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Table of Content

FOREWORD FROM GENERAL CHAIR 4 th FIRST 2020 INTERNATIONAL CONFERENCE	2
FOREWORD FROM DIRECTOR OF STATE POLYTECHNIC OF SRIWIJAYA.....	4
ORGANIZING COMMITTEE.....	5
KEYNOTE SPEAKER	7
Prof. Dr. Chiaki Ogino.....	7
KEYNOTE SPEAKER	8
Wahyu Caesarendra, PhD	8
KEYNOTE SPEAKER	9
Prof. Yuliansyah, M.S.A., Ph.D, Akt, CA	9
KEYNOTE SPEAKER	10
Dr. H. Dodi Reza Alex Lic, Econ, MBA.....	10
KEYNOTE SPEAKER	11
Dr. Muhammad Haikal Satria, IPM	11
KEYNOTE SPEAKER	12
Assoc. Prof. Dr. Mohammed N. Abdulrazaq Alshekhly	12
RUNDOWN	13
The 4 th FIRST 2020 INTERNATIONAL CONFERENCE.....	13
(FORUM IN RESEARCH SCIENCE AND TECHNOLOGY)	13
SNAPTEKMAS (Seminar Nasional Aplikasi Teknologi pada Masyarakat) 2020.....	13
RUNDOWN	16
TRACK 1.....	16
(Engineering and Science)	16
RUNDOWN	19
TRACK 1.....	19
(Engineering and Science)	19
RUNDOWN	22
TRACK 1.....	22
(Engineering and Science)	22
RUNDOWN	26
TRACK 2.....	26
(Computer Science, , Computer Engineering, Information System, Informatics Management)	26
.....	26
RUNDOWN	30
TRACK 2.....	30
(Computer Science, , Computer Engineering, Information System, Informatics Management)	30
.....	30

RUNDOWN	33
TRACK 3 (Social Science).....	33
RUNDOWN	36
TRACK 3 (Social Science).....	36
CHARACTERIZATION OF BLENDING COMPOSITION VARIATIONS IN FATTY ACID METHYL ESTER (FAME) BIOFUELS WITH DIESEL TO BIODIESEL	51
ID : 2079	51
Yusabri ^{1,2} , Muhammad Yerizam ³ , Aida Syarif ⁴	51
¹ Applied Master of Renewable Energy Engineering, Politeknik Negeri Sriwijaya, Jalan Srijaya Negara, Palembang, 30139 Indonesia.....	51
² Crude Distillation and Gas Plant Production, PT. Pertamina (Persero) Refinery Unit III, Jalan Beringin, Kompleks Pertamina Refinery Unit III Plaju, Palembang, 30268 Indonesia.	51
³ Chemical Engineering Department, Politeknik Negeri Sriwijaya, Jalan Srijaya Negara, Palembang, 30139 Indonesia.....	51
⁴ Renewable Energy Engineering Department, Politeknik Negeri Sriwijaya, Jalan Srijaya Negara, Palembang, 30139 Indonesia.	51
PROCESSING PLASTIC WASTE HDPE AND PP ON PYROLYSIS TEMPERATURE USING CU-AL2O3 CATALYST INTO AN ALTERNATIVE LIQUID FUEL.....	52
ID : 2082	52
Pamilia Coniwanti ¹ , Fitri Hadiah ¹ , David Bahrin ¹ , Liza Novriani ¹ , Gracia Mei Lie Justina ¹ , Robinsyah ¹	52
¹ Chemical Engineering Department, Sriwijaya of University, Jl. Raya Palembang-Prabumulih KM. 32, Inderalaya, Ogan Ilir 30662, Indonesia	52
THE PURIFICATION OF BIOGAS WITH MONOETHANOLAMINE (MEA) SOLUTION BASED ON THE BIOGAS FLOW RATE	53
Id : 2749.....	53
Yohandri Bow ¹ , Leila Kalsum ² , Abu Hasan ² , A. Husaini ³ , Rusdianasari ²	53
¹ Energy Engineering Department, Politeknik Negeri Sriwijaya, Palembang, 30139 Indonesia.....	53
² Renewable Energy Engineering Department, Politeknik Negeri Sriwijaya, Jalan	53
Srijaya Negara, Palembang, 30139 Indonesia.....	53
³ Chemical Engineering Department, Politeknik Negeri Sriwijaya, Jalan Srijaya,	53
Negara, Palembang, 30139 Indonesia.	53
FILTRATION AND ELECTROCOAGULATION AS A COMBINED PROCESS FOR ELECTROPLATING WASTEWATER.....	54
ID : 2758	54
Rusdianasari ^{1,*} , Yohandri Bow ² , Adi Syakdani ³ , Muhammad Taufik ³	54
¹ Renewable Energy Engineering Department, PoliteknikNegeri Sriwijaya, Palembang, Indonesia.....	54

2 Energy Engineering Departmen, Politeknik Negeri Sriwijaya, Palembang, Indonesia..	54
3Chemical Engineering Department, Politeknik Negeri Sriwijaya, Palembang, Indonesia	54
STUDY OF TEMPERATURE AND USE OF CATALYSTS IN THE PYROLYSIS OF LDPE PLASTIC WASTE ON THE QUANTITY OF OIL FUEL PRODUCTS PRODUCED	55
ID : 2415	55
Novarini ¹ , Sigit Kurniawan ² , Rusdianasari ³ , Yohandri Bow ⁴	55
¹ Mechanical Engineering Department, Politeknik Jambi, Jambi, Indonesia.....	55
² Electronic Engineering Department, Politeknik Jambi, Jambi, Indonesia	55
³ Chemical Engineering Department, Politeknik Negeri Sriwijaya, Palembang, Indonesia	55
⁴ Energy Engineering Department, Politeknik Negeri Sriwijaya, Palembang, Indonesia .	55
TITANIUM DIOXIDE SOAKING TIME EFFECTS ON DSSC POWERS AND EFFICIENCY	56
ID : 2077	56
Rika Musiana ¹ , Abu Hasan ² , RD Kusumanto ³	56
¹ Applied Renewable Energy Engineering Study Program, Politeknik Negeri Sriwijaya,...	56
Jalan Srijaya Negara, Palembang, 30139 Indonesia.	56
² Renewable Energy Engineering Department, Politeknik Negeri Sriwijaya, Jalan	56
Srijaya Negara, Palembang, 30139 Indonesia. ³ Renewable Energy Engineering Department, Politeknik Negeri Sriwijaya, Jalan	56
Srijaya Negara, Palembang, 30139 Indonesia.....	56
EFFECT OF FEED COMPOSITION AND PRODUCT QUANTITY OF CO-PROCESSING REFINED BLEACHED DEODORIZED PALM OIL (RBDPO).....	57
Id : 2086.....	57
Juarsa ^{1,2} , Aida Syarif ³ , Leila Kalsum ³	57
¹ Applied Master of Renewable Energy Engineering, Politeknik Negeri Sriwijaya,.....	57
Jalan Srijaya Negara, Bukit Besar, Palembang, 30139, Indonesia.....	57
² Crude Distillation and Light End Production, Pertamina Ltd. (Persero) Refinery Unit III, Beringin Road, Complex of Pertamina Refinery Unit III Plaju, Palembang, 30268 Indonesia	57
³ Renewable Energy Engineering Department, Politeknik Negeri Sriwijaya,.....	57
Jalan Srijaya Negara, Bukit Besar, Palembang, 30139, Indonesia.....	57
TOFU INDUSTRIAL LIQUID WASTE TREATMENT BY ELECTROCOAGULATION METHOD	58
ID : 2748	58
Ibnu Hajar ^{1,*} , Fadarina ¹ , Mustain Zamhari ¹ , Selastia Yuliaty ¹	58
³ Chemical Engineering Department, Politeknik Negeri Sriwijaya, Palembang, Indonesia	58
EFFECT OF TEMPERATURE ON BIOFUELS PRODUCTION WITH CATALYTIC CRACKING PROCESS.....	59
ID : 2626	59

KA Ridwan ^{1,2} , Aneasari M ¹ , Taufik Jauhari ¹ , Ida Febriana ¹	59
¹ Chemical Engineering Department, State Polytechnic of Sriwijaya, South Sumatra, Indonesia.....	59
EFFECT OF BENTONITE ON THE YIELD AND COMPOSITION OF PRODUCTS FROM THERMOLYSIS OF POLYSTYRENE WASTE	60
ID : 2573	60
Lety Trisnaliani ^{1a} , Aida Syarif ¹ , Sahrul Effendy ¹ , Tahdid ¹ , Rima Daniar ¹	60
¹ Energy Department, Politeknik Negeri Sriwijaya	60
PRODUCTION OF BIO-PELET BRIQUETTES FROM COCONUT SHELL WASTE AS ALTERNATIVE ENERGY FOR HOUSEHOLD SCALE	61
ID : 2665	61
Muhammad Yerizam* ¹ , Muhammad Zaman 1, Taufiq Jauhari1 , Nur Yuli 1, Riwen Setiawan1 , Umaidella Afrilla1.....	61
¹ Jurusan Teknik Kimia,Politeknik Negeri Sriwijaya Jl. Srijaya Negara, Bukit Besar, Palembang 30139, Indonesia.....	61
CATALYTIC PYROLYSIS OF STYROFOAM WASTE USING ZEOLITE CATALYST TO PRODUCE LIQUID FUEL	62
ID : 2707	62
Zurohaina ^{1*} , Irawan Rusnadi, Fatria, Arizal Aswan, Rima Daniar	62
¹ Department of Chemical Engineering, Polytechnic of Sriwijaya, Palembang, Indonesia	62
PRODUCTION OF GREEN DIESEL FROM CRUDE PALM OIL (CPO) THROUGH HYDROTREATING PROCESS BY USING ZEOLITE CATALYST.....	63
ID : 2715	63
Ahmad Zikri* , Indah Puspita, Erlinawati, Sutini PL, Agus M Elbi Zalita P, Andre Krismantoro	63
Energy Engineering, Chemical Engineering Department, State Polytechnic of Sriwijaya 63	
Jl. Srijaya Negara Bukit Besar Palembang 30139, Telp +62711353414 / fax +62711355918.....	63
EFFECT OF ADDING PALM OIL MILL EFFLUENT (POME) AND SLURRY ON BIOGAS FROM COW MANURE TO PRODUCED METHANE GAS	64
ID : 2723	64
Muhammad Hanif Fatin ^{1,*} , A. Husaini ² , Leila Kalsum ³	64
¹ Applied Renewable Energy Engineering Study Program, Politeknik Negeri Sriwijaya, Jalan Srijaya Negara, Palembang, 30139 Indonesia.....	64
² Chemical Engineering Department, Politeknik Negeri Sriwijaya, Jalan Srijaya Negara, Palembang, 30139 Indonesia.....	64
³ Renewable Energy Engineering Department, Politeknik Negeri Sriwijaya, Jalan Srijaya Negara, Palembang, 30139 Indonesia.	64
CHARACTERIZATION OF THERMAL ACTIVATED FLY ASH ADSORBENT BY STUDYING THE EFFECT OF TEMPERATURE	65

