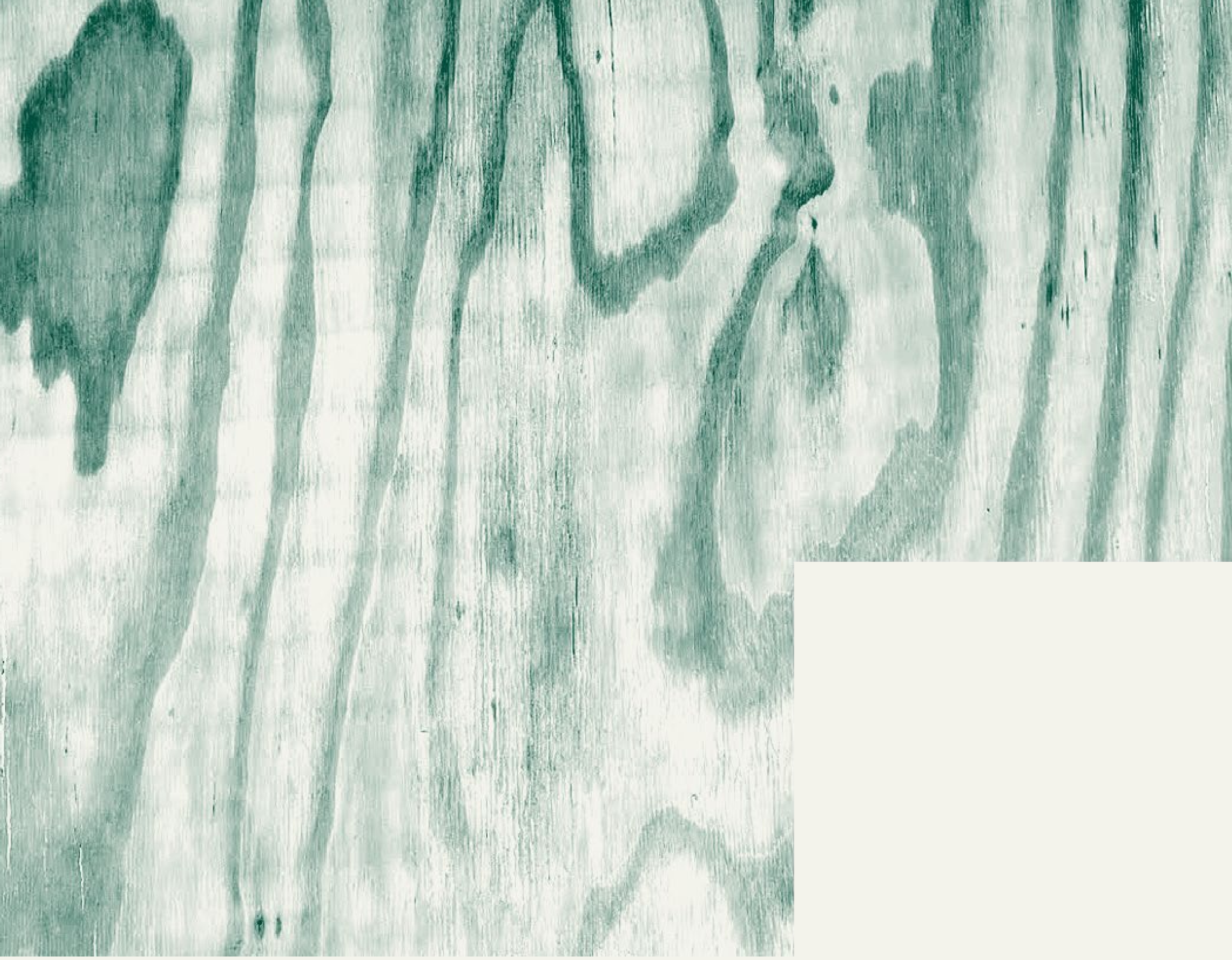

SLUTRAPPORT

RESTART

Återanvändning av hockeyklubbor i energiabsorberande strukturer

Patrik Fernberg, Luleå tekniska universitet

RE:
SOURCE

Slutrapport för projekt:

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Preface

The current report provides summary information on activities and outcome of a pre-study project, RESTART. The study was conducted from September 2022 to August 2023 by four collaborating partners: Gestamp Hardtech, Luleå Hockey, Luleå university of technology and Rise. The objective of RESTART was to investigate a novel re-use approach for high-tech advanced composite ice-hockey sticks as crash energy absorbing elements in car components.

RESTART was funded by the Swedish Energy Agency, Vinnova and Formas via the strategic innovation programme RE:Source.

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1. Summary

RESTART is a pre-study that investigated and demonstrated a novel re-use approach for fibre reinforced composite ice-hockey sticks as crash energy absorbing elements.

As such, hockey sticks may at a first glance appear as a “marginal” component from a recycling and repurposing aspects. However, specific features make them interesting in the context of circular use of composites. One important is their inherent short lifetime; a typical ice-hockey player consumes many sticks. This in combination with widespread interest for the sport in Europe and North America makes the market substantial. The costs for hockey sticks are unlikely an issue for professional hockey players. However, the environmental impact of all areas of society, also sports and leisure, need to contribute to the transition to a more sustainable society.

The first underpinning hypothesis investigated by RESTART was whether parts of the remaining shaft structure may be re-used in new products. This hypothesis was studies through fundamental structural investigation of shafts from scrapped ice-hockey sticks. The investigations revealed that the majority of the scrapped hockey stick shafts remained being of high material quality also after the break. This means that that the composites still had high fibre content, low porosity and relatively few defects.

The second hypothesis of RESTART was that closed composite cross-section of an ice-hockey shaft could be re-purposed into efficient crash energy absorption elements. Already prior to the RESTART study it was well established that when designed properly, fibre composite structures outperform metallic structures in term of crash energy absorption per unit weight. Through experimental characterization of the crushing behaviours of stick shaft segments from scrapped sticks, RESTART was able to demonstrate that shaft sections can perform on par with the best composite structures and consequently can outperform metal structures.

