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# PREFACE

The GREDIT Conference 2016 (GREEN Development, Infrastructure and Transport) was held in Skopje, Republic of Macedonia, from 30$^{th}$ of March till 2$^{nd}$ of April 2016. The Conference was organized by: Ss. Cyril and Methodius University in Skopje, Faculty of mechanical engineering, Faculty of electrical engineering and information technologies, Faculty of technology and metallurgy, Faculty of medicine; BENA – Balkan environmental association; FUEL – R&D Centre for fuels engines and lubricants; 6$^{th}$ Star and Pakomak from Skopje.

The venue of the Conference was the Technical Campus of the University. 230 articles from 543 authors from 13 countries were presented at the plenary session, 6 oral sessions and 4 poster sessions of the Conference.

The topics of the GREDIT 2016 were:

- Air – water – soil pollution
- Risk assessment – sustainable development
- Renewable energy resources and management of natural resources
- Agriculture, Agro ecology, Food Quality safety
- Management of urban and industrial waste
- Climate change – biodiversity – Energy efficiency
- Green smart cities/societies – green architecture and landscape design
- Public health – environmental medicine
- Legal framework – GIS and remote sensing control and
- Round table on: Higher education and Industrial environment

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# ПРЕДГОВОР

Конференцијата ГРЕДИТ 2016 (Зелен развој, инфраструктура и транспорт) се одржа во Скопје, Република Македонија од 30 март до 2. април 2016 година. Организатори на конференцијата се: Универзитетот Св. Кирил и Методиј во Скопје, Машинскиот факултет, Факултетот за електротехника и информациски технологии, Технолошко-металуршкиот факултет, Медицинскиот факултет; БЕНА – Балканската асоцијација за животна средина; ФУЕЛ – Центарот за истражување и развој на горива, мазива и мотори; $6^{\text{-та}}$ ѕвезда и Пакомак од Скопје.

Настаните од Конференцијата земаа место на Техничкиот кампус на Универзитетот. 230 трудови, од 543 автори од 13 земји, беа презентирани во рамките на пленарната, $6^{\text{те}}$ орални и $4^{\text{те}}$ постер сесии на Конференцијата.

Темите на Конференцијата ГРЕДИТ 2016 беа:

– Загадување на воздух, почва и вода
– Процена на ризик – одржлив развој
– Обновливи извори на енергија и управување со природните ресурси
– Земјоделие, Агроекологија и безбедност на храна
– Управување со урбан и индустриски отпад
– Климатскипромени – биодиверзитет – енергетска ефикасност
– Зелени градови/општества – зелена архитектура и просторно планирање
– Јавно здравје, Медицина поврзана со животната средина
– Правна рамка во животната средина и ГИС системи и
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Избор на трудови од Меѓународната конференција ГРЕДИТ 2016 е објавен во ова издание на Машинско инженерство – научно списание.

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# UTILIZATION OF GARMENT INDUSTRY TEXTILE WASTE

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A b s t r a c t: Because of increasing environmental demands, especially on dealing with product life phase end, manufacturers and designers must consider future disposal of their products. In recent years, an increased emphasis on developing recycling techniques for industrial waste products has been placed, with the goals of protecting the environment. The aim of the work is investigation of the possibilities of reusing of cotton textile waste, generated during the manufacture in garment industry, as reinforcement in production of composite materials. The main focus has been put on the preparation and characterization of composites based on cut waste from garment industry. The materials have been cotton fabric and cotton textile waste as reinforcements and phenol phormaldehyde resin as matrix. The composites containing 60 % wt. reinforcement were manufactured by compression molding. For the composites, the mechanical and thermal properties were analyzed and compared to those of commonly used continuous fiber reinforced composites based on cotton fabric and phenloic resin. It was found that the composites based on cotton textile waste are more sensitive to processing cycles with respect to continuous fiber reinforced composites. The mechanical properties for composites based on cotton textile waste are lower for about 25% compared to continuous one. The thermal stability, investigated by Martens method for both composites reinforced with cotton fabric and with cotton textile waste is very similar. The obtained results have shown that cotton textile waste could be reused for production of composite with acceptable mechanical properties and they can be successfully used in various industries as construction material.