ID : 2796	65
Aida Syarif ¹ , Rusdianasari, M.Yerizam,Sayhirmanyusi,	65
¹ Jurusan Teknik Kimia Program Studi Magister Terapan Teknik Energi Baru Terbarukan	65
Politeknik Negeri Sriwijaya, Jalan Srijaya Negara Bukit Besar Palembang	65
DRYING RATE OF SKIM MILK FROM VIRGIN COCONUT OIL REMAINING WATER	66
ID : 2516	66
A Hasan ¹ , I Purnamasari ^{1,2} , M Yerizam ¹ , A Hasan ¹ and R Junaidi ¹	66
¹ Chemical Engineering Department, State Polytechnic of Sriwijaya, South Sumatera, Indonesia.....	66
TOFU INDUSTRIAL WASTEWATER TREATMENT BY ELECTROCOAGULATION METHOD	67
ID : 2656	67
Ibnu Hajar ¹ ,* Fadarina ¹ , Mustain Zamhari ¹ , Selastia Yuliaty ¹	67
³ Chemical Engineering Department	67
BIOCELLULOSE MEMBRANE OF COCONUT WATER.....	68
ID : 2792	68
Elina Margaretty ¹ , Erwana Dewi ² , Leila Kalsum ³ , Aisyah Suci Ningsih ¹	68
¹). Lecturer D3-Chemical Engineering Sriwijaya State Polytechnic, Palembang, Indonesia	68
²).Lecturer D4- Industrial Chemical Technology, Sriwijaya State Polytechnic, Palembang, Indonesia.....	68
³). Lecturer S2- Renewable Energy Engineering, Sriwijaya State Polytechnic, Palembang, Indonesia.....	68
SURFACTANT METHYL ESTER SULFONATE FROM CRUDE PALM OIL (CPO)- BASED METHYL ESTER.....	69
ID : 2794	69
Jaksen ¹ , Idha Silviyati ¹ , Endang Supraptiah ¹ , Rima Daniar ²	69
¹).Lecturer of Chemical Engineering Department, Politeknik Negeri Sriwijaya, Palembang, Indonesia.....	69
²).Lecturer of Energy Engineering Department, Politeknik Negeri Sriwijaya, Palembang, Indonesia.....	69
OIL PALM EMPTY BUNCHES AS AN ALTERNATIVE RAW MATERIAL FOR MAKING BIOPLASTICS	70
ID : 2250	70
Husaini A ¹ , Zaman M ¹ , Chodijah S ¹ , Hilwatullisan ¹ , Ibrahim ²	70
¹ Chemical engineering Department, Politeknik Negeri Sriwijaya, Jalan Srijaya Negara, Palembang, 30139 Indonesia.....	70
² Chemical engineering Study Program, Politeknik Negeri Sriwijaya, Jalan Srijaya Negara, Palembang, 30139 Indonesia.....	70
<i>Corresponding author E-mail address :husaini@polsri.ac.id</i>	70

THE EFFECT OF THE CATALYST (NaOH) ON THE PROCESSING OF WASTE USED OIL INTO LIQUID FUEL	71
ID : 2511	71
Azharuddin ¹ , Syafei ¹ , Didi Suryana ¹ , Indra HB ¹ , M R Rahmaddy ¹	71
Y Pratomo ¹ , M A Ariasya ¹	71
¹) Mechanical Engineering Department, State Polytechnic of Sriwijaya, Palembang, 30154, Indonesia.....	71
DESIGN AND PROTOTYPE OF PAVING BLOCK MAKING MACHINE	72
ID : 2766	72
Ella Sundari ¹ , Soegeng Witjahjo ¹ , Eka Satria Martomi ¹ , Dodi Tafrant ¹	72
Lecturer of Mechanical Engineering Departement, Sriwijaya State Polytechnic	72
*Jln. Srijayanegara Bukit Lama, Palembang.....	72
WATER QUALITY MONITORING SYSTEM IN GURAME FISH CULTIVATION BASED ON ESP32	73
ID : 2094	73
Sujito ¹ , Mokh. Sholihul Hadi ¹ ,I Made Wirawan ¹ , Faiz Syaikhoni ² , Abdullah Iskandar Syah ² ,	73
Danny Mayrawan ²	73
¹ Dosen Jurusan Teknik Elektro, Fakultas Teknik, Universitas Negeri Malang	73
² Mahasiswa Jurusan Teknik Elektro, Fakultas Teknik, Universitas Negeri Malang.....	73
OPTIMIZATION OF STROKE REHABILITATION HAND COMPONENT OF 3D PRINTING WITH TAGUCHI METHOD APPROACH.....	74
ID : 2426	74
Fatahul Arifin ¹ , Fenoria Putri ¹ , Iskandar ¹ , Mulyadi ¹ , Suparjo ¹ , Franando ¹ , Yusuf Dewantoro Herlambang ^{2(*)}	74
¹ Mechanical Engineering Department, Politeknik Negeri Sriwijaya, Palembang, 30154, Indonesia.....	74
² Mechanical Engineering Department, Politeknik Negeri Semarang, Semarang, 50275, Indonesia.....	74
EXPERIMENTAL RESEARCH OF THE INFLUENCE OF HOT MACHINING METHOD ON AISI 4340 LATHE MACHINE PROCESS TOWARDS SPECIFIC CUTTING ENERGY AND SURFACE ROUGHNESS.....	75
ID : 2457	75
Ismail T ¹ , Dyos S ² , Joni Y ³ , Samuel S ⁴ ,Abdurahman W ⁵ , Aldi Y ⁶	75
¹²³⁴⁵⁶ Mechanical Engineering, Engineering Faculty of Sriwijaya University,.....	75
Jln Raya Palembang - Inderalaya Km 32, Indonesia.....	75
STUDY OF CAPACITOR PLACEMENT TO IMPROVE THE VOLTAGE PROFILE IN CONTINGENCY CONDITIONS OF THE 150 KV MADURA ELECTRICITY POWER SYSTEM	76
ID : 2487	76
Sujito ^{1*} , M. Z. Falah ¹ , M. R. Faiz ¹	76

¹ Electrical Engineering Department, Universitas Negeri Malang, Indonesia	76
THE INVESTIGATION OF SEA SALT SOILING ON PV PANEL	77
ID : 2488	77
Tresna Dewi ¹ , Ahmad Taqwa ² , Rusdianasari ² , RD Kusumanto ¹ , and Carlos Sitompul ¹ ...	77
¹ Electrical Engineering Department, Politeknik Negeri Sriwijaya, Jalan Srijaya Negara, Palembang, 30139 Indonesia.....	77
² Renewable Energy Engineering Department, Politeknik Negeri Sriwijaya, Jalan	77
Srijaya Negara, Palembang, 30139 Indonesia.....	77
REAL-TIME WIRELESS CONCEPT OF VEHICLE TO VEHICLE CHARGING SYSTEM.....	78
ID: 2490	78
Yurni Oktarina ¹ , Tresna Dewi ¹ , Pola Risma ¹ , and Muhammad Nawawi ¹	78
¹ Electrical Engineering Department, Politeknik Negeri Sriwijaya, Jalan Srijaya Negara Palembang, Indonesia 30139.....	78
OPTIMIZATION OF FDM 3D PRINTING PROCESS PARAMETER FOR IMPROVING POROSITY ACCURACY OF PLA SCAFFOLD.....	79
ID : 2522	79
Zainal Abidin ¹ , M. Yanis ¹ , M. Zahri Kadir ¹ , Astuti ¹ , Akbar Teguh Prakoso ¹ , Edo Syahrizal ¹ , Ardiyansyah Syahrom ^{2,3} , Hasan Basri ^{1,*}	79
Department of Mechanical Engineering, Faculty of Engineering, Universitas Sriwijaya, Indralaya 30662, Ogan Ilir, South Sumatera, Indonesia	79
Department of Applied Mechanics and Design, Faculty of Mechanical Engineering, Universiti Teknologi Malaysia, Skudai 81310, Johor, Malaysia	79
Medical Device and Technology Center (Meditec), Institute of Human-Centered and Engineering (IHCE), Universiti Teknologi Malaysia, Skudai 81310, Johor, Malaysia.....	79
FATIGUE PREDICTION OF POROUS MAGNESIUM BONE SCAFFOLD USING FINITE ELEMENT METHOD	80
ID: 2527	80
Risky Utama Putra ¹ , Akbar Teguh Prakoso ¹ , Amir Putra Md Saad ^{2,3} , Ardiyansyah Syahrom ^{2,3} , Hasan Basri ^{1,*}	80
Mechanical Engineering Master Study Program, Faculty of Engineering, Universitas Sriwijaya, Indralaya 30662, Ogan Ilir, South Sumatera, Indonesia	80
Department of Applied Mechanics and Design, Faculty of Mechanical Engineering, Universiti Teknologi Malaysia, Skudai 81310, Johor, Malaysia	80
Medical Device and Technology Center (Meditec), Institute of Human-Centered and Engineering (IHCE), Universiti Teknologi Malaysia, Skudai 81310, Johor, Malaysia.....	80
THE GROUNDING SYSTEM IN FEEDER TOMAT PT. PLN (PERSERO) ULP MARIANA	81
ID : 2763	81
Bambang Guntoro, Siswandi, Zainuddin Idris, M. Yunus	81
Email : bguntoro57@gmail.com	81
OPTIMIZATION OF PRODUCTION PROCESS PARAMETERS OF DLP TYPE 3D PRINTER DESIGN	

FOR PRODUCT ROUGHNESS VALUE.....	82
ID : 2510	82
DP Putra ¹ , Romli ² , D Seprianto ² , Hasan Basri ^{1,*}	82
¹ Mechanical Engineering Master Study Program, Universitas Sriwijaya	82
Jalan Srijaya Negara Bukit Besar Palembang, Sumatera Selatan, 30139, Indonesia	82
² Mechanical Engineering Department, Politeknik Negeri Sriwijaya.....	82
Jalan Srijaya Negara Bukit Besar Palembang, Sumatera Selatan, 30139, Indonesia	82
DESIGN OF ELECTRONIC INSTRUMENTS AS TOOLS AIR POLLUTION DETECTION.....	83
ID : 2592	83
Ali Nurdin ¹ (ali_viking_kps@yahoo.com . aalinurdin67@gmail.com), Jon Endri,	83
Ibnu Ziad ³ , Ciksadan ⁴	83
^{1,2,3,4} Politeknik Negeri Sriwijaya.....	83
<i>Jl. Srijaya Negara Bukit Besar – Palembang</i>	83
Datalogger experimental analysis based on arduino mega 2560 on a 100 wp monocrystalline solar panel using perforated plate.....	84
ID : 2249	84
W Adipradana ¹ , A Sofijan ² , Rahmawati ³ , I Bizzy ⁴ , R Sipahutar ⁵ , M A Fajri ⁶	84
^{1,2,3,6} Department of Electrical Engineering, Engineering Faculty, Sriwijaya University, Indonesia.....	84
^{4,5} Department of Mechanical Engineering, Engineering Faculty, Sriwijaya University, Indonesia.....	84
A_sofijan@ft.unsri.ac.id.....	84
THE EFFECT OF INDUCTION HEATING ON TENSILE TEST SPECIMENS' CLAMPING PRODUCTS THROUGH THE MEDIUM CARBON STEEL MATERIALS' ENGINEERING TECHNIQUE	85
ID : 2722	85
Romli ^{1,*} , M. Afif Rizkiawan ¹ , Karmin ¹ , Sairul Effendi ¹ , Firdaus ¹	85
¹ Mechanical Engineering Department, State Polytechnic of Sriwijaya, Indonesia	85
DEVELOPMENT INTERNET OF THINGS FOR WATER QUALITY MONITORING SYSTEM FOR GOURAMY CULTIVATION.....	86
ID: 2484	86
D Mayrawan ² , Sujito ^{1,2*} , I M Wirawan ² , F S Aziz ^{1,2} , A I Syah ² , M A A Shidiqi ²	86
¹ Electrical Engineering Postgraduate, Universitas Negeri Malang, Indonesia	86
² Electrical Engineering Department, Universitas Negeri Malang, Indonesia	86
CONTINGENCY ANALYSIS ON 150 KV ELECTRICITY POWER SYSTEM ON THE MADURA ISLAND BASED ON THE 1P1Q METHOD	87
ID : 2485	87
M Z Falah ¹ , Sujito ^{1*} , I M Wirawan ¹	87
¹ Electrical Engineering Department, Universitas Negeri Malang, Indonesia	87
PROTOTYPE OF SMALL SAVONIUS WIND TURBINE	88