Figure 1 A crushed hockey shaft section

The third hypothesis, that scrapped hockey-stick segments may be used as low weight crash energy absorbing unit for a car, was also investigated. Due to practical constraints within the project, this investigation resulted in a highly simplified demo structure that turned out insufficient for very firm practical verification purpose.

In all, the overall conclusions from the pre-study verified that the technical potential for re-using composite shafts is very high. The availability of scrapped sticks is also high, however not infinite. As such the opportunities to form a sustainable circular value cycle appear good. Next step required to exploit findings of the prestudy further involves to verify the technical performance also for dynamic loading scenarios, identifying new end-use case scenarios, further enhancements of the understanding of property variations of sticks including a more comprehensive understanding on the expected amount of damage accumulated post-use and to establish guidelines and predictive tools that will enable design of robust multi-shaft energy absorbing structures.

2. Sammanfattning

RESTART är en förstudie som undersökt och demonstrerat potentialen hos ett nytt sätt att återanvända hockeyklubbor av komposit som energiabsorberande element vid krock.

Vid en första anblick kan hockeyklubbor framstå som en ”marginell” komponent ur återvinnings- och återanvändningsperspektiv. Det finns dock specifika egenskaper gör dem speciellt intressanta ur ett cirkulärt perspektiv. En sådan aspekt är deras inneboende korta livslängd; en typisk ishockeyspelare förbrukar och skrotar klubbar i hög takt. Detta i kombination med det breda intresset för sporten i Europa och Nordamerika gör att marknaden för nya och skrotade klubbor är betydande. Kostnaderna för hockeyklubbor är inte nödvändigtvis ett problem för professionella hockeyspelare, men för ungdomar och dess föräldrar är de betydande. Detta, tillsammans med att miljöpåverkan från alla samhällsområden, även idrott och fritid, behöver bidra till omställningen till ett mer hållbart samhälle utgör en motivation för studien.

Den första underliggande hypotesen som RESTART undersökt var ifall delar av den skrotade klubbans skaft var av tillräcklig kvalitet för att återanvändas i nya produkter. Denna hypotes testades genom studier av grundläggande struktur på materialet i skrotade klubbskaft. Undersökningarna visade att majoriteten av de skrotade hockeyklubborna fortfarande höll hög materialkvalitet även för skrotade klubbor. Det betyder att kompositerna fortfarande hade hög fiberhalt, låg porositet och relativt få defekter.

Den andra hypotesen för RESTART var att kapade tvärsnitt från klubbskaft kan återanvändas genom att omvandlas till effektiva krockenergiabsorberande element. Sedan tidigare, långt före RESTART-studien har det varit väletablerat att fiberkompositstrukturer, när de utformas på rätt sätt, överträffar metalliska strukturer när det gäller krockenergiabsorption per viktenhet. Genom experimentell karaktärisering av krossningsbeteendet hos skaftsegment från skrotade klubbor, har vi inom RESTART visa att hypotesen stämmer; skaftsektioner kan prestera i paritet med de bästa kompositstrukturerna och kan följaktligen överträffa metallstrukturer.

Den tredje hypotesen, att skrotade hockeyklubbor kan användas som en lätt och energiabsorberande struktur för en bil, undersöktes också. På grund av praktiska begränsningar i projektet resulterade denna undersökning i en mycket förenklad demostruktur som visade sig vara otillräcklig för att dra långtgående, och experimentellt verifierade, slutsatser när det gäller hur mycket konkreta praktiska verifieringsändamål.

Sammanfattningsvis verifierade resultaten från förstudien att den tekniska potentialen för att återanvända skrotade hockeyklubbor är mycket hög. Tillgången på trasiga klubbor är också hög, dock inte oändlig. Därmed framstår möjligheterna att utveckla en hållbar cirkulär värdecykel som goda. För att ta nästa steg, i processen att exploatera teknologin, behöver man ytterligare verifiera den tekniska prestandan speciellt för dynamiska belastningar, identifiera nya slutanvändningsområden, ytterligare förbättra förståelsen för egenskapsvariationer mellan klubbor och etablera en mer omfattande förståelse av hur mycket skador som ackumuleras under användning av klubborna samt att upprätta riktlinjer och designverktyg som behövs för att möjliggöra design av nya robusta strukturer.

3. Introduction and background

RESTART is a pre-study aiming to investigate a novel re-use approach for high-tech advanced composite ice-hockey sticks as crash energy absorbing elements in car components.

As such, hockey sticks may at a first glance appear as a “marginal” component from a recycling and repurposing aspects. There are however some specific features making them interesting in the context of circular use of composites. One of the more important aspects is their inherent short lifetime; a typical ice-hockey player consumes many sticks. This in combination with widespread interest in Europe and North America making the market substantial. A very gross estimation based on number of registered players in Europe (around 500 000) is that the annual market of scrapped sticks is around 700 thousand to 1 million. The economic costs for hockey sticks are unlikely an issue for professional hockey players. However, the environmental impact of all areas of society, also sports and leisure, need to contribute to the transition to a more sustainable society.

Modern hockey sticks are high quality composite structures optimized for very specific use. The sticks are manufactured using so-called carbon fibre prepregs by manufacturing methods commonly associated with aeronautics or space-industry. One consequence of the stick material and manufacturing is the high cost for hockey sticks. Costs that largely arises from very high energy use during the carbon fibre manufacturing and expensive fossil-based precursors. Sticks cost around 250-300 Euro per item - a substantial cost especially for non-professionals such as youth players and their parents. Materials engineering towards this extremely lightweight product have over the years lead to a stick with tailored flexural performance but at the expense of safety margins towards failure. The stick shaft is sensitive to impacts, even small impacts cause micro damages (often not visible) that propagate upon repeated loading and fail once damages reach a critical dimension.

The first underpinning hypothesis investigated by RESTART was whether parts of the remaining shaft structure may be re-used in new products. This hypothesis was investigated by fundamental structural investigation of shafts from scrapped ice-hockey sticks.

The second hypothesis of RESTART is that closed composite cross-section of an ice-hockey shaft can be turned into a very efficient crash energy absorption element whenever crushing along the shaft-direction is attained. When designed properly, fibre composite structures can outperform metallic structures in term of crash energy absorption. The hypothesis was investigated by RESTART through experimental characterization of the crushing behaviours of stick shaft segments.

