MSF.996

by

Materials Science Forum
ISSN: 1662-9752, Vol. 966, pp 151-156
doi:10.4028/www.scientific.net/MSF.966.151

Submitted: 2018-12-04
Revised: 2019-04-09
Accepted: 2019-05-16
Online: 2019-08-06

Study on Formalization of Oil Palm Trunk Modified by Melamine Formaldehyde

Tetti Novalina Manik[1,2,a], Mashuri[1,b], and Darminto[1,c*]

[1]Advanced Materials Research Group, Department of Physics, Institut Teknologi Sepuluh Nopember, Kampus ITS Sukolilo, Surabaya 60111, Indonesia

[2]Physics Study Program, Faculty of Mathematics and Natural Sciences, Universitas Lambung Mangkurat, Jl. Ahmad Yani Km 36, Kampus Banjarbaru Kalimantan Selatan 70714, Indonesia

[a]tetti.manik@ulm.ac.id,[b]mash@physics.its.ac.id, [c*]darminto@physics.its.ac.id

Keywords: acidic, alkaline, formalization, oil palm trunk

Abstract. Structure, composition and water content of an oil palm wood influence its dynamic-mechanical properties. These are very important to be studied in relation to wood applications. The quality of oil palm wood can be improved through chemical modification, that is by formalization treatment in acid and alkaline conditions followed by an impregnation process using melamine formaldehyde. Variation of formalization time and curing temperature after impregnation on samples were investigated. Based on physical properties and FTIR characterizations, the modification in alkaline conditions is better than that in acidic conditions. The modification in alkaline condition can reduce the water content and increase the density of samples better than those in the acidic condition. The FTIR spectra also evidence this, there are emerging the new functional group and a shift in wave numbers on FTIR spectra with strong absorption peak for the samples after modification.

Introduction

Oil palm plants that have productive age of 25-30 years must be replaced immediately and enter a period of replanting. Waste from the logging of these oil palm trees are usually burned or stacked and allowed to rot. This problem be a challenge and opportunity for researchers and industries, to convert the waste of oil palm trunks into wooden planks that can be used, among others, as a substitute for conventional wood, furniture, partitions or even musical instruments. However, oil palm trunk is classified as low-quality wood with class levels of wood on IV and V [1] (see Table 1 [2]), high hygroscopic and low dimensional stability [3], hence it is rarely used. This is due to the chemical composition of oil palm trunk, in which the portion of parenchymal tissue is larger than that of the vascular bundle. The vascular bundle composes the outside of the oil palm trunk and supports the mechanical properties of the trunk and also helps in transporting water and nutrients. The middle part of the trunk is composed of 70% of parenchymal tissue that contains hydroxyl groups and many water molecules content in the formation of hydrogen bonds. The vascular amount of the bundle determines the density and mechanical properties of the oil palm trunk [4].

Table 1. Class level of Indonesia wood [2].

Class level of wood	Density (gr/cm^3)	Modulus of rupture (kg/cm^2)	Impact strength (kg/cm^2)
I	> 0.9	> 1100	> 650
II	0.6 - <0.9	725 - <1100	425 - <650
III	0.4 - <0.6	500 - <725	300 - <425
IV	0.3- <0.4	360 - <500	215 - <300
V	<0.3	< 360	< 215

The quality of oil palm trunk waste can be improved to wood class I, II or III by chemical, heat, and impregnation modification or their combination, by penetrating wood pores with polymeric materials and compacting the wood pores in the vacuum machine which has been set at a certain pressure and temperature [4]. To get a good quality of the logs, the lignin and hemicellulose content must be as minimal as possible, because lignin and hemicellulose are amorphous heteropolymers. This content prevents the wood structure from becoming hard, impermeable and susceptible to microbiological disturbances and oxidative stress [5]. Modification of lignin with other polymers is another way to have changes in the wood structure, that can enlarge its application and improve its product performance. Lignin is a macromolecule compound and more reactive than cellulose or others natural polymer. The reactivity of lignin is determined by its particular structure that can be seen from specific functional groups. Lignin is reacted to formaldehyde and makes a cross-linking reaction [6].