**Key words:** textile waste; cotton fabric; reinforcement; composite material, garment industry

## УПОТРЕБА НА ТЕКСТИЛНИОТ ОТПАД ОД КОНФЕКЦИСКАТА ИНДУСТРИЈА

А п с т р а к т: Поради повисоките еколошки норми, особено за справувањето со крајот на животната фаза на производот, призводителите и дизајнерите мора да го имаат во предвид идното депонирање на нивните производи. Во последните години, се става зголемен акцент на развојот на техники за рециклирање на индустрискиот отпад, со цел да се заштити животната средина. Целта на овој труд е да се истражат можностите за повторна употреба на памучниот текстилен отпад создаден за време на производството во конфекциската индустрија како зајакнувач во производството на композитни материјали. Главниот фокус е ставен на подготовката и карактеризацијата на композитите на база на отпадот при кроеење од текстилната индустрија. За производство на композитите беа користени памучна ткаенина и текстилен памучен отпад како зајакнувачи и фенолформалдехид како матрица. Композитните материјали кои содржеа 60 % мас.. зајакнувачи беа произведени со техниката обликување под притисок. Механичките и термичките својства на композитите зајакнати со текстилен отпад беа анализирани и споредени со комвенционални композити зајакнати со континуирани влакна базирани на памучна ткаенина и фенолна смола. Произлезе дека композитите базирани на отпад од памучен текстил се почувствителни на циклусите на обработка во однос на композитите зајакнати со континуирани влакна. Механичките својства на композитите базирани на отпад од памучен текстил се за 25% пониски во споредба со континуираните. Термичката стабилност, испитувана со Мартенс методот, и на композитите зајакнати со памучна ткаенина и со отпадот од памучен текстил е многу слична. Добиените резултати покажаа дека отпадот од памучен текстил може повторно да се употреби за производство на композитни материјали со прифатливи механички својства и можат успешно да се употребуваат во различни индустрии како конструкциски материјал.

**Клучни зборови:** текстилен отпад; памучна ткаенина; зајакнувач; композитен материјал; конфекциска индустрија

## INTRODUCTION

As result of the development in industrial production, the level of waste of different type and background has been significantly increased becoming worrying problem for today's civilization. Although in the last two to three decades progress in technological processes has been reported, the amounts of various waste materials represents huge problem in today's modern lifestyle.

The quantities of textile wastes that increase on daily basis, the energy used in the process of waste disposal or incineration, whether performed correctly or not, impose a need for creating sustainnable waste management practices. Sustainable management of textile waste will contribute to reducing waste generation, more efficient use of raw materials and decreasing the cost of disposal. This inevitably implies the necessity of restructuring of the garment companies and raising the environmental awareness of all generators of waste.

Usually the company's modernization is the first step for an effective implementation of the integrated system for managing textile waste, effective in terms of cost. Modernization is usually associated with technological and operational changes. This is further accompanied by changes of equipment, operational settings, and exploring the possibilities for reuse of the generated textile waste as potencial raw material. On one hand, this will ensure reduction of costs for the disposal. On other hand, the sale or reuse of the textile waste will lead to increasing the profitability and competitiveness of the company. One of the potential applications of the generated textile waste is the production of a composite material.

Preparation of composite materials using textile waste as a reinforcement is a research challenge, which involves solving multiple problems, such as:

– appropriate choice of textile waste as a reinforcement regarding polymer matrix;

–achieving their compatibility with the application of various accessories;

– establishing suitable technology for their interference;

– determination of optimal process parameters for manufacturing composites of required properties.

Acquiring these prerequisites will depend on the features of the resulting composite material.

The purpose of this study is to investigate sustainable technology for production of composite materials based on textile waste, in order to archieve additional profits and reduce the costs for the disposal of the textile waste.

## EXPERIMENTAL

For preparation of the composite materials the following constituents were used:

*– 60% wt. of cotton textile waste as a* reinforcements

Different and irregular shapes and sizes of cotton waste fabric from (25 × 50) mm to (50 × 500) mm and larger, purified from various admixtures and impurities.

*– 40% wt. of phenol Formaldehyde resin as m*atrices.

Phenol Formaldehyde resin was modified with thermoplastic polyvinylbutiral (PVB) and diluted with alcohol in relation 1:0.2–0.5.

