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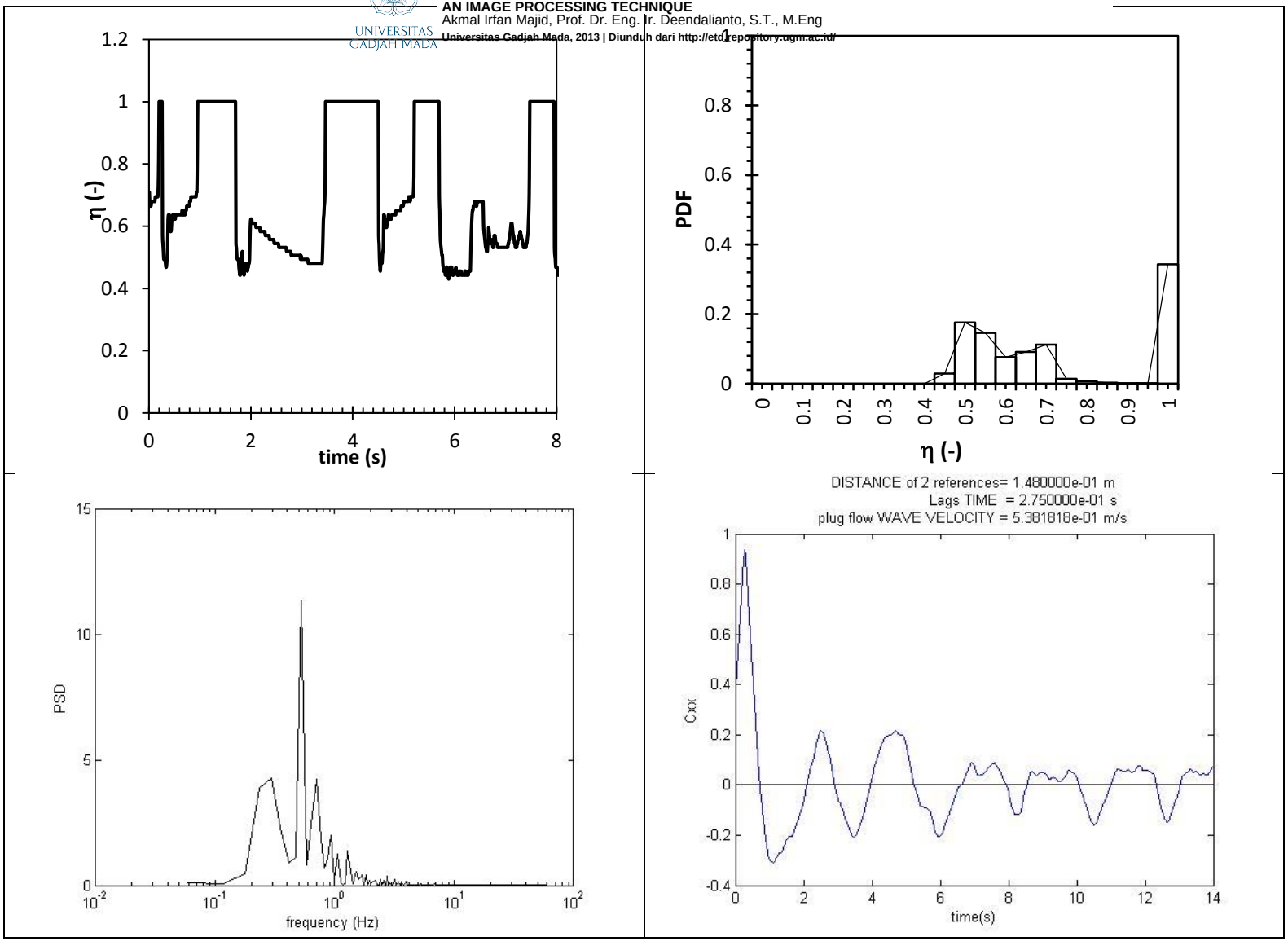
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Statistical analysis

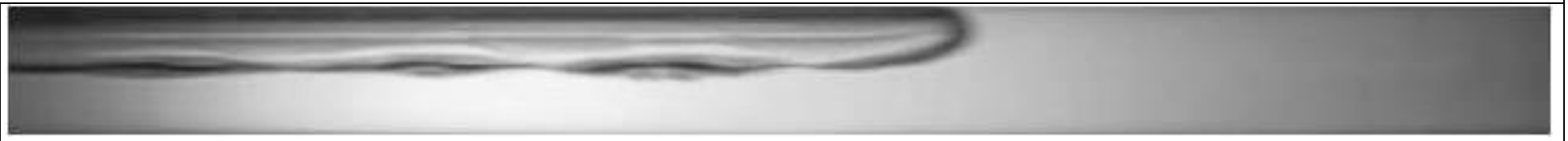
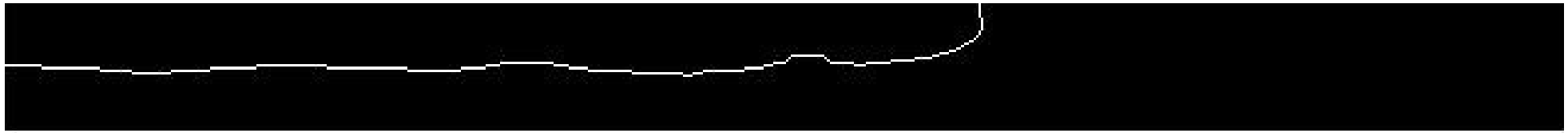


Important flow parameters

Average liquid hold-up	0.713	
Wave velocity	0.538	m/s
Wave frequency	0.234	Hz
Plug wavelength	1.021	M

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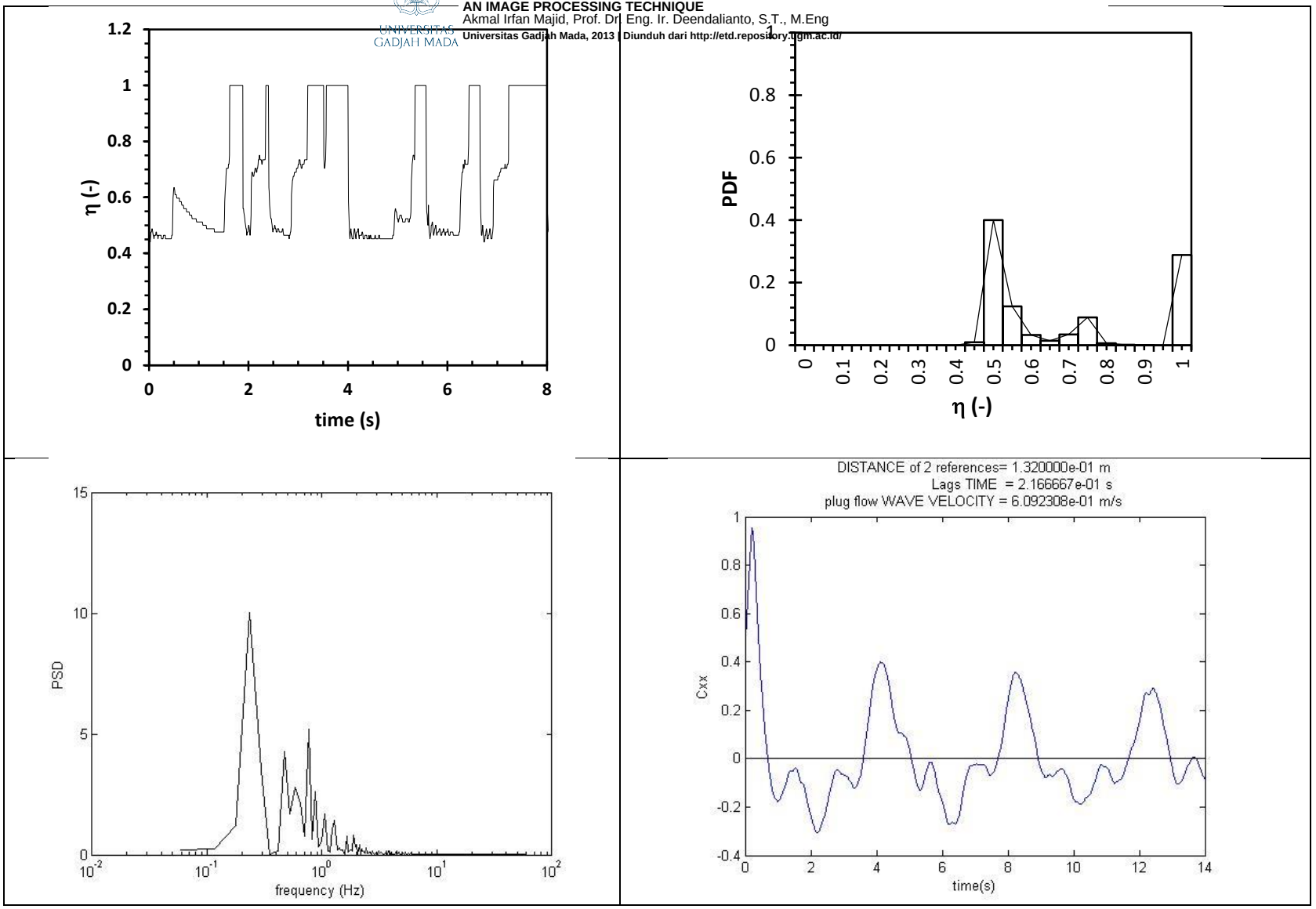
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J_L	=	0.25	m/s

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Statistical analysis

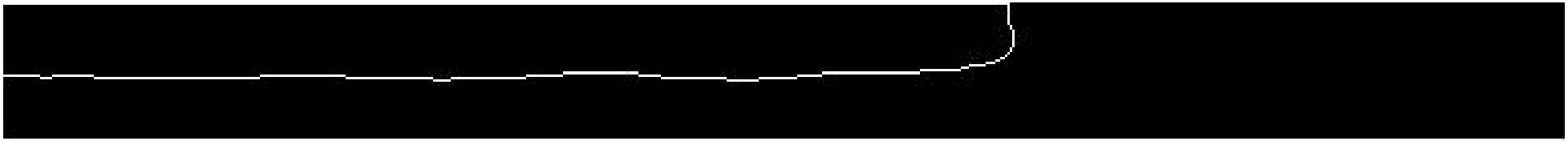


Important flow parameters

Average liquid hold-up	0.666	
Wave velocity	0.609	m/s
Wave frequency	0.234	Hz
Plug wavelength	0.737	m

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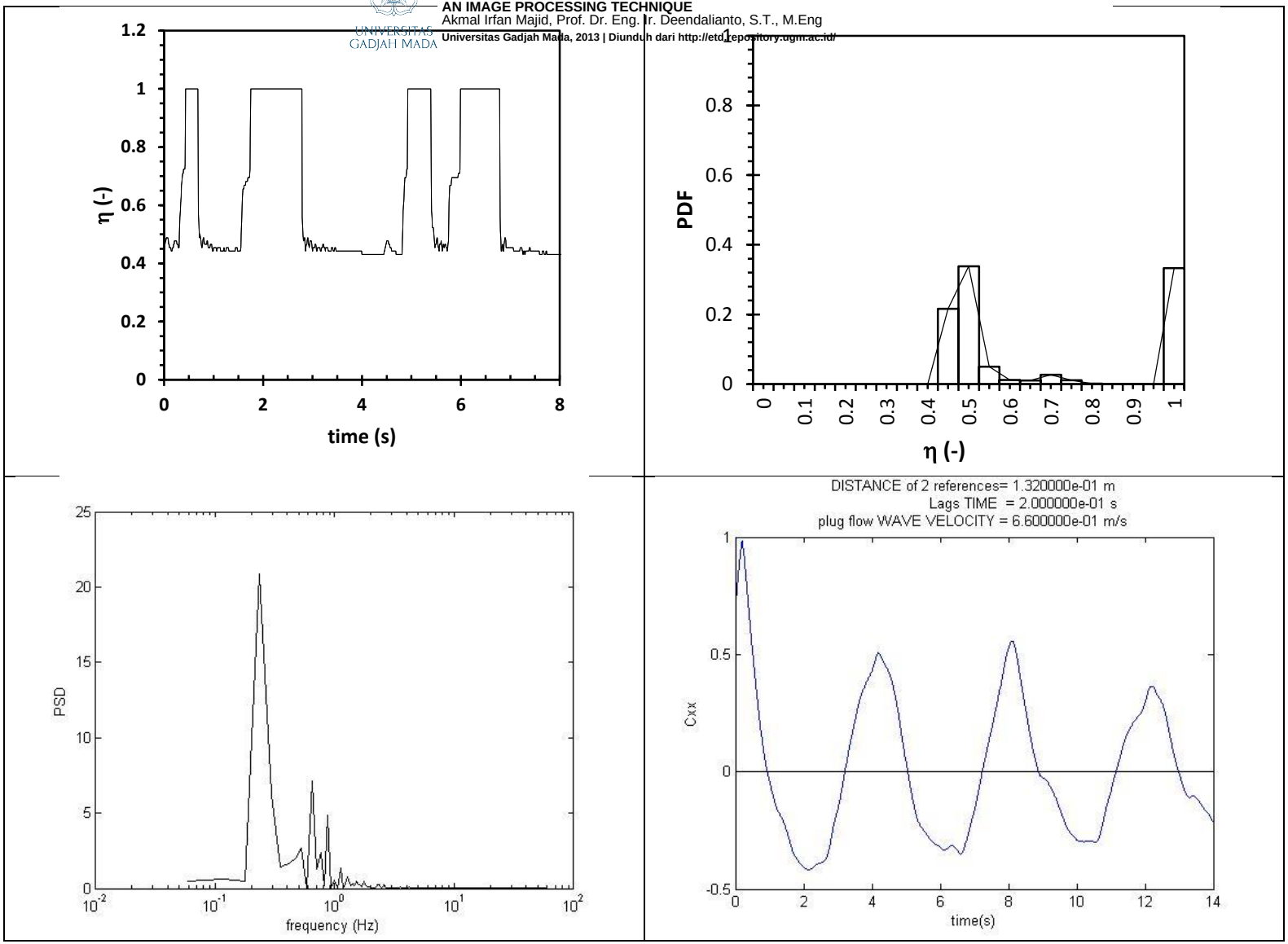
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Statistical analysis