This paper is aimed to study on the relationship between the structural change of the oil palm wood structure due to chemical modification and their physics properties. Chemical modification is divided into two steps, first is the formalization by using formaldehyde solution in acid and alkaline conditions, and the second is the impregnation using melamine formaldehyde resin. Chemical modification of the wood cell-wall polymers has been shown to affect the vibrational properties of wood [7], improve the dimensional stability, reduce the moisture absorption and mechanical strength [8].

Experimental

Material preparation. Wood samples were from Banjarbaru of South Kalimantan over 30 years old. The samples were cut into the dimension (2 x 5 x 15) cm that was selected one meter from the ground. All of the samples were initially dried at 60^{o}C for 24 hours to prevent shrinkage and later dried at 103±2^{o}C for 24 hours to get a moisture content of less than 20%. The dried samples were stored in a room temperature before treatment. The average moisture content of the raw sample is 107.03%.

Modification materials. Formaldehyde solution, 37 wt%, NaOH 3 wt% and melamine formaldehyde resin supplied from commercial products.

Modification process. The dried samples were modified in two steps, formalization with a formaldehyde solution and then impregnated with a melamine formaldehyde resin. For investigating the effect of the formalization on the oil palm trunk toward to changes of structure, formalization was carried out in two conditions, in acidic (pH 4) and alkaline (pH 10), with the immersion times of 1, 3, 5 and 6-days. Afterwards, the samples were dried in the air for seven days or until the samples did not smell formaldehyde anymore. The next step, for improving the physics properties, the specimens were impregnated with melamine-formaldehyde resin by using immersion in a closed container for 4-days to obtain a maximum absorption [8]. After the impregnation treatment, all specimens were air-dried for 1-day before being cured at a temperature of 100^{o}C and 120^{o}C for 1 hour for polymerization. Finally, the samples were dried in an oven 103 ± 2^{o}C for 24 hours to achieve a water content of <20% for the investigation [9].

Water content is a percentage of the oven-dry mass of wood. Water contents will be higher than 100% if the mass of water exceeds the oven-dry mass of the wood. This occurs in green wood of many lower density species. To determination of water content of samples before and after treatment was calculated by using Eq. 1 by SNI 01-4449-2006 [9].

$$KA = \frac{BA-BKO}{BKO} x100\% \quad (1)$$

where, KA is the water content, BA is the initial weight and BKO is the oven dry weight.

The densities of the oil palm trunk samples, before and after the modification treatment, were determined in accordance with SNI01-4449-2006 [10] in Eq. 2.

$$\rho = \frac{m}{V} \quad (2)$$

Where ρ, m, and V are density (gr/cm^3), mass and volume of the sample respectively.

The structural change of the oil palm trunk was analyzed by Fourier transform infrared spectroscopy (FT-IR), Bruker Alpha RT-DLaTGS, with plate attenuated total reflection (ATR) to investigate functional group presented in the untreated and treated samples.

Results and Discussions

The effects of modification treatment for physical properties of the oil palm trunk samples were given in Table 2. The formalization conditions treatment followed by the impregnation process can increase the density of samples. Modification in acidic conditions with curing temperatures of 100°C can increase the density of untreated sample from 0.37 gr/cm^3 to 0.78 gr/cm^3 and 0.63 gr/cm^3, but when the curing temperature is raised to 120°C, the density decreases to 0.37 gr/cm^3 and 0.48 gr/cm^3. It was caused by water content contained in the wood, at when the curing temperature increases the water in the samples also evaporates. Contrast to the alkaline treatment, the density of the samples after treatment increased with almost the same value, both in the curing temperature of 100°C and 120°C. This is indicating that the polymerization occurs between melamine formaldehyde and the O-H group in the wood structure.

Table 2. Physics properties of the oil palm trunk modified.

Formalization time (day)	Curing temperature (°C)	Water content (%)		Density (gr/cm^3)	
Untreated		15		0.37	
Treated		Acid condition	Alkaline condition	Acid condition	Alkaline condition
3	100	15.95	10.62	0.78	0.55
5	100	13.37	9.26	0.63	0.65
3	120	10.6	6.19	0.37	0.52
5	120	8.93	5.82	0.48	0.51

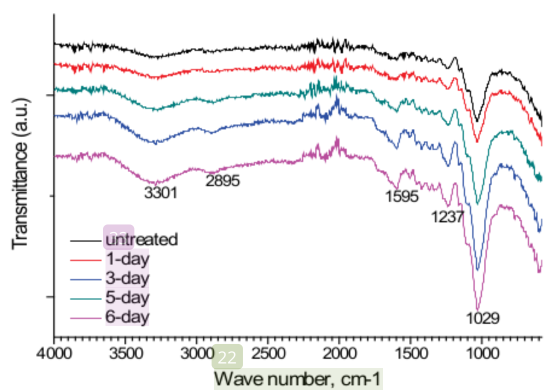

Fig. 1. FTIR spectra of the oil palm trunk samples at different formalization time.

