Grant Agreement N°: 820869
Call: H2020-SC5-2018-2019-2020
Topic: CE-SC5-01-2018
Type of action: RIA

RECYCLING OF WASTE ACRYLIC TEXTILES

# D5.2: RESULTS OF WARPING/WEAVING SAMPLES AND LABORATORY TESTING – EXECUTIVE SUMMARY

| | |
|---|---|
| Work package | WP 5 |
| Task | Task 5.1 |
| Due date | 30/08/2020 |
| Submission date | 30/08/2020 |
| Deliverable lead | Parà |
| Version | v0.2 |
| Authors | Barbara Ferrari |
| Reviewers | Roberto Vannucci |

| | |
|---|---|
| Abstract | Description of finishing trials, on lab scale machinery, including technical parameters and results of tests executed to evaluate the performances of the finished textiles |
| Keywords | finishing trials - lab scale machinery |

**Document Revision History**

| Version | Date | Description of change | List of contributors(s) |
|---|---|---|---|
| V0.1 | 27/06/2022 | ToC | Barbara Ferrari (Parà) |
| V0.2 | 30/06/2022 | Internal review | Daniele Piga, Donatella Macchia (Centrocot), Mara |

**Disclaimer**



**Acknowledgment**

** REPORT: Document, report (excluding the periodic and final reports)*

*DEM: Demonstrator, pilot, prototype, plan designs*

*DEC: Websites, patents filing, press & media actions, videos, etc.*

*OTHER: Software, technical diagram, etc*

| **Project co-funded by the European Commission in the H2020 Programme** | | |
|---|---|---|
| **Nature of the deliverable *:** | Report | |
| **Dissemination Level** | | |
| PU | Public, fully open, e.g. web | ✓ |
| CI | Classified, information as referred to in Commission Decision 2001/844/EC | |
| CO | Confidential to REACT project and Commission Services | |

## EXECUTIVE SUMMARY

This deliverable has been created in the context of the WP 5 (Textile production, finishing and testing) of the H2020-funded project REACT (Grant No. 820869).

The document provides Description of warping and weaving trials, on lab scale machinery, including technical parameters and results of tests executed to evaluate the performances of the obtained textiles

# TABLE OF CONTENTS

# LIST OF FIGURES

# LIST OF TABLES

# ABBREVIATIONS

## WARPING AND WEAVING STEPS

The different qualities of waste coming from the entire production chain were subjected to the fraying process and then to the chemical treatment developed in this project in order to eliminate all finishing substances, whenever required. The clean waste was then spun with open end or ring spinning, also mixed with virgin fibre. The different types of yarns were warped on Sulzer Nas 300 samples warper and then woven either on a rapier loom or on an air loom.

We prepared 20 fabrics using different type of waste. We used always recycled yarn in warp and in weft and in some cases virgin yarn only in weft.

These fabrics were finished with different finishing recipes developed with a partner of the project and so tested in our laboratories. The finishing recipes are different if the final use of the fabric is for awnings or for furniture or beach umbrellas. We compared the features of the fabrics finished with the standard finish and those with the new recipes where we used more sustainable substances, bio-based and fluorine free.

Summary of warping results: during warping no significant problems were observed, only in some cases the formation of a greater quantity of dust which in any case did not influence the outcome of the operation was observed.

Summary of weaving results: in general, we observed a greater hairiness of the recycled yarn especially if open end yarn and the presence of imperfections (tangles and swelling) that have caused numerous breaks. In any case we didn't add any type of finish product to weave the recycled yarn.

