# MECHANICAL RECYCLING OF TEXTILE WASTE

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**Abstract:** *During mechanical recycling several mechanical treatments are used to degrade textile waste and make it ready for new application in different other industries. Mechanical recycling process consists of several work steps. Pre or post-consumer textile waste is firstly cut in small pieces by a shredding machine. Blending boxes with different storage capacities are used to blend cut textile waste. A feeding unit is placed in between a blending box and a tearing machine. Tearing machines separate individual fibers by tearing small pieces of shredded textile material apart. At the end of the textile recycling process the opened fibers are compressed in needed size bundles to store and transport for their further use. Insufficiently sorted waste is the most serious problem that complicates mechanical recycling processes, reduces the quality of recycled fibers. Currently there are not available efficient methods to recycle coated, laminated textiles and materials with elastan. Compared with other recycling methods the mechanical recycling of textile waste has already decades of experience, it is the most developed, most widely used, requires much lower investments and energy resources.*

**Keywords:** textile waste, mechanical recycling, waste shredding, tearing machine.

# MEHANIČKA RECIKLAŽA TEKSTILNOG OTPADA

**Apstrakt:** *U toku mehaničke reciklaže se izvodi nekoliko postupaka da bi se tekstilni otpad degradirao i spremio za primenu u drugim industrijama. Mehanička reciklaža sastoji od nekoliko radnih koraka. Prvo, tekstilni odpad se seče na sitne komadiće. Tako usitnjen tekstilni otpad se meša u kontejnerima velike zapremine. Sistemi dostave se koriste za prenos i pripremu sečenog tekstilnog otpada za proces cepanja. Mašine za cepanje odvajaju pojedinačna vlakna iz iseckanog tekstilnog otpada. Na kraju posebno odvojena vlakna se presuju u bale uz pomoć specijalnih presa. Nedovoljno sortirani otpad je najozbiljniji problem koji otežava procese mehaničke reciklaže i smanjuje kvalitet recikliranih vlakana. Trenutno ne postoje efikasne metode za reciklažu laminiranog tekstila i materijala sa elastanom. U poređenju sa drugim metodama reciklaže, kod mehaničke reciklaže tekstilnog otpada postoji već višedecenijsko iskustvo, najrazvijenija je, najčešće korišćena, zahteva mnogo manja ulaganja i energetske resurse.*

**Ključne reči:** tekstilni otpad, mehanička reciklaža, sečenje otpada, mašina za cepanje.

## 1. INTRODUCTION

Generally, recycling of textile waste can be divided into two main groups: mechanical and chemical. There are several sub-groups that combine two main ones or additional recycling principles and methods: thermal, thermo-mechanical, thermo-chemical [1,2,3]. During mechanical recycling several mechanical treatments are used to degrade textile waste and make it ready for new application in different other industries. Mechanical treatment methods ensure so called *down cycling* of textile products, as the end product of the process- recycled fibers - have lower quality (shorter, have lower strength) than virgin fibers [4]. This recycling method retains the content and colour of the original material. The mechanically recycled fibers are used to create non-wovens for thermo, sound and vibration isolation in auto, furniture and other industries. They can also be used in composite materials to reduce the content of virgin other origin components [1,2,3,4,5].

Chemical recycling depolymerizes synthetic origin textile waste (polyester) or dissolve cellulose based waste (cotton, viscose). Chemical recycling can use *fiber-to-fiber* (F2F) technologies to ensure *up*

*cycling* of textile waste. Chemically recycled textile waste can be used again to produce fibers and yarn for similar quality textile products [6].

## 2. MECHANICAL RECYCLING PRINCIPLE

Mechanical recycling can be used for all origin pre and post-consumer textile waste. However, the type of fiber and structure of the processed material (knitted, woven, yarn twist, weave type) determine the selection of the optimal machinery and quality of the recycled fibers [1]. Currently mechanical textile recycling has the most developed technologies and application. Mechanical recycling process consists of several work steps [1,2,6]:

1. shredding of textile waste,
2. separation of hard waste,
3. blending of shredded textile waste,
4. preparation and delivery of shredded textile waste to tearing machines,
5. tearing of shredded textile waste,
6. final pressing of processed recycled fibers.