The third hypothesis is that scrapped hockey-stick segments may be used as low weight crash energy absorbing units that may be integrated in car structures to provide low weight crash energy absorption capability. To test this hypothesis RESTART have built and test a simplified section consisting of six parallel shaft block units in a geometry that is representative for an energy absorbing car structure.

4. Implementation

The project was carried out in the following main stages: 1) collection of scrapped sticks, classification of different types of hockey sticks based on their mechanical characteristics; sorting and collection of shafts depending on the extent of damage; 2) characterization of internal structure of shafts and the type of micro-damage within different sections of the stick; 3) evaluation of energy dissipation capacity of single shaft in quasi-static and dynamic loading conditions and 4) design and manufacturing of multiple-shaft energy dissipation substructure with the ambition of characterization of this sub-structure in terms of energy dissipation under compressive crushing.

Luleå Hockey (LHF) contributed by collecting, sorting and initial selection of the scrapped ice hockey sticks by the end-of-life. Luleå University of Technology (LTU) performed classification, identification of damage, mechanical testing, designs of multi-shaft structures for testing and analytical modelling of stick material performance. Rise (Rise) performed quasi-static crushing tests as well as contributed to the design and manufacturing of multi-shaft structures. Gestamp Hardtech (Gestamp) contributed with specialist advise on crash-absorbing structures, contributed to design aspects of the multi-shaft structure and performed crash experiments.

5. Results and discussion

5.1. Analysis of scrapped hockey-stick

A first batch of scrapped hockey-sticks, Figure 2, were collected by LHF during 2021-2022 and provided to the partners. This batch was used as reference throughout the evaluation within RESTART. A thorough initial inventory was performed and the results were summarized in a database. The database contains information on brand, model, shaft dimension, length of scrapped sections, failure location as well as information on curve, flex and lie (whenever possible to determine).

Figure 2 Scrapped hockey-sticks provided by Luleå Hockey

In the RESTART study there is a pronounced bias towards sticks originating from the brand Bauer. 97% of the scrapped sections were Bauer, 2% were CCM and 1% not possibly to identify. The underlying reason is that LHF were at the time for the collection having an agreement with Bauer.

Analysis of the length of straight shaft sections (not considering scrap from blades) gave that the 132 individual stick segments analysed had an accumulated length of 129.8 m. The entire shaft does not have a completely uniform cross-section along its entire length. When approaching the blade, the cross-section tends to deviate from rectangular becoming oval or some other irregular shape. Figure 3 illustrates some irregularly shaped cross-sections observed.

Figure 3 Photograph of broken stick section (left and middle) an cut-outs from scrapped sticks with various cross-sections (right) [1]

The accumulated length of rectangular stick segments was 93.1 m i.e., around 72% of the total. Representative samples of stick shaft cross-sections were selected and average data for rectangular sections were determined to be of heights 30.0±0.3 mm and width 19.5±0.5 mm. A comprehensive description of all results is provided in the report by Irulegi [1].

Investigations, seeking to characterise the meso- and microstructure of the fibre composite shaft walls were conducted in different studies. Various important features such as fibre volume fraction, fibre orientations, void content and occurrence of other potential defects such as ply wrinkles or gaps between fibres were analysed using methods like optical microscopy of polished cross-sections, studies on fibre residues after removal of polymer matrix as well as micro-X-ray computer tomography (μXCT) [1-3]. An example of a polished cross-section, studied by optical microscopy, is shown in Figure 2. Bright areas correspond to reinforcing fibres. Circular fibres cross-section (bright areas) indicate that cross-section is perpendicular to fibre orientation, elliptical cross-sections implies that the section is made at an angle with respect to fibres.

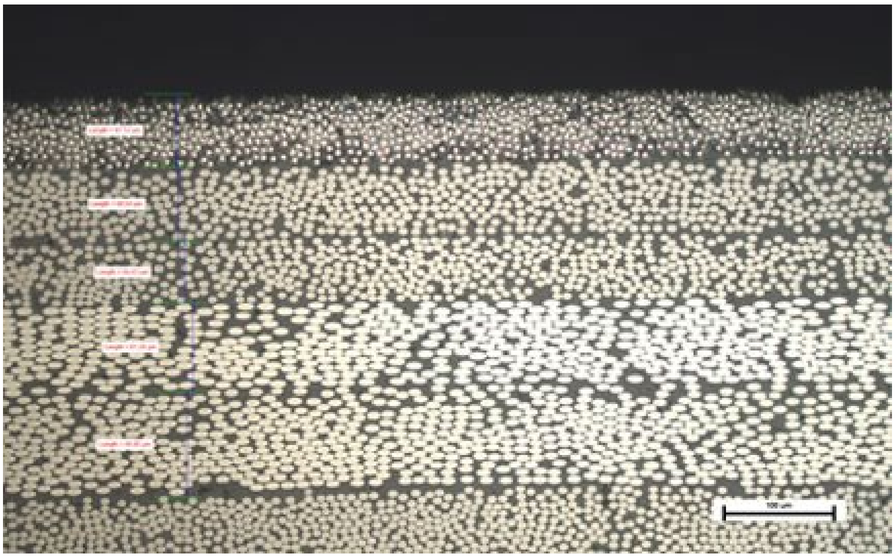


Figure 4 Optical microscopy showing six fibre reinforced layers within the composite wall of a Bauer stick shaft.

The microstructure study revealed that the overall quality of the composites is good i.e., high fibre fractions between 50 - 60% and void content is low. It also showed that a typical stick shaft wall is made up from between 15 - 30 fibre reinforced layers. The variation in layer numbers was primarily due to differences in type of fabric used i.e., whenever thin fabric layers (case of Bauer sticks) were used then number of layers approached the upper limit. When more traditional fabric layers (e.g. for CCM sticks) were used then number of layers were lower. Typically, the layers were oriented within the layered stack so that only a few are oriented with fibre in 0° or 90°-direction (with 0° being oriented along the stick shaft in the reference coordinate system). A majority of fibres are oriented in off-axis angles, in what sometimes appears to be 45° and -45°-orientation. However, in practice there are rather large variations in fibre orientation between and within different sticks. Whether this variation is intentional, and results from attempts to tailor bending vs. torsional stiffness or unintentional due to manufacturing variations remain unclear [1-3].

