

Recycling of Powders from Cutting of Medium Density Fiberboard

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Abstract. Medium density fiberboard (MDF) is a wood-based engineered material, largely implemented in the manufacturing of in-house structures. Large panels are usually manufactured and shaped via machining; in this way powders are produced. Dismissed structures can also be pulverized to facilitate transportation of waste. MDF is generally dismissed through landfill or incineration. The aim of this work is to determine a recycling method for MDF powders that make it possible to obtain ready-to-use panels without using virgin or additional materials. Powders granulometry is evaluated and then grains are "direct molded" by a parallel plate hot press. Compression molding was used for this aim. Recycled panels had the size of 200x200 mm², a thickness of 5 mm, and a smooth surface without evident defects. Burrs were absent. Mechanical properties were evaluated under bending test, and a maximum strength over 8 MPa was found. Results show the feasibility of this recycling technology for MDF powders. Agglomeration occurred thanks to the powder re-activation, and possible residual reactivity.

Introduction

Generally, life cycle of every-day objects has a linear evolution: resources are extracted and processed, products are manufactured, used and then dismissed in landfills or incinerated. Linear economy is not long-time sustainable as it does not take into the account important environmental and social impacts of the full product life, and some natural resources are considered to be timeless. Nowadays, it is evident that this approach is not suitable anymore, and a transition toward a circular economy is continuously stimulated also for difficult-to-recycle products.

In the last year, circular economy has become the focus of researching activities in numerous fields; that is because climate changes as well as natural resource consumption have driven the public attention toward environmental issues related to people life style and industrial processes. The most industrialized countries around the world are subscribing accords to reduce humans impact and to preserve the Earth. Some countries are working to drive the citizens toward a more sustainable life style that allows to preserve the environment for future generations.

One of the most important circular economy tools is recycling. Dismissed product can be re-used, re-manufactured or repaired in such a way to decrease the amount of waste, to save energy, and to preserve natural resource consumption. Green practices are promoted not only on a social level but also on industrial scenarios. Almost all industrial fields are moving toward more green procedures aiming for safer processes for employers, people, and environment. Toxic substances for and from industrial processes are reduced, and new recycling technologies and strategies for end-of-life products and production residues are assessed.

In this very dynamic scenario, the case study of this work seems to be very appropriate as it combines natural resource consumption, synthetic substances, and mass production. The starting point of the manufacturing chain is wood, which theoretically matches all the principles of circular economy. By itself, it is natural, bio-degradable, inexpensive and its production has a much lower environmental impact if compared to many other synthetic materials. For this reason, from the early

2000s the use of wood has recorded a considerable growth [1]. However, wood may be used as raw material for the production of secondary materials which do not share the same environmental quality. The best example is the medium density fiberboard (MDF) which is one of the most famous and used wood-based materials. MDF is an engineered material obtained by the grinding several types of wood, and mixing particles with wax and resins to produce panels through the combination of pressure and heat. Depending on the amount of hardwood and softwood used in the fabrication of MDF, properties can be tailored for specific designs. MDF is mainly used to produce in-house objects, such as furniture.

Nowadays, MDF is still under investigation mainly to improve the manufacturing process. In particular, cutting operations have been assessed to determine the wear behavior of the abrasive belts, and how it affects the material properties [2]. It was found out that 3 phases can be identified in the belt life cycle, and that fracture and abrasion are predominant in belt wear. Being used mainly in furniture, MDF behavior under air blasting has been studied to evaluate potential risks when building explosion occurs [3]. When MDF panels are blast-loaded, several cracks appear on the surface of the material, and also fragmentation failures can be observed. Consequently, the overall stiffness of the panels is reduced. MDF durability has been investigated, as well [4]. Toughness increases with temperature up to 80 °C. If the temperature still raises the toughness decreases. Oriented strand board exhibits the same behavior than particleboard, which is manufactured with a different resin.

Since high volumes of MDF are currently implemented in the manufacturing of furniture, and there is a continuous growth in its use, a great attention should be paid on MDF end-of-life. Wood is a natural and bio-degradable material, but MDF contains also resins and wax that make recycling much more complicated. Actually, chemical bonds are formed between wood fibers, wax and resin during MDF consolidation. Moreover, additional substances can be added to give extra properties to the final composite, such as barrier to moisture absorbance or fire retardancy.