We use always the same construction (canvas) with 30 yarn/Cm in warp and 13,5 till 11 picks/cm in weft. We must decrease the picks/cm number in case of are very hairy and with high number of breaks. No finish has been used during warping or weaving phases

These are the recycled fibre codes and relevant code of fabrics

| YARN CODE | FABRIC CODE |
|---|---|
| 0006NO1001020 | 1A |
| | 1B |
| 0006NR0700321 | 2A |
| 0006NO0600921 | 3A |
| in warp 004WNR0701021 | 3B |
| 08A1YO0601021 | 4A |
| 8AW1YO0700222 | 6A |
| 004WNR0701021 | 8A |
| 007AYO0701021 | 9A |
| 007AYR0600122 | 10A |
| 009ANO0700222 | 11A |
| 08A1OY0700222 | 15A |
| 68A1YO1001221 | 18A |
| 004WNO0700222 | 19A |

*Table 1. Samples code.*

The yarn code example: 0006NO1001020

- the first four numbers define the type of waste (see previous deliverable)
- N or Y defines if the fibre has been subjected to the chemical treatment (N=no and Y=yes)
- R or O defines the type of spinning R=ring O=open end
- These three numbers define the percentage recycled fibre content
- The last four number define the delivery date of the yarn to our plant

We use air looms and rapier loom to verify the process rate on both types of looms and to put in evidence possible difference of yield. Of course, these data are only indicative due to the very small quantity processed for each sample of yarn

In both cases we had to decrease the speed of loom and the tension of yarns in comparison with the standard conditions. In table 2 we resume the weaving conditions.

| FABRIC | LOOM TYPE | METRES | WEAVING SPEED | BREAKING IN WARP | YIELD |
|---|---|---|---|---|---|
| | | | beats/min | N° | breaks/m |
| 1A | AIR | 10 | 500 | 25 | 2,5 |
| 1B | AIR | 2 | 500 | 0 | 0,0 |
| 2A | AIR | 70 | 500 | 12 | 0,2 |
| 2B | AIR | 38 | 500 | 12 | 0,3 |
| 3A | RAPIER | 77 | 300 | 5 | 0,1 |
| 3B | RAPIER | 63 | 350 | 81 | 1,3 |
| 4A | RAPIER | 126 | 290 | 47 | 0,4 |
| 8A | RAPIER | 126 | 290 | 5 | 0,0 |
| 9A | RAPIER | 63 | 290 | 11 | 0,2 |
| 6A | RAPIER | 122 | 250 | 46 | 0,4 |
| 10A | RAPIER | 70 | 250 | 43 | 0,6 |
| 11A | RAPIER | 84 | 250 | 110 | 1,3 |
| 15A | RAPIER | 107 | 250 | 38 | 0,4 |
| 18A | RAPIER | 83 | 250 | 26 | 0,3 |
| 19A | RAPIER | 108 | 250 | 27 | 0,3 |
| | | | | | |
| | | | | | |
| | FABRIC WITH THE HIGHEST YIELD | | | | |

*Table 2. Weaving conditions of samples.*

The fabrics have been washed in water or with solvent due to the different types of finishing machines available as the air loom allows to obtain fabrics of greater width which are washed in water, while the rapier looms are able to work fabrics with lower width that are more suitable for solvent washing.
All fabrics were finished using a laboratory equipment- foulard and rameuse.
Firstly, we applied the standard recipes for awnings and for furniture just to compare the performances of fabric made with recycled yarn with those of fabrics made with virgin yarn and after we applied different finishes were fluorine free and bio-based resins were used.
In table 3 we resume all types of woven fabrics finished with different recipes and the results