Variations in lay-up and fibre angle will, alongside with volume fraction and type of fibre used, have an influence on the mechanical performance of the stick wall. The actual variation between different individual sticks is demonstrated in Figure 5. Experimentally determined tensile modulus in the direction of the shaft for five different sticks (Bauer). The results are obtained be subjecting 200 mm long flat stripes/samples, taken from each stick in at least two locations, to tensile loading while tracking the relative deformation of the specimen and thereby obtaining the wall stiffness. It can be seen that while the variation within a stick remains moderate (and to largest extent can be attributed to experimental uncertainties), there is a pronounced variation between sticks. Supplementary studies on flexural stiffness (bending tests on stick segments) as well as micromechanics-based analysis of wall material structural performance were also performed [2-3].

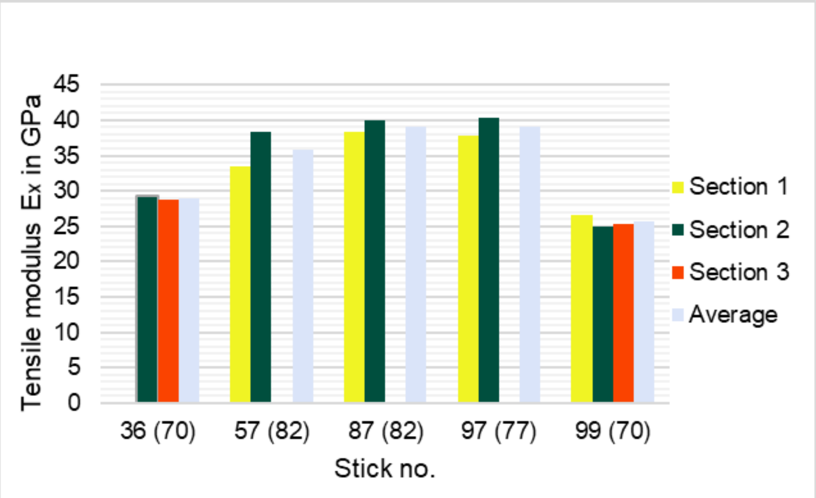


Figure 5 Results from tensile tests on test specimens extracted from shafts

5.2. Single shaft crushing tests

One of main hypothesis of the project was that sections from scrapped hockey-sticks can find new use by repurposing/reusing them in crash energy absorption applications. A natural step, to test the hypothesis was to perform tests of the energy absorption capacity of the hollow shaft sections when undergoing compressive quasi-static crushing. Quasi-static crushing implies that tests are conducted using constant loading/deformation rates that are substantially lower than the rates experienced during an actual dynamic crash event. In RESTART crash energy absorption capacity was estimated based on tests conducted at 5 mm/min on shaft segments placed between two parallel steel plates mounted on a universal testing machine, Figure 6. A 30° bevel trigger was introduced on one sample end by grinding the composite material.

Figure 6 Examples of 100 mm long shaft sections with 30° bevel trigger introduced at one end (left) and photograph of crushing test setup (right).

Upon conducting compressive crushing, curves like the ones indicated in Figure 7 were obtained when plotting the applied compressive load versus the displacement of the steel plates. Four samples obtained from one single scrapped shaft are presented in the graph and can be considered as representative for most sticks tested. Common for all tests is that there is always an initial, close to linear load increase until compressive crushing is initiated. Initiation occurs at between 15 and 25 kN for the actual stick model of concern. This indicates that the simple bevel trigger managed to initiate a stable and progressive failure for all samples. It was also seen that the crushing load remains more or less constant as the crushing distance increased during the test. During the tests, the characteristic splaying type of failure was obtained. A photograph of a sample after completed tests is displayed in Figure 7.

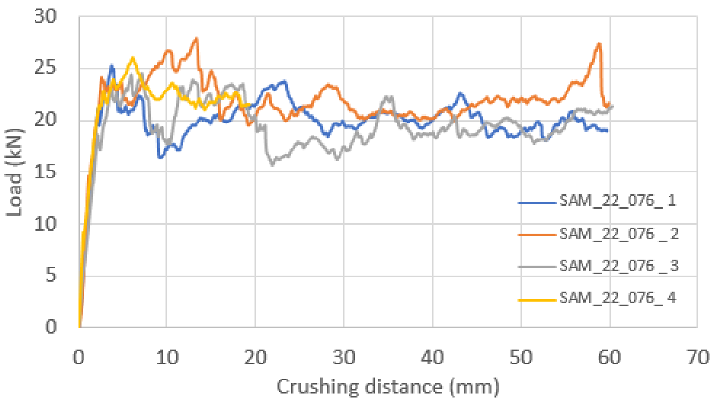


Figure 7 Results from four quasi-static crushing tests of specimens from same scrapped hockey stick shaft (left) and photograph of sample after tests (right)

The compressive crushing tests were performed over a 60 mm distance. The average crushing load and corresponding average crushing stress (by dividing load with stick shaft wall cross-sections) were registered from each test. Average loads and stresses from tests on seven different sticks are presented in Table 1. Loads vary in the range between 15.7 to 22.5 kN while stresses vary between 104 and 173 MPa. Total energy absorbed during the crushing event was determined by performing numerical integration of the area under the load vs displacement curve (Figure 7). Table 1 display SEA-values for the shafts tested. SEA values ranging from 87±4 to 112±12 kJ/kg was obtained.

