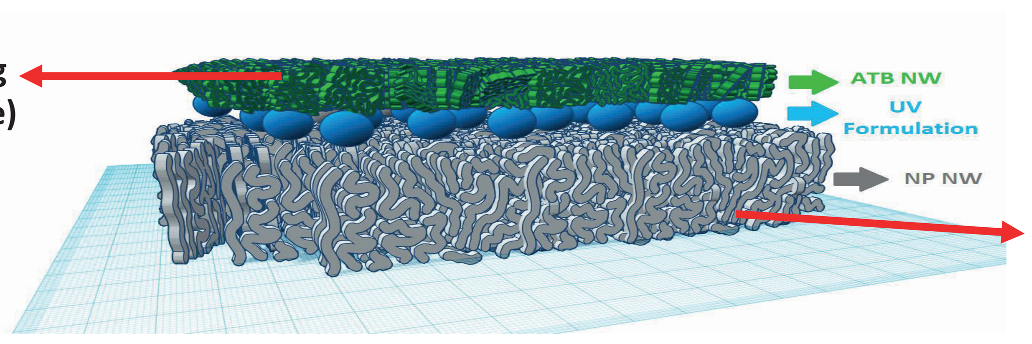
GRAPHICAL ABSTRACT & OBJECTIVES

- The goal of this Project is to obtain a nonwoven based filter material that is laminated with eco-friendly Ultraviolet (UV) radiation curing mechanism.
- Needlepunched (NP) and Air-Through-Bonded (ATB) nonwoven technologies are utilized to provide filtering against finer and coarser particles respectively.
- Elimination of volatile solvents and curing in fractions of seconds are the main advantages of employing UV radiation technology instead of conventional curing.



INTRODUCTION

- Nonwoven based filtering materials have increased in the last decade as health concerns increase. Needle-punched and Air-Through-Bonded nonwovens are laminated with each other through Ultraviolet curing mechanism rather than conventional curing.
- Nonwoven layers are binded with photopolymerization reactions in which monomers, oligomers, photoinitiators and reactive species are used. ATB nonwoven layer provides pre-filtering due to bigger pores where NP nonwoven layer provides fine filtration due to smaller pores.
- UV curing mechanism eliminates the need for drying tunnels that cause time and energy consumption in the manufacturing lines.
- **UV curing mechanism is a novel, sustainable lamination method for combining nonwoven layers.**

Hybdrid structure:
Combining nonwoven surface produced by Air-Through Bonding (ATB) method and nonwoven surface produced by Needle-Punched (NP) method with UV curing

Advantages:
 Disposable
 Extending machine life
 Healthy filtering
 Environmentally friendly
 Time-energy saving

Table: Comparison of conventional and radiation curing methods [1].

Properties	Conventional Curing	Radiation Curing
Physical Drying	Yes	No
Chemical Crosslinking	Yes (up to binders)	Yes
Volatile Solvents	Yes	No
Drying Time	From minutes to days	In fractions of a second

TESTING

In the testing of the hybrid air filter to be developed within the scope of the project, the methods specified in the following standards were applied:
1. Unit area mass: **EN 29073-1** [2].
2. Thickness: **ISO 9073 – 2** [3]
3. Air permeability: **NWSP 070.1R0 (20)** [4]
4. Tensile Strength and Elongation: **TS EN ISO 139**34-1 [5]
5. Tear Strength: **TS EN ISO 13937-2** [6]
6. Method of Testing General Ventilation Air-Cleaning Devices for Removal Efficiency by Particle Size: **ASHRAE 52.2** [7]