ID : 2797	88
Ozkar F. Homzah ^{1,*} Tri Widagdo ¹ Mardiana ¹ Ibnu Asrofi ¹ Destra A Pratama ²	88
¹ Department of Mechanical Engineering, Politeknik Negeri Sriwijaya, Palembang, Indonesia.....	88
² Department of Electrical Engineering, Politeknik Negeri Sriwijaya, Palembang, Indonesia	88
THE FORMATION OF MACHINE COMPONENTS USING POWDER METALLURGY METHOD UTILIZING METAL POWDER FROM GRINDING PROCESS	89
ID : 2780	89
Yahya, S.T.,M.T ¹ , Muhammad Rasid, S.T.,M.T ² ,.....	89
Dicky Seprianto, S.T.,M.T. ³ , Siproni, S.T.,M.T. ⁴	89
<i>Departement of Mecahanical Engineering, Politeknik Of Sriwijaya, Palembang, Indonesia</i>	89
SIMULATION-BASED ANALYSIS ON VACUUM ACTUATED SOFT ROBOTIC GRIPPER: TRAJECTORY AND STRESS INTENSITY FACTOR	90
ID :2736	90
Noer Fadzri Perdana Dinata ¹ , Hasan Basri ^{1,*}	90
¹ Mechanical Engineering Master Study Program, Universitas Sriwijaya, Jalan Srijaya Negara Bukit Besar Palembang, Sumatera Selatan, 30139, Indonesia.....	90
*Corresponding author. Email: hasan_basri@unsri.ac.id	90
FAILURE ANALYSIS AND PERFORMANCE ASSESSMENT OF TUBULAR AIR HEATER AT PLTU SOUTH SUMATRA V	91
ID : 2731	91
Lulu Khoirunnisa ¹ , Hasan Basri ^{2,*}	91
¹ Mechanical Engineering Master Study Program, Universitas Sriwijaya.....	91
Jalan Srijaya Negara Bukit Besar Palembang, Sumatera Selatan, 30139, Indonesia	91
AUTOMATIC SIMULATION OF MOVING PRODUCTS USING LINE FOLLOWER AND CONVEYOR	92
ID : 2787	92
Almadora Anwar Sani ^{1,*} Rachmat Dwi S ² , Irawan Malik ³ , Ali Medi ⁴ , Agus Nugraha ⁵	92
¹ mechanical engineering, Politeknik Negeri Sriwijaya,	92
² mechanical engineering, Politeknik Negeri Sriwijaya	92
³ mechanical engineering, Politeknik Negeri Sriwijaya	92
⁴ mechanical engineering, Politeknik Negeri Sriwijaya	92
⁵ mechanical engineering, Politeknik Negeri Sriwijaya	92
MONITORING DEPTH OF DISCHARGE OF A VALVE REGULATED LEAD ACID BATTERY IN A STANDALONE PV SYSTEM.....	93
ID : 2751	93
Mirdiansyah ^{1,*} Ahmad Taqwa ² , Yohandri Bow ³	93

¹ Applied Renewable Energy Engineering Study Program, Politeknik Negeri Sriwijaya, Jalan Srijaya Negara, Palembang, 30139 Indonesia.....	93
² Renewable Energy Engineering Department, Politeknik Negeri Sriwijaya, Jalan Srijaya Negara, Palembang, 30139 Indonesia	93
³ Energy Engineering Department, Politeknik Negeri Sriwijaya, Jalan Srijaya Negara, Palembang, 30139 Indonesia.....	93
The Effect of Parameter Process 3D Printer Technology Digital Light Processing to Geometric of Shaft.....	94
ID : 2650	94
A Zamheri ^{1,*} D Seprianto ² , Carlos RS ³ , Indri A ⁴ , TC Persada ⁵	94
¹ Mechanical Engineering Department, State Polytechnic of Sriwijaya, Indonesia	94
² Mechanical Engineering Department, State Polytechnic of Sriwijaya, Indonesia	94
³ Electrical Engineering Department, State Polytechnic of Sriwijaya, Indonesia	94
⁴ Informatics Management Department,, State Polytechnic of Sriwijaya, Indonesia.....	94
⁵ Mechanical Engineering Department, State Polytechnic of Sriwijaya, Indonesia.....	94
BENDING TEST GALVALUM COLD FORMED STEEL BEAM WITH VARIATION MORTAR AND REINFORCEMENT BARS.	95
ID : 2073	95
Fadhila Firdausa, Sri Rezki Artini, Ahmad Syapawi, Puryanto	95
Civil Engineering Polytechnic of Sriwijaya.....	95
INDEX OF RETAINED STRENGTH AND WEIGHT LOSS ON FLEXIBLE PAVEMENT AC-WC AND HRS-WC USING POLYMER PRODUCTS ETHYLENE VINYL ACETATE (EVA) AND STYRENE-BUTADIENE-STYRENE (SBS)	95
ID : 2089	95
Pataras M ¹ , Kadarsa E ² , Permata D Y ³ , Khairunnisa S ⁴ , Akbar M A ⁵ , Pratama Y ⁶	96
¹ Civil Engineering Department, Sriwijaya University, Raya Prabumulih Road, Indralaya, Sumatera Selatan	96
² Civil Engineering Department, Sriwijaya University, Raya Prabumulih Road, Indralaya, Sumatera Selatan	96
³ Civil Engineering Department, Sriwijaya University, Raya Prabumulih Road, Indralaya, Sumatera Selatan	96
UTILIZATION OF RESIDUAL SAND MATERIALS FROM THE MINING OF KAOLIN AND TIN IN BANGKA ISLAND ON FLEXIBLE PAVEMENT STRUCTURE	97
ID : 2101	97
Adhitya B B ¹ , Pataras M ² , Kurnia A Y ³ , Wiranda N ⁴ , Wulansari W ⁵ , Islami B M ⁶	97
¹ Civil Engineering Department, Sriwijaya University, Indralaya, Sumatera Selatan	97
² Civil Engineering Department, Sriwijaya University, Indralaya, Sumatera Selatan	97
³ Civil Engineering Department, Sriwijaya University, Indralaya, Sumatera Selatan	97
THE INFLUENCE OF ANADARA GRANOSA'S SHELL WASTE AS A SUBSTITUTE OF FINE AGGREGATE IN MIXED ASPHALT CONCRETE WEARING COURSE (AC-WC)	98

ID : 2218	98
Ika Sulianti ¹ , Ibrahim ¹ , Indah Ayu Wiloka ¹ , Reta Iftitah Sari ¹	98
1. State Polytechnic of Sriwijaya, Jl. Sriwijaya Negara Bukit Besar Palembang 30139,	98
South Sumatera – Indonesia.....	98
ANALYSIS OF THE IMPACT OF PALEMBANG- INDRALAYA (PALINDRA) TOLL ROAD TO PALEMBANG – INDRALAYA NATIONAL ROAD SERVICE LEVELS	99
ID : 2236	99
S Nisumanti*, N Puspita, and S Mulyaningsih,	99
Civil Engineering Department, Universitas Indo Global Mandiri, Jalan Jend. Sudirman KM.4 No.629 Palembang, Indonesia	99
THE EFFECT OF FLY ASH AS A PART CEMENT INSTITUTION ON HIGH-QUALITY CONCRETE FC'35	100
ID: 2402	100
Sazili Harnawansyah¹, Herlinawati^{1(*)}, Bastoni Hasasi¹, Radius Pranoto¹	100
1 Civil Engineering Department, Sriwijaya State Polytechnic, Palembang, 30154, Indonesia	100
THE USE OF COLD-FORMED STEEL AS A SUBSTITUTE FOR REINFORCEMENT ON STRUCTURAL OF LIGHTWEIGHT CONCRETE BEAMS.....	101
ID : 2553	101
Mahmuda ¹ , Revias ² , Siswa Indra ³ , Sumiati ⁴	101
Civil Engineering Departement, State Polytechnic Sriwijaya, Sriwijaya Negara street, Bukit Besar Palembang, 30139, Indonesia.....	101
THE EFFECT OF AIR PRESSURE ON FOAMED MORTAR PRODUCTION.....	102
ID : 2724	102
Ibrahim ¹ , Amiruddin ¹ , and Ika Sulianti ¹ , and Agus Subrianto ¹	102
1. State Polytechnic of Sriwijaya, Jl. Sriwijaya Negara Bukit Besar Palembang 30139,	102
South Sumatera – Indonesia.....	102
THE CHARACTERISTICS OF FOLDING BICYCLE USERS AGAINST THE SELECTION OF TRANSPORTATION MODES IN PALEMBANG CITY.....	103
ID : 2767	103
Efrilia Rahmadona ¹ , Sudarmadji ² , Norca Praditya ³ , M. Ade Surya Pratama ⁴	103
¹ Politeknik Negeri Sriwijaya	103
² Politeknik Negeri Sriwijaya	103
³ Politeknik Negeri Sriwijaya	103
⁴ Politeknik Negeri Sriwijaya	103
EFFECT OF AMOUNT POTASSIUM HYDROXIDE, METHANOL, AND ELECTRICITY CURRENT ON THE PRODUCTION PROCESS OF METHYL ESTERS FROM USED FRYING OIL	104
ID : 2081	104
Rosdiana Moeksin.....	104

Teknik Kimia, Universitas Sriwijaya Palembang-Indonesia.	104
OPTIMIZATION OF PUBLIC TRASPORT SERVICEBUS RAPID TRANSIT (BRT) TRANS MUSI IN THE CITY OFPALEMBANG	105
ID : 2611	105
Moch.Absor,Yusri, A.Latif, A. Fuad Z.Muhammad Yusri R.Civil Engineering, Politeknik Negeri Sriwijaya, Palembang, Indonesia	105
absorputrasyam@gmail.com, yusribermawi18@gmail.com,Latiftamim56@yahoo.com,fuadzainin13@yahoo.com, muhammadyusririzki@gmail.com	105
LIFE CYCLE ASSESSMENT (LCA) IN PULP & PAPER MILLS: COMPARISON BETWEEN MFO WITH BIOMASS IN LIME KILN	106
ID : 2109	106
Yonki Alexander Volta ¹ , Rusdianasari ² , Syahirman Yusi ³	106
¹ Applied Renewable Energy Engineering Study Program, Politeknik Negeri Sriwijaya, Jalan Srijaya Negara, Palembang, 30139 Indonesia.	106
² Renewable Energy Engineering Department, Politeknik Negeri Sriwijaya, Jalan Srijaya Negara, Palembang, 30139 Indonesia.	106
³ Business Administration Department, Politeknik Negeri Sriwijaya, Jalan Srijaya Negara, Palembang, 30139 Indonesia.....	106
EFFECT OF VARIATIONS CONCENTRATION AND PH OF LIQUID SMOKE IN THE IMMERSION WITH VARIOUS TYPES OF FISH	107
ID : 2120	107
by	107
Farida Ali, Corresponding author, Lecturer, Faculty of Chemical Engineering, Universitas Sriwijaya.....	107
Lia Cundari, Lecturer, Faculty of Chemical Engineering, Universitas Sriwijaya.....	107
Siti Miskah, Lecturer, Faculty of Chemical Engineering, Universitas Sriwijaya.....	107
Hendri Prasetyo, Student, Faculty of Chemical Engineering, Universitas Sriwijaya.....	107
COMPARISON OF THE USE OF FLY ASH AND RICE HUSK ASH IN THE MAKING OF GEOPOLYMER CONCRETE.....	108
ID : 2154	108
Indrayani ^{1*} , Andi Herius ¹ , Akhmad Mirza ¹ , Ricky Ravsyhan Alhafez ¹	108
¹ Civil Engineering Department, Politeknik Negeri Sriwijaya, Palembang, Indonesia	108
FLEXURAL STRENGTH ANALYSIS OF CONCRETE WITH THE ADDITION OF B3 WASTE AS AN ADDITIVE TO ORDINARY PORTLAND CEMENT (OPC).....	109
ID :2235	109
N Puspita*, Y Arti and Febriyandi	109
Civil Engineering Department, Universitas Indo Global Mandiri, Jalan Jend. Sudirman KM.4 No.629 Palembang, Indonesia	109
SIMULATION OF SILAGE PRODUCTION FROM WATER HYACINTH (<i>EICHORNIA CRASSIPES</i>)	