Important flow parameters

Average liquid hold-up	0.654	
Wave velocity	0.660	m/s
Wave frequency	0.234	Hz
Plug wavelength	0.813	m

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J_G	=	0.31	m/s
J_L	=	0.25	m/s

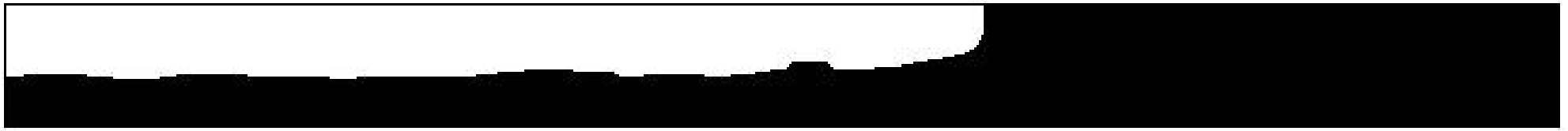
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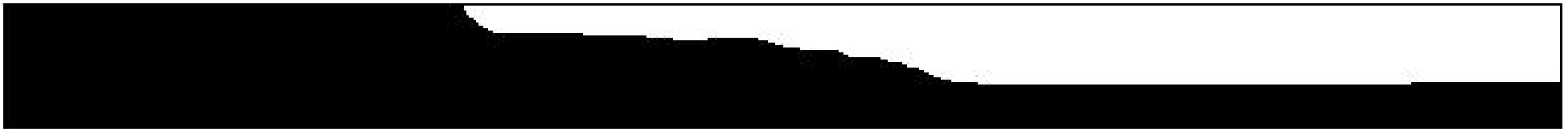


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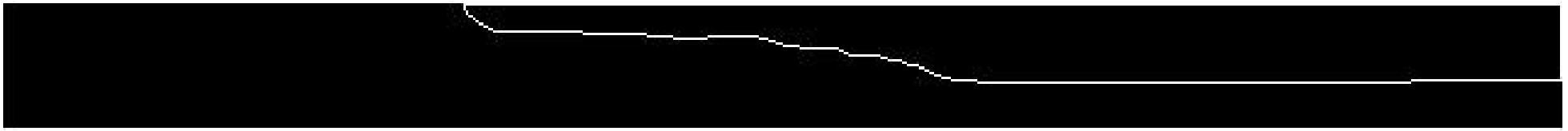
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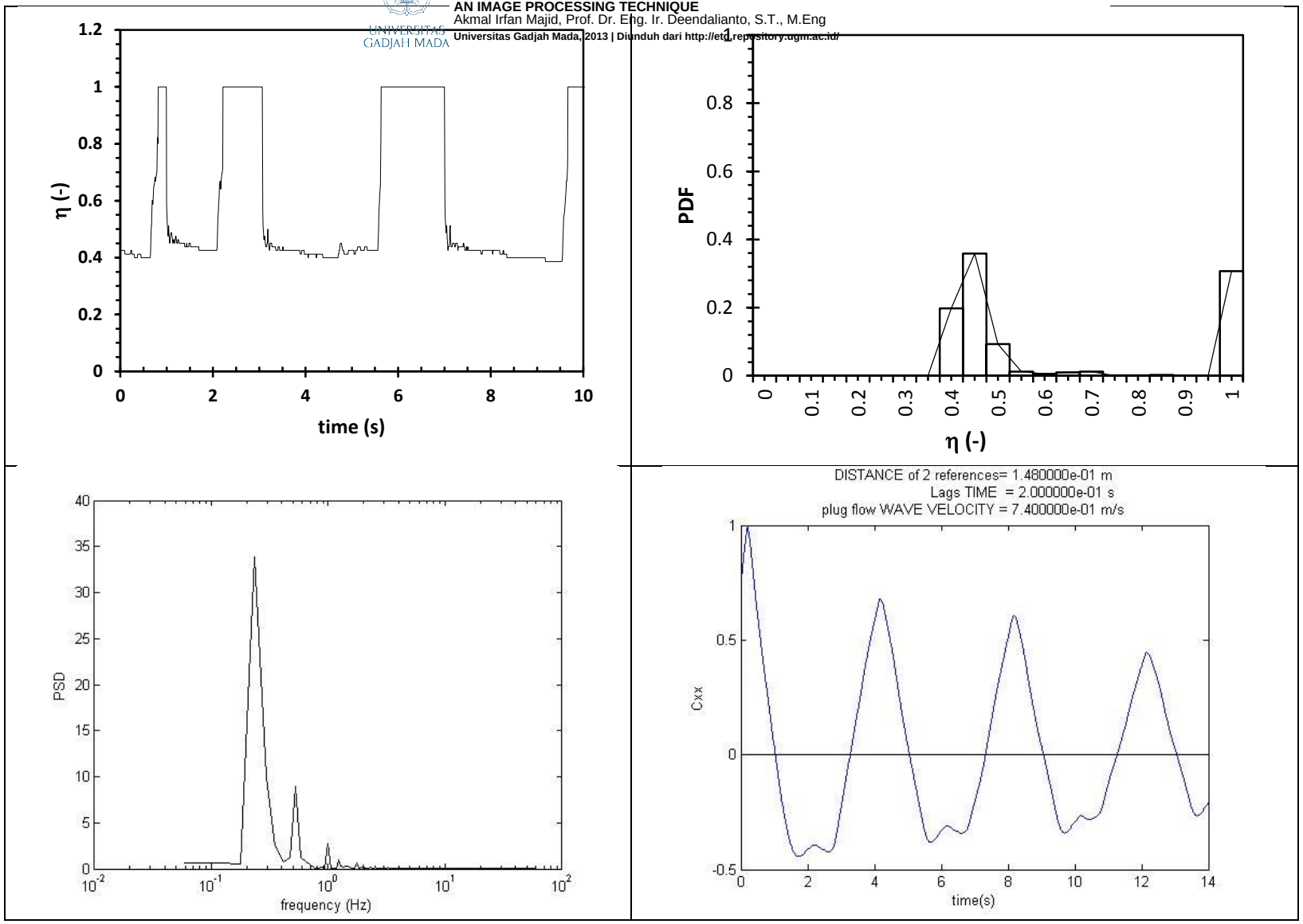


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Statistical analysis

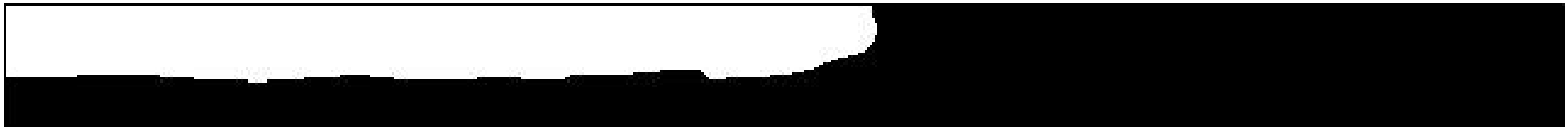
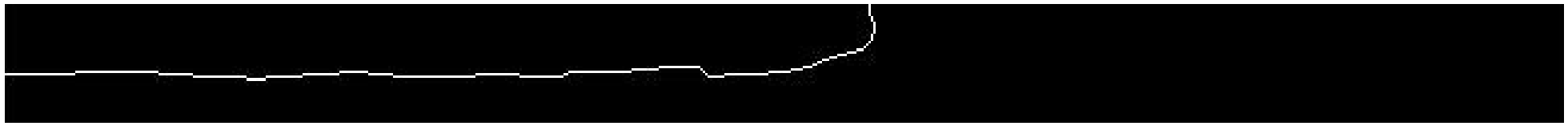


Important flow parameters

Average liquid hold-up	0.607	
Wave velocity	0.740	m/s
Wave frequency	0.234	Hz
Plug wavelength	0.364	m

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J_L	=	0.25	m/s

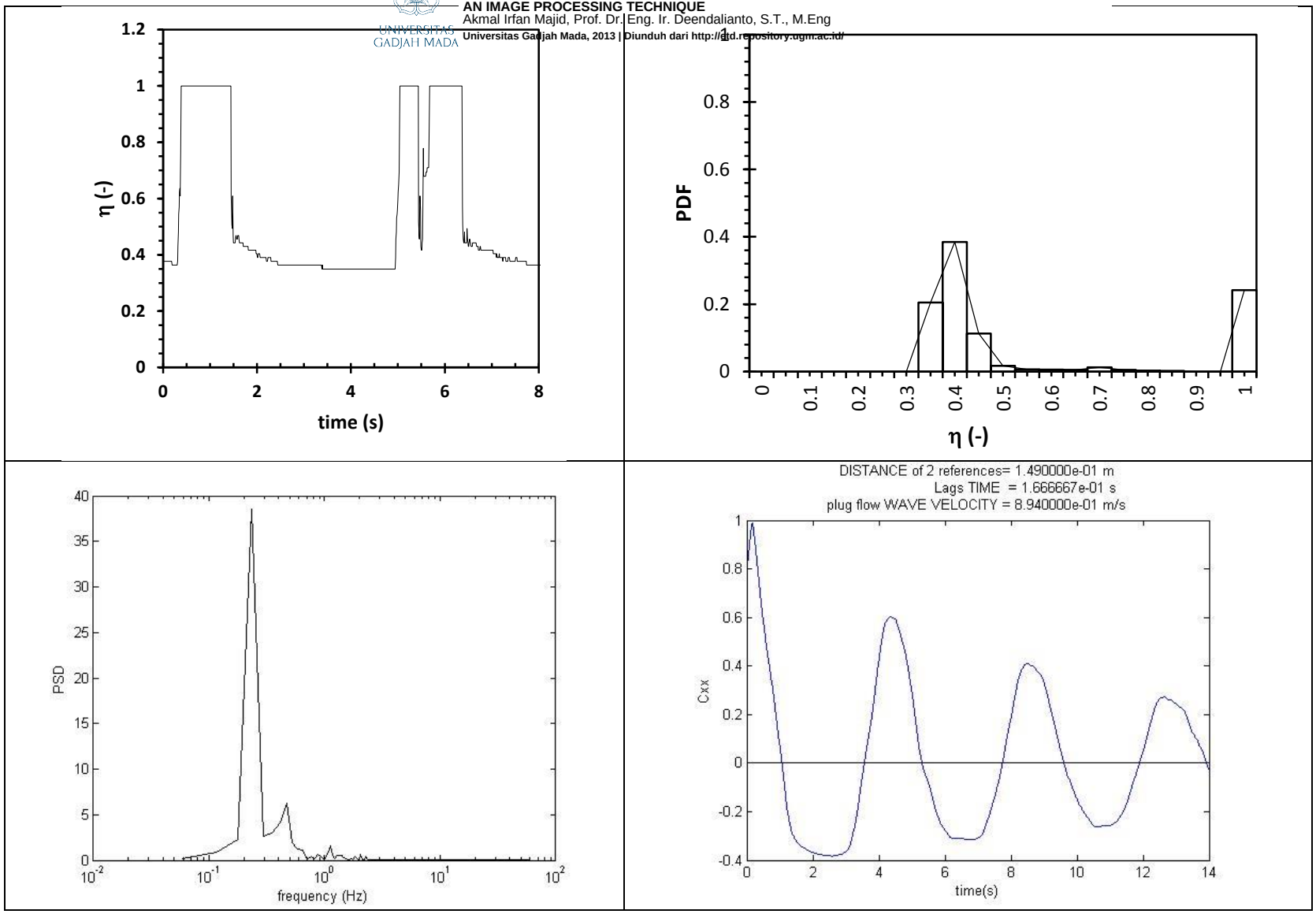
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Statistical analysis



Important flow parameters

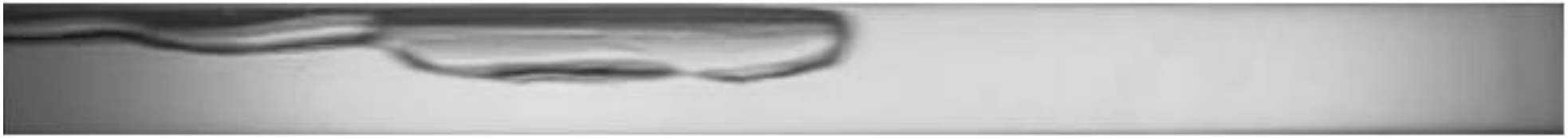
Average liquid hold-up	0.537	
Wave velocity	0.894	m/s
Wave frequency	0.234	Hz
Plug wavelength	0.384	m

