KOKKUVÕTE

Antud bakalaureusetöö põhieesmärgiks oli välja selgitada, kas biolagunevatest komposiitidest on võimalik valmistada mehaanilist tugevust nõudvaid tooteid. Selle käigus uuriti erinevaid taaskasutatud tekstiilide purustamis-jahvatamis meetodeid. Seejärel koostati tabelid hindamaks tekstiilikiudude mõõtmeid, mida hiljem siduda tõmbeteimi tulemustega. Saadud tekstiilikiudusid mõõdeti käsitsi tõmmatud joontelt - pikkuseid mõõdeti valgusmikrosoobiga ning diameetreid elektronmikroskoobiga tehtud pildilt. Sellest sõltuvalt olid tulemused ebatäpsed ning suure mõõtemääramatusega, sest mõõtmiseks kasutati ainult väikest osa kiududest.

Esimeste komposiitide valmistamise käigus selgus, et kriitiliseks aspektiks kogu protsessi juures on komposiitide segamine ühtlaseks massiks. Segati polüetüleenkotis ning hiljem rulliti plaadile, millest hiljem valmistati katsekehad tõmbeteimi jaoks. Esimestest tõmbeteimi tulemustest järeldus, et mida pikemad on kiud, seda tugevam on komposiit, kuid seda suurem on standardhälve ehk kõrvalekalle keskmisest, millest omakorda järeldus heterogeenne struktuur, mis mehaanika perspektiivist on ohtlikum kui väiksem tõmbetugevus, kuna materjal on nii tugev kui tugev on tema ohtlik ristlõige. Kõige nõrgema tulemuse andis puuvilla kiud, millest otsejahvatatud kiududega komposiidist ei saanud valmistada katsekehi, sest need lagunesid valmistamise käigus. Valiti välja villa peen- ja jämekiud lõpptoote valmistamiseks, et tekiks otsene võrdlusmoment peenkiu ja jämekiu omaduste vahel läbi tugevuskatsete.

Lõpptootena otsustati valmistada silindriline toru, sest mehaanika perspektiivist on ümartoru universaalne toode, mida saab rakendada mitmetes valdkondades alates näiteks mööblist kuni jalgrattani. Selleks valmistati katsekehad tõmbeteimi jaoks, kuid paraku näitas katse, et täiendus segamismooduli näol ei tasunud end ära, sest teised tõmbeteimi tulemused olid märkimisväärselt kehvemad kui esimesed. Probleem seisneb maatriksi puhul suures viskoossuses, mis jäi segamisdetaili külge kinni ning pikemate kiudude inertsist, mis ei segunenud ühtlaselt ära.

Torude valmistamiseks kasutati silindrilist metallvormi, kuhu pressiti komposiit hüdropressiga, ent mille käigus vigastati mitmeid vorme õige aparatuuri puudumisel ja kõik lahendused pakuti protsessi käigus välja. Suureks probleemiks oli toru vormist kättesaamine, sest hõõrdejõud oli, vormi seina ja komposiidi vahel, suur. Selle vähendamiseks ja toru vormist kergemini kättesaamiseks kasutati prototüübi jaoks küpsetuspaberit.

Lõpuks testiti ümartorusid paindeteimil, millele eelnes teoreetiline tugevusarvutus kasutades terastele mõeldud metoodikat. Selgus, et komposiidid vajavad teist lähenemist, sest teoreetiline arvutus ning katsetulemused erinesid teineteisest drastiliselt, mida autor alguses ka oletas, sest armatuuril ja maatriksil on erinevad omadused ning võrreldes terasega heterogeenne struktuur. Probleem võis olla ka erinevas valmistamismeetodis, sest torusid pressiti teise jõuga kui plaate ning ahjus/pressi vahel olemise aeg samuti varieerus.

Nagu nähtus katsetest, siis aspekte, mida peab arvestama komposiitide valmistamisel, on mitmeid. Samuti prooviti antud töö käigus erinevaid retsepte, kus eksperimenteeriti maatriksi ja armatuuri osakaaluga.