The structural changes of oil palm wood, before and after formalization treatment, shown in Fig. 1. The FTIR spectra of 1-day formalization have the same tendency as the untreated sample, and the 3-day formalization has the same trend as the samples with 6-day formalization. So, for further studies, we used the samples with formalization treatment at 3 and 5-days. After formalization, the peak 2885-2921 cm^{-1} presence in the formalization 3, 5 and 6-days. This is associated with the functional group of methyl (formaldehyde) C-H stretching on aliphatic lignin. The peak of wave number 3293-3325 cm^{-1} is related to the vibration of O-H stretching which shows that the sample is hydrophilic. The peak 1595 cm^{-1} is related to aromatic skeletal vibration and C=O stretching associated with vibrations in lignin. The peak of 1229-1243 cm^{-1} is the syringyl ring C-O vibration stretching functional group associated with the acetyl group in lignin, and the peak of 1025-1033 cm^{-1} is related to C-O-C stretching in polysaccharides. The peak intensity of the functional groups is getting negative with increasing formalization time because of the interaction of hydroxyl group of wood with formaldehyde [11].

The FTIR spectra of the oil palm trunk modified by melamine formaldehyde in the acid condition are shown in Fig. 2. The cross-linking in the structure of wood modified by melamine-formaldehyde is more clearly shown in the samples with formalization for 3-days cured at 100ºC. Some peaks were not found in other samples. Peaks of 1640 cm^{-1} and 1535 cm^{-1} associated with the absorption peak of the triazinyl and the peak of 1375 cm^{-1} corresponds to the methylene C–H bending vibration for deformation of the polysaccharides [11,12]. The peak 809-815 cm^{-1} presence in the spectra of 3-day formalization cured at 100ºC and 120ºC, and the samples with 5-day formalization cured at 120ºC. These peaks are attributed to the absorption peak of the triazine ring, which indicates that binding of melamine formaldehyde has occurred to the surface of the cell wall of wood [9,13]. The absorbance peak of this spectra is weak, and this is indicated that penetration melamine formaldehyde to the cell wall of the wood is weak too. The shift of wave number from 1033 cm^{-1} to 1003 cm^{-1} occurs in the sample with 3-day formalization cured at 100ºC which is caused by the transfer of the hydroxyl group on the wood wall to the polymer chain due to polymerization. It can be seen in Fig. 2. that the intensity of the functional group at 2885-2921 cm^{-1} is getting weak after treatment for all samples. The reduction of this peak indicates that some formaldehyde disappeared from the wood during the curing process.

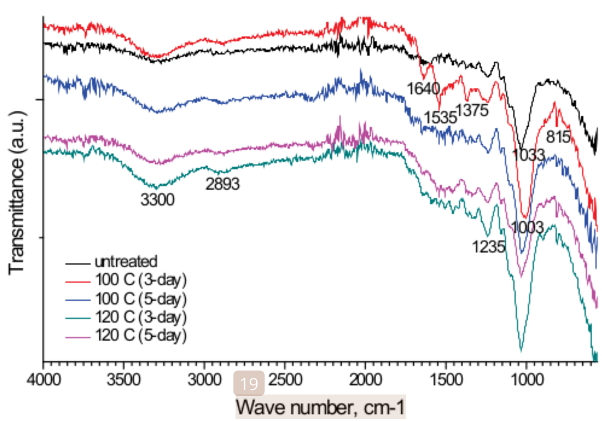

Fig. 2. FTIR spectra of the oil palm trunk samples for the acid condition formalization at the varied curing temperature.