| TYPE OF WASTE<br>SELVEDGES<br>*without finish* | YARN CODE | FABRIC CODE | %RECYCLED FIBRE | FINISHED FABRIC CODE | NOTE | WARPING /WEAVING RESULTS |
|---|---|---|---|---|---|---|
| open end 100% recycled fibre | 0006NO1001020 | 1A | 100 | 1A1 | finish standard awnings (fluorocarbon + thermosetting standard resin) | WARPING ON SAMPLE WARPER - WEAVING ON AIR LOOM WITH REDUCED SPEED- 30ENDS/CM IN WARP 14 PICKS/CM IN WEFT .SCOURING IN WATER |
| | *fabric with virgin fibre in weft* | 1B | 70 | 1B1 | finish standard awnings (fluorocarbon + thermosetting standard resin)<br>warp recycled yarn- weft virgin yarn | |
| ring 70% recycled fibre | 0006NR0700321 | 2A | 70 | 2A1 | finish standard awnings (fluorocarbon + thermosetting standard resin) | |
| | | | | 2A2 | finish for awnings with fluorin free TYPE 1 and thermosetting standard resin | WARPING ON SAMPLE WARPER - WEAVING ON AIR LOOM WITH REDUCED SPEED - YARN VERY HAIRY.SCOURING IN WATER |
| | | fabric width 250 | | | | |
| | | | | 2A4PU61 | finish with fluorine free TYPE 1 and polyuretane biobased resin TYPE C | |
| | | 2B | 70 | 2B1 | finish standard for furniture (fluorocarbon) | |
| | | fabric width 304 | | 2B2 | finish for furniture fluorine free TYPE 1 | |
| open end 60% recycled fibre | 0006NO0600921 | 3A | 60 | 3A1 | finish standard awnings (fluorocarbon + thermosetting resin) | WARPING ON SAMPLE WARPER-WEAVING ON RAPIER LOOM HIGH NUMBER OF BREAKS IN WARP SCOURING IN SOLVENT |
| | | | | 3A4PU61 | finish with fluorine free TYPE 1 and polyuretane biobased resin TYPE C | |
| | | | | 3AB2 | finish for beach umbrellas fluorine free TYPE 1 | |
| | *004WNR0701021 used in warp* | 3B | 65 | 3B1 Caravaggio | finish standard furnishing (fluorocarbon) | WARPING ON SAMPLE WARPER-WEAVING ON RAPIER LOOM HIGH NUMBER OF BREAKS IN WARP PROBABLY DUE TO THE HIGHER NUMBER OF YARN/CM SCOURING IN SOLVENT |
| | | | | 3B2 Caravaggio | finish for furniture fluorine free TYPE 1 | |
| *finished selvadge* | | | | | | |
| open end with chemical treatment | 007AYO0701021 | 9A | 70 | 9A1 | finish standard awnings (fluorocarbon + thermosetting resin) | WARPING ON SAMPLE WARPER - WEAVING ON RAPIER LOOM WITH REDUCED SPEED - SCOURING IN SOLVENT |
| 70% recycled fibre | treated selvedge | | | 9A4 | finish with fluorine free TYPE 1 and polyuretane biobased resin TYPE A | |
| | | | | 9B2 | finish for furniture fluorine free TYPE 1 | |
| ring with chemical treatment | 007AYR0600122 | 10A | 60 | 10A1 | finish standard awnings (fluorocarbon + thermosetting resin) | WARPING ON SAMPLE WARPER - WEAVING ON RAPIER LOOM WITH REDUCED SPEED - SCOURING IN WATER |
| 70% recycled fibre | treated selvedge | | | 10A5 | finish with fluorine free TYPE 3 and polyuretane biobased resin TYPE A | |
| | | | | 10B2 | finish for furniture fluorine free TYPE 1 | |
| | | | 40 | 10C5 | finish with fluorine free TYPE 3 and polyuretane biobased resin TYPE A<br>warp recycled yarn- weft virgin yarn | |
| *coated selvedge* | | | | | | |
| waste coming from W7B coated selvadge | material not processable either open end or ring | | | | | |