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J_L	=	0.31	m/s

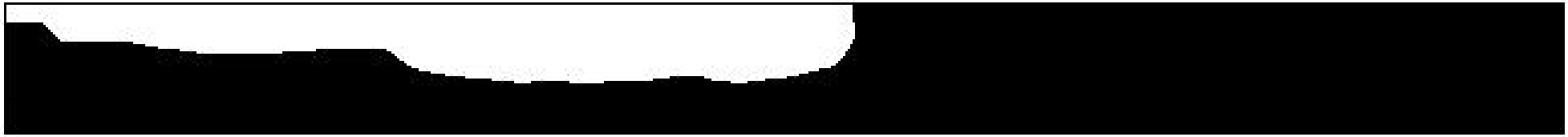
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Binary



Perimeter

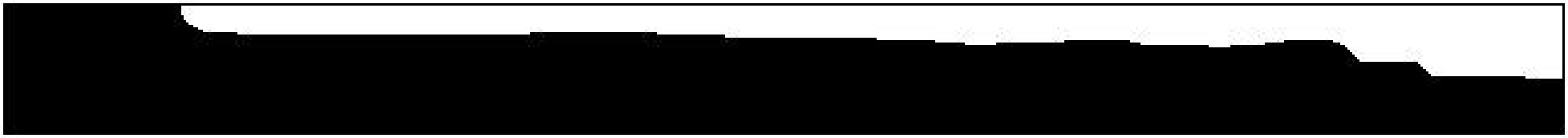


BUBBLE-TAIL CONTOURS

Original



Binary

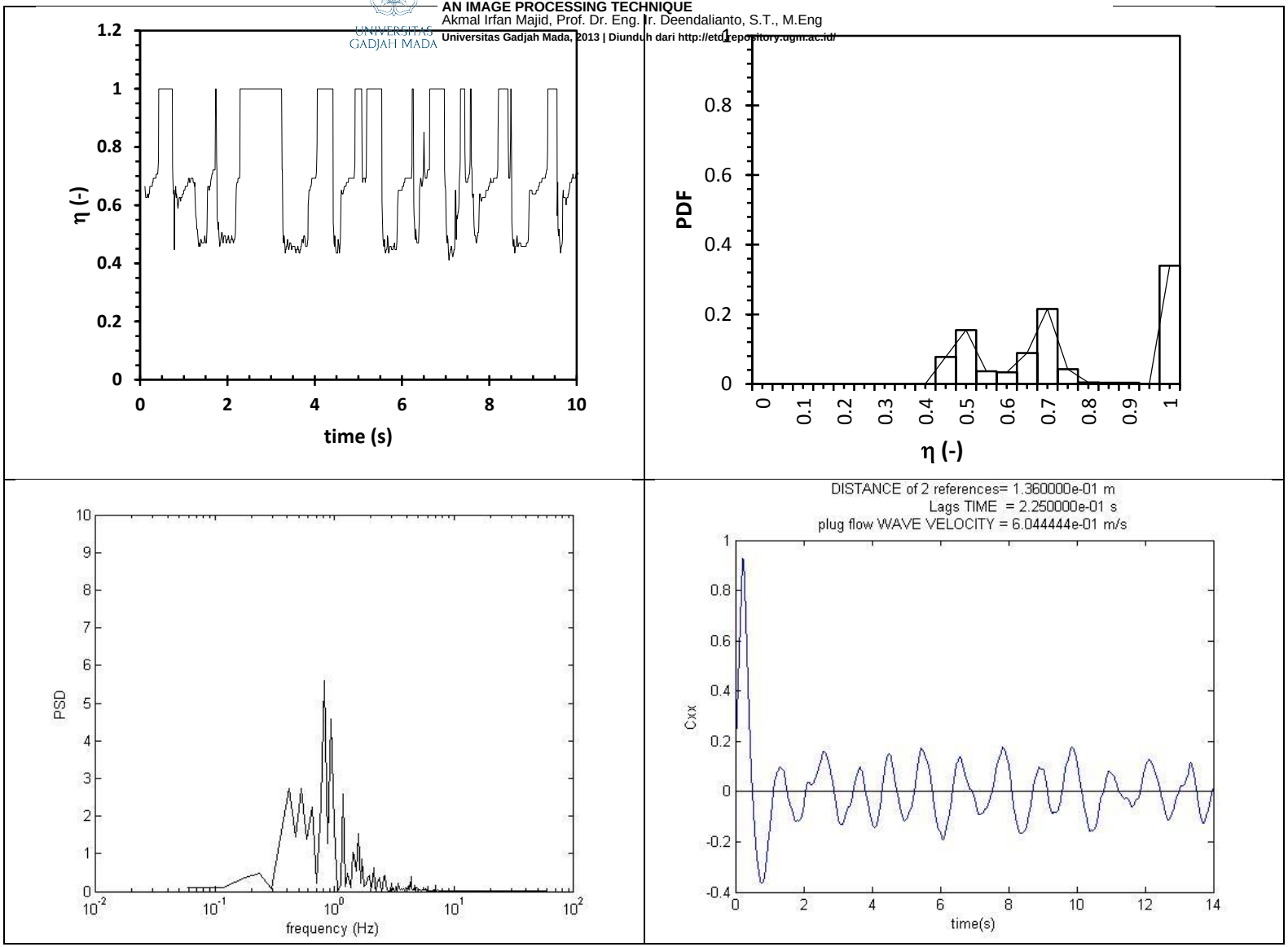


Perimeter



THE INTERFACIAL CHARACTERISTICS OF GAS-LIQUID PLUG TWO-PHASE FLOW IN A HORIZONTAL PIPE BY USING
AN IMAGE PROCESSING TECHNIQUE
Akmal Irfan Majid, Prof. Dr. Eng. Ir. Deendalianto, S.T., M.Eng
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Statistical analysis



Important flow parameters

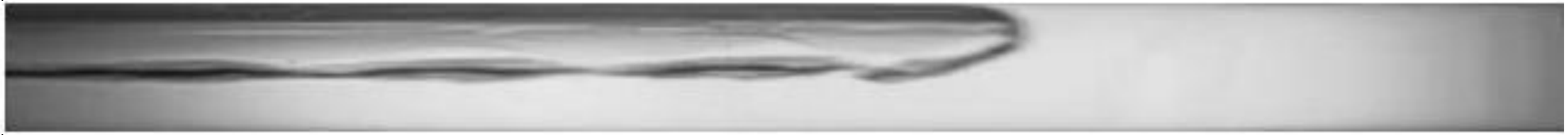
Average liquid hold-up	0726	
Wave velocity	0.604	m/s
Wave frequency	0.820	Hz
Plug wavelength	2.599	m

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Data no : 22			
J_G	=	0.18	m/s
J_L	=	0.31	m/s

BUBBLE-NOSE CONTOURS

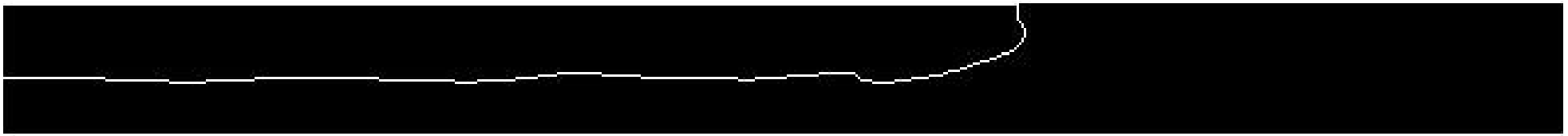
Original



Binary



Perimeter



BUBBLE-TAIL CONTOURS

Original



Binary

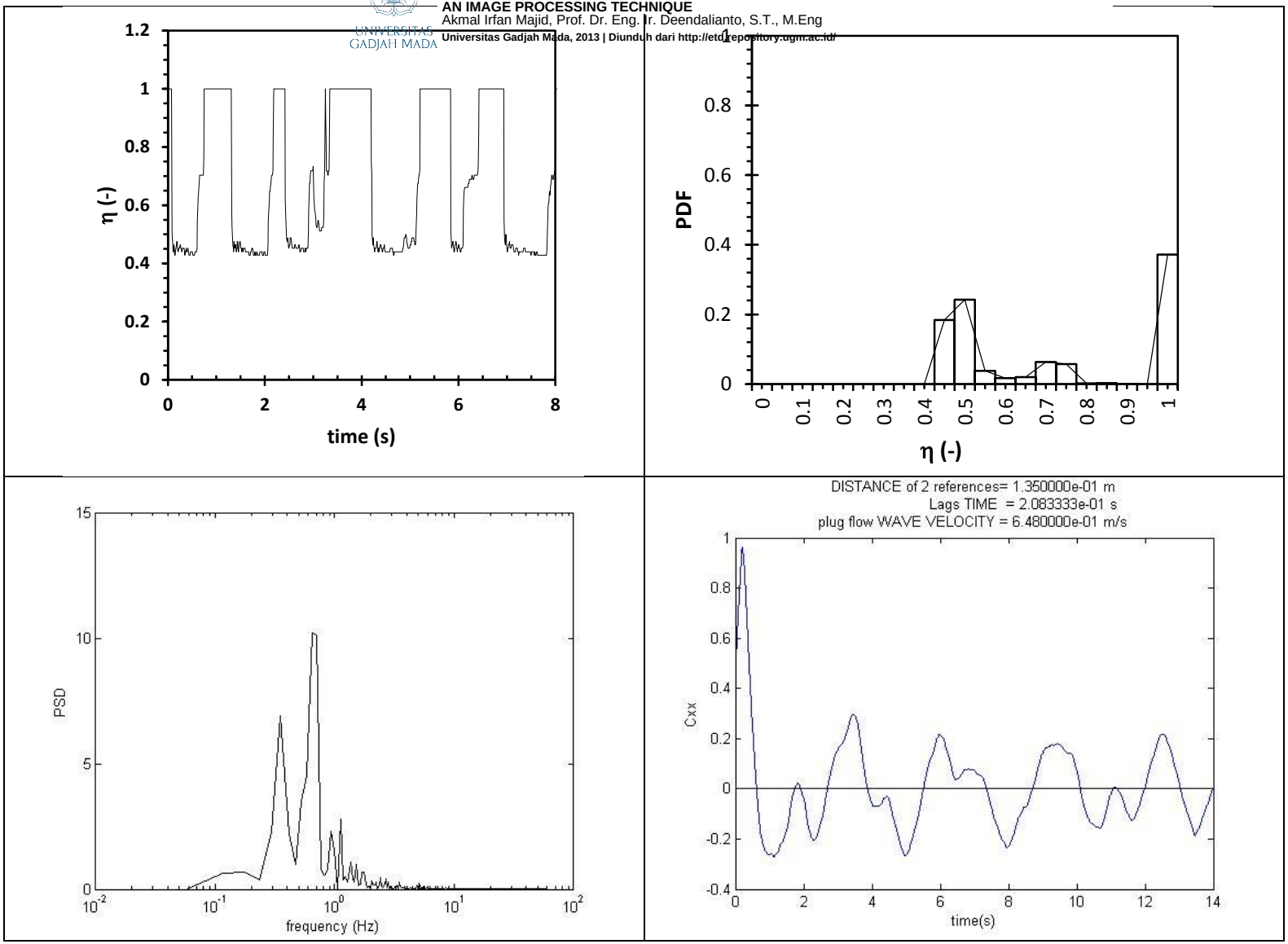


Perimeter



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Statistical analysis



Important flow parameters

Average liquid hold-up	0.699	
Wave velocity	0.648	m/s
Wave frequency	0.645	Hz
Plug wavelength	1.005	M

Data no : 23			
J_G	=	0.24	m/s
J_L	=	0.31	m/s

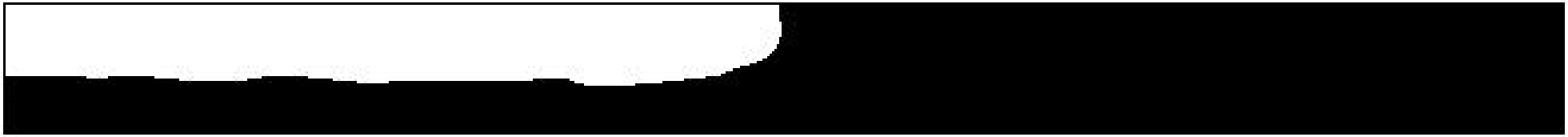
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BUBBLE-NOSE CONTOURS