Steam has been used to recover wood fibers. In particular, resin hydrolyzation occurs, and an hemicellulose-rich compound is extracted to be used in bio-refinery processes. In quantitative terms, a 70% fibre 30% carbohydrate compound has been already obtained by steam refining [5]. Steam treatment effects on the MDF fibers have also been studied [6]. In presence of high hardwood content, an increase in the steam treatment severity leads to a strength gain. On the other hand, a high softwood content in the MDF does not lead to any change in the fiber morphology whatever is the severity of the steam treatment.

The aim of current work is to discuss a technological alternative to close the MDF life-cycle in sustainable way. MDF powder, originating from panel sawing, has been collected and re-manufactured into new plates that can be used for structural applications without any further manufacturing process, according to the approach of Fig. 1.

Powders are originated almost from all the existing manufacturing processes, comprising MDF. Pulverization can also be carried out for dismissed structures to reduce their volume and, consequently, the transportation costs of waste. For recycling, by following a new approach, thermoset and other organic-base cross-linked powders can be agglomerated in absence of any additional binder or linking agent if sufficient residual reactivity is present, or a good secondary reactivity is promoted into those particles.

In the case of powder re-activation, the average diameter of ground particles has a fundamental role in powder re-processing because the smaller particles have higher contact surface and, consequently, reactivity [7].

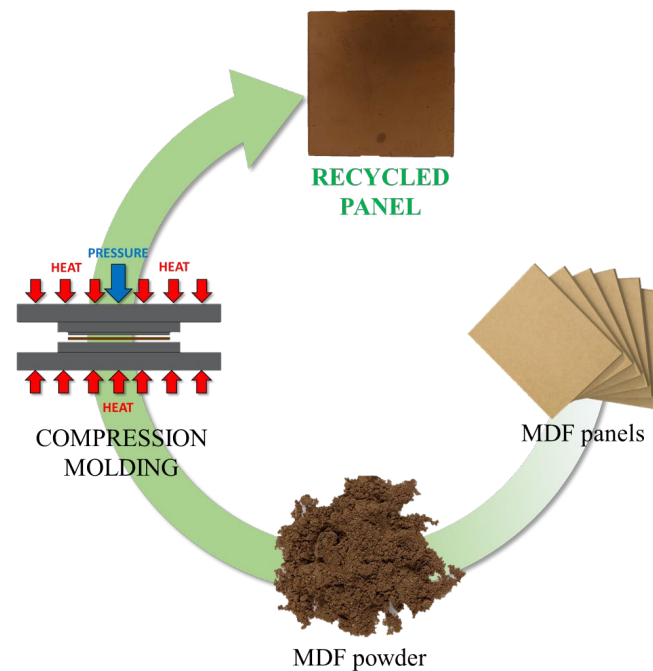


Figure 1 MDF powder recycling through direct moulding

Powders may have different size distributions depending on the manufacturing or pulverization process from which they are produced. The example of MDF is still meaningful as MDF sawing can be performed by numerous technologies and tools such as circular saw and CNC machines.

In this study, “direct molding” of powders from MDF machining is studied. Direct molding refers to compression molding of powder as is. In the current case, a hot parallel plate press was used to achieve the powder consolidation, and a good surface finishing. Burrs are not formed during consolidation, and so almost finished products are fabricated in one step. Painting can be performed on the recycled panels to improve their aesthetics.

Materials and Methods

Sawing is a typical secondary working for MDF panels, since it allows achieving good dimensional tolerances as well as a fast processing time. Main issues are related to powder production and management, being critical both in terms of safety, health and environmental impact. As powder production may be reduced in size but not eliminated, it is necessary to define a recycling strategy to reduce their environmental impact.

Powders originated by sawing of MDF panels have been collected from Arken S.p.A. (Italy), a top-quality furniture manufacturer. At first, powders have been analyzed to evaluate their granulometry by using a stereo-microscope (Leica S9i). This preliminary analysis is important to assess the process re-processability. In such cases, additional pulverization process could be required to achieve required homogeneity in grain size or shape.