The preparation of composites has been performed by mixing the resin and cotton textile waste into a universal mixer Werner Pfliderer with two S-fins, which can rotate in two majors.

***The regime of mixing was as follows:*** Half of the quantity of cotton textile waste and half of the amount of resin was mixed first. It was mixed for 2–3 minutes and then the other half of the cotton textile waste and resin was added. The total time of mixing was 60 minutes:10 minutes movement of the fins of a mixer one versus another, and five minutes movements in the opposite direction. The mode of mixing was based on the previous experience of industrial practice of the company "Eurokompozit". The mixed mass was evenly divided in a layer with about 50 mm height. The resulting mass was dried in a dryer at a temperature of 80 $^{o}$C. The total drying time was 90 minutes: 60 minutes on the one side and 30 minutes on the other side. Presence of impurities, ingredients, fibers, fabric pieces and other substances in cotton waste fabric were not allowed, which were visual controlled in the early stage.

Thermal pressing of all samples was performed on polyindustrial press under the following conditions:

$P$ = 75 bar;

$T$ = 160 $^{o}$C;

$t$ = 20 minutes.

From the composite mass test samples were fabricated and certain physical, thermal and mechanical properties of composite materials were examined.

For testing the physical and mechanical properties of composite based on cotton textile waste and phenolic formaldehyde resin standard methods and procedure were used. Flexural strength and modulus of elasticity was tested according ASTM D 790 standard, impact strength according ASTM D 256, and the compression strength according ASTM D 695 standard. Thermal degradation temperature was measured by the method of Martens, DIN 53462.

## RESULTS AND DISCUSSION

### *Influence of the content of PVB on the characteristics of the polymer system and composites*

The basic physical and chemical characterristics of polymer systems controlled in terms of industrial exploitation are: content of dry substance, density and viscosity by Ford (Table 1).

In order to assess the reactivity of produced resin systems, B-time at different temperatures is investigated (Figure 1).

Table 1

*Physical-chemical characteristics of the polymer systems*

| Characteristics | PVB/phenolic formaldehyde resin | | | | | |
|---|---|---|---|---|---|---|
| | 10/90 | 20/80 | 25/75 | 30/70 | 40/60 | 50/50 |
| Content of dry substance, mas. % | 15.2 | 14.8 | 14.6 | 15.2 | 16.3 | 16.1 |
| Density at 20ºC, g/cm$^3$ | 1.11 | 1.10 | 1.11 | 1.11 | 1.12 | 1.12 |
| Viscosity at 20º C according to Ford (4 mm/20º C), s | 220 | 210 | 215 | 225 | 195 | 210 |

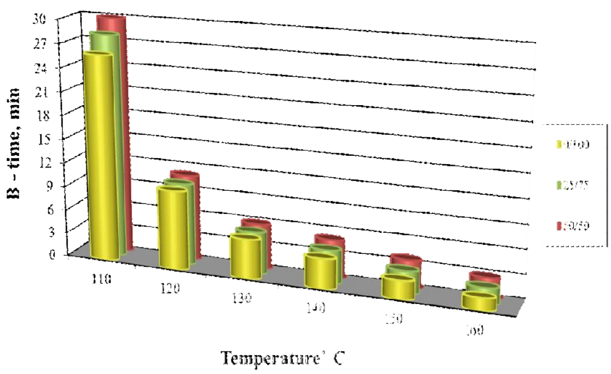


**Fig. 1.** B-time of phenol-formaldehyde resin modified with PVB at various temperatures

As shown in Figure 1, all B-time are in a narrow range, the pure phenol-formaldehyde resin has the shortest time and the modified resin with PVB (50/50) has the longest B-time. With increasing the content of PVB, B-time of resin systems slightly increases. The biggest change in the B-time occurs between 110ºC and 120ºC, where it is reduced about 60%, while from 120ºC to 160ºC, the decline is significantly lower.

Table 2 shows the summary of shear strength results for resin systems. From the statistical indicators it can be concluded that there are many good clustering of results around the mean value (Xsr), i.e. it has a good reproducibility of results (the standard deviation, Sd). It can be noted that PVB has great influence on the shear strength, i.e adhesion properties of the resin systems: the lowest shear strength was showed the non-modified system-pure phenol-formaldehyde resin. With increasing the content of PVB, shear strength increases, so when only 10% of PVB is used in resin system, it increases about 28% (from 7.55 MPa to 9.64 MPa). The highest shear strength showed the resin system with the highest content (50%) of PVB and that more than 150% from non-modified resin system.