Original



Binary



Perimeter



BUBBLE-TAIL CONTOURS

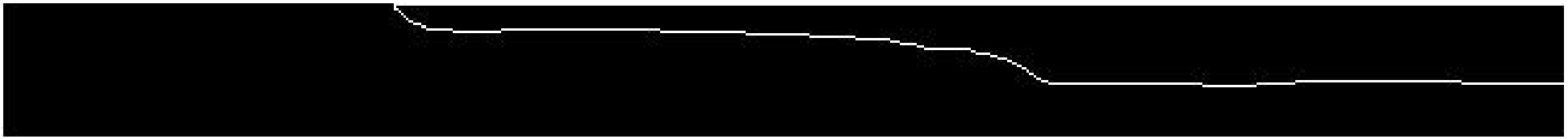
Original



Binary

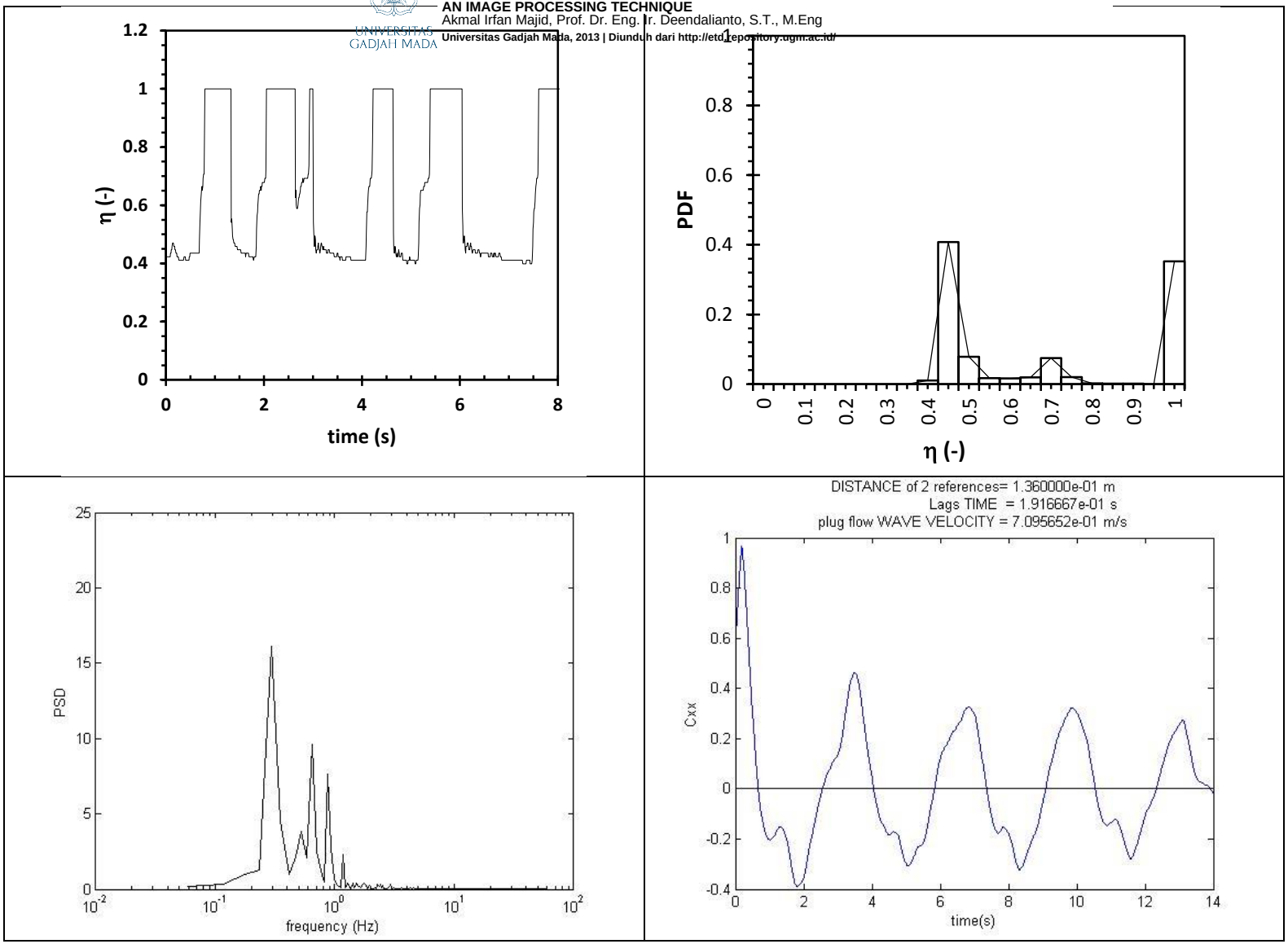


Perimeter



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Statistical analysis



Important flow parameters

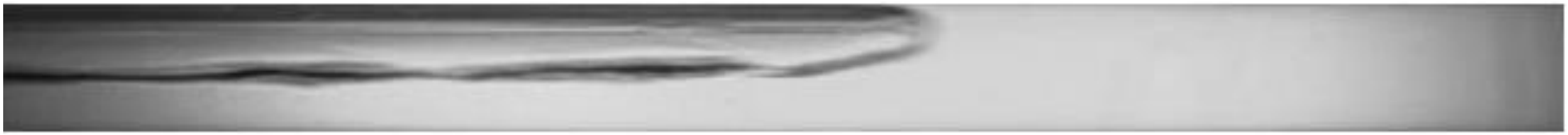
Average liquid hold-up	0.666	
Wave velocity	0.710	m/s
Wave frequency	0.293	Hz
Plug wavelength	0.474	m

Data no : 24			
J_G	=	0.31	m/s
J_L	=	0.31	m/s

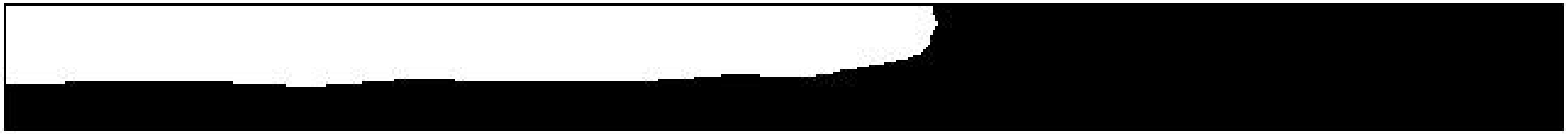
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BUBBLE-NOSE CONTOURS

Original



Binary



Perimeter

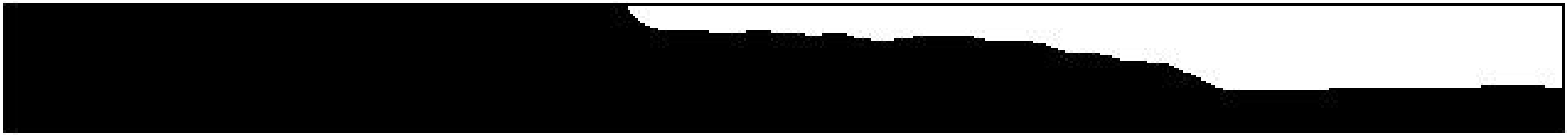


BUBBLE-TAIL CONTOURS

Original



Binary

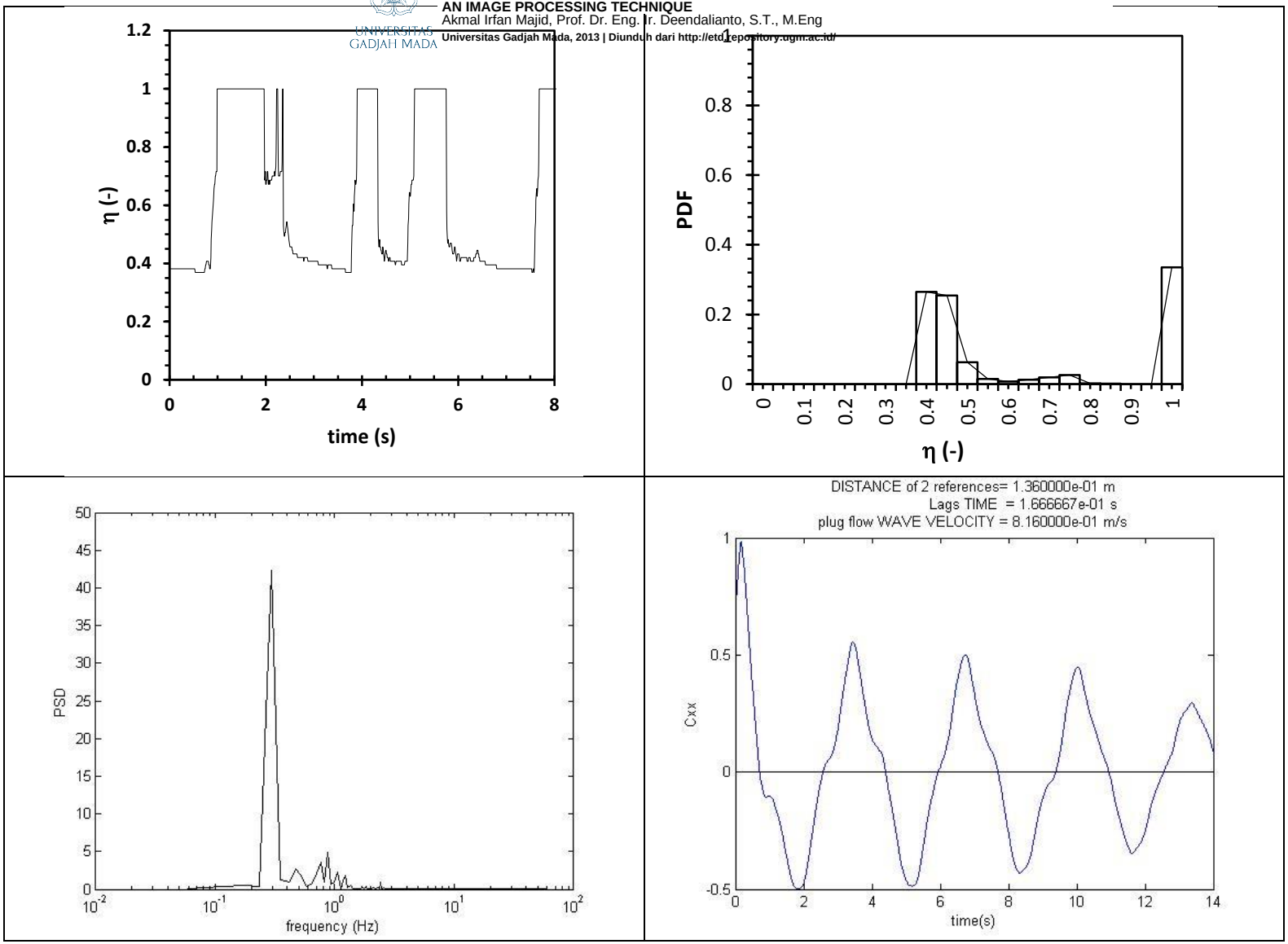


Perimeter



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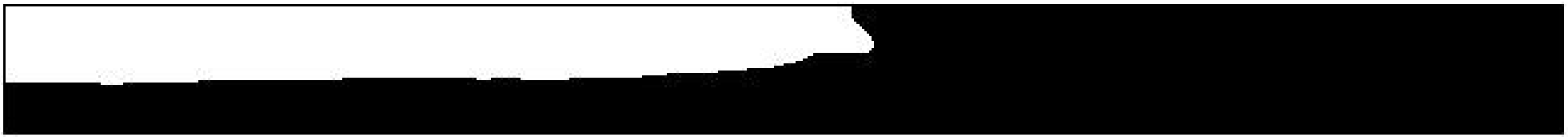


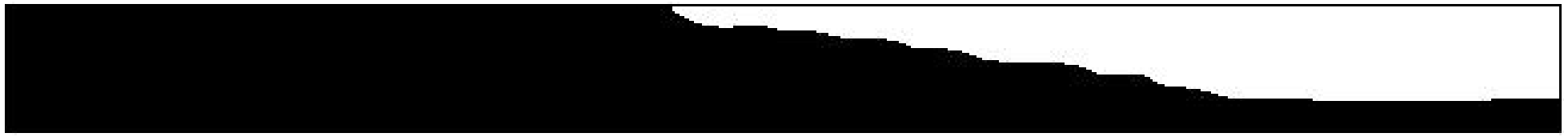
Important flow parameters

Average liquid hold-up	0.628	
Wave velocity	0.816	m/s
Wave frequency	0.293	Hz
Plug wavelength	0.349	m