MDF powders have been re-processed through direct moulding which is a hot compression moulding process in absence of virgin materials. Powders have been positioned in a closed mould and a hydraulic press with heated plates has been used. In the current experimentation, moulding has been carried out at 250 °C, at the pressure of 12 MPa, and for a holding time of 30 min. The long moulding time depended on the need of filling the mould at room temperature due to the adopted laboratory practice, therefore most of that time was spent for mould pre-heating from room temperature. The recycled plates were moulded into an aluminium mould with a cavity size of 200x200 mm². After moulding, surface finishing and agglomeration of recycled plate have been evaluated with the stereo microscope. In the end, their mechanical properties were tested under bending. Rectangular samples with a section of 100x20 mm² were extracted from one recycled

plate, and tested up to break: 3-point bending tests were performed by a universal material testing machine (MTS Insight 5) with a span of 80 mm at the rate of 1 mm/min.

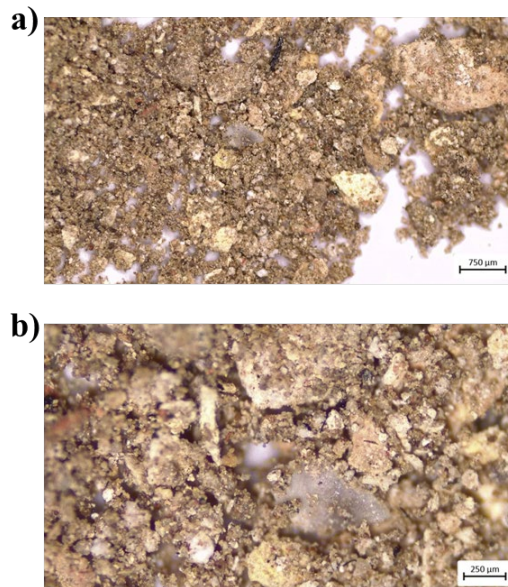


Figure 2 MDF powder

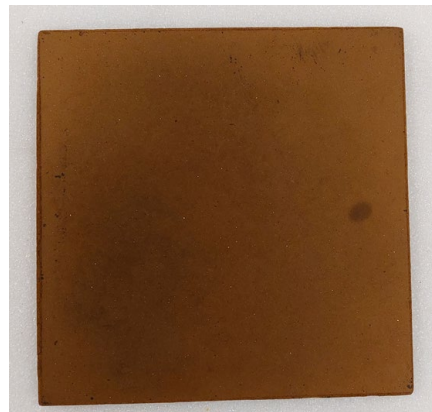


Figure 3 Recycled panel



Figure 4 Detail of the recycled panel surface

Results

Results from stereo microscope are reported in Fig. 2 at different magnifications. From these acquired images, the grain average diameter was estimated. The powders are characterised by few big particles (up to 1 mm) and aggregates of small particles into a sea of homogeneous small grains. Most of the particles have comparable dimensions and consequently no further pulverization

processes is needed. The average diameter of the small-size grains is about 110 μm . A prototype of the MDF recycled panel is shown in Fig. 3.

It is rigid, and it does not show any distortion or warpage. The surface analysis by the stereo microscope shows a uniform and smooth surface with very small asperities (Fig. 4). The achieved level of compaction is qualitatively appreciable. No burrs are formed during consolidation and, consequently, trimming is not necessary. A uniform thickness of 5 mm has been reached, therefore the moulding parameters and procedure can be considered valid for the expected preliminary goals.