*Martha Aznury ¹ Elina Margerty ¹ Melianti ¹ Sofiah ¹ Yuniar ¹ Sufi Awwaliyah ¹	115
1Department of Chemical Engineering, Politeknik Negeri Sriwijaya, Palembang, Indonesia	115
ROAD DAMAGE CONDITIONS ANALYSIS OF TANJUNG API-API - GASING DISTRICT ROAD BASED ON SURFACE DISTRESS INDEX (SDI) METHOD.....	116
ID : 2744	116
R. Marpen ¹ , A. Hasan ² , AN. Sari ³ , HWS. Putra ⁴ , R. Pranoto ⁵	116
¹²³⁴⁵ Jurusan Teknik Sipil, Politeknik Negeri Sriwijaya, Palembang Jl. Srijaya Negara Bukit Besar, Palembang, Sumatera Selatan 30139	116
DATA MODEL PATTERN FOR DATA WAREHOUSE WEB APPLICATION OF INFORMATION PORTAL (Case study : Hidayatullah Integrated Islamic Boarding School, Banyuasin Regency)	117
ID : 2550	117
M Aris Ganiardi ¹ ,Nita Novita ² , Indri Ariyanti ³ , Delta Khairunnisa ⁴	117
Informatics Management Department, Politeknik Negeri Sriwijaya, Srijaya Negara Street, Palembang, 30139, Indonesia.....	117
INVENTORY CONTROL AND EOQ FORECASTING TOOLS AS EFFECTIVE DECISION-MAKING MODEL.....	118
ID : 2577	118
Ahmad Rifai ¹ , Dedy Kurniawan ^{2*} , Ariansyah Saputra ³ ,	118
Dinna Yunika Hardiyanti ⁴	118
1-4 Faculty of Computer Science, Universitas Sriwijaya, Indonesia	118
2*Advanced Programming Laboratory, Faculty of Computer Science, Universitas Sriwijaya, Indonesia.....	118
3 Department of Computer Engineering, Politeknik Negeri Sriwijaya, Indonesia	118
INCREASING SENSITIVITY OF PH DETECTION USING COMPUTER VISION BASED BIOSENSORS.....	119
ID : 2096	119
Faiz Syaikhoni Aziz ^{1,2} , Sujito ^{1,2} , Aji Prasetya Wibawa ^{1,2} , I Made Wirawan ² , Ari Priharta ^{1,2} , Abdullah Iskandar Syah ² , Tran Huu Duy ³	119
¹ Electrical Engineering Postgraduate, Universitas Negeri Malang	119
² Electrical Engineering Department, Universitas Negeri Malang	119
³ Electrical Engineering Department, Dalat University	119
ADAPTIVE FUZZY TIME SERIES METHOD TO FORECASTING ENROLLMENTS OF NEW STUDENT (CASE STUDY : DEPARTMENT OF COMPUTER ENGINEERING, STATE POLYTECHNIC OF SRIWIJAYA).....	120
ID : 2603	120
Ica Admirani ¹ , Ikhthison Mekongga ² , Isnaini Azro ³ , Hidayati Ami ⁴ , Rian Rahmanda Putra ⁵	120
1Department of Computer Engineering, State Polytechnic of Sriwijaya, JL.Srijaya Negara Bukit Besar, Palembang,30139, Indonesia.	120

2Department of Computer Engineering, State Polytechnic of Sriwijaya, JL.Srijaya Negara Bukit Besar, Palembang,30139, Indonesia.	120
3Department of Computer Engineering, State Polytechnic of Sriwijaya, JL.Srijaya Negara Bukit Besar, Palembang,30139, Indonesia.	120
4Department of Computer Engineering, State Polytechnic of Sriwijaya, JL.Srijaya Negara Bukit Besar, Palembang,30139, Indonesia.	120
5Department of Computer Engineering, State Polytechnic of Sriwijaya, JL.Srijaya Negara Bukit Besar, Palembang,30139, Indonesia	120
ROOM SAFETY SYSTEM USING FACE RECOGNITION USING TELEGRAM AND RASPBERRY PI BASED HISTOGRAM OF ORIENTED METHOD.....	121
ID : 2613	121
Azwardi, Yulian Mirza, Alan Novi Tomponu, Ariansyah Saputra	121
Program Studi Teknik Komputer, Politeknik Negeri Sriwijaya	121
Jl. Srijaya Negara Bukit Besar- Palembang 30139	121
Telp. 0711-353414, Fax. 0711- 355918	121
TELEMETRY DESIGN ACCURATION OF PATIENT’S TEMPERATURE WITH IOT APPROACH.	122
ID : 2618	122
Ahyar Supani ^{1,*} , Ahmad Bahri Joni Malyan ¹ , Herlambang Saputra ¹ , Indarto ¹ , Yuli Andriani ²	122
¹ <i>Department of Computer Engineering, Polytechnic State of Sriwijaya, Palembang, Indonesia.....</i>	122
² <i>Department of Mathematics, Sriwijaya University, Palembang, Indonesia.....</i>	122
Image processing system for pH classification using biosensors	123
ID : 2097	123
Sujito ^{1,2*} , A P Wibawa ^{1,2} , I M Wirawan ² , Aripriharta ^{1,2} , F S Aziz ¹ , A I Syah ² , T H Duy ³	123
¹ Electrical Engineering Postgraduate, Universitas Negeri Malang, Indonesia	123
² Electrical Engineering Department, Universitas Negeri Malang, Indonesia	123
³ Electrical Engineering Department, Dalat University, Vietnam	123
QUALITY MEASUREMENT EVALUATION OF THE POLSRI LEARNING MANAGEMENT SYSTEM WEBSITE USING IMPORTANCE PERFORMANCE ANALYSIS (IPA) METHOD	124
ID : 2274	124
Irma Salamah ¹ , Lindawati ² , Asriyadi ³ , M.Fadhli ⁴	124
^{1,2,3,4} Telecommunication Program Studi State Polytechnic of Sriwijaya.....	124
RESTFUL WEB SERVICE AS DATA GENERATOR FOR REPORTING OF ACADEMIC INFORMATION SYSTEM.....	125
ID : 2620	125
M. Miftakul Amin ^{*1} , Slamet Widodo ² , Adi Sutrisman ³ , Ervi Cofriyanti ⁴ , Ali Firdaus ⁵	125
^{1,2,3,4,5} Department of Computer Engineering, Politeknik Negeri Sriwijaya, Jl. Srijaya Negara Bukit Besar, Palembang, 30139, Indonesia	125

DESIGN AND IMPLEMENTATION OF LEARNING E-SCHEDULING IN SRIWIJAYA STATE POLYTECHNIC - TELECOMMUNICATION ENGINEERING STUDY PROGRAM.....	126
ID : 2666	126
Abdul Rakhman ¹ , Irawan Hadi ² , Nasron ³ , Martinus Mujur Rose ⁴	126
^{1,2,3,4} Politeknik Negeri Sriwijaya	126
Jl. Sriwijaya Negara Bukit Besar – Palembang	126
PHP PROGRAMMING FOR ACHIEVING STUDENTS IN INFORMATICS MANAGEMENT DEPARTMENT STATE OF POLYTECHNIC SRIWIJAYA.....	127
ID : 2702	127
Yusniarti ¹	127
Henny Madora ²	127
Ida Wahyuningrum ³	127
Muhammad Noval ⁴	127
¹²³⁴ .Jurusan Manajemen Informatika Politeknik Negeri Sriwijaya.....	127
MEDICAL SERVICES APPLICATION OF LECTURERS, STAFF AND STUDENTS IN THE SRIWIJAYA STATE POLYTECHNIC POLYCLINIC	128
ID : 2704	128
Robinson ¹ , Deri Darfin ² , Zulkarnaini ³ , Ridwan Effendi ⁴ ,	128
¹ Polsri Jl. Sriwijaya Negara Bukit Besar Palembang Sumatera Selatan	128
² Polsri Jl. Sriwijaya Negara Bukit Besar Palembang Sumatera Selatan	128
³ Polsri Jl. Sriwijaya Negara Bukit Besar Palembang Sumatera Selatan	128
⁴ Polsri Jl. Sriwijaya Negara Bukit Besar Palembang Sumatera Selatan.....	128
PROTOTYPE DEVELOPMENT OF MOTORBIKE TOWING HOOK TOWARD AUTHORIZED MECHANIC PERCEPTION AND INVESTIGATION	129
ID : 2768	129
Rahman Hakim ¹ , Muhammad Hasan Albana ¹ , Widodo ¹ , Hanifah Widiastuti ¹ and Wahyu Caesarendra ^{2*}	129
¹ Department of Mechanical Engineering, Politeknik Negeri Batam, Jl. A. Yani, Batam Center, Kota Batam 29461, Indonesia	129
² Faculty of Integrated Technologies, Universiti Brunei Darussalam, Jalan Tungku Link, Gadong BE1410, Brunei Darussalam.....	129
INVESTIGATION STUDY OF PRESSURE DIFFERENT EFFECT AT EVAPORATOR IN ORGANIC RANKINE CYCLE SIMULATOR (ORCS) USING LOW-GRADE WASTE HEAT	130
ID : 2770	130
Mochamad Denny Surindra ¹ , Wahyu Caesarendra ^{2*}	130
¹ Mechanical Engineering, Politeknik Negeri Semarang, Semarang 50275, Indonesia; Email: dennysurindra@polines.ac.id	130
² Faculty of Integrated Technologies, Universiti Brunei Darussalam, Jalan Tungku Link, Gadong BE1410, Brunei Darussalam.....	130
APPLICATION OF TRACKING LETTER DISPOSITION AT STATE POLYTECHNIC OF SRIWIJAYA	