Data no : 25			
J_G	=	0.51	m/s
J_L	=	0.31	m/s

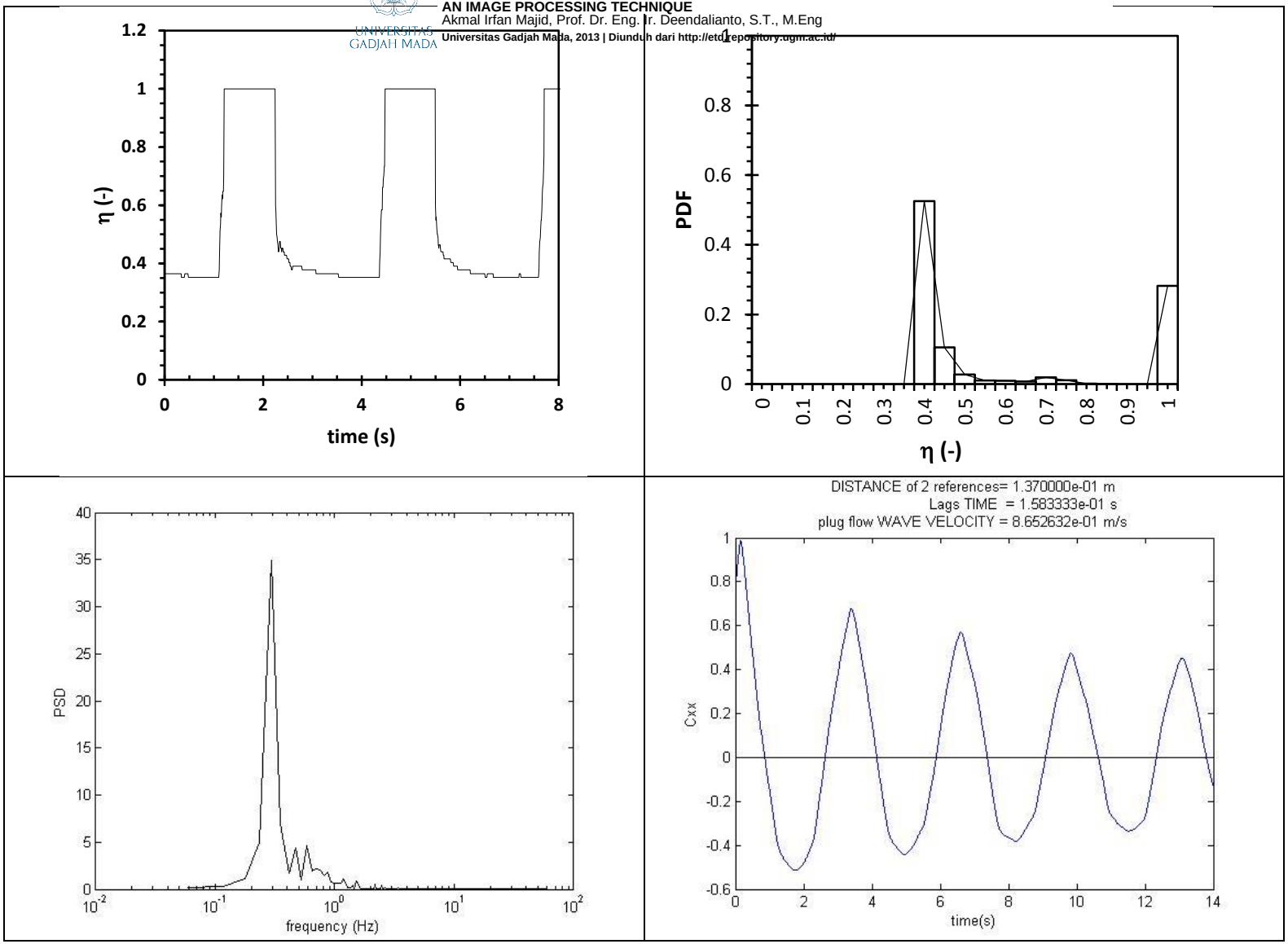
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Statistical analysis

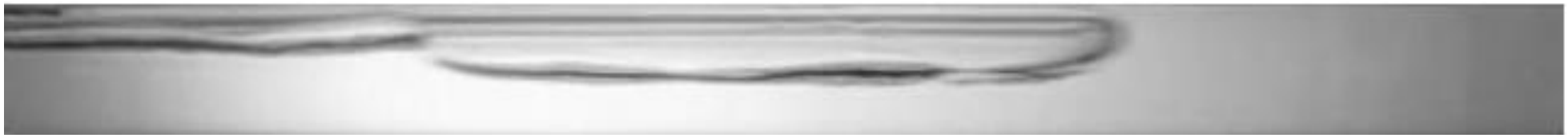


Important flow parameters

Average liquid hold-up	0.570	
Wave velocity	0.865	m/s
Wave frequency	0.293	Hz
Plug wavelength	0.255	m

Data no : 31			
J_G	=	0.12	m/s
J_L	=	0.44	m/s

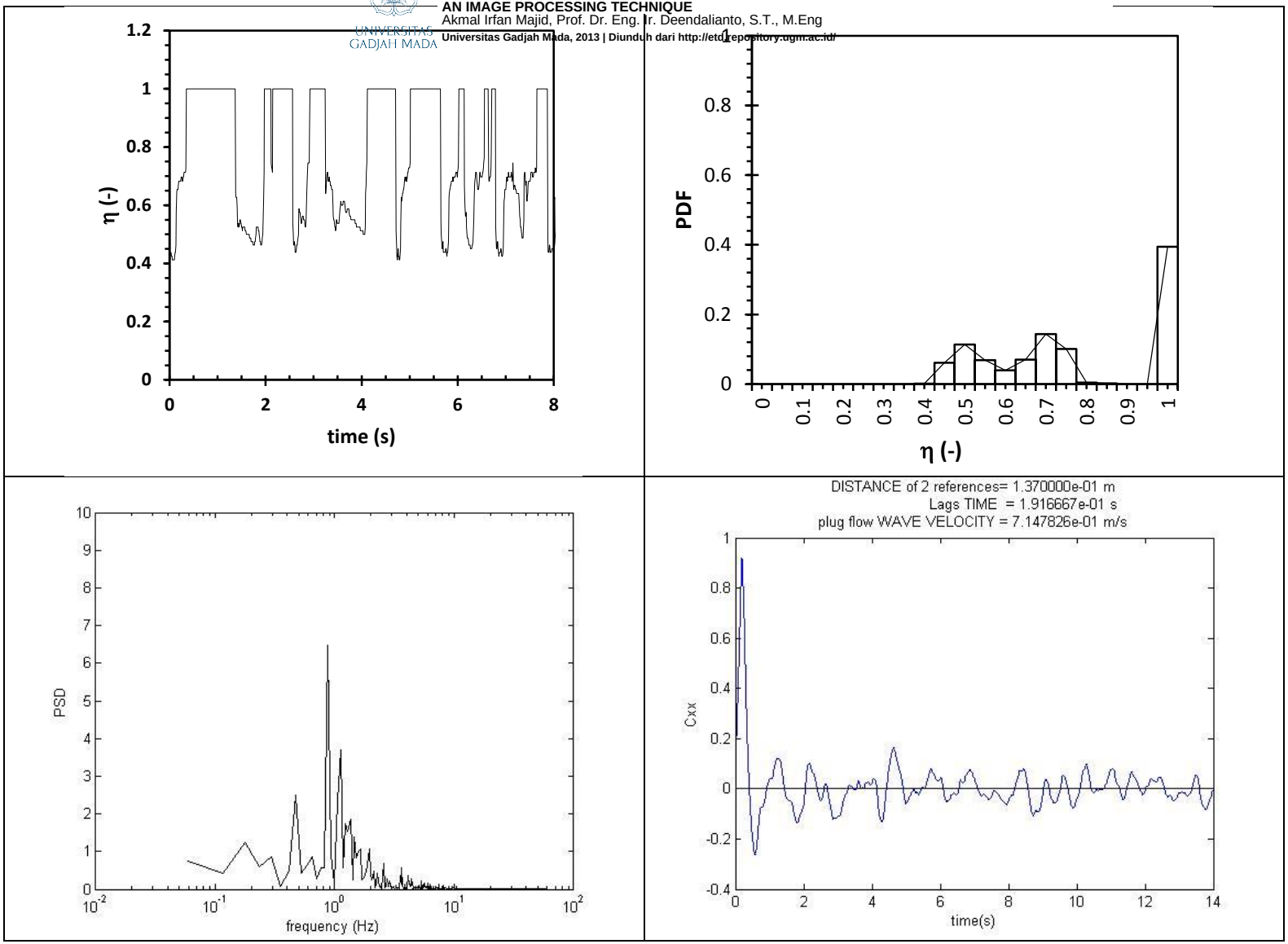
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Statistical analysis



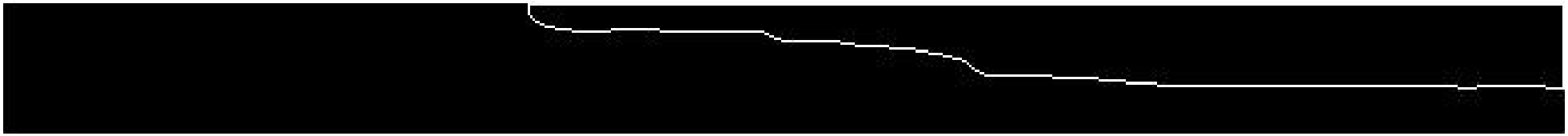
Important flow parameters

Average liquid hold-up	0.753	
Wave velocity	0.715	m/s
Wave frequency	0.879	Hz
Plug wavelength	2.816	m

Data no : 32			
J_G	=	0.18	m/s
J_L	=	0.44	m/s

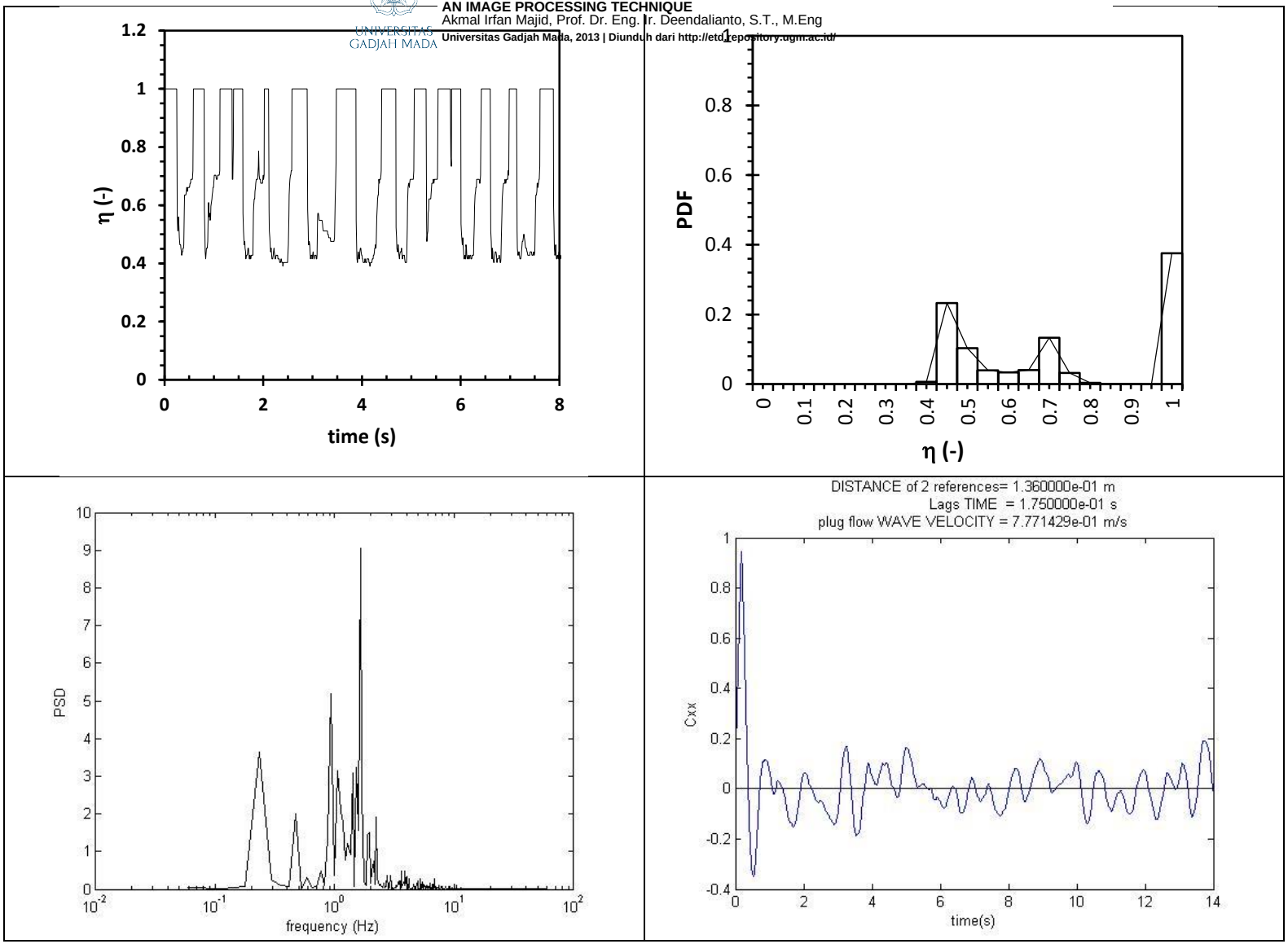
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Statistical analysis



Important flow parameters

Average liquid hold-up	0.707	
Wave velocity	0.777	m/s
Wave frequency	1.641	Hz
Plug wavelength	2.422	m

Data no : 33			
J_G	=	0.24	m/s
J_L	=	0.44	m/s

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BUBBLE-NOSE CONTOURS

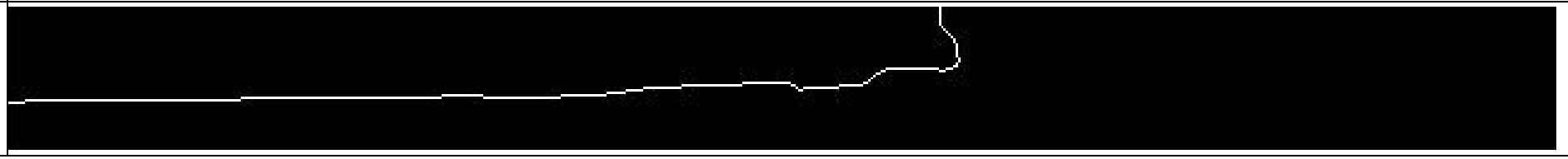
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Binary