Edaspidiseks teen ettepaneku töötada koolil välja biokomposiitide valmistamiseks mõeldud spetsiaalne moodul, mis koosneks segamis- ja pressimismoodulist. Pressimise käigus selgus, et pressimine segab materjali hästi kokku. See oleks üks arendusidee perspektiiv, millega TTÜ võiks edasi tegeleda. Näiteks hakklihamasina printsiibil põhinev segamismoodul, mis suunab pikemaid kiudusid, sest kiu suund komposiidis on ülioluline. Samuti innustan kooli täiendavalt uurima või välja töötama biokomposiitide erinevaid valmistamisviise, näiteks eelnevalt kiudusid lamineerida ning seejärel siduda maatriksiga. Kindlasti tuleks mõelda ka hüdrofoobsusele, näiteks katta komposiidid sünteetilise õhukese polümeerkihiga. Antud töö kinnitas, et biokomposiidil arengupotentsiaali on ning tulevikus võiks tänavatel sõita biokomposiidist jalgrattad ja kodudes aiamööbel kasutusel olla.

SUMMARY

The main goal of this bachelor's thesis was to find possibilities for making products from biodegradable composites that require strenght of the mechanism. During this, different crushing-grinding methods for recycled textiles were examined. Tables were prepared to estimate the dimensions of the textile fibers, which were later linked to the results of the pull team. The resulting textile fibers were measured from hand-drawn lines - lengths were measured with a light microscope and diameters were measured with an electron microscope image. The resulting results were imprecise and with a large measurement uncertainty, because only a small part of the fibers was used for measurement.

During the production of the first composites, it became apparent that mixing the composites into a uniform mass was a critical aspect of the entire process. It was mixed in a polythene bag and later rolled onto a plate, from which the test specimens were later prepared for the tensile test. The conclusion from the first results of the tensile test is that the longer the fibers are, the stronger the composite is, but the greater the standard deviation or deviation from the average, which results in a heterogeneous structure, which from a mechanical perspective is more dangerous than a lower tensile strength, because the material is as strong as its dangerous cross section. The weakest result was given by cotton fibers, from which the composite with directly ground fibers could not be made into test specimens, because they decompose during the manufacturing process. A comparison product of fine and coarse wool fiber final product was selected to create a direct moment between fine fiber and coarse fiber through strength tests.

The final product was decided on a cylindrical tube, because from the perspective of mechanics, a round tube is universal, which means the product can be used in many areas, from swords to bicycles. For this purpose, test bodies were prepared for the drag team, but unfortunately it turned out that the addition in the form of a mixing module did not pay off, because the results of the other drag team were worse than the first. The problem is the high viscosity of the matrix, which sticks to the mixing element, and the inertia of the longer fibers.

The second mold for the pipes was cylindrical, where the composite was pressed with a hydraulic press, during which several molds were damaged because there was no proper equipment. All the solutions were removed during the process. A big problem was getting the finished pipe out of the mold, because the friction between the wall of the mold and the composite was great. To reduce this, the prototype used baking paper, which made it easier to remove the tube from the mold.

Finally, the round pipes were tested in a bending test, which was preceded by a theoretical strength calculation using the methodology for steel. It turned out that composites need a different approach, because the theoretical calculation and the experimental results differed drastically from each other, which the author thought at first, because reinforcement and the matrix have different properties and a heterogeneous structure compared to steel. The problem could also be in different manufacturing method because the tubes were pressed with a different force than the plates, and the time between the furnace/press also varied. There are several aspects that must be considered when manufacturing composites. Various recipes were also tried in the course of this work, where the proportion of matrix and reinforcement was experimented with.

In the future, I propose that the school develop a special module to produce biocomposites, which would consist of both a mixing and pressing module. During the pressing, it became clear that pressing mixed the material well. This would be one perspective for the development idea that TUT could continue to work on. For example, a mixing module based on the principle of a meat grinder, which directs long fibers, because the direction of the fibers in the composite is crucial. I also encourage the school to further research or develop different ways of making biocomposites, such as laminating the fibers first and then bonding them to the matrix. Hydrophobicity should also be considered, for example covering the composites with a thin synthetic polymer layer. This work confirmed that there is development potential and that in the future we see biocomposite bicycles in the streets and homes with relevant garden furniture.