The FTIR spectra of the oil palm trunk modified by melamine formaldehyde in an alkaline condition are shown in Fig. 3. The figure shows that cross-linked of melamine formaldehyde in the cell wall of the wood in alkaline condition is better than that in acid condition. The absorption peak of triazine ring at 807-813 cm^{-1} presences in all samples and becomes prominent in the samples with the 3-day formalization cured at 100ºC and 5-days formalization cured at 120ºC. The peaks of

3293-3319 cm^{-1} are related to the vibration of O-H stretching and stretching vibration of secondary amine [12]. The reduction of the peak intensity for samples with 3-day formalization cured at 120°C indicates that hydroxyl group is significantly diminished after modification because crosslink melamine formaldehyde is weak. For the sample with 3-day formalization cured at 100°C, there is also a shift in a wave number from 1033 cm^{-1} to 1001 cm^{-1} caused by polymerization. The presence of strong intensity of the peaks at 1375 cm^{-1} and 1551 cm^{-1} in the samples with 3-day formalization cured at 100°C and 5-days cured at 120°C indicates that those samples are the most thoroughly impregnated. This shows that the reaction of melamine formaldehyde to the walls of wood cells is more absorbed in alkaline condition. Finally, for this modification, only the sample with 3-day formalization cured at 100°C which still had an aldehyde functional group after the curing process.

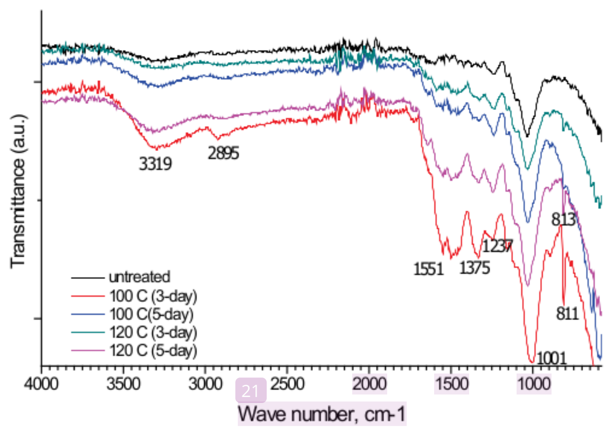

Fig. 3. FTIR spectra of the oil palm trunk samples for the alkaline condition formalization at the varied curing temperature.

Conclusion

Improving the physical properties of oil palm trunk by changing its wood structure has been carried out by the chemical modification method. The modification in an alkaline condition can reduce the water content of wood better than that in an acidic condition. Increasing the density of oil palm wood is also better in alkaline conditions for all curing temperatures. In acidic conditions, the water content is still high if the samples are cured at 100°C and decreases when curing temperature is raised. This situation occurs because the absorption of melamine-formaldehyde on the cell wall is not impregnated thoroughly, as evidenced by the presence of triazine ring group with weak intensity, and this is in contrast to the alkaline formalization. Modification in an alkaline condition is found to be more effective since formaldehyde compounds can be completely removed after the curing process, except for the samples with the formalization of 3-days with a curing temperature at 100°C. Based on the value of physical properties and the changed in the chemical composition of the samples, we can be concluded that the modification in alkaline conditions is better than that in acid conditions.

Acknowledgements

This research was supported by Beasiswa Pendidikan Pascasarjana Dalam Negeri (BPPDN) Kemenristek DIKTI Indonesia.

References

[1] Erwinsyah, Improvement of oil palm wood properties using bioresin, PhD Thesis, Technische Universität, Dresden, German, 2008.

[2] R. I. M. Damanik, Kekuatan kayu, e-USU Repository, 2005.

[3] Mamiński, Mariusz, P. Kozakiewicz, W. Jaskółowski, K. L. Chin, P. S. H'ng, and R. T. Mamińska. (2016), Enhancement of technical value of oil palm (elaeis guineensis jacq.) waste trunk through modification with 1,3-dimethylol-4,5-dihydroxyethyleneurea (DMDHEU), Eur. J. Wood Wood Prod. 74 (2016) 837–844.

[4] J. Lamaming, R. Hashim, C. P. Leh, O. Sulaiman, T. Sugimoto, and M. Nasir, Isolation and characterization of cellulose nanocrystals from parenchyma and vascular bundle of oil palm trunk (elaeis guineensis), Carbohydr. Polym. 134 (2015) 534–40.

[5] B. Chieng, S. Lee, N. Ibrahim, Y. Then, Y. Loo, Isolation and characterization of cellulose nanocrystals from oil palm mesocarp fiber, Polymers 9 (2017) 355.