Sample	**Crushing load (kN)**	**Crushing stress (MPa)t**	**SEA (kJ/kg)**
1	21.1 (±2.5)	172.8 (±19.0)	112.4 (±12.3)
2	22.5 (±1.2)	174.3 (±9.1)	112.6 (±5.9)
3	18.0 (±1.2)	139.3 (±9.4)	88.0 (±6.0)
4	17.9 (±1.1)	129.7 (±6.0)	87.0 (±4.0)
5	20.1 (±1.3)	140.9 (±9.3)	99.4 (±6.6)
6	15.7 (±2.4)	104.4 (±16.3)	70.3 (±10.9)
7	17.1 (±0.7)	145.7 (±5.3)	88.2 (±3.2)

Table 1 Summary of results from crushing tests of single shaft sections from seven different stick (data on standard deviation in brackets)

By comparing SEA-values in Table 1 with values in Figure 8 one notice that the energy absorption of the tested hockey stick shafts are on par with the highest literature values reported for carbon/epoxy composites and higher than corresponding structures from steel or aluminium [4]. The potential to use shaft sections as energy absorbers hence was verified, with a clear margin.

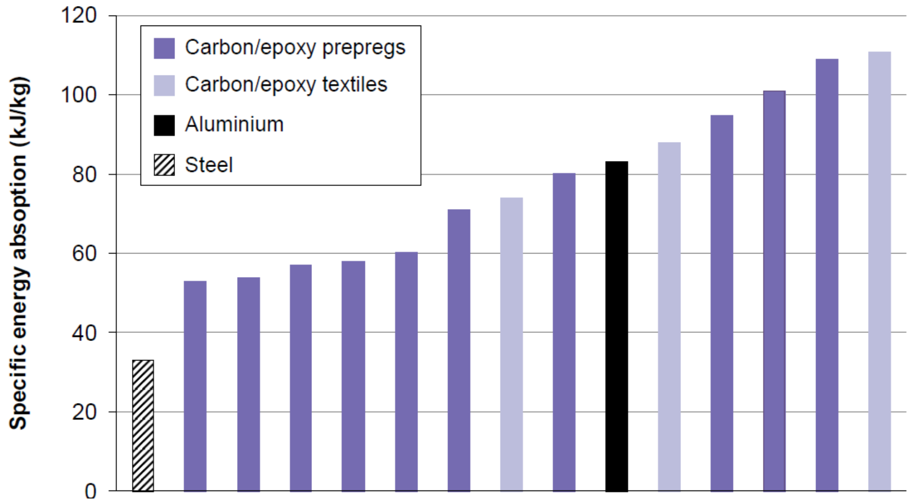


Figure 8 Comparison of the SEA of literature values of carbon/epoxy composite crash structures and metallic crash structures as presented in the licentiate thesis of Bru [5]. Full references are provided in the thesis.

5.3. Multi-shaft crushing tests

While the initial quasi-static experiments on single shaft sections exhibited very high energy absorption it remained unknown as to whether shafts can be positioned parallel next to each other and maintain their favourable behaviour. Tests on eight multi-shaft samples were therefore also performed.

These samples were prepared by taking 350 mm long sections from randomly selected sticks. A 30° bevel trigger on one end was prepared for each section. A laboratory fixture - consisting of 3D-printed guides that were used to position six parallel shaft section so that they could be fixated in a circular PVC-base by use of polyurethane foam - was used for the preparation of multi-shaft test samples. A photograph of the samples under preparation is shown in Figure 9.

Figure 9 Items used for preparation of multi-shaft test specimens (left) end illustrating shaft sections (middle) and prepared sample before cutting base (left)

The multi-shaft samples were tested by Rise in quasi-static crushing tests. For one the samples, an Instron 250kN testing machine was used whereas the rest of the sample was tested and equipment called “Rörpressen 1000kN”, see Figure 10.

Figure 10 Photographs of test setups for crushing tests of multi-shaft sections: In the Instron 250 kN testing machine (left) and in the machine” Rörpressen” (right).

Results from the tests are presented in Figure 11. A similar load vs- displacement performance is observed i.e., a rather linear increase to start with, followed by a to-various degree constant load during the subsequent crushing. Naturally the maximum load is higher compared to single shafts. The maximum load was around 5 to 8 times higher compared to single shafts. From this point of view our study was non-conclusive; having parallel shaft section may either have a beneficial (when maximum load is more than 6 times higher) or adverse (maximum load less than six times higher) effect. Moreover, compared to single shaft specimens a substantially larger variation between specimens and at various distances with a specimen was noticed. The variations could be traced to varied level of bending - excessive bending of the stick could be observed during some tests - between different samples as well as failure away from triggered-stick end in some cases.

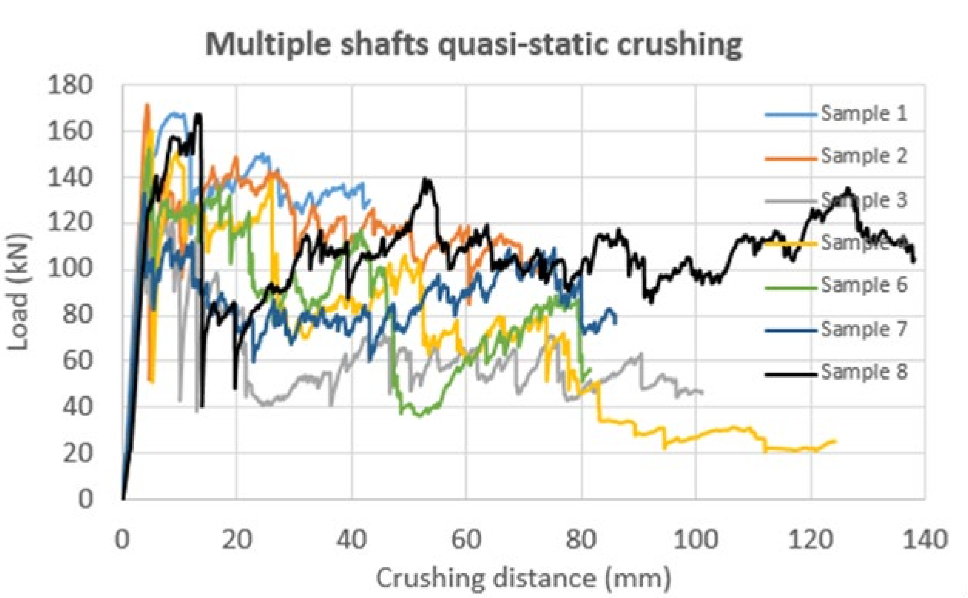


Figure 11 Results from compressive crushing of multi-stick samples

5.4. Simple multi-shaft crash box demo

Encouraged by the relative success with single and multi-shaft crushing test the project also prepared a number (eight) of simplified crash box prototype/demo component with features relevant to automotive crash box structures. The final appearance of the prototypes is shown in Figure 12. Protytpes were prepared by aligning and mounting six parallel stick-shaft sections (similar to procedure displayed in Figure 9) in a carbon fibre SMC composite base-plate designed to fit on a load carrying automotive structure. The base-structure was prepared and developed by Gestamp Hardtech in other projects. Once sticks were mounted, the array of sticks was over-wrapped by carbon fibre prepregs that was consolidated and cured.