WORKS AND METHODS

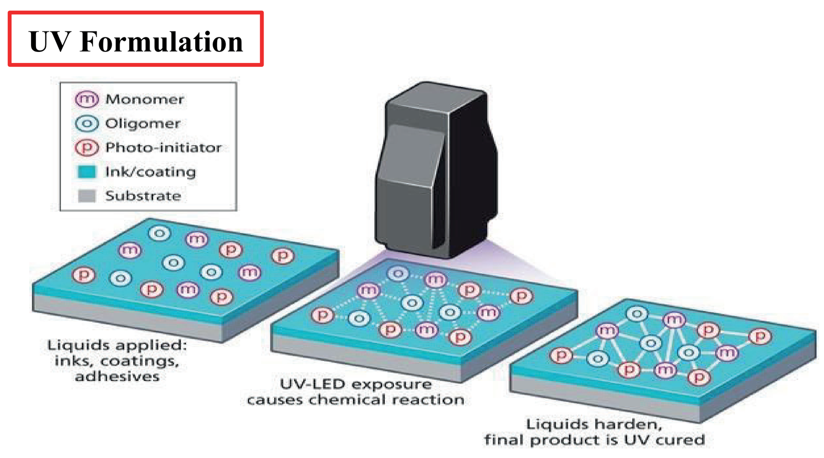
PRODUCTION METHOD OF NONWOVEN LAYERS

 CARDING
 NEEDLE-PUNCHING

 CARDING
 AIR-THROUGH BONDING

ATB Bigger pore: pre-filtration
NP Smaller pore: fine filtration

UV Formulation



LAMINATION METHOD OF NONWOVEN LAYERS

Photopolymerization

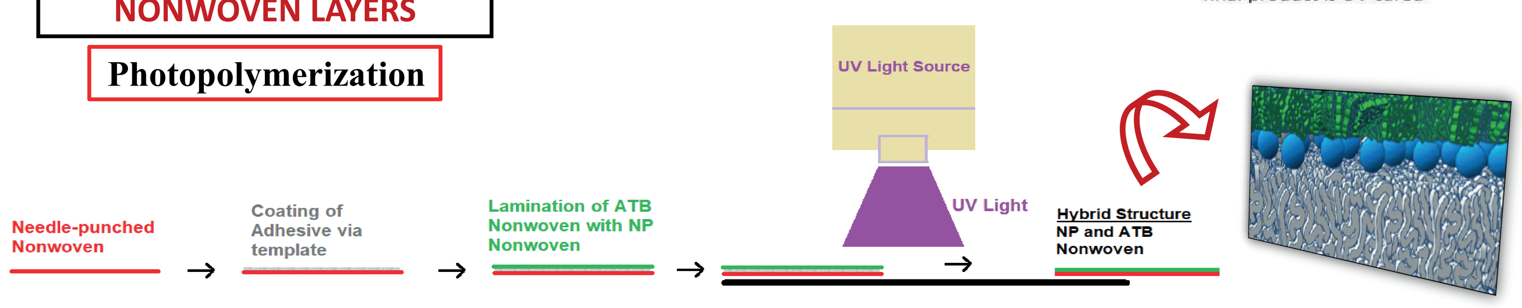


Table: Experiment plan created within the scope of the project.

NO	Speed (m/min)	Mercury-Gallium Lamp Energy (watt/cm)	ATB Nonwoven	Needle-punched Nonwoven
1	10	80	35 g/m² PE/PP	%50/%50 3/1,5 den PET
2	10	80	35 g/m² PE/PP	%80/%20 3/1,5 den PET
3	10	80	50 g/m² PET/coPET	%50/%50 3/1,5 den PET
4	10	80	50 g/m² PET/ coPET	%80/%20 3/1,5 den PET
5	10	100	35 g/m² PE/PP	%50/%50 3/1,5 den PET
6	10	100	35 g/m² PE/PP	%80/%20 3/1,5 den PET
7	10	100	50 g/m² PET/coPET	%50/%50 3/1,5 den PET
8	10	100	50 g/m² PET/coPET	%80/%20 3/1,5 den PET
9	10	120	35 g/m² PE/PP	%50/%50 3/1,5 den PET
10	10	120	35 g/m² PE/PP	%80/%20 3/1,5 den PET
11	10	120	50 g/m² PET/coPET	%50/%50 3/1,5 den PET
12	10	120	50 g/m² PET/coPET	%80/%20 3/1,5 den PET
13	15	80	35 g/m² PE/PP	%50/%50 3/1,5 den PET
14	15	80	35 g/m² PE/PP	%80/%20 3/1,5 den PET
15	15	80	50 g/m² PET/coPET	%50/%50 3/1,5 den PET
16	15	80	50 g/m² PET/coPET	%80/%20 3/1,5 den PET
17	15	100	35 g/m² PE/PP	%50/%50 3/1,5 den PET
18	15	100	35 g/m² PE/PP	%80/%20 3/1,5 den PET
19	15	100	50 g/m² PET/coPET	%50/%50 3/1,5 den PET
20	15	100	50 g/m² PET/coPET	%80/%20 3/1,5 den PET
21	15	120	35 g/m² PE/PP	%50/%50 3/1,5 den PET
22	15	120	35 g/m² PE/PP	%80/%20 3/1,5 den PET
23	15	120 ✔	50 g/m² PET/coPET	%50/%50 3/1,5 den PET
24	15	120	50 g/m² PET/coPET	%80/%20 3/1,5 den PET
25	18	80	35 g/m² PE/PP	%50/%50 3/1,5 den PET
26	18	80	35 g/m² PE/PP	%80/%20 3/1,5 den PET
27	18	80	50 g/m² PET/coPET	%50/%50 3/1,5 den PET
28	18	80	50 g/m² PET/coPET	%80/%20 3/1,5 den PET
29	18	100	35 g/m² PE/PP	%50/%50 3/1,5 den PET
30	18	100	35 g/m² PE/PP	%80/%20 3/1,5 den PET
31	18	100	50 g/m² PET/coPET	%50/%50 3/1,5 den PET
32	18	100	50 g/m² PET/coPET	%80/%20 3/1,5 den PET
33	18	120	35 g/m² PE/PP	%50/%50 3/1,5 den PET
34	18	120	35 g/m² PE/PP	%80/%20 3/1,5 den PET
35	18	120 ✔	50 g/m² PET/coPET	%50/%50 3/1,5 den PET
36	18	120	50 g/m² PET/coPET	%80/%20 3/1,5 den PET