[6] T. Malutan, R. Nicu, V. I. Popa, Contribution to the study of hydroxymetylation reaction of alkali lignin, BioResources 3 (2008) 13-20.

[7] H. Akitsu, M. Norimoto, R. M. Rowell, effect of humidity on vibrational properties of chemically modified wood, Wood and Fiber Science 25 (1993) 250-260.

[8] H. Yano, K. Minato, Controlling the timbre of wooden musical instruments by chemical modification, Wood Sci. Technol. 27 (1993) 287-293.

[9] W. Gindl, C. Hansmann, N. Gierlinger, M. Schwanninger, B. Hinterstoisser, and G. Jeronimidis, Using a water-soluble melamine-formaldehyde resin to improve the hardness of norway spruce wood, J. Appl. Polym. Sci. 93 (2004) 1900–1907.

[10] Information on https://www.scribd.com/document/367906138/SNI-01-4449-2006-Papan-serat.

[11] R. Herrera, T. Krystofiak, Jalel Labidi, Rodrigo, Llano-Ponte, Characterization of thermally modified wood at different industrial condition, Drewno. Pr. Nauk. Doniesienia Komun. 59 (2016) 150-164.

[12] D. J. Merline, S. Vukusic, and A. A. Abdala, Melamine formaldehyde: curing studies and reaction mechanism, Polym. J. 45 (2013) 413–419.

MSF.996

ORIGINALITY REPORT

17%	12%	14%	%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

PRIMARY SOURCES

1	www.researchgate.net Internet Source	1%
2	archive.org Internet Source	1%
3	test.techscience.com Internet Source	1%
4	docecity.com Internet Source	1%
5	Geoffrey R. Mitchell, Supatra Pratumshat, Robert Olley. "Polyethylene and the Nucleating Agent: Dibenzylidene Sorbitol, a Neutron Scattering Study", Applied Mechanics and Materials, 2019 Publication	1%
6	healthdocbox.com Internet Source	1%
7	oparu.uni-ulm.de Internet Source	1%

8	Darmono, F Ma’arif, S Widodo, M S Nugroho. "Determination of Modulus of Dynamic Elasticity of Wood Using Ultrasonic Pulse Velocity Testing", IOP Conference Series: Earth and Environmental Science, 2019 Publication	1 %
9	Wiedenhoeft, Alex. "Structure and Function ofWood", Handbook of Wood Chemistry and Wood Composites Second Edition, 2012. Publication	1 %
10	Alessandra M.S. Marton, Francisco M. Monticeli, Noelle C. Zanini, Rennan F.S. Barbosa et al. "Revalorization of Australian royal palm (Archontophoenix alexandrae) waste as reinforcement in acrylonitrile butadiene styrene (ABS) for use in 3D printing pen", Journal of Cleaner Production, 2022 Publication	<1 %
11	Lamaming, Junidah, Rokiah Hashim, Cheu Peng Leh, Othman Sulaiman, Tomoko Sugimoto, and Mohammed Nasir. "Isolation and characterization of cellulose nanocrystals from parenchyma and vascular bundle of oil palm trunk (Elaeis guineensis)", Carbohydrate Polymers, 2015. Publication	<1 %
12	Xingang Chen, Lei Zhu, Zhipeng Ma, Meilin Wang, Rui Zhao, Yueyue Zou, Yijie Fan.	<1 %

"Derivatization reaction-based surface-enhanced Raman scattering for detection of methanol in transformer oil using Ag/ZnO composite nanoflower substrate", Applied Surface Science, 2022
Publication

13	eujournal.org Internet Source	<1 %
14	philjournalsci.dost.gov.ph Internet Source	<1 %
15	Ankita Hazarika, Tarun K. Maji. "Study on the Properties of Wood Polymer Nanocomposites Based on Melamine Formaldehyde-furfuryl Alcohol Copolymer and Modified Clay", Journal of Wood Chemistry and Technology, 2013 Publication	<1 %
16	Ramin Bairami Habashi, Mahdi Abdollahi. "Hydroxymethylation followed by α-bromoisobutyrylation as an effective and precise method for characterization of functional groups of hydroxymethylated lignin", Wood Science and Technology, 2020 Publication	<1 %
17	V. Veeranaath, Mobashir Faiyaz, Ravi Shankar. "Analysis and Optimization of Machinability of Al_2O_3 and Fly Ash Reinforced Aluminum	<1 %