BASED ON ANDROID WEBVIEW	131
ID : 2644	131
Satriadi, Indra ^{1,*} Oktapriandi, Sony., Meileni, Hetty., Aprianty, Desy.....	131
¹ State Polytechnic of Sriwijaya	131
THE SHORTEST PATH SEARCH APPLICATION FOR BASE TRANSCIEVER STATION (BTS) USING A* ALGORITHM	132
ID : 1994	132
Ikhthison Mekongga ¹ , Aryanti Aryanti ^{2,3}	132
¹ Computer Engineering, Politeknik Negeri Sriwijaya, Palembang, Indonesia	132
² Electrical Engineering, Politeknik Negeri Sriwijaya, Palembang, Indonesia.....	132
³ Electrical Engineering, Southern Taiwan University of science and Technology, Tainan, Taiwan	132
COMPATIBILITY OF LINUX ARCHITECTURE FOR DISKLESS TECHNOLOGY SYSTEM.....	133
ID : 2615	133
Aryanti Aryanti ^{1,2*} , Ade Silvia Handayani ² , Ibnu ziad ² , Ikhthison Mekongga ³ , Farid Jatri Abiyyu ²	133
¹ Electrical Engineering, Southern Taiwan University of science and Technology, Tainan, Taiwan	133
² Electrical Engineering, Politeknik Negeri Sriwijaya, Palembang, Indonesia.....	133
³ Computer Engineering, Politeknik Negeri Sriwijaya, Palembang, Indonesia	133
RESERVOIR IRRIGATION SYSTEM DESIGN BASED WIRELESS SENSOR NETWORK	134
ID : 2636	134
M. Zakuan Agung ¹), Eka Susanti ²), R.A Halimatussa'diyah ³), Susanzefi ⁴), Amirah Fakhirah ⁵)	134
^{1,2,3,4,5} Department of Polytechnic Sriwijaya, Jalan Srijaya Negera, Bukit Besar, Palembang - Indonesia	134
USING NIGHT VISION CAMERA ROBOT BASED ON INTERNET OF THING	135
ID : 2817	135
Sarjana ¹), Adewasti ²), Sholihin ³), Emilia Hesti ⁴), Amirah Fakhirah ⁵)	135
¹ Department of Polytechnic Sriwijaya, Jalan Srijaya Negera, Bukit Besar, Palembang - Indonesia.....	135
² Department of Polytechnic Sriwijaya, Jalan Srijaya Negera, Bukit Besar, Palembang - Indonesia.....	135
³ Department of Polytechnic Sriwijaya, Jalan Srijaya Negera, Bukit Besar, Palembang - Indonesia.....	135
⁴ Department of Polytechnic Sriwijaya, Jalan Srijaya Negera, Bukit Besar, Palembang - Indonesia.....	135
⁵ Department of Polytechnic Sriwijaya, Jalan Srijaya Negera, Bukit Besar, Palembang - Indonesia.....	135
Biometric Fingerprint Implementation for Presence Checking and Room Access Control System	

.....	136
ID : 2726	136
Yudi Wijanarko ¹ , Selamat Muslimin ² , *Renny Maulidda ³ ,	136
Yordan Hasan ⁴ , Abdurrahman ⁵	136
¹ Politeknik Negeri Sriwijaya.....	136
² Politeknik Negeri Sriwijaya	136
³ Politeknik Negeri Sriwijaya.....	136
⁴ Politeknik Negeri Sriwijaya	136
Prototype Design of Landslide Early Detection System Using LoRa and IoT	137
ID : 2663	137
Ahmad Taqwa ¹ , Mohammad Fadhli ² , Sopian Soim ³ , Ade Silvia ⁴ , Suroso Suroso ⁵	137
^{1,2,3,4,5} Politeknik Negeri Sriwijaya	137
IMPLEMENTATION OF USTADZ SEARCH SOFTWARE FOR MUBALIGH, QORI AND QORIAH CATEGORIES IN PALEMBANG USING AN ANDROID-BASED USABILITY APPROACH.....	138
ID : 2078	138
M. Rudi Sanjaya ¹ , Yadi Utama ² , Dedy Kurniawan ³ , Ariansyah Saputra ⁴ , Novita Sari ⁵ , Rahma Destriani ⁶ , Muhammad Raihan Udda Rahmany ⁷	138
¹ Internet Programming Laboratory Department of Computer Engineering, Faculty of Computer Science, Universitas Sriwijaya, Indonesia	138
² Department of Computer Engineering, Faculty of Computer Science, Universitas Sriwijaya, Indonesia.....	138
³ Department of Computer Engineering, Faculty of Computer Science, Universitas Sriwijaya, Indonesia.....	138
⁴ Department of Computer Engineering, Politeknik Negeri Sriwijaya, Indonesia	138
^{5,6,7} Student Department of Computer Engineering, Faculty of Computer Science, Universitas Sriwijaya, Indonesia.....	138
APPLICATION OF CAMPUS PARKING AREA FOR STATE POLYTECHNIC OF SRIWIJAYA BASED ON SMARTPHONE	139
ID: 2619	139
Leni Novianti ¹ , Devi Sartika ² , Dewi Irmawati ³ , Ienda Meiriska ⁴	139
^{1,2,3,4} Study Program of Informatics Management, State Polytechnic of Sriwijaya	139
ANDROID-BASE m-VOTING APPLICATION DEVELOPMENT WITH SIMPLE ADDITIVE WEIGHTING METHOD	140
ID : 2669.....	140
Devi Sartika ¹ , Leni Novianti ² , Dewi Irmawati ³ , Ienda Meiriska ⁴	140
^{1,2,3,4} Study Program of Informatics Management,State Polytechnic of Sriwijaya.....	140
DESIGN WEB BASED ONLINE TUTORING APPLICATION IN PALEMBANG CITY USING THE SUS (SYSTEM USABILITY SCALE) METHOD.....	141
ID : 2098	141

M. Rudi Sanjaya ¹ , Ariansyah Saputra ² , 3Bayu Wijaya Putra, Novita Sari ⁴ , Rahma Destriani ⁵ , Muhammad Raihan Udda Rahmany ⁶	141
1,3 Program in Informatics Management of Computer Engineering, Faculty of Computer Science, Universitas Sriwijaya, Indonesia	141
2 Department of Computer Engineering, Politeknik Negeri Sriwijaya, Indonesia	141
3,4,5 Student Department of Computer Engineering, Faculty of Computer Science, Universitas Sriwijaya, Indonesia.....	141
BLACK BOX TESTING USING EQUIVALENCE PARTITION METHOD IN SINTANA APPLICATION	142
ID : 2225	142
Yayuk Ike Melani ¹ and Mahmud ²	142
¹ S1 Information System, STMIK PalComTech, Palembang	142
² S1 Informatic, STMIK PalComTech, Palembang.....	142
THE DESIGN OF A TOOL TO MEASURE THE EFFECTIVENESS AND EFFICIENCY OF USERS TOWARDS THE APPLICATION OF POLISIKU APPLICATION.....	143
ID : 2366	143
¹ Eko Setiawan and ² Wiza Yunifa.....	143
^{1,2} Information Systems Study Program, Politeknik PalComTech Palembang.....	143
DATABASE DESIGN FOR CHILD SPECIAL DEVELOPMENT INSTITUTION'S SERVICE PERFORMANCE E-DASHBOARD (CASE STUDY: PALEMBANG CHILD SPECIAL DEVELOPMENT INSTITUTION).....	144
ID : 2432	144
Hendra Hadiwijaya ¹ , Febrianty ² , Rezania Agramanisti Azdy ^{3*}	144
^{1, 2} Accounting Study Program, Palembang Palcomtech Polytechnic, Indonesia	144
^{3*} Informatics Study Program, STMIK PalComTech, Indonesia	144
EXTENDING THE UNDERSTANDING OF BUSINESS INTELLIGENCE AND ITS APPLICATION IN STARTUPS.....	145
ID : 2440	145
Dedy Kurniawan ¹ , Ariansyah Saputra ² , M. Rudi Sanjaya ³ , Zaqqi Yamani ⁴	145
¹ Advanced Programming Laboratory, Faculty of Computer Science, Universitas Sriwijaya, Indonesia.....	145
² Department of Computer Engineering, Politeknik Negeri Sriwijaya, Indonesia	145
³ Internet Programming Laboratory, Faculty of Computer Science, Universitas Sriwijaya, Indonesia.....	145
⁴⁻⁵ Faculty of Computer Science, Universitas Sriwijaya, Indonesia.....	145
THE APPLICATION OF DIGITAL MARKETING FOR UKM IN FACING THE COVID-19 PANDEMIC	146
ID : 2472	146
Hetty Meileni ¹ , Sony Oktapriandi ² , Desi Apriyanti ³	146
¹⁻³ Informatic Management Department, Politeknik Negeri Sriwijaya	146

DESIGNING STUDENT AND LECTURER ATTENDANCE SYSTEM APPLICATION USING PROGRESSIVE WEB APPS (PWA)	147
ID : 2586	147
Hartati Deviana ¹	147
¹ Department of Computer Engineering, Politeknik Sriwijaya,Jl. Srijaya Negara Bukit Besar,Palembang,30139, Indonesia.....	147
DESIGNING AUGMENTED REALITY-BASED COMPUTER DEVICES LEARNING MEDIA ON ANDROID PLATFORM	148
ID : 2760	148
Dony Novaliendry ^{1,2} , Arif Subagia ¹ , Titi Sriwahyuni ¹ , Fegie Y Wattimena ³ , Axelon S Renyaan ³ , Ceng-Hong Yang ² , Muhammad Ariyon ⁴	148
¹ Departement of Electronics Engineering, Faculty of Engineering, Universitas Negeri Padang, Padang, Indonesia	148
² Departement of Electronics Engineering, National Kaohsiung University of Science and Technology, Kaohsiung, Taiwan.....	148
³ Fakultas Sains & Teknologi, Universitas Ottow Geissler Papua, Indonesia	148
⁴ Teknik Perminyakan, Universitas Islam Riau, Pekanbaru, Indonesia	148
PUBLIC SERVICE ANNOUNCEMENT IMPLEMENTATION OF LEARNING AT THE SRIWIJAYA STATE POLYTECHNIC IN MINIMIZING THE RISKS AND IMPACTS CAUSED BY THE COVID-19 PANDEMIC.....	149
ID : 2706	149
Alan Novi Tompunu ¹ , Nelly Masnila ² , Zakaria ³ , Azwardi ¹ and Ainun Nabila ¹	149
¹ Computer Engineering Department, State Polytechnic of Sriwijaya, Indonesia.....	149
² Accounting <i>Department</i> , State Polytechnic of Sriwijaya, Indonesia.....	149
³ <i>English Department</i> , State Polytechnic of Sriwijaya, Indonesia	149
PRINCIPAL COMPONENT ANALYSIS METHOD FOR IMAGE SEGMENTATION OF SMART METER DIGITAL.....	150
ID : 2087	150
Husnawati ¹ , Shinta Puspasari ² , Rian Rahmanda Putra ³	150
^{1,2} Department of computer science, Indo Global Mandiri University, Palembang,	150
Indonesia.....	150
³ Department of computer science, Politeknik Negeri Sriwijaya, Palembang,	150
Indonesia.....	150
DESIGN OF SOLAR POWERED VACCINE BACKPACK	151
ID : 2838	151
Muhammad Haikal Satria ^{1,*} , Ariep Jaenul ¹ Adhes Gamayel ¹	151
¹ Dept. of Electrical Engineering, Faculty of Engineering and Computer Science, Jakarta Global University	151
TRAINER MODULE DESIGN OF ITEM SORTING EQUIPMENT BASED ON HEIGHT AND PLC-BASED TRAFFIC LIGHT PROTOTYPE IN THE SYSTEM LABORATORY.....	152