Overwrapping with carbon fibres was intended to prevent bending and outward splaying sometimes observed for multi-shaft crushing tests.

Figure 12 Photograph of crash box demo-component

5.5. Crash tests of crash box demo

On June 22, 2023 some initial crash test experiments were planned at Gestamp Hardtech, Luleå. Two crash boxes of the type illustrated in Figure 12 were mounted on an instrumented frontal beam structure of a rolling sledge in the crash testing facilities of the company. While the initial ambition was to conduct testing of some of the structures the initial testing revealed some shortcomings with the demo design that prevented a full test series. Unfortunately, it was not possible to upgrade and verify the new design to conclude the test program of the crash box demo within the time- or economical frame of the current pre-study.

6. Conclusions, benefits and next steps

The results from the pre-study clearly demonstrate that the technical potential for reusing hockey stick segments in light weight crash-absorbing application is high. It was conlcluded that large part of the scrapped stick segments (around 75% if only rectangular sections are considered) could be reused and the general quality of the scrapped segments are high. The results from crushing tests of single shaft elements showed that Specific Energy Absorption (SEA) is very high, on par with the best composites structures and better than metal structures. It was also concluded that mounting parallel shafts is an effective way and practically feasible to enhance absorption capacity. Designing and building reliable crash boxes from shaft segments is possible but the pre-study results revealed that further efforts to mature technology will be required in the area.

It is anticipated that the results generated in the prestudy will pave the way for new developments where energy absorbing structures are developed. Whether these structures are to be found in high volume serial production of cars can be questioned, not because of the technical merits of the concept but due to potential uncertainties with supply. Communications with stick manufacturers during the prestudy have confirmed that an annual production rate of sticks is in the order a few million (2 – 3) sticks per year. Assuming that the amount of scrapped sticks is in the same order of magnitude as the produced, it means that the amount of recycled sticks will not be sufficient to feed the car industry as a whole, barely enough to feed a single car model (produced in several 100 000 units per year). Potential application areas are instead more likely to be found in other industrial areas.

Next step to exploit findings of the prestudy involves to verify the technical performance also for dynamic loading scenarios, identifying new end-use case scenarios, develop the understanding of property variations of sticks including a more comprehensive understanding on the expected amount of damage accumulated post-use and to establish guidelines and predictive tools that will enable design of robust multi-shaft energy absorbing structure.

7. List of reports and publications

Conference publications:

Fernberg P, Bru T, Joffe R. *Scrapped composite ice-hockey stick shafts for reuse in crash energy absorbers*. 23d International Conference on Composite Materials (ICCM23), July 30 -Aug 4, Belfast, UK

Internal project reports:

Aitana Beata Irulegi. *Characaterizatioin of composites in sport application after service.* LTU project report, June 7, 2022

Ethan Segura Estévez, *Biobased-environmentally benign products for outdoor leisure and sport*. LTU project report, January 16, 2023

Vanessa Haschel, *Utilization of sport equipment composites after their service life*, June 8, 2023

8. Project communications

The project and its objectives were initially communicated towards a broader public via a press-release [6] and via information on homepages. The press-release was received well by the general public. Many news journals, TV and radio contacts were made. Examples include: radio interview in P4 Norrbotten, radio-interview in P3& P4 Vaken, a report on SVT news and interview for the VI (magazine). Additionally, the press-release was also cited/published in many newspapers. The following pages contains a selection of screen-shots from media that have published news related to RESTART.