### *Mechanical properties of the polymer systems*

The mechanical and thermal properties of composites based on cotton textile wastes were compared with conventional (laminated) composites based on continuous cotton fibers. Tables 3 and 4 show the summary of the obtained results from the testing of physical and mechanical properties of the laminated composites and the composites based on cotton textile wastes.

The properties of the composite reinforced with short fibers heavily depend on the content and distribution of fiber orientation, and on the adhesion between the fibers and matrix. The content of fibers is usually precisely controlled, although it may come to segregation of the fibres and resin during the production. The orientation of fibers changes when we change the conditions of pressing, but that it is too difficult to control. The properties of the thermoreactive composites reinforced with cotton textile waste is sensitive to processing conditions and particularly from the methods of processing, especially for composite based on phenol resin, and can greatly differ even for identical samples.

Table 2

*Shear strength of resin systems (MPa)*

| Tube | PVB/phenolic formaldehyde resin | | | | | | |
|---|---|---|---|---|---|---|---|
| | 0/100 | 10/90 | 20/80 | 25/75 | 30/70 | 40/60 | 50/50 |
| 1 | 7.34 | 9.38 | 11.87 | 13.65 | 15.45 | 16.84 | 18.64 |
| 2 | 7.46 | 9.91 | 12.46 | 14.12 | 15.22 | 17.36 | 18.45 |
| 3 | 7.55 | 9.49 | 13.12 | 14.85 | 14.95 | 18.12 | 19.29 |
| 4 | 7.86 | 9.64 | 12.86 | 14.55 | 16.12 | 16.57 | 18.26 |
| 5 | 7.59 | 9.75 | 12.95 | 13.74 | 16.03 | 17.36 | 19.23 |
| 6 | 7.81 | 9.70 | 13.22 | 13.63 | 15.88 | 17.10 | 19.15 |
| 7 | 7.38 | 9.41 | 11.98 | 15.02 | 15.96 | 16.91 | 19.49 |
| 8 | 7.67 | 9.55 | 13.78 | 14.52 | 15.64 | 17.35 | 18.82 |
| 9 | 7.43 | 9.67 | 12.81 | 13.85 | 15.23 | 17.15 | 18.42 |
| 10 | 7.23 | 9.90 | 12.54 | 13.22 | 15.74 | 17.39 | 19.75 |
| Statistical processing of results | | | | | | | |
| Xsr | 7.55 | 9.64 | 12.76 | 14.12 | 15.77 | 17.22 | 18.95 |
| Sd | 0.2 | 0.2 | 0.6 | 0.6 | 0.4 | 0.4 | 0.5 |

Table 3

*Physical and mechanical properties on the laminated composites*

| Physical properties | COMPOSITE | |
|---|---|---|
| | Cotton fabric/phenolic formaldehyde resin | |
| Specific weight, g/cm$^3$ | 1.3 – 1.4 | |
| Water absorption, % | 0.4 – 0.8 | |
| Mechanical properties | Test method | |
| Flexural strength, MPa | DIN 53457 | > 150 |
| Modulus of elasticity at flexural GPa | DIN 53457 | 7 |
| Impact strength, kJ/m$_2$ | DIN 53453 | > 30 |
| Compression strength, MPa | DIN 53454 | > 170 |

Table 4

*Physical and mechanical properties on the composites based on cotton textile wastes*

| Physical properties | COMPOSITE | |
|---|---|---|
| | Cotton textile waste/phenolic formaldehyde resin | |
| Specific weight, g/cm$^3$ | 1.3 – 1.4 | |
| Water absorption, % | 0.4 – 0.8 | |
| Mechanical properties | Test method | |
| Flexural strength, MPa | DIN 53457 | 128±8.8 |
| Modulus of elasticity at flexural, GPa | DIN 53457 | 5±0.5 |
| Impact strength, kJ/m$^2$ | DIN 53453 | 20±6.4 |
| Compression strength, MPa | DIN 53454 | 140±9.6 |

The results from the comparison of physical-mechanical properties of conventional (laminated) composites and composites based on cotton textile wastes, with respect to the constituents matrix / fiber of 40/60 are shown as diagram (Figures 2, 3 and 4).