| | | | | | | |
|---|---|---|---|---|---|---|
| WHITE FIBER FROM SPINNING | | | | | | |
| ring - 70% recycled yarn | 004WNR0701021<br>white fibre | 8A | 70 | 8A1<br>8A4 | finish standard awnings ( fluorocarbon + thermosetting resin)<br>finish with fluorine free TYPE 1 and polyuretane biobased resin TYPE A | WARPING ON SAMPLE WARPER - WEAVING ON RAPIER LOOM WITH REDUCED SPEED -SCOURING IN SOLVENT |
| | | 8B | | 8B2 | finish fluorine free FFM | |
| open end 70% recycled fibre | 004WNO0700222<br>white fibre | 19A | 70 | 19A1<br>19A5 | finish standard awnings ( fluorocarbon + thermosetting resin)<br>finish with fluorine free TYPE 3 and polyuretane biobased resin TYPE A | WARPING ON SAMPLE WARPER - WEAVING ON RAPIER LOOM WITHS REDUCED SPEED -SCOURING IN WATER |
| | | | | 19B2 | finish for furniture fluorine free TYPE 1 | |
| FABRICS | 08A1YO0601021 | 4A | 60 | 4A1 | finish standard awnings | WARPING ON SAMPLE WARPER-WEAVING ON RAPIER LOOM HIGH NUMBER OF BREAKS IN WARP PROBABLY DUE TO THE HIGHER NUMBER OF YARN/CM SCOURING IN SOLVENT |
| fabric for awnings open end frayed and with | FRAYED AND TREATED | | | 4A4 | finish with fluorine free TYPE 1 and polyuretane biobased resin TYPE A | |
| chemical treatment 60% recycled fibre | | 4B | | 4B2 | finish for furniture fluorine free TYPE 1 | |
| fabric for awnings open end with chem.treat. | 08A1OY0700222 | 15A | 70 | 15A1 | finish standard awnings | WARPING ON SAMPLE WARPER - WEAVING ON RAPIER LOOM WITHOUT PROBLEM -SCOURING IN WATER |
| and after frayed 70% recycled fibre | TREATED AND FRAYED | | | 15A5 | finish with fluorine free TYPE 3 and polyuretane biobased resin TYPE A | |
| | | | 47 | 15C5 | finish with fluorine free TYPE 3 and polyuretane biobased resin TYPE A<br>warp recycled yarn- weft virgin yarn -awnings | |
| | | | | 15B2 | finish for furniture fluorine free TYPE 1 | |
| white fabric frayed and with chem. treat. | 08AWYO0700222 | 6A | 70 | 6A1 | finish standard awnings | WARPING ON SAMPLE WARPER - WEAVING ON RAPIER LOOM WITHOUT PROBLEM -SCOURING IN WATER |
| open end 70% recycled fibre | | | | 6A5 | finish with fluorine free TYPE 3 and polyuretane biobased resin TYPE A | |
| | | | 47 | 6C5 | finish with fluorine free TYPE 3 and polyuretane biobased resin TYPE A<br>warp recycled yarn- weft virgin yarn -awnings | |
| | | | | 6B2 | finish for furniture fluorine free TYPE 1 | |
| fabric from end use beach umbrellas | 009ANO0700222 | 11A | 70 | 11A1 | finish standard awnings | WARPING ON SAMPLE WARPER - WEAVING ON RAPIER LOOM WITHOUT PROBLEM -SCOURING IN WATER |
| only frayed -no chem. treat. 70% recyc. fibre | | | | 11A5 | finish with fluorine free TYPE 3 and polyuretane biobased resin TYPE A | |
| | | | 47 | 11C5 | finish with fluorine free TYPE 3 and polyuretane biobased resin TYPE A<br>warp recycled yarn- weft virgin yarn -awnings | |
| | | | | 11B2 | finish for furniture fluorine free TYPE 1 | |
| waiting for yarn coming from end use frayed and treated | | 12A | | | | |
| SELVEDGE AND FABRIC | 68A1YO1001221 | 18A | 100 | 18A1 | finish standard awnings | WARPING ON SAMPLE WARPER - WEAVING ON RAPIER LOOM WITHOUT PROBLEM -SCOURING IN WATER |
| 50% weaving selvedge-50%fabric for awnings | | | | 18A5 | finish with fluorine free TYPE 3 and polyuretane biobased resin TYPE A | |
| frayed with chem treatment.OE | | | 90 | 18C5 | finish with fluorine free TYPE 3 and polyuretane biobased resin TYPE A<br>warp recycled yarn-weft white recycled yarn (004WN0701021) | |
| | | | | 18B2 | finish for furniture fluorine free TYPE 1 | |