Perimeter



BUBBLE-TAIL CONTOURS

Original



Binary

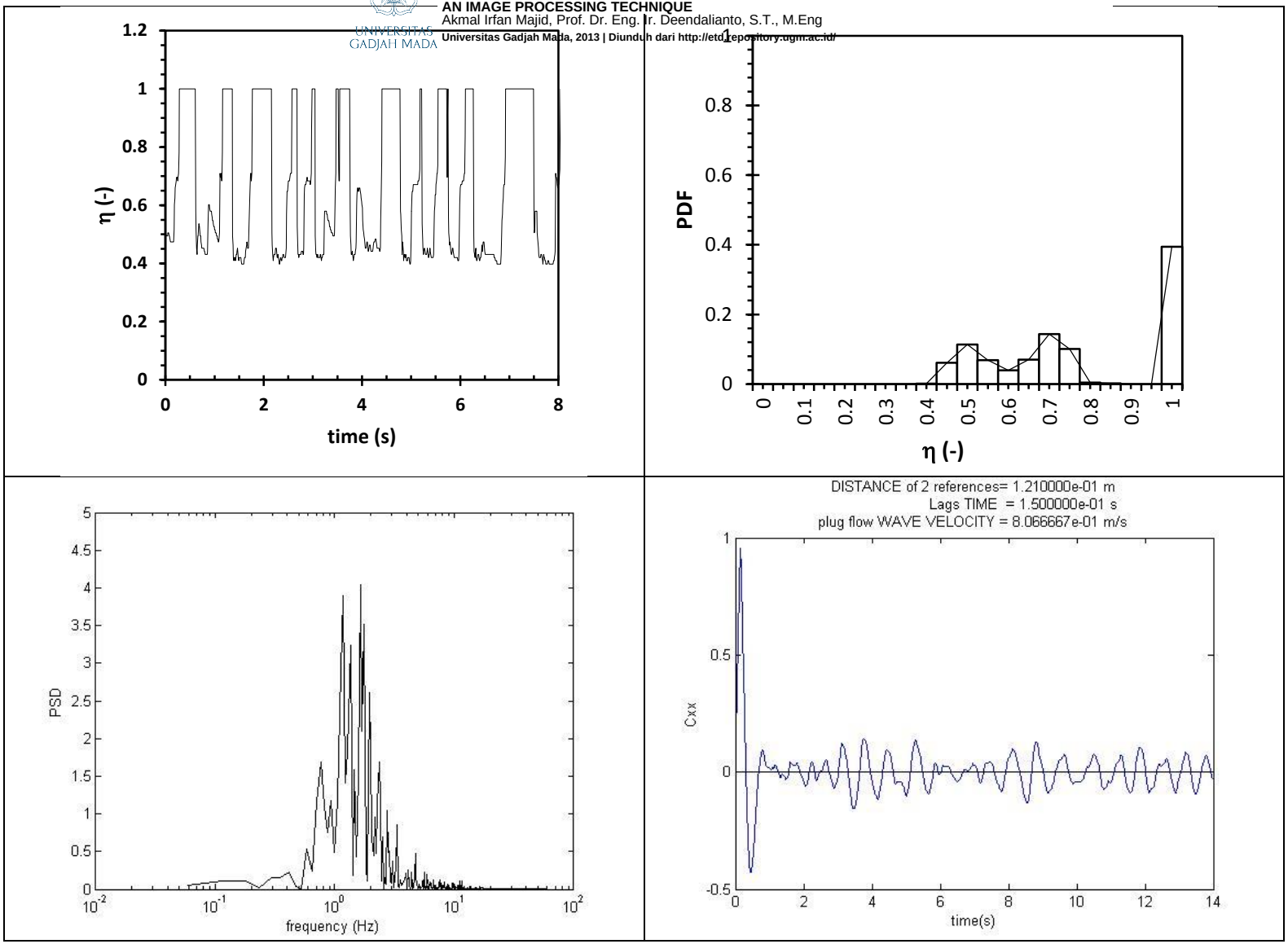


Perimeter



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Statistical analysis



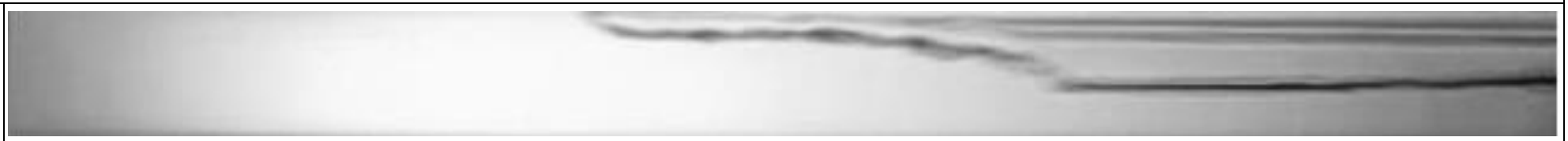
Important flow parameters

Average liquid hold-up	0.666	
Wave velocity	0.807	m/s
Wave frequency	1.641	Hz
Plug wavelength	0.492	m

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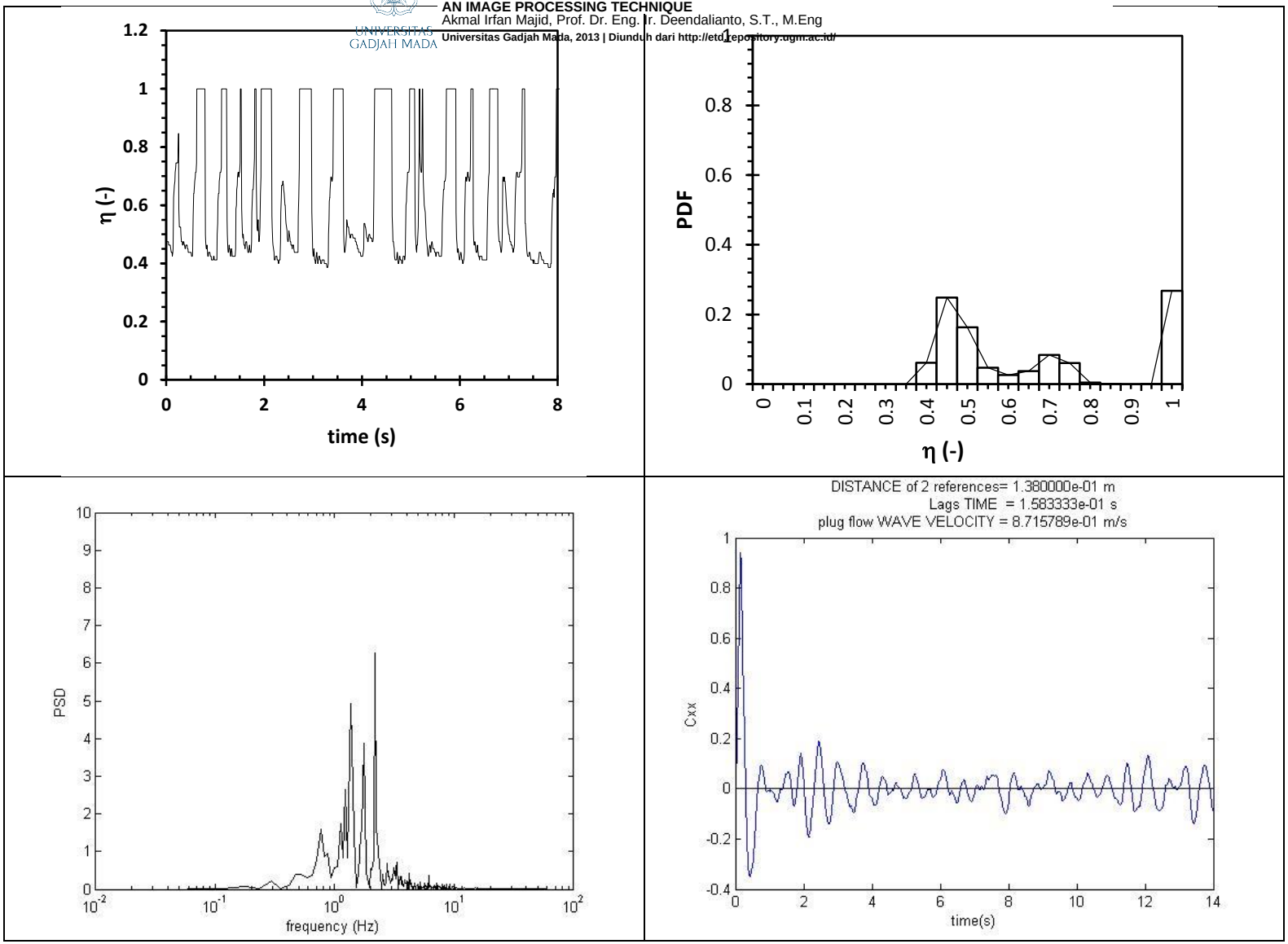
Data no : 34			
J_G	=	0.31	m/s
J_L	=	0.44	m/s

BUBBLE-NOSE CONTOURS	
Original	
Binary	
Perimeter	

BUBBLE-TAIL CONTOURS	
Original	
Binary	
Perimeter	

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Statistical analysis



Important flow parameters

Average liquid hold-up	0.642	
Wave velocity	0.872	m/s
Wave frequency	2.168	Hz
Plug wavelength	0.452	m

Data no : 35			
J_G	=	0.51	m/s
J_L	=	0.44	m/s

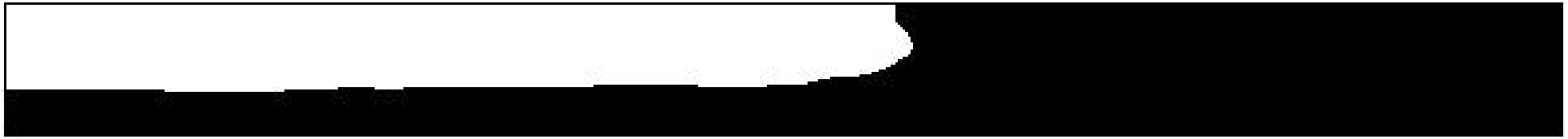
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BUBBLE-NOSE CONTOURS

Original



Binary



Perimeter

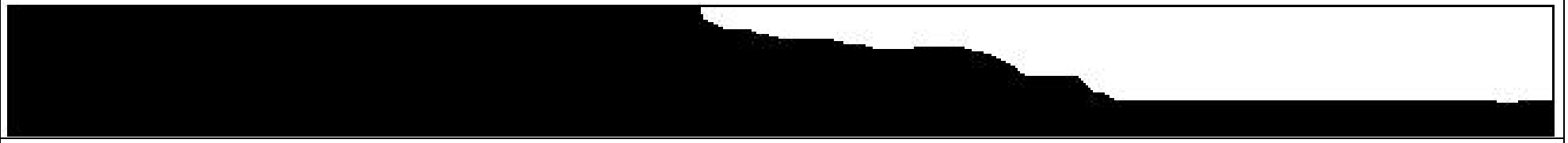


BUBBLE-TAIL CONTOURS

Original



Binary

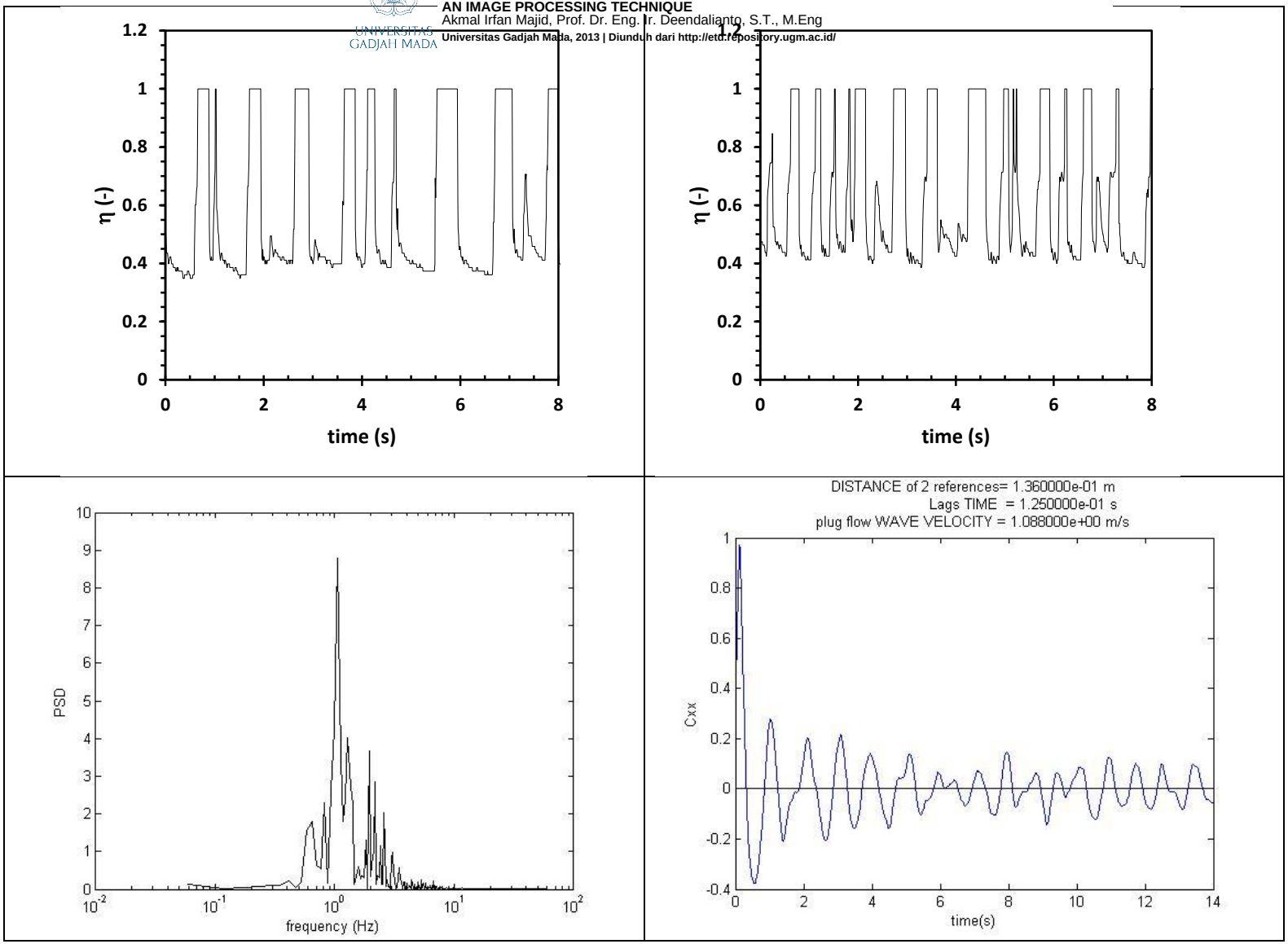


Perimeter



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Statistical analysis



Important flow parameters

Average liquid hold-up	0.586	
Wave velocity	1.088	m/s
Wave frequency	1.055	Hz
Plug wavelength	0.406	m