Prototype 37 and 38 are carried out in the final Work Package according to specified successful prototypes as seen above.

RESULTS & CONCLUSION

Table: Mechanical strength properties of prototypes.

Prototype No/Name	Tensile Elongation (%)		Tensile Strength (N/mm)		Tear Strength (N/mm)	
	CD	MD	CD	MD	CD	MD
ATB: 50 g/m² PET/coPET	68,5	16,1	0,1	0,5	1,1	1,6
NP: %50/50 3/1,5 den PET	122,0	75,0	5,8	6,2	53,3	65,3
Hybrid Structure: Prototype-37	120,1	70,1	7,4	6,1	52,1	55,4
ATB: 50 g/m² PET/coPET	68,5	16,1	0,1	0,5	1,1	1,6
NP: %40/45/15 3/1,5/4 den PET/coPET	95,2	60,7	8,2	7,5	61,7	72,3
Hybrid Structure: Prototype-38	90,1	57,3	9,3	7,2	60,8	61,9

Hydrophobic treatment is applied to enhance the lamination of layers.

Table: Comparison of filtering results.

Prototype	Particulate Efficiency (%)			MERV	Air Permeability (l/m²/s)	Air Flow Resistance (“wg)
	E1	E2	E3			
Prototype-37	11	21	60	7	1200	0.05
Prototype-38	17	28	59	7	987	0.03

 The improvements have increased the filtration performance of particles with small particle sizes considerably, providing better filtration efficiency at low micron levels, resulting in more successful results.
 Since the resistance of prototype-38 is lower, it can be said that a longer-lasting structure is obtained at the same filtration capacity.
 When the MERV test performed on the samples is compared with the ISO 16890 standard, the result of MERV 7 corresponds to the ISO Coarse Filtration >95% **classification.** Accordingly, a coarse filtering efficiency close to ePM_{10} was achieved through employing a **sustainable lamination method**.

REFERENCES

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[2] EN 290 Tests for Textile-Non-Woven fabrics – Part 1: Selection of unit area-1.
[3] ISO 9073-2 Contents for Textile-Non-Woven things - Part 2: Determination of thickness.
[4] NWSP 070.1.R0 (20) Air Permeability of Nonwovens.
[5] TS EN ISO 13934-1 Properties of Textile-Fabrics - Part 1: Determination of the highest strength and elongation under the greatest force by method.
[6] TS EN ISO 13937-2 Textile- Part 2: Properties of samples of fabrics - Part 2: Determination of samples of samples of Pantalonki samples (tekma methods).
[7] National Air Filtration Association, 2018, Understanding MERV, NAFA User's Guide to ANSI/ASHRAE Standard 52.2-2017, Wisconsin.

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