Machinery for mechanical recycling of textile waste is manufactured by companies: Andritz (Austria), Treutzschler (Germany), Pierret (Belgium), Lidem (Spain), Margasa (Spain), Dellorco & Villani (Italy), Eldan (Denmark), Balkan (Turkey), Dawn Machinery Technology (China), Gaomi (India), others.

### 2.1. Shredding of textile waste

The shredding is the first step in the mechanical recycling process. Pre or post-consumer textile waste is firstly shredded in small pieces. The material can be cut in 15-60 $cm^2$ pieces. The size of the shredded waste determines the length and quality of recycled fibers - from larger cut pieces longer fibers can be obtained [1,7].

The textile waste is placed on an input conveyer of the shredding machine, compressed by the help of pressing cylinders and delivered to its steel roll assembly [8]. Textile waste is shredded utilizing scissor effect by one or two guillotine type or rotary cutters of a shredding machine. The guillotine type shredder cuts the waste by one oscillating and one fixed knife. The second knife is positioned perpendicularly to the first one to ensure smaller and more uniform size to the cut textile pieces [9,10]. The shredding machines use metal detectors (in front of the 1st knife) to stop the work process if a hard metal object is found. They can also be equipped with a knife sharpener and a de-dusting system [7,9,10].

**Figure 1:** Rotors with knives of the double rotor fine shredder of GSD series by company Gep Ecotech

In case of rotary cutters the machines use one or two rotors with a large number of knives fixed on them (see Fig. 1). The waste is delivered into the shredding area and getting in contact with rotating knives is cut in small pieces [12] .

### 2.2. Separation of hard waste

After shredding of the waste, cut pieces of textile can be processed by a machinery (*cleaning drum, beater*) that separates heavy and non textile parts - parts of leathers labels, cut parts of buttons and zippers and other accessories, as well as, uncut larger textile pieces. Non-textile origin cut pieces have to be avoided as later they can negatively influence fiber opening process. The hard pieces can even damage the mechanisms of the recycling machinery [1]. The cleaning machine uses a perforated drum in which the pieces of cut textile waste is rotated. By help of centrifugal force and magnets unwanted pieces falls out through the holes of a drum. Metallic origin pieces can be separated by magnets, while other ones - by centrifugal forces [1].

### 2.3. Blending of shredded textile waste

After the textile waste is shredded it has to be uniformly mixed. A wide variety of blending boxes

**Figure 2:** Shredded textile waste blendidng boxes by company Margasa

with different storage capacities are used to blend and store cut textile waste before next recycling steps (see Fig.2). In professional literature such equipment is named differently: *blending and storage boxes, box-rooms, blending boxes, blending rooms* [7,9,10,12]

## 2.4. Preparation and delivery of shredded textile waste to tearing machines

A machinery called a *feeding unit* is placed in between a blending box and a tearing machine to deliver the cut textile waste to the mechanisms that will separate small textile pieces in fibers. By help of vibration the pieces of textile are uniformly spread on the belt of a delivery conveyor which moves the waste to the main mechanisms of a tearing machine.

## 2.5. Tearing of shredded textile waste

Tearing machines separate individual fibers by tearing small pieces of shredded textile material apart. Usually they have a modular system with one to seven sections (up to 9) - drums or cylinders covered with steel pins or saw wires (see Fig.3). The shredded textile pieces pass through sequential drums with more and finer pins or saw wires in every section. As a result, separate fiber tufts and individual fibers are opened and impurities are taken away (see Fig.4). Rotation speed of drums and shredded textile material transportation speed is adjusted to the qualities of the textile waste and demands for recycled fiber properties [5,9,13].

The tearing as an aggressive mechanical action causes reduction of the length and strength of recycled fibers. The degradation level of the obtained fibers depends on:

- size of shredded textile pieces - from larger pieces longer fibers can be separated, however, their opening process is more difficult and can negatively influence fiber quality,
- origin of the processed materials - different origin textiles (natural or synthetic) react differently to the tearing process,