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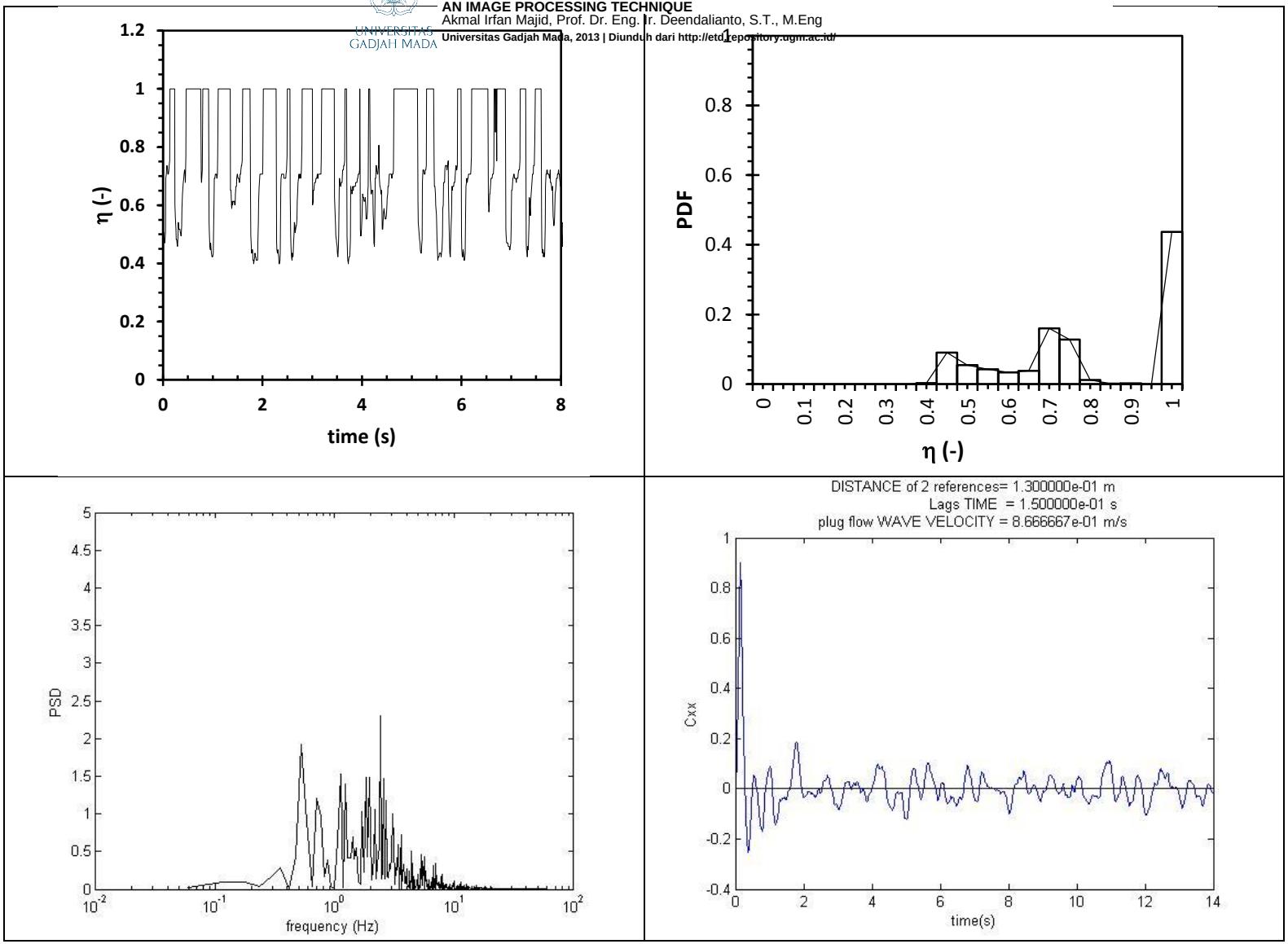
Data no : 51			
J_G	=	0.12	m/s
J_L	=	0.77	m/s

BUBBLE-NOSE CONTOURS	
Original	
Binary	
Perimeter	

BUBBLE-TAIL CONTOURS	
Original	
Binary	
Perimeter	

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Statistical analysis



Important flow parameters

Average liquid hold-up	0.779	
Wave velocity	0.873	m/s
Wave frequency	2.402	Hz
Plug wavelength	3.157	m

Data no : 52			
J_G	=	0.18	m/s
J_L	=	0.77	m/s

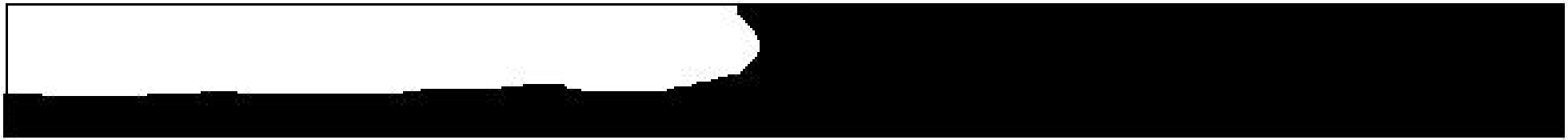
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BUBBLE-NOSE CONTOURS

Original



Binary

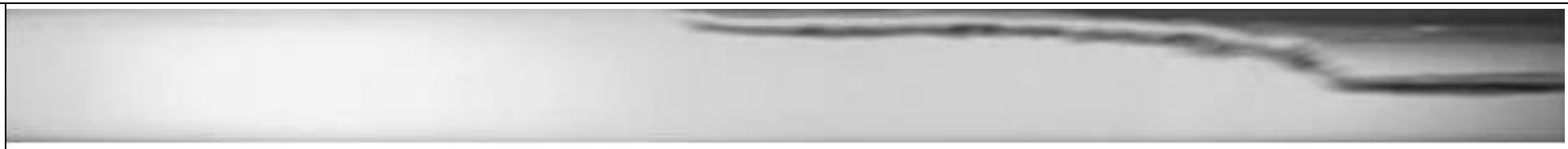


Perimeter



BUBBLE-TAIL CONTOURS

Original



Binary

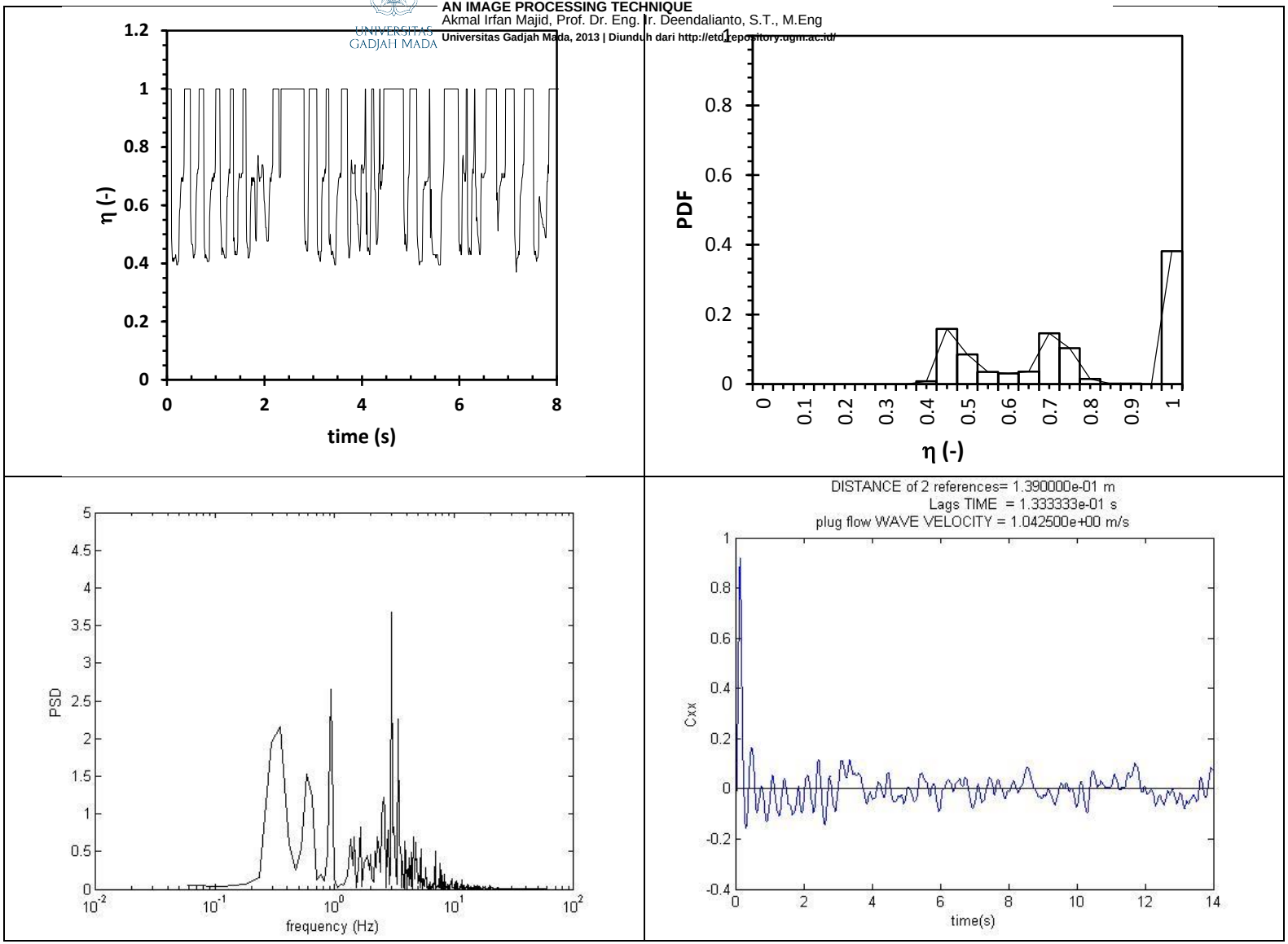


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Statistical analysis



Important flow parameters

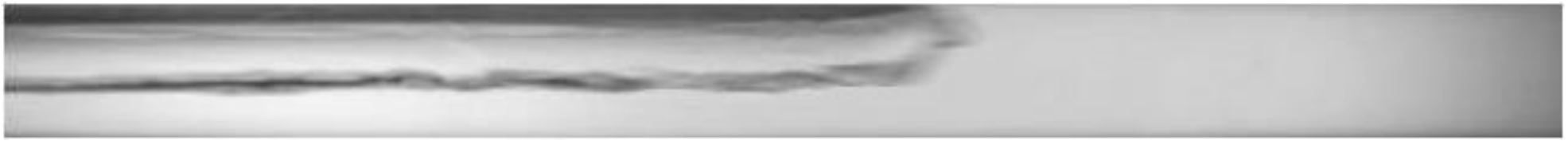
Average liquid hold-up	0.738	
Wave velocity	1.043	m/s
Wave frequency	2.988	Hz
Plug wavelength	2.785	m

Data no : 53			
J_G	=	0.24	m/s
J_L	=	0.77	m/s

UNIVERSITAS GADJAH MADA
THE INTERFACIAL CHARACTERISTICS OF GAS-LIQUID PLUG TWO-PHASE FLOW IN A HORIZONTAL PIPE BY USING AN IMAGE PROCESSING TECHNIQUE
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BUBBLE-NOSE CONTOURS