From the obtained results we can see that there is a difference in mechanical properties between the composites. The mechanical properties for composites based on cotton textile waste are lower for about 25%, but the thermal stability investigated by Martens method for both composites reinforced with cotton fabric and with cotton textile waste is very similar. It is obvious that for all the same parameters: ratio of the constituents and conditions of production, the main reason for the difference in mechanical properties is different reinforcing of the textile product. The fibers are processed differently in various textile products. In the fabric, fibers are with a continuous length, crossed or tangled around each other, while the fibres from the cotton textile waste are short and chaotically distributed.

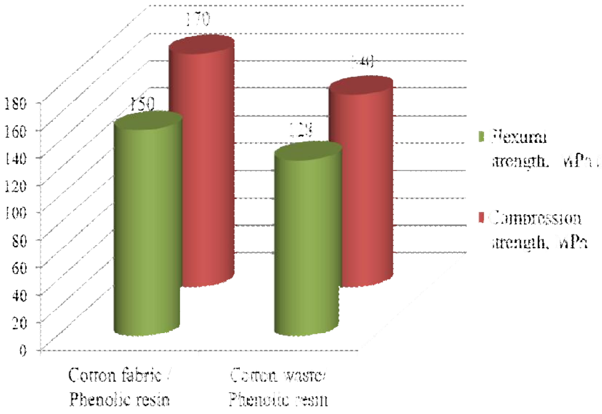


**Fig. 2.** Flexural and Compression strength, MPa

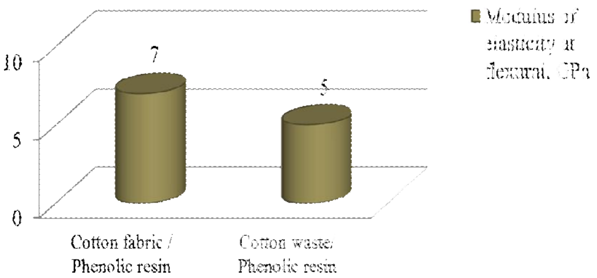


**Fig. 3.** Modulus of elasticity at flexural, GPa

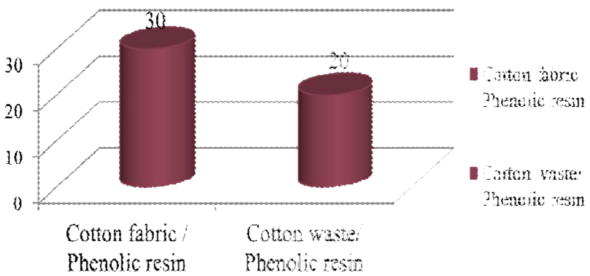


**Fig. 4.** Impact strength, kJ/m$^2$

Thermoreactive composites reinforced with short fibers have the advantage of being able to offer a unique combination of properties. However, the differences in orientation and distribution of the fibers usually occur in the samples themselves, especially in thickness. It affects the optimal properties and can lead to imbalances of the mechanical properties of the material.

## CONCLUSION

The composite materials have been produced from cotton textile waste, generated during the manufacture in textile industry, as a reinforcing phase and phenol-formaldehyde resin modified with thermoplastic polymer (PVB) as a matrix.

- The mechanical properties on composites based on cotton textile waste are about 25% lower compared to the composites based on continuous cotton fibers.
- The main reason for the difference in mechanical properties at all parameters being equal: ratio of the constituents and conditions of production, the difference is in configuration of reinforcing textile product. The lower properties of the composites are obtained where the reinforcement phase is cotton textile waste of fibers of various lengths and random orientation. On the opposite, the conventional composites have continuous reinforcement fiber.
- The thermal stability investigated by Martens method for both composites reinforced with cotton fabric and with cotton textile waste is very similar. All composites are thermo stable at temperature up to 200 $^oC$.
- The obtained results have shown that the new produced composite material has relatively good properties and they can be successfully used in many industries as a construction and non construction material.
- The conventional composites are mostly used in applications where quality is a priority.
- The composites reinforced with textile waste are mostly used in applications where the cost is a priority.
- Generally, composites based on cotton waste are applying as non load construction elements.

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