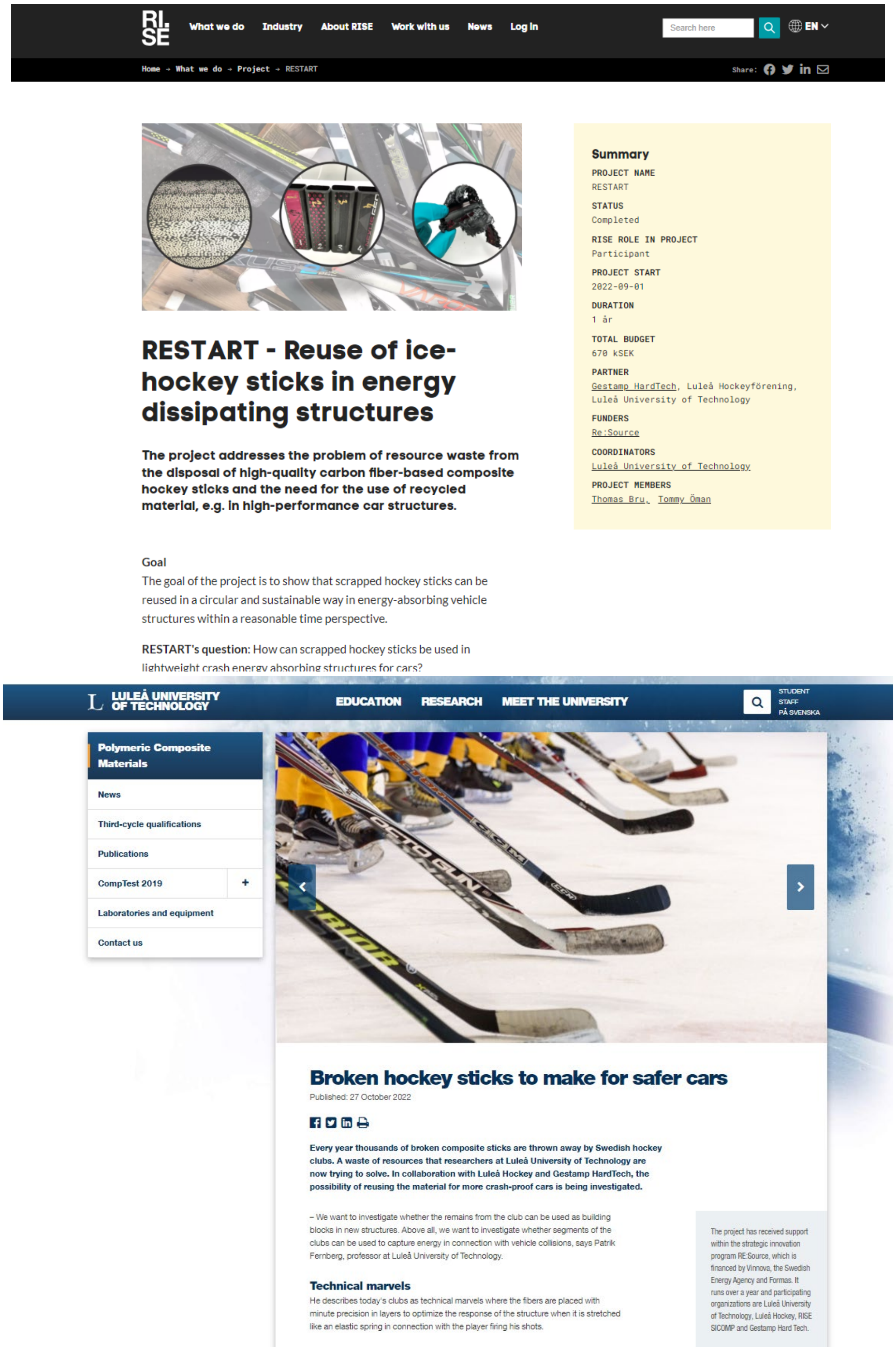
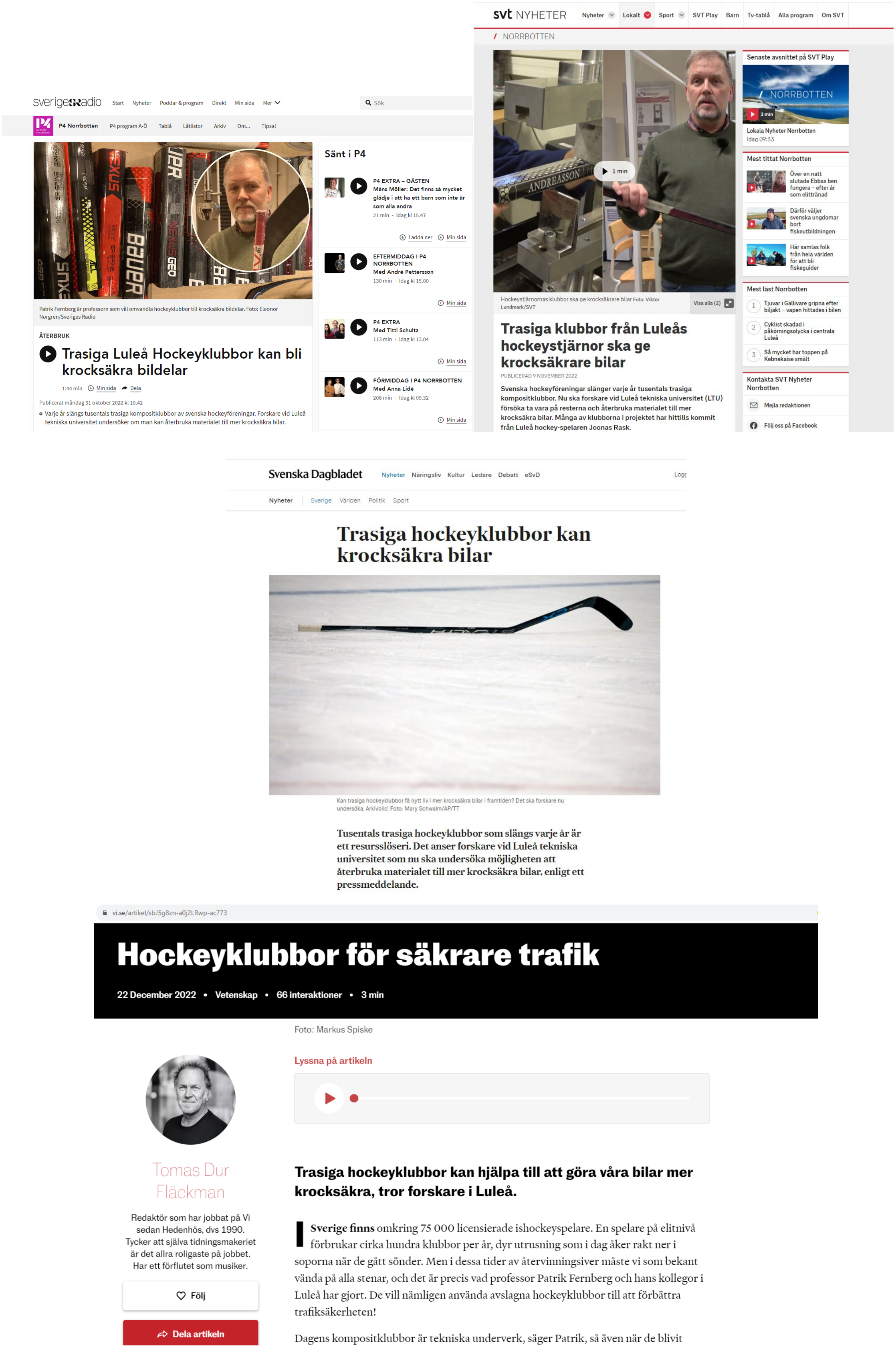


Figure 13 Examples of web-pages (LTU and Rise) displaying and mentioning RESTART.