ID : 2798	152
Evelina ¹ , Amperawan ² , Dewi Permata Sari ³ , Sabilal Rasyad ⁴	152
¹ Electrical Engineering, Department of Electrical Engineering	152
² Electrical Engineering, Politeknik Negeri Sriwijaya	152
PROTOTYPE DEVELOPMENT OF HEARTBEAT AND BODY TEMPERATURE MONITORING SYSTEM BASED ON INTERNET OF THINGS	153
ID : 2599	153
Ade Silvia Handayani ¹⁾ , Ahmad Taqwa ²⁾ , Arsyiil Shiddik ³⁾ Nyayu Latifah Husni ⁴⁾	153
¹⁾⁻³⁾ Telecommunication Engineering, Politeknik Negeri Sriwijaya	153
⁴⁾ Elektronics Engineering, Politeknik Negeri Sriwijaya	153
IMPLEMENTATION OF FUZZY LOGIC TYPE-2 ON MOBILE ROBOT NAVIGATION SYSTEM .	154
ID : 2661	154
Ade Silvia Handayani ¹ , Jefri Alkausar ¹ , Sarjana ¹ , Nyayu Latifah Husni ¹ , Siti Nurmaini ² , Irsyadi Yani ³	154
¹ Electrical Department, Politeknik Sriwijaya, ² Intelligent System Research Group, Faculty of Computer Science, Universitas Sriwijaya, ³ Mechanical Engineering Department, Faculty of Engineering, Universitas Sriwijaya	154
WIRELESS DETECTOR FOR LUNG SOUND DISORDER BASED ON DSP TMS320C6416 MODULE	155
ID : 2805	155
Nyayu Latifah Husni ¹ , Arganda Meranda ² , Destra Andika Pratama ³ , Ekawati Prihatini ⁴ , Selamat Muslimin ⁵ , Ade Silvia Handayani ⁶	155
¹⁻⁶ Electrical Engineering, State Polytechnic of Sriwijaya	155
NEW NAVIGATION STRATEGY FOR G-BOT	156
ID : 2806	156
Nyayu Latifah Husni ¹ , Qodry Maulana ² , Ekawati Prihatini ³ , Ade Silvia Handayani ⁴ , Firdaus ⁵	156
¹⁻⁴ Electrical Engineering, State Polytechnic of Sriwijaya ⁵ Computer Engineering, Sriwijaya University	156
AIR DETECTION ENVIRONMENT SYSTEM (ADEV) USING ANDROID APPLICATION FOR AIR QUALITY IN PARK AREA	157
ID : 2824	157
Ade Silvia Handayani ¹ , Nyayu Latifah Husni ² , Al Fatur Sayid ³ , Rosmalinda Permatasari ⁴ , Carlos R Sitompul ⁵ , Sopian Soim ⁶	157
^{1,2,3,5,6} Department of Polytechnic Sriwijaya, Jalan Srijaya Negera, Bukit Besar, Palembang - Indonesia	157
⁴ Universitas Tridinanti Palembang-indonesia	157
THE CONDITION OF THE SURFACE SEVERITY OF THE POLLUTED INSULATOR BASED ON HARMONIC MEASUREMENTS OF LEAKAGE CURRENTS	158
ID : 2775	158

Carlos R Sitompul, Zainuddin Nawawi, Irfan Jambak, Rumiasih Rumiasih, Anton Firmansyah, Indah Susanti	158
THE INFLUENCE OF TRAVEL EXPERIENCE AND DESTINATION QUALITY ON TOURIST SATISFACTION VISITING CULINARY TOURISM DESTINATIONS.....	159
ID : 2575	159
Abd. Hamid* ¹ , Ummasyroh* ² , Jusmawi Bustan * ³ , Heri Setiawan * ⁴	159
^{1,2,3,4} Business Administration Department, State Polytechnic of Sriwijaya, Palembang, Indonesia.....	159
THE EFFECT OF ORGANIZATIONAL SUPPORT AND JOB CHARACTERISTICS ON EMPLOYEE ENGAGEMENT.....	160
ID : 2576	160
A.Jalaludin Sayuti ¹ , Munparidi ² , L.Suhairi Hazizma ³ , Alditia Detmuliati ⁴	160
^{1,2,3,4} Business Administration Department, State Polytechnic of Sriwijaya, Palembang, Indonesia.....	160
THE LINKAGE BETWEEN MARKET ORIENTATION, LEARNING ORIENTATION, AND INNOVATION CAPABILITIES OF SMALL SCALE RESTAURANT.....	162
ID : 2581	162
Purwati ¹ , Yusleli Herawati ² , Elisa ³ , Marieska Lupikawati ⁴	162
Business Administration Department, State Polytechnic of Sriwijaya, Palembang, Indonesia.....	162
STRENGTHENING STUDENTS' WRITING ON PROJECT REPORT VIA PROJECT BASED LEARNING TO THE ENGLISH DEPARTMENT STUDENTS OF SRIWIJAYA STATE POLYTECHNICS	163
ID : 2589	163
Yusri, Sri Gustiani,Tiur Simanjuntak, Evi Agustinasari.....	163
(Lecturers of English Department, Sriwijaya Polytechnics)	163
ANALYSIS OF DAILY CONVERSATION FOR ONLINE DRIVERS	164
ID: 2596	164
Desloehal Djumrianti ¹ , Pridson Mandiangan ² , Hanifati ³ , Alfitriani ⁴	164
^{1,2,3,4} Business Administration Department, Politeknik Negeri Sriwijaya, Palembang, Indonesia.....	164
THE STUDENTS` PERCEPTIONS OF RELIGIOUS RADICALISM AT STATE POLYTECTNIC OF SRIWIJAYA.....	165
ID : 2711	165
Farida Husin* ¹ , Ibnu Maja* ² , Yulianto Wairan* ³ , Lindawati* ⁴	165
Lecturer of State Polytechnic of Sriwijaya Palembang.....	165
The Correlation between Students' Listening Comprehension Strategy and Their TOEIC Score at State Polytechnic of Sriwijaya	166
ID: 2733	166
Koryati ^{1,*} , Aisyah Shahab ^{2,*} , Zulkifli ^{3,*} , Nian Masna Evawati ^{4,*}	166

<i>1,2,3,4 English Department of Sriwijaya State Polytechnic.....</i>	166
DESCRIPTION OF ANXIETY LEVELS OF PRE SCHOOL CHILDREN WITH THALASEMIA WHO WILL GET BLOOD TRANSFUSE IN THE THALASEMIA POLY AT AL-IHSAN BALEENDAH HOSPITAL, BANDUNG.....	167
ID : 2734	167
Lisbet Octovia Manalu ¹ , * Budi Rustandi ² , Budi Somantri ³	167
¹ Rajawali Health Institute Bandung.....	167
² Rajawali Health Institute Bandung	167
³ Rajawali Health Institute Bandung	167
A STORY OF A CUP OF COFFEE REVIEW OF GOOGLE LOCAL GUIDE REVIEW.....	168
ID : 2759	168
Setiawan Priatmoko ^{1, 2*} , Dávid Lóránt ¹	168
Szent Istvan University School of Economics and Regional Science Gödöllő, Hungary ¹	168
STIE Pariwisata API Yogyakarta, Indonesia ²	168
ASIAN WOMEN'S ROLES IN FAMILY HOLIDAY: A CASE STUDY OF INDONESIAN FEMALES	169
Paper ID 2788	169
Desloehal Djumrianti ¹ , Augustus E. Oseso-Asare ²	169
¹ <i>Business Administration Department, Politeknik Negeri Sriwijaya, Palembang, Indonesia</i>	169
² <i>Faculty Business and Law, University of Sunderland, United Kingdom</i>	169
Analysis of Daily Conversation for Online Drivers.....	170
ID 2789	170
Desloehal Djumrianti ¹ , Augustus E. Oseso-Asare ²	170
¹ <i>Business Administration Department, Politeknik Negeri Sriwijaya, Palembang, Indonesia</i>	170
² <i>Faculty Business and Law, University of Sunderland, United Kingdom</i>	170
The Customary Philosophy of the Anak Dalam Tribe as part of the soul of the nation's law	171
ID 2791	171
Muhamad Erwin ¹ , Ahmad Taqwa ² , Dicky Seprianto ³ , Ahmad Zamheri ⁴	171
¹ State Polytechnic of Sriwijaya, Palembang, Indonesia,	171
² Electrical Engineering Departemet State Polytechnic of Sriwijaya, Palembang, Indonesia,	171
³ Mechanical Engineering Departement State Polytechnic of Sriwijaya Palembang, Indonesia,.....	171
⁴ Mechanical Engineering Departement State Polytechnic of Sriwijaya Palembang, Indonesia	171
THE INFLUENCE OF LEADERSHIP STYLE, AND MOTIVATION WORK STRUCTURE TO MUARA ENIM COMMUNITY HEALTH CENTER (EQUATION STRUCTURAL METHOD APPROACH) ...	172

Paper ID 2612	172
AlHushori ¹ , Yusnizal Firdaus ¹ , Markoni Badri ¹ , Muhammad Yusuf ^{1*}	172
¹ Department of Business Administration, State Polytechnic of Sriwijaya, Palembang, Indonesia.....	172
alhushori@gmail.com,yusnizalfirdaus@yahoo.co.id,markonibadri@yahoo.com,m.yusuf@polsri.ac.id*	172
SETTLEMENT OF CASES OF TERMINATION OF EMPLOYMENT AT THE INDUSTRIAL RELATION COURT IN PALEMBANG CITY	173
Paper ID 2713	173
Ayu Puspasari, WasitohMeirani, Muhammad Erwin, Suroso.....	173
Politeknik Negeri Sriwijaya.....	173
Jl. Sriwijaya Negara, Bukit Lama, Bukit Besar, Kota Palembang, Sumatera Selatan.	173
THE EFFECT OF FINANCIAL TECHNOLOGY ON FINANCIAL INCLUSION IN SMES IN PALEMBANG CITY	174
ID : 2845	174
Nur Rizka Erlianta ¹ , Marieska Lupikawaty ^{2*} , Titi Andriyani ³	174
¹ Bachelor Program in Business Management.. Department of Business Administration, Sriwijaya State Polytechnic	174
² Bachelor Program in Business Management.. Department of Business Administration, Sriwijaya State Polytechnic	174
³ Diploma Program in Business Administration, Department of Business Administration, Sriwijaya State Polytechnic	174
THE EFFECT OF PATIENT SATISFACTION LEVELS ON COMPETENCY AND FACILITIES AT SITI KHADIJAH ISLAMIC HOSPITAL, PALEMBANG CITY	175
ID : 2217	175
Sarikadarwati ¹ , Henny Yulsiati ² , Sandrayati ³ , Susi Ardiani ⁴	175
Department Accounting Polytechnic of Sriwijaya.....	175
THE ROLE OF SMALL AND MEDIUM ENTERPRISES (SMES) AND ECONOMIC GROWTH IN INDONESIA: THE VECM ANALYSIS	176
ID : 2579	176
Aladin ¹ , Evada Dewata ² , Yuliana Sari ³ , Yuli Antina Aryani ⁴	176
^{1,2,3,4} ,Department of Accounting, Politeknik Negeri Sriwijaya, Indonesia	176
POVERTY IN SOUTH SUMATRA PROVINCE IS VIEWED FROM VILLAGE FUND AND VILLAGE FUND ALLOCATION.....	177
ID :2583	177
Rita Martini ^{1*} , Endah Widyastuti ¹ , Sukmini Hartati ¹ , Zulkifli ¹ , Riana Mayasari ¹	177
¹ Accounting Department, Polytechnic State of Sriwijaya, Palembang 30139, Indonesia	177
IMPACT OF BUMDESA MANAGEMENT ON PADESA IN PENUKAL ABAB LEMATANG ILIR REGENCY	178