*Table 3. List of samples created during WP5 activities.*

## CONCLUSIONS

Considering the data obtained, we can summarize our conclusions below

- the recycled yarns coming from all individuated source mixed in spinning with 30-40% of virgin white fibre can be warped and woven with air and rapier looms, even if with reduced speed in order to decrease the number of breakings of yarn in warp and weft;
- considering the new finishings formulated with fluorine free and with bio-based resins, the fabrics made with yarn coming from selvedge have a lower absorption in comparison with all the other fabrics made with recycled types of yarn. Probably this fact is due to the different stress strain applied during the fraying phase on selvedge or on fabrics (?)
- The type of washing to be done on raw fabrics before finishing step is important for the final results: the washing in solvent of the fabric made with recycled yarn seems to decrease the resistance to the hydrostatic pressure, also using the standard finishing recipe (water repellent with fluorine and standard thermosetting resin). Probably the fibre after chemical treatment and fraying is more cracked on surface and therefore a solvent-based washing treatment with its speed of movement of the fabric and the temperatures reached interacts more with the recycled fibre than washing in water at lower temperatures and with greater stativity of the fabric
- For the fabrics for furniture, we obtained always good results with all types of recycled yarn;
- For the fabrics for awnings:
    - Fabrics 1A-2A-3A made with recycled yarn coming from waste of selvedge without finish: the yield of yarn from OE or Ring spinning is similar using air loom, where also the yarn with 100% recycled yarn OE has an acceptable processing rate. The characteristics of the obtained fabrics are acceptable.
    - Fabrics 9A-10A made with recycled yarn coming from waste of selvedge with finishing and then subjected to the chemical treatment: the ring yarn has best performances (better dimensional stability) even if the content of recycled yarn has been decreased to 60% (OE 70%). If we used virgin yarn in weft in case of fabric 9A, we could increase the performances.
    - Fabrics 8A-19A made with recycled yarn coming from waste of white yarn of spinning: in this case we have the same content of recycled yarn (70%) . The characteristics of fabric 8A (ring spinning) are better than those of fabric 19A (OE spinning) and meet all the minimum requirement. We had to decrease the picks/cm for the fabric 19A for increasing the weaving rate. The ring spinning gives a more resistant and performing fibre, but we know that this type of spinning can not processes some types of waste.
    - Fabrics 4A-15A-6A made with recycled yarn coming from waste of finished fabrics for awnings with OE spinning: there is no difference between the fabric made with waste before frayed and after treated (4A) or before treated and after frayed. Only using virgin yarn in weft, the fabric meets the minimum requirements (15C5). The same results for the fabric 6A
    - Fabric 11A: made with recycled yarn coming from waste of fabrics for beach umbrellas at the end of their life (OE with 70% of recycled fibre) without any chemical treatment: this fabric has a low resistance in warp and therefore to meet the minimum requirements we should take one (or more) of the following actions:
        1. To increase the content of virgin fibre in the yarn
        2. To use ring spinning
        3. To weave with air loom

In the next months we should receive a quantity of the same yarn but with the chemical treatment and we could apply one or all these actions to improve the performance of this type of waste that is relevant to a very important quantity of waste that could be recovered.

- Fabric 18A: made with recycled yarn coming from waste 50% of selvedge (w6) and 50% of fabrics for awnings (w8A1) frayed and subjected to the chemical treatment -open end spinning: this is the fabric most interesting because we have very good results using in weft the recycled yarn coming from white waste from spinning. We are testing the performances after aging but all the other features are good. In this case we don't use any quantity of virgin fibre and also with a weaving with rapier loom we have good results.

While there are no problems on upholstery fabrics that comply with all the minimum requirements established by the regulations whatever the type of recycled acrylic waste used, the results of tests on fabrics made for awnings have highlighted the critical points of the different types of waste but everyone can meet the minimum requirements if some simple measures are adopted such as those suggested for fabric 11.