Trasiga Luleå Hockeyklubbor kan bli krocksäkra bildelar

Trasiga klubbor från Luleås hockeystjärnor ska ge krocksäkrare bilar

Svenska hockeyföreningar slänger varje år tusentals trasiga kompositklubbor. Nu ska forskare vid Luleå tekniska universitet (LTU) försöka ta vara på resterna och återbruka materialet till mer krocksäkra bilar. Många av klubborna i projektet har hittills kommit från Luleå hockey-spelaren Joonas Rask.

Svenska Dagbladet

Trasiga hockeyklubbor kan krocksäkra bilar

Tusentals trasiga hockeyklubbor som slängs varje år är ett resursslöseri. Det anser forskare vid Luleå tekniska universitet som nu ska undersöka möjligheten att återbruka materialet till mer krocksäkra bilar, enligt ett pressmeddelande.

Hockeyklubbor för säkrare trafik

22 December 2022 • Vetenskap • 66 interaktioner • 3 min

Foto: Markus Spiske

Tomas Dur Fläckman

Redaktör som har jobbat på Vi sedan Hedenhös, dvs 1990. Tycker att själva tidningsmakeriet är det allra roligaste på jobbet. Har ett förflutet som musiker.

Trasiga hockeyklubbor kan hjälpa till att göra våra bilar mer krocksäkra, tror forskare i Luleå.

Sverige finns omkring 75 000 licensierade ishockeyspelare. En spelare på elitnivå förbrukar cirka hundra klubbor per år, dyr utrustning som i dag åker rakt ner i soporna när de gått sönder. Men i dessa tider av återvinningsiver måste vi som bekant vända på alla stenar, och det är precis vad professor Patrik Fernberg och hans kollegor i Luleå har gjort. De vill nämligen använda avslagna hockeyklubbor till att förbättra trafiksäkerheten!

Dagens kompositklubbor är tekniska underverk, säger Patrik, så även när de blivit

Figure 14 Examples of articles (Sveriges Radio, SVT, SvenskaDagbladet and VI) mentioning the RESTART-project.

9. References

1. Aitana Beata Irulegi. *Characaterizatioin of composites in sport application after service.* LTU project report, June 7, 2022

2. Ethan Segura Estévez, *Biobased-environmentally benign products for outdoor leisure and sport*. LTU project report, January 16, 2023

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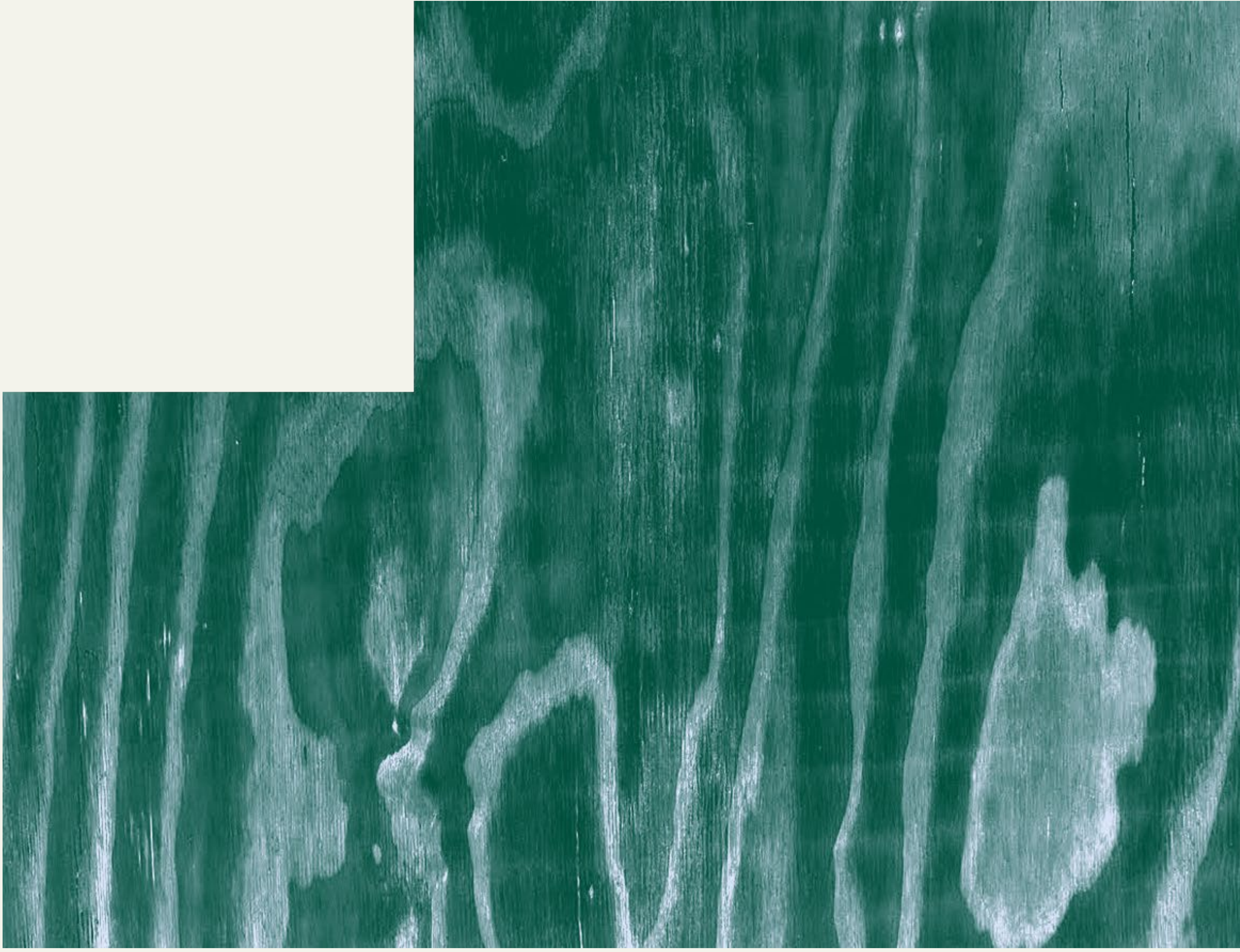

RE:Source är ett strategiskt innovationsprogram som fokuserar på att utveckla cirkulära, resurseffektiva materialflöden. Vårt mål är att uppnå en hållbar materialanvändning där vi håller oss inom planetens gränser.