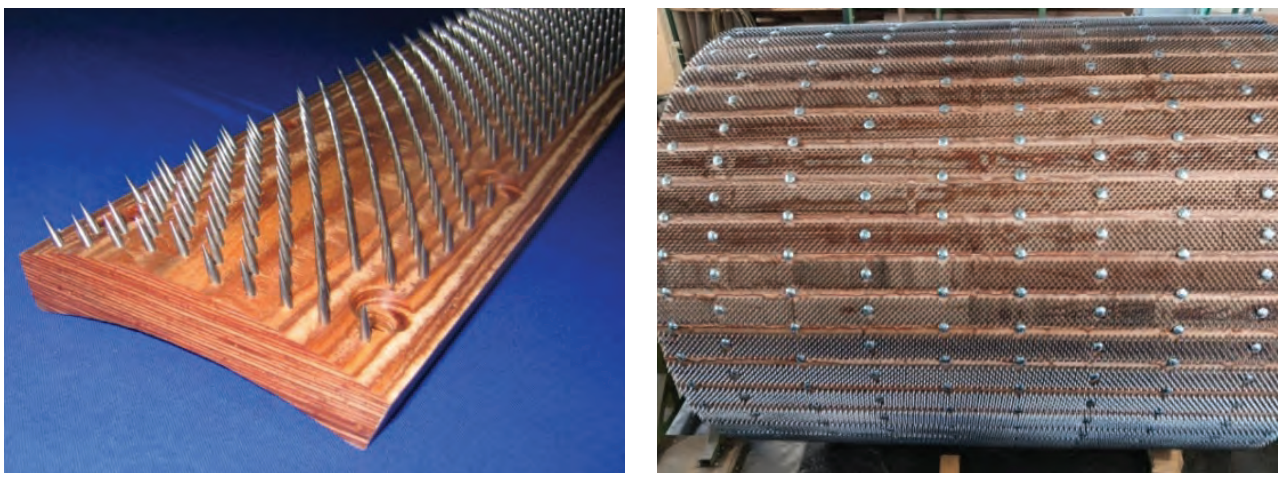

**Figure 3:** Drums with needles to open textile fibers

a b

**Figure 4:** Shredded denim textile waste (a) and fiber tufts after tearing process (b)

- structure of the textile waste - knitted and loosely woven waste can be opened easier obtaining higher quality and longer recycled fibers [1].

It is estimated that only 25-50% of recycled fibers are longer than 10mm. They are not usable for re-spinning into yarn and 80-90% of them are later processed into non-wovens [1].

## 2.6. Final pressing of processed recycled fibers

At the end of the textile recycling process the opened fibers are compressed by a *baler*/*baling press* in needed size bundles to store and transport for their further use.

## 2.7. Dust collection and filtration

During all steps of the recycling process large amounts of dust and other impurities are released in the ambient air. To avoid contamination of the machinery and health problems to its operators, dust collectors capture dust at every recycling machine and transfer it to a centralized filtration system.

## 3. CHALLENGES OF THE MECHANICAL RECYCLING PROCESS

Insufficiently sorted waste is the most serious problem that complicates recycling processes, reduces the quality of recycled fibers, as well as limits their further use [1]. Although very promising automated sorting systems have already been invented, the most part of textile waste is still sorted manually [14,15]. This process is very much time consuming and cannot ensure qualitative reorganization of fiber origin. As a result, textile waste of unknown composition and different fiber blends generates down-recycled fibers that can only be used for processing lower quality textile goods, non-wovens, composites and filling materials [1,2,15,16].

Different origin textile waste reacts differently to mechanical treatments. The natural fibers are more damaged than synthetic one during the recycling process. This problem complicates recycling of blended materials [17].

Currently there are not available efficient methods to recycle coated and laminated textile materials. The coating keeps the structure of the material fixed and does not allow the release of mechanically separate threads and fibers. Similarly, the recycling of textile blends with elastane is also very challenging. Performing mechanical recycling the textile material with elastan is stretching and with it complicates shredding and tearing of the waste [1,15].

## 4. CONCLUSIONS

Compared with other recycling methods the mechanical recycling of textile waste has already decades of experience, it is currently the most developed, most widely used, requires much lower investments and energy resources. The main recycling processes are not utilizing water and chemicals, all recycled fibers preserve their origin. However, above mentioned difficulties and challenges complicate the work process and reduce the quality of recycled fibers. The standard mechanical recycling technologies can ensure only down-recycling of the textile materials. Future developments of mechanical recycling will focus on improvement of machinery and new technologies to preserve quality of recycled fibers close to virgin fibres [7,18,19,20].

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