ID : 2602	178
Rosy Armaini ^{1*} , Maria Maria ² , Nurhasanah Nurhasanah ³ , Yevi Dwitayanti ⁴	178
<i>¹⁻⁴ Accounting Major, State Polytechnic of Sriwijaya, Palembang, South Sumatera, Indonesia.....</i>	<i>178</i>
FACTORS AFFECTING ECONOMIC GROWTH IN REGENCIES AND CITIES IN THE PROVINCE OF SOUTH SUMATRA IN 2010 – 2018.....	179
ID : 2803	179
Sri Hartaty ¹ , Eka Jumarni F ² , Anggeraini O ² , L. Vera R.P. ²	179
ABSTRACT	179
THE EFFECT OF LOCAL GOVERNMENT CHARACTERISTICS AND BPK AUDIT OPINIONS ON THE FINANCIAL PERFORMANCE OF LOCAL GOVERNMENTS (STUDY ON LOCAL GOVERNMENTS IN SOUTH SUMATRA).....	180
ID : 2621	180
Indra Satriawan, Ardiyan Natoen, Periansya, Sopiyan AR	180
1234 Department of Accounting, Sriwijaya State Polytechnic	180
DIMENSIONS OF WOMEN’S EMPOWERMENT	181
ID :2519	181
Neneng Miskiyah ^{1*} , Sari Lestari Zainal Ridho ¹ , Hadi Jauhari ¹ , Ketu Purnamasari ¹	181
¹ Department of Business Administration, Sriwijaya State Polytechnic, Palembang, Indonesia.....	181
THE EFFECT OF ENTREPRENEURIAL COMPETENCIES ON BUSINESS PERFORMANCE (EMPIRICAL STUDY ON MSMES OF PALEMBANG WOVEN FABRIC)	182
ID : 2658	182
Edwin Frywaruwah ¹ , Bainil Yulina ² , Sulaiman ³ , Siska Aprianti ⁴	182
^{1,2,3,4} Politeknik Negeri Sriwijaya.....	182
Analysis Of Marketing Mix Strategy On Consumer Value In Small And Medium Enterprises In Palembang, South Sumatra (Case Study Of Palembang's Traditional Processed Food)	183
ID : 2756	183
Riza Wahyudi, M.Thoyib, Firmansyah, Darul Amri	183
Accounting Department Politeknik Negeri Sriwijaya, thoyib1958@gmail.com	183
THE EFFECT OF PLANNING ON RISK OF LOSS.....	184
IN INVESTING IN THE CAPITAL MARKET	184
ID 2804	184
Mariska. Z ¹ , Hendra Sastrawinata ² , Dr. Dewi Fadilah ³ , M. Riska Maulana ⁴	184
State Polytechnic of Sriwijaya	184
The Effect of Bank Credibility and Service Convenience on Bank Customer Attitudes	185
ID 2567	185
Esya Alhadi ¹ , 2nd Gst Ayu Oka Windarti ² , Elvia Zahara ³ , Titi Andriani ⁴	185
^{1,2,3,4} Business Administration Department, State Polytechnic of Sriwijaya, Palembang,	

Indonesia.....	185
The Influence of Information Quality and Information System Quality of Regional Assets on User Satisfaction at the Provincial Government of South Sumatera	186
ID 2814	186
Kartika Rachma Sari ^{1,*} Zainal Arifin ² , Desi Indriasari ³ , Choiruddin ⁴	186
Politeknik Negeri Sriwijaya.....	186
Looking beyond Students' Writing: Its Relation to Their Academic Achievement	187
ID 2822	187
Beni Wijaya, Zakaria, Munaja Rahma, Moehamad Ridhwan	187
Politeknik Negeri Sriwijaya.....	187
Determinants of Regional Budget Absorption in the Regional Apparatus Organization of Palembang City.....	188
ID 2830	188
Vega Nabila Putri ¹ , Kuo Keo Pisey ² , Sukmini Hartati ¹ , Rita Martini ^{1*}	188
¹ Accounting Department, Polytechnic State of Sriwijaya, Palembang 30139, Indonesia	188
² Entrepreneurship Development Institute, CIEDI Cambodia-India, Cambodia	188
*Corresponding author. Email: ritamartini@polsri.ac.id	188
ASPECTS AFFECTING THE ACCOUNTABILITY PERFORMANCE OF GOVERNMENT AGENCIES BANYUASIN DISTRICT.....	189
ID: 2834	189
Rita Martini ^{*1} , Muhammad Aulia Ramadhan ^{*1} , Sukmini Hartati ^{*1}	189
¹ Accounting Department, Polytechnic State of Sriwijaya, Palembang 30139, Indonesia	189
PERCEPTION OF HUMAN RESOURCES ASPECT ON ABILITY TO MANAGE BUMDES	190
Paper ID 2846	190
Nelly Masnila ¹ , Faridah ² , M. Husni Mubarak ³ , Desri Yanto ⁴	190
Politeknik Negeri Sriwijaya.....	190

Effect of Bentonite on the Yield and Composition of Products From Thermolysis of Polystyrene Waste

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ABSTRACT

Economic growth and population explosion are chronic problems in big cities which trigger an increase in energy consumption in society. The flow of plastic used has been a dilemma for a long time, so there are thoughts on how to turn plastic waste into something that can be useful. One of the polystyrene plastic wastes can be processed into liquid fuel by cracking. In this research, the process of cracking polystyrene plastic had been conducted by a catalytic cracking process using a bentonite catalyst. This research aims to be determined the effect of the percentage of the catalyst on the percentage of product yield and the characteristics resulting from the catalytic cracking of polystyrene plastic waste using a bentonite catalyst. The catalytic cracking process will be carried out in a thermal catalytic reactor where the process takes place at a temperature of 250°C with a cracking time of 20, 40 and 60 minutes and the weight of catalyst 4, 6 and 8% as polystyrene waste is 250 gr. The analysis carried out on the final product is a GCMS analysis showed the characteristic nearly to a standard gasoline.

Keywords: Bentonite, Yield, Thermolysis, Polystyrene, Plastic Waste

1. INTRODUCTION

The extraordinary increase in worldwide consumption of plastics for a wide variety of products is causing serious waste disposal and environmental problems. One of the most dominant plastic waste is plastic made from polystyrene, which is a plastic material that is safe for use by the community because this based plastic has properties that tend to be tougher and resistant to high temperatures and is not translucent. Thus, it is widely used as a common plastic material. Polystyrene plastic is often found in the form of plastic bags, food containers, tires and others. This reminds us of the importance of plastic recycling and processing technology to deal with this problematic waste in an environmentally friendly way [1]. Nox, Sox, Cox etc creates potentially harmful gaseous by products that could contaminant groundwater and air [3]. To convert plastic waste to liquid fuel is an alternative to manage it.

Pyrolysis is a promising technology used to convert plastic waste into liquid oil and other valuable by-products such as charcoal and gas under controlled conditions and is considered a relatively more environmentally friendly technology than uncontrolled combustion [4]. The product pyrolysis yield depends on

a number of process parameters such as temperature, heating rate, moisture content, retention time, plastic type and particle size. Yields of up to 80% of liquid oil by weight can be achieved from plastic waste [5]. The resulting liquid oil has similar characteristics to conventional diesel including, density (0.8 kg / m³), viscosity (up to 2.96 mm² / s), flash point (30.5°C) and energy content (41.58 MJ / kg), and can be used as an energy source. Tar produced from pyrolysis can be activated under standard conditions for use in wastewater treatment, heavy metal removal, and smoke and odor removal. The gases produced from pyrolysis are H₂, CO and CO₂ and can be used as energy carriers. High temperatures and retention times are the main limitations of plastic waste pyrolysis, which need to be optimized to make the process more economical and environmentally friendly [6].

This research will optimize the conversion process of polystyrene plastic waste using a thermal cracking / pyrolysis reactor with a bentonite catalyst to produce liquid fuel that has almost the same characteristics as conventional liquid fuel (gasoline).

Based on the above background, research will be carried out on the conversion of polystyrene plastic into liquid fuel using a bentonite catalyst in a thermal

cracking reactor. In this study, the fixed variables are the amount of raw material and temperature, while the variable is the percentage of catalyst. The problem that will be discussed by the researcher is to know the characteristics of the thermolysis product of polystyrene plastic waste in the form of density, spgr and API Gravity in accordance with the standards and quality of the Directorate General of Oil and Gas No.0117.K / 10 / DJM.T / 2018 [7] which is influenced by temperature and performs compound analysis liquid fuel chemistry using GC-MS based on the highest% yield obtained.

2. LITERATURE REFENCES

Plastics are a type of macromolecule formed by a polymerization process. Polymerization is the process of combining several simple molecules (monomers) through a chemical process into large molecules (macromolecules or polymers). Plastics are polymer compounds whose main constituent elements are carbon and hydrogen. To make plastics, one of the most commonly used materials is naphtha, which is a material produced from refining petroleum or natural gas. As an illustration, to make 1 kg of plastic requires 1.75 kg of petroleum, to meet the needs for raw materials and energy needs for the process [8].

Polystyrene is a polymer plastic that is easily formed when heated, the molecular formula is $(\text{CHC}_6\text{H}_5\text{-CH}_2\text{-})_n$ [9]. Very stiff at room temperature. Polystyrene can be found in plastic utensils, CD cases, plastic cups, food containers, trays and smoke detector housings [10].

Pyrolysis, also called thermolysis (Greek: pur = fire, thermos = warm; luo = loosening), is a chemical and thermal decomposition process, generally leading to smaller molecules. Thermolysis is a more appropriate term than pyrolysis because fire indicates the presence of oxygen. In most pyrolysis processes, air is removed for reasons of safety, product quality and yield. Pyrolysis can be carried out at various temperatures, reaction times, pressures, and in the presence or absence of gases or liquids, and reactive catalysts. The thermal pyrolysis process takes place at temperatures between 500-800°C and is generally carried out at atmospheric pressure [11].

Bentonite is a commercial term for clay containing montmorillonite and a dioctohedral group. Bentonite is the result of sedimentation from volcanic activity of very fine falls which then undergoes the process of being worked on by water and re-deposited in other areas, possibly in the deep sea environment.

The physical properties of bentonite include a waxy finish, generally soft and plastic. Pale in color with the appearance of white, light green, gray to pink in a fresh

state and becomes creamy when weathered which then turns yellow, red brown to black. When you touch it feels slippery like soap. When put into water, it will absorb water, a little or a lot, if it is exposed to rain water, bentonite can turn into slurry and when it dries it will cause noticeable cracks. Other physical properties are density 2,2-2,8 g / L; refractive index from 1.547 to 1.557; and a melting point of 1330-1430 °C.

3. EXPERIMENT

The raw materials used in this research are polystyrene plastic in the form of food and cosmetic packaging waste Bentonite catalyst is purchased directly from the Bratachem company. The experimental procedure for converting plastic waste into liquid fuel using a bentonite catalyst and a thermal catalytic reactor. There are two kinds of polystyrene plastic waste that is used in this research. These are food container and foam packaging. Food particle are cleaned with liquid soap and water inside laboratory by manually, then drying naturally by using sunlight. After that food container and foam packaging are shredded into small pieces by using wire brush. Selected particle size range to set is between 4 mm and 6 mm. Prepared raw materials are weighted by using digital balance. Catalyst obtained from Bratachem company couldn't directly use. It should be treated to activate the catalyst. In this research to activate the catalyst, it is used thermal method. Catalyst is placed in Porcelain dish, then put into the oven for 3 hours at temperature 300°C.

3.1. Catalytic Cracking of Polystyrene

Post-consumer, municipal solid waste mixed polystyrene obtains from several communities in Palembang city. Polystyrene plastic waste cleaned by using soap and water then drying naturally under sunlight. The size reduction of polystyrene using scissor to cut the particle size into 4 – 6 mm. Bentonite catalyst mixed with feed, its varied 4, 6 and 8% of the total load. A semi-batch unstirred stainless-steel reactor is operated at 250°C and using time 20, 40 and 60 minutes to liquefy them. The fuel oil will be collected and kept for further analysis. To analyze the composition contained in the liquid fuel resulting from catalytic pyrolysis, a GC-MS test was carried out at the Laboratory with the required sample size of 10 ml.

4. RESULT AND DISCUSSION

In the catalytic cracking process, the reaction is performed at the temperature 250°C, the catalyst was used is bentonite as much as 4%, 6%, and 8%. The cracking time was varied, which are 20, 40 and 60 minutes. Liquid, solid and gases are the main products of process.