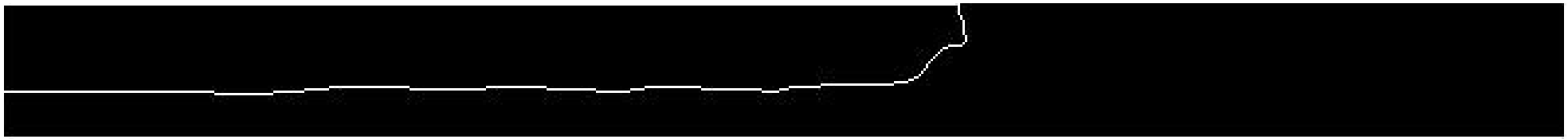
Original



Binary



Perimeter



BUBBLE-TAIL CONTOURS

Original



Binary

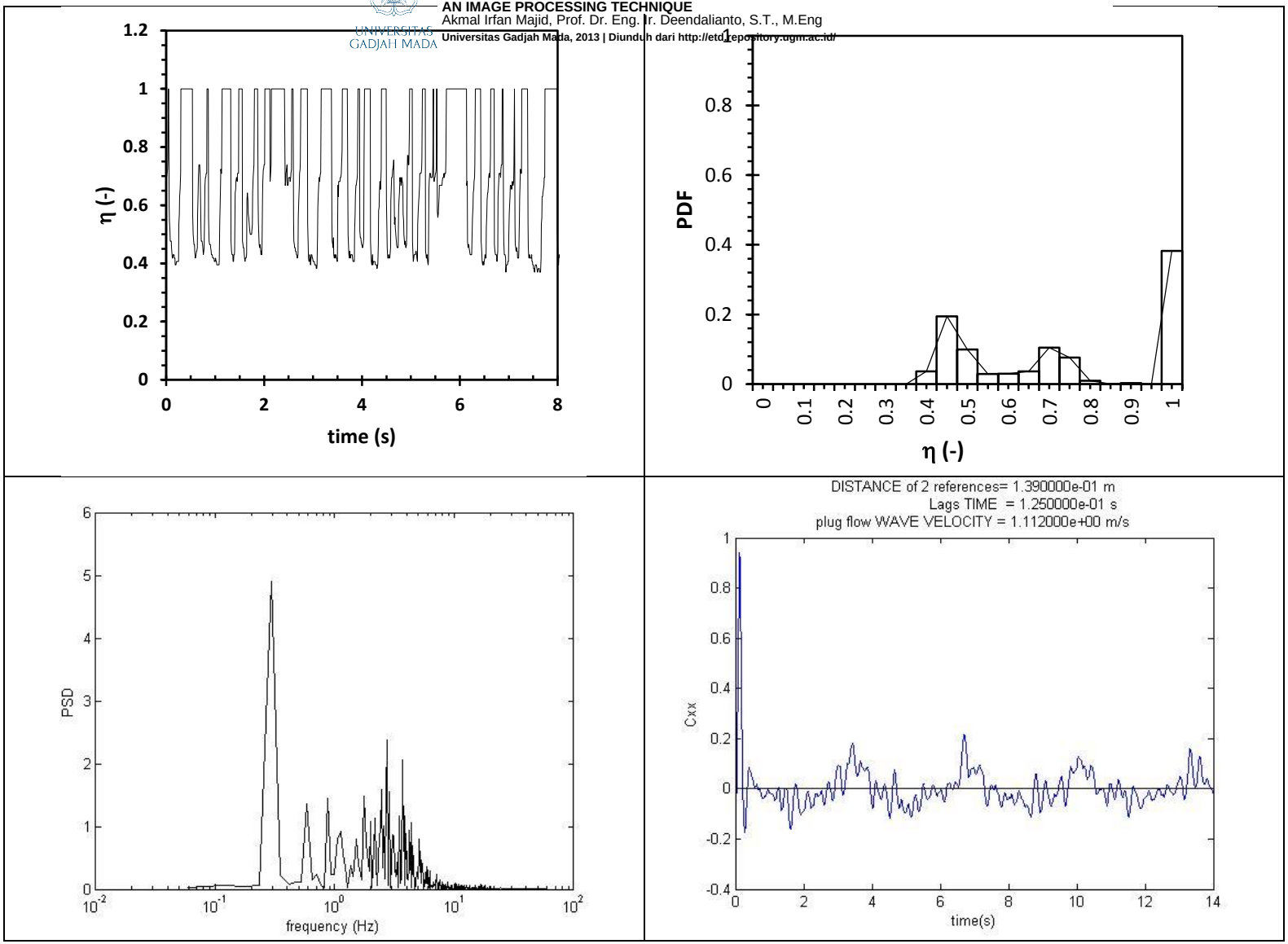


Perimeter



THE INTERFACIAL CHARACTERISTICS OF GAS-LIQUID PLUG TWO-PHASE FLOW IN A HORIZONTAL PIPE BY USING
AN IMAGE PROCESSING TECHNIQUE
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Statistical analysis



Important flow parameters

Average liquid hold-up	0.716	
Wave velocity	1.112	m/s
Wave frequency	0.293	Hz
Plug wavelength	0.402	m

Data no : 54			
J_G	=	0.31	m/s
J_L	=	0.77	m/s

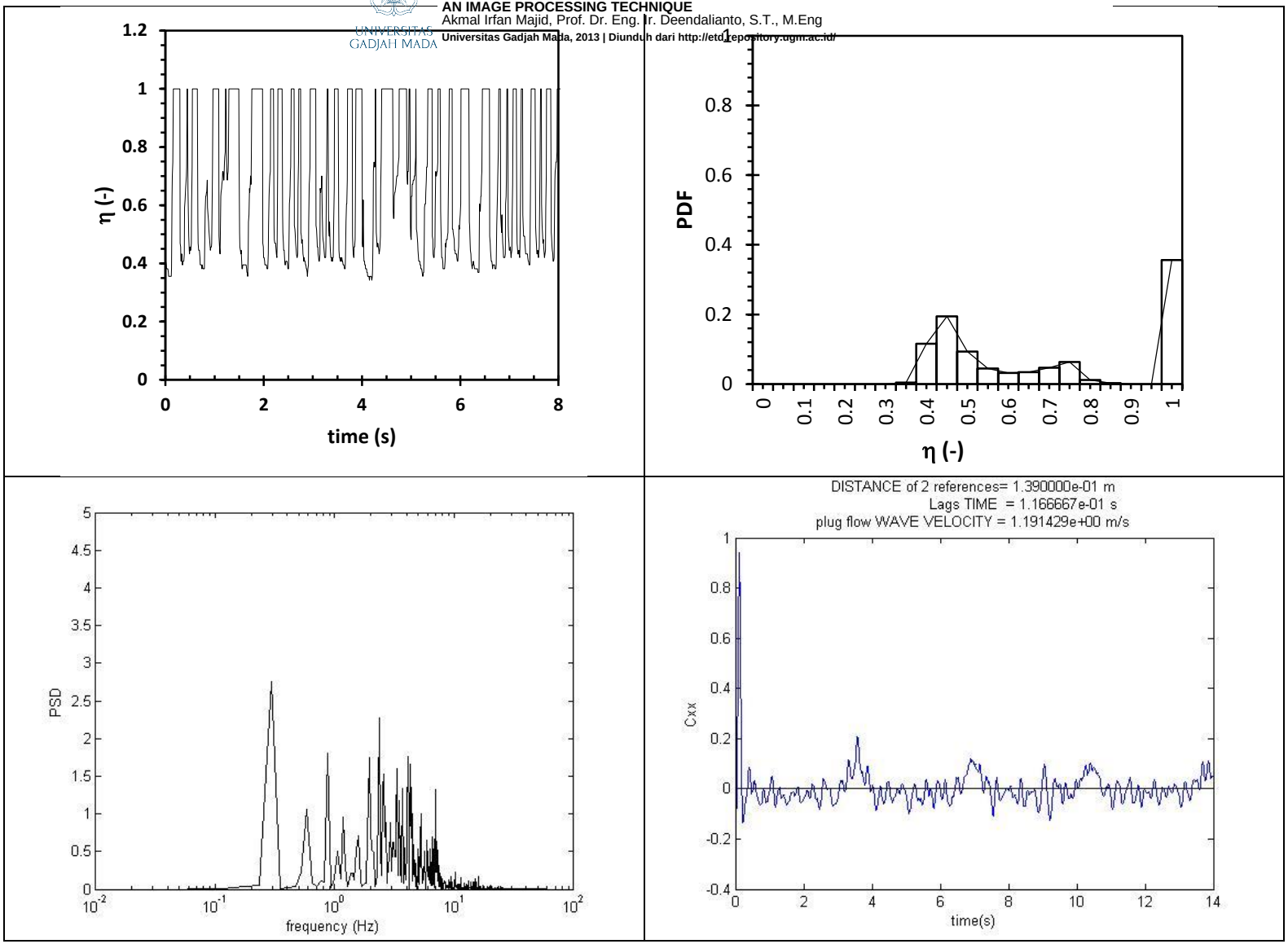
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BUBBLE-NOSE CONTOURS	
Original	
Binary	
Perimeter	

BUBBLE-TAIL CONTOURS	
Original	
Binary	
Perimeter	

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Statistical analysis



Important flow parameters

Average liquid hold-up	0.681	
Wave velocity	1.191	m/s
Wave frequency	0.293	Hz
Plug wavelength	0.508	m

Data no : 55			
J_G	=	0.51	m/s
J_L	=	0.77	m/s

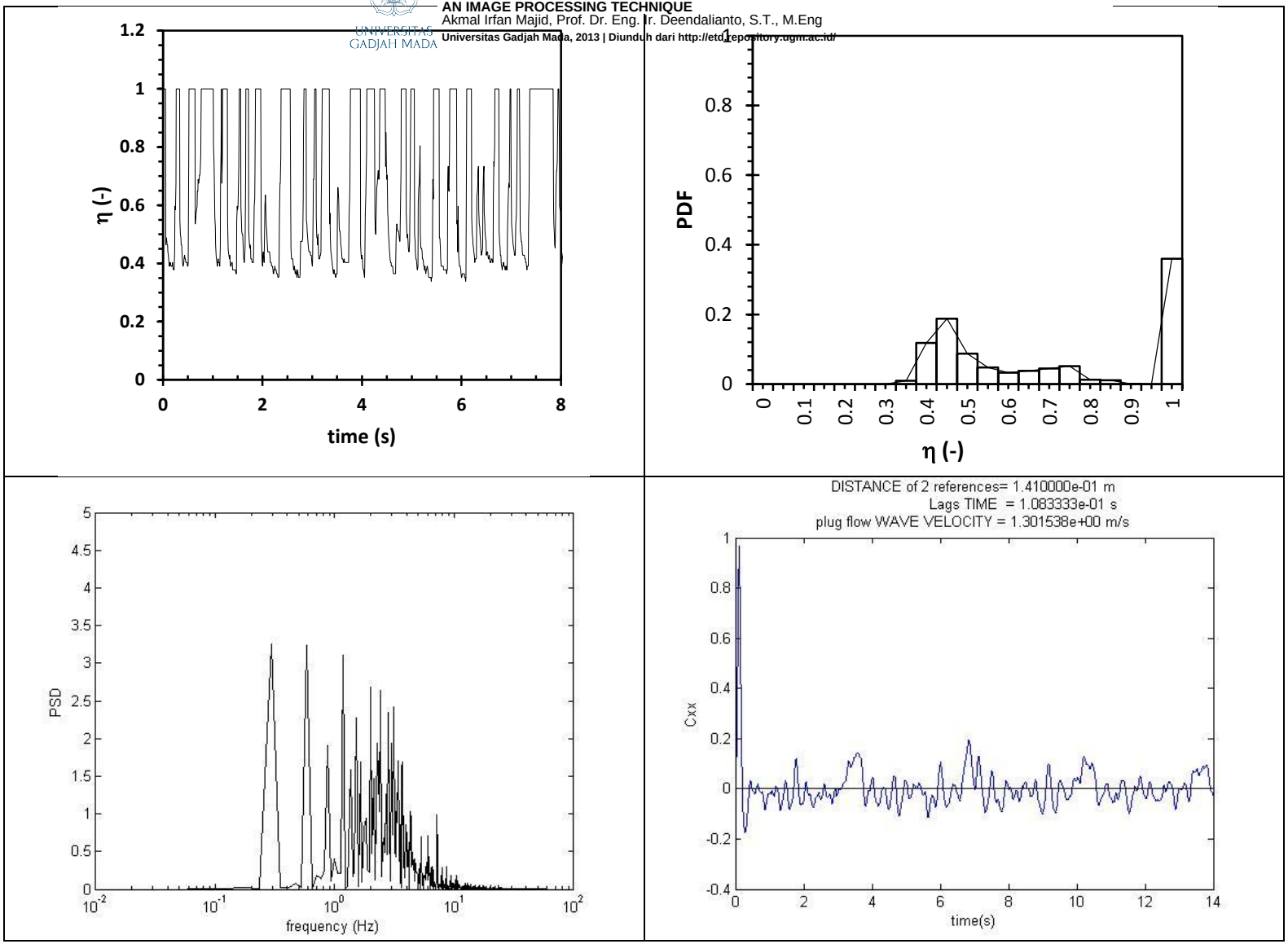
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BUBBLE-NOSE CONTOURS	
Original	
Binary	
Perimeter	

BUBBLE-TAIL CONTOURS	
Original	
Binary	
Perimeter	

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Important flow parameters

Average liquid hold-up	0.658	
Wave velocity	1.302	m/s
Wave frequency	0.293	Hz
Plug wavelength	0.323	m

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