Hybrid Composites Using Carbide Inserts", Materials Science Forum, 2023
Publication

18 Wolfgang Gindl, Christian Hansmann, Notburga Gierlinger, Manfred Schwanninger, Barbara Hinterstoisser, George Jeronimidis. "Using a water-soluble melamine-formaldehyde resin to improve the hardness of Norway spruce wood", Journal of Applied Polymer Science, 2004
Publication
<1%

19 d-nb.info
Internet Source
<1%

20 espace.library.uq.edu.au
Internet Source
<1%

21 moam.info
Internet Source
<1%

22 revroum.lew.ro
Internet Source
<1%

23 www.ncbi.nlm.nih.gov
Internet Source
<1%

24 Elham Karami, Sandrine Bardet, Miyuki Matsuo, Iris Bremaud, Milan Gaff, Joseph Gril. "Effects of mild hygrothermal treatment on the physical and vibrational properties of spruce wood", Composite Structures, 2020
Publication
<1%

25	Voichita Bucur. "Handbook of Materials for String Musical Instruments", Springer Science and Business Media LLC, 2016 Publication	<1%
26	Young Hoon Cha, Sungyong Mun, Ki Bong Lee. "Development of modified zeolite for adsorption of mixed sulfur compounds in natural gas by combination of ion exchange and impregnation", Applied Surface Science, 2023 Publication	<1%
27	encyclopedia.pub Internet Source	<1%
28	www.jurnal.ugm.ac.id Internet Source	<1%
29	www.researchsquare.com Internet Source	<1%
30	www.thefreelibrary.com Internet Source	<1%
31	Hamid Essabir, Radouane Boujmal, Mohammed Ouadi Bensalah, Denis Rodrigue, Rachid Bouhfid, Abou el kacem Qaiss. "Mechanical and thermal properties of hybrid composites: Oil-palm fiber/clay reinforced high density polyethylene", Mechanics of Materials, 2016 Publication	<1%

32	Yun Zhang, Zhongliang Xie, Lijuan Zhai, Mingping Shao. "Unbalanced vibration suppression of a rotor with Rotating-Frequency faults using signal purification", Mechanical Systems and Signal Processing, 2023 Publication	<1%
33	discovery.ucl.ac.uk Internet Source	<1%
34	ltu.diva-portal.org Internet Source	<1%
35	noesis.uis.edu.co Internet Source	<1%
36	Anis Izzati Ibrahim, Nurjannah Salim, Rasidi Roslan, Mohammad Ashry Jusoh, Rokiah Hashim. "Properties of microwave modified oil palm trunk lumber", AIP Publishing, 2018 Publication	<1%
37	Anis Izzati Ibrahim, Nurjannah Salim, Rasidi Roslan, Mohammad Ashry Jusoh, Rokiah Hashim. "The effect of power intensity properties of microwave modified oil palm trunk lumber", IOP Conference Series: Materials Science and Engineering, 2018 Publication	<1%
38	E Prihatini, A Maddu, I S Rahayu, M Kurniati, W Darmawan. " Improvement of physical	<1%

properties of jabon (Anthocephalus cadamba) through the impregnation of nano-SiO and melamin formaldehyde furfuril alcohol copolymer ", IOP Conference Series: Materials Science and Engineering, 2020

Publication

39	Mohana Baskaran, Rokiah Hashim, Jin Yen Leong, Ying Ni Ong, Mohd Firdaus Yhaya, Othman Sulaiman. "Flame retardant properties of oil palm trunk particleboard with addition of epoxy resin as a binder and aluminium hydroxide and magnesium hydroxide as additives", Bulletin of Materials Science, 2019 Publication	<1 %
40	Sudarmanto, Ariadne L. Juwono, Subyakto, Ismail Budiman et al. "Effect of cold-water treatment and hydrothermal carbonization of oil-palm-trunk fibers on compatibility with cement for the preparation of cement-bonded particleboard", Wood Material Science & Engineering, 2021 Publication	<1 %

Exclude quotes	On	Exclude matches	Off
Exclude bibliography	On		

MSF.996

GRADEMARK REPORT

FINAL GRADE

/0

GENERAL COMMENTS

Instructor

PAGE 1

PAGE 2

PAGE 3

PAGE 4

PAGE 5

PAGE 6