The detailed product distribution is as listed in Table 1.

Catalytic cracking breaks down the long chain of hydrocarbons (polymers) present in waste plastic into short chain hydrocarbons that resemble fuel. Catalytic

catalyst 6 %, the highest conversion is 83.36%, for the catalyst 8 %, the highest conversion is 85.92%. And so is the liquid yield percentage, without catalyst the highest liquid yield percentage is 9.76%. For catalyst 4 %, the highest liquid yield percentage is 13.28 %.

Table 1. Product Distribution of Catalytic Cracking Process of Polystyrene

Cracking Time (minutes)	Catalyst (%)	Operating Temp (°C)	Liquid (g)	Solid (g)	Gas (g)
20	0	250	20.1	68.3	161.6
40	0	250	22.6	65.7	161.7
60	0	250	24.4	63.6	162.0
20	4	250	24.6	62.2	163.2
40	4	250	28.3	58.1	163.6
60	4	250	33.2	53.1	163.7
20	6	250	35.8	49.5	164.7
40	6	250	37.7	47.4	164.9
60	6	250	43.3	41.6	165.1

cracking process yielded three different products. The yield percentage of product obtained is showed in Table 2.

According to table 2, the increase of cracking time increased conversion and yield percentage. Without catalyst, the highest conversion is 74.56 %. For the catalyst 4 %, the highest conversion is 78.76 %. For the

catalyst 6 %, the highest liquid yield percentage is 17.32%. For catalyst 8 %, the highest liquid yield percentage is 19.36 %. The solid yield was almost constant in all the experiments. The gas and liquid were strongly influenced by cracking time. Percentage of liquid and gas yield were increased at longer cracking time. As cracking time increased, liquid yield was also increased and so was gas yield.

Table 2. The conversion and yield percentage of products of polystyrene catalytic cracking process

Research Variable			% Conversion	% Yield		
Cracking Time (minutes)	Reaction Temp. (T) °C	Catalyst (%)		Liquid (g)	Solid (g)	Gas (g)
20	250	0	72.68	8.04	27.32	64.64
40	250	0	73.72	9.04	26.28	64.68
60	250	0	74.56	9.76	25.44	64.80
20	250	4	75.12	9.84	24.88	65.28
40	250	4	76.76	11.32	23.24	65.44
60	250	4	78.76	13.28	21.24	65.48
20	250	6	80.20	14.32	19.80	65.88
40	250	6	81.04	15.08	18.96	65.96
60	250	6	83.36	17.32	16.64	66.04
20	250	8	83.80	17.40	16.20	66.40
40	250	8	84.40	17.88	15.60	66.52
60	250	8	85.92	19.36	14.08	66.56

Liquid yield percentage of product at different cracking time is shown in **figure 1**. The longer cracking time and more catalyst added, percentage of liquid yield was increased. From that figure, it's known that the highest percentage of liquid yield is sample with 8% catalyst and cracking time 60 minutes that is 19.36 %.

Hazrat et al., 2015 explained that the increase of catalyst content increases the amount of desired fuel of liquid products, there is an optimal range. The conversion efficiency even decreases after the optimal range of catalyst to waste plastic ratio based on the type of catalyst, plastic and reaction temperature.

Conversion percentage of product at different cracking time is shown in **figure 2**. The longer cracking time and more catalyst added, percentage of conversion was increased. From that figure, it's known that the

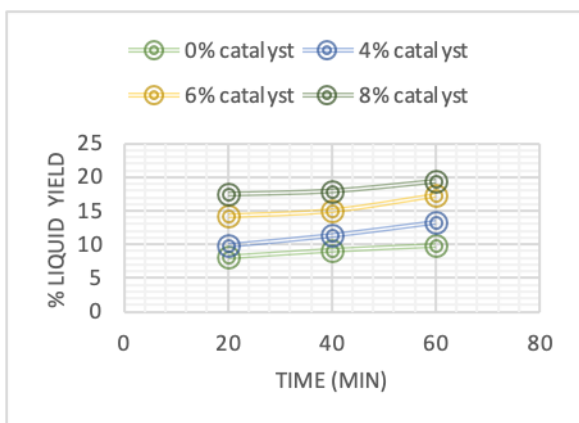


Figure 1. Effect of cracking time on liquid yield

highest percentage of liquid yield is sample with 8% catalyst and cracking time 60 minutes that is 85.92 %.

Liquid yield percentage of product at different catalyst amount is shown in **figure 3**. As catalyst amount increased, conversion percentage was also increased. From the figure, it's known that the highest percentage

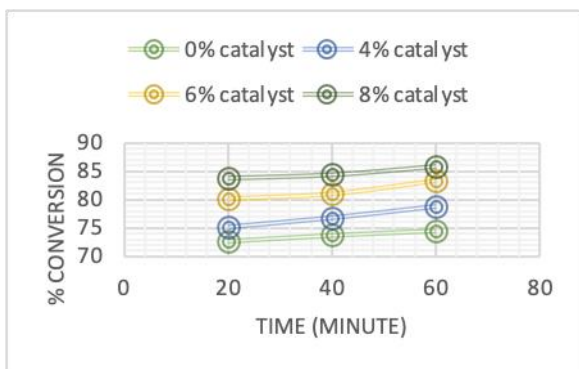


Figure 2. Effect of cracking time on conversion percentage

is sample with 60 minute cracking time and 8% catalyst that is 19.36 %. The increasing of catalyst amount, increased % liquid yield. Catalyst helps reducing the activation energy of the feedstock so that the required temperature in the thermal cracking process is reduced [12]. The ratio between catalyst and the polymer waste also controls the liquid fuel conversion efficiency of the process.

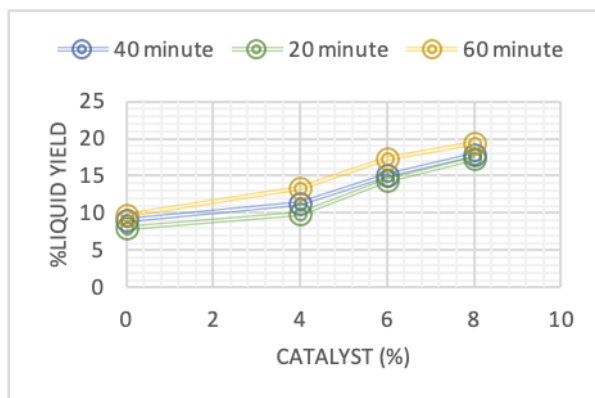


Figure 3. Effect of catalyst amount on liquid

Conversion percentage of product at different catalyst amount is shown in **figure 4**. As catalyst

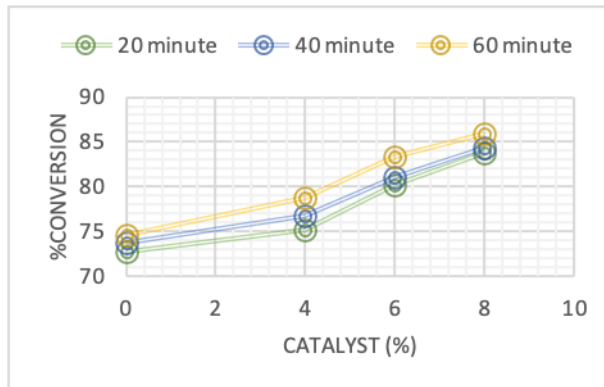


Figure 4. Effect of catalyst amount on conversion percentage

amount increased, conversion percentage was also increased. From the figure, its known that the highest percentage is sample with 60 minute cracking time and 8% catalyst, that is 85.92 %. The increasing of catalyst amount, increased % conversion.

The obtained liquid from thermo catalytic cracking process was characterized as it was without any futher processing. The fuel properties like density (g/mL), spgr, and API gravity was measured. As given the **table 3**.

Table 3. Physical properties of liquid fuel from polystyrene plastic waste

Research Variable			Analyzed Parameters		
Cracking Time (minutes)	Reaction Temp. (T) °C	Catalyst (%)	Density (g/ML)	Spgr	API Gravity
Gasoline Standard			0.735 - 0.755	0.7528	50.46
20	250	0	0.747	0.762	54.1
40	250	0	0.753	0.768	52.6
60	250	0	0.761	0.776	50.7
20	250	4	0.719	0.734	61.2
40	250	4	0.720	0.735	61.0
60	250	4	0.756	0.772	51.9
20	250	6	0.760	0.776	50.9
40	250	6	0.762	0.777	50.6
60	250	6	0.753	0.768	52.6
20	250	8	0.756	0.772	51.9
40	250	8	0.756	0.772	51.8
60	250	8	0.750	0.766	53.3

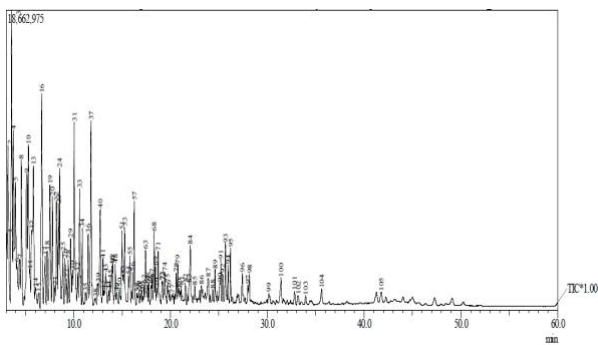


Figure 5. GCMS Analysis of Sample

After all program set up PS-6 fuel analyzed by GCMS. From GCMS analysis, following types of hydrocarbon compounds are appeared. Many compounds are emerged on the analysis carbon range C₅ to C₂₅. A liquid fraction consisting of paraffin, olefin, naphthene and aromatics (PONA). GCMS analysis for sample (T =250°C, catalyst 6%, t = 60 minute) can be seen in **figure 5**.

GCMS analysis of sample upon retention time following compounds are found initially such as at retention time 3.086, compound is C₅H₁₀, at retention time 3.199, compound is C₃H₆O, at retention time 3.545, compound is C₆H₁₄, at retention time 3.749, compound is C₆H₁₄, at retention time 3.954, compound is C₆H₁₄.

According to GCMS analysis, it is noted that composition of liquid fuel can be classified as paraffin, olefin, naphthene, aromatic and other compound which does not include the composition of petroleum, and its present was not expected, because it can decrease the quality of petroleum. Classification of liquid fuel composition can be seen in table 4.

Table 4. Classification of liquid fuel composition sampel (60-minute, 6% catalyst, 250°C)

Liquid fuel composition	%
Paraffin	59.17
Olefin	14.8
Naphthene	3.93
Aromatic	21.93
Others	0.17

Table 4 shows that paraffin is the most abundant product with percentage 59.17 %. Subsequent abundant products are aromatic (21.93 %), naphthene (3.93 %), Olefin (14.8 %) and another compound (0.17 %).

5. CONCLUSION

This experiment used bentonite catalyst that intended to find the optimum condition. There are some factors to be considered such as the use of the catalyst, length of cracking time and the optimum operating condition.

From the data showed the variation of catalyst weight influenced the percentage yield of product. In summary we can get the best product yield is influenced by the catalyst concentration of 6% with a cracking time of 60 minutes and from the GCMS analysis, the product yield shows the characteristics of gasoline.

AUTHORS' CONTRIBUTIONS

All authors contributed equally to this work.

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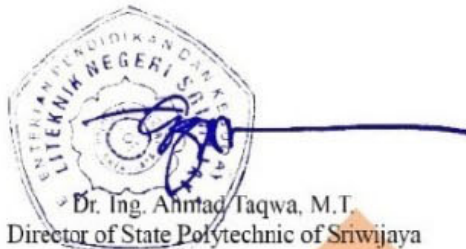
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