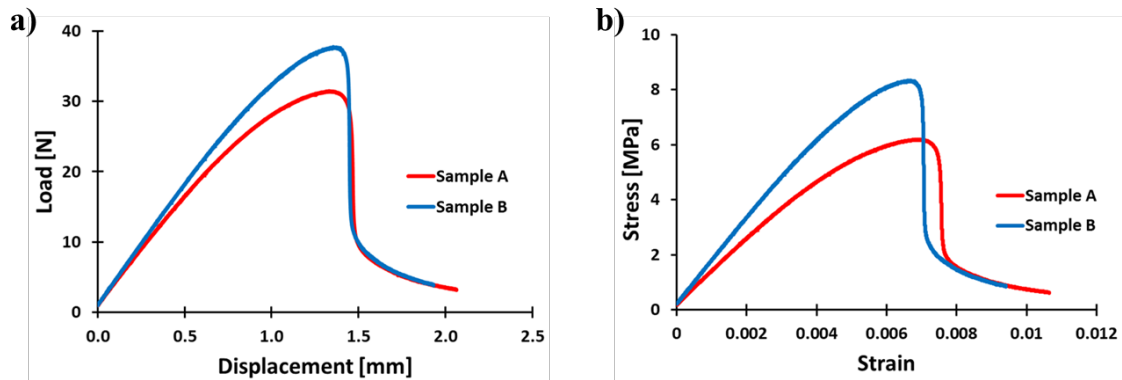


Figure 5 Bending test curves

Results in terms of load-displacement and stress-strain curves are reported in Fig. 5 for 2 different samples. These curves exhibit a brittle behaviour which is typical for aggregated materials. This behaviour is amplified by the rigidity of thermoset powders as well as data scattering. From a quantitative point of view, the maximum bending strength of 8.34 MPa was measured on the sample with an elastic modulus of 1.55 GPa.

Discussion

MDF is particularly suitable for mass production because of its mechanical properties and its low cost. Since it rapidly degrades in humid environments, its main use is limited to the manufacturing of in-house structures. MDF can be produced by using various types of woods thus tailoring the properties of the panels to satisfy any design requirement. Usually, it is manufactured in large panels to be sawed or shaped by machining, and after joined to fabricate furniture. Panel joining is a critical phase not only for the performances during the product life, but also for its end-of-life. Panels can be joined both mechanically and chemically: in the first case mechanical fasteners such as nails and screws are used whereas chemical joining occurs thanks to specific glues or adhesives. Mechanical fasteners can be easily removed from end-of-life furniture, but this operation can require a lot of time in the case of many elements to remove so that the process would not be sustainable. On the other hand, glues are extremely difficult to remove and thus they have to be considered as a contamination of the material to recycle.

Another important aspect is related to paints used for lacquering or coating. Since a very thin layer is deposited on the MDF surface, it cannot be separated from the panel and thus it has to be recycled with the whole structure. In the end, the MDF to be recycled contains many impurities of various nature that may affect the quality of the recycling process. Unfortunately, designing specific procedures to increase the purity of the waste MDF is not a sustainable solution because of the high costs. Instead, direct moulding technology is not affected by this kind of contamination and, in opposite, could take advantage for a higher residual reactivity.

In order to decrease the transportation costs due to dismissal of furniture, it can be economically convenient to pulverize the material in such a way to move more material in one time. Also cutting and sawing produces lots of powders that currently are dismissed via landfill or incineration, and, instead, could be recycled by direct moulding.

Recycling MDF powders is a primary target to reduce the related environmental imprint. Direct moulding make it possible to recover powders by taking advantage from powders themselves, in particular from their reactivity. Smaller grains lead to higher reactivity. For this reason, having a small-size granulometry is very important to guarantee the quality of the recycling panels. High reactivity ensures that consolidation takes place without the addition of any extra material. In the case of proper powder reactivity, compression moulding is able to manufacture MDF recycled plates that have good mechanical properties and good surface finishing. These plates are ready to be used and no further processes are need. Painting can be performed on the recycled panels if specific colours are needed. The easiness of the technology is a great advantage for its transfer into the industrial context, since commercial machines can be used and no specific designs are required. In laboratory, a rigid panel has been obtained with a bending strength higher than 8 MPa by using sawing powder as is. This is an evidence of the process feasibility. No powder treatment or sorting was necessary before moulding.

Conclusions

The aim of this work is to show the feasibility of an innovative recycling technology for waste MDF. In direct moulding, MDF particles undergo compression moulding, without any previous treatment or process to manufacture panels with good mechanical properties. Additional materials are not necessary to favour consolidation and agglomeration. The recycled panel shows a very good agglomeration and no cavities can be seen on the surface. The surface is smooth and distortions cannot be seen. Burrs are not formed during moulding so that trimming is not required and the recycled panels are ready to be used.

For the future, new MDF powders will be tested as is or after previous mixture with other waste powders. In fact, a great amount of dismissed MFD furniture can be found. Issues can be related to powders management; indeed, small particles are associated with high risks for human health. For this reason, specific procedures have to be used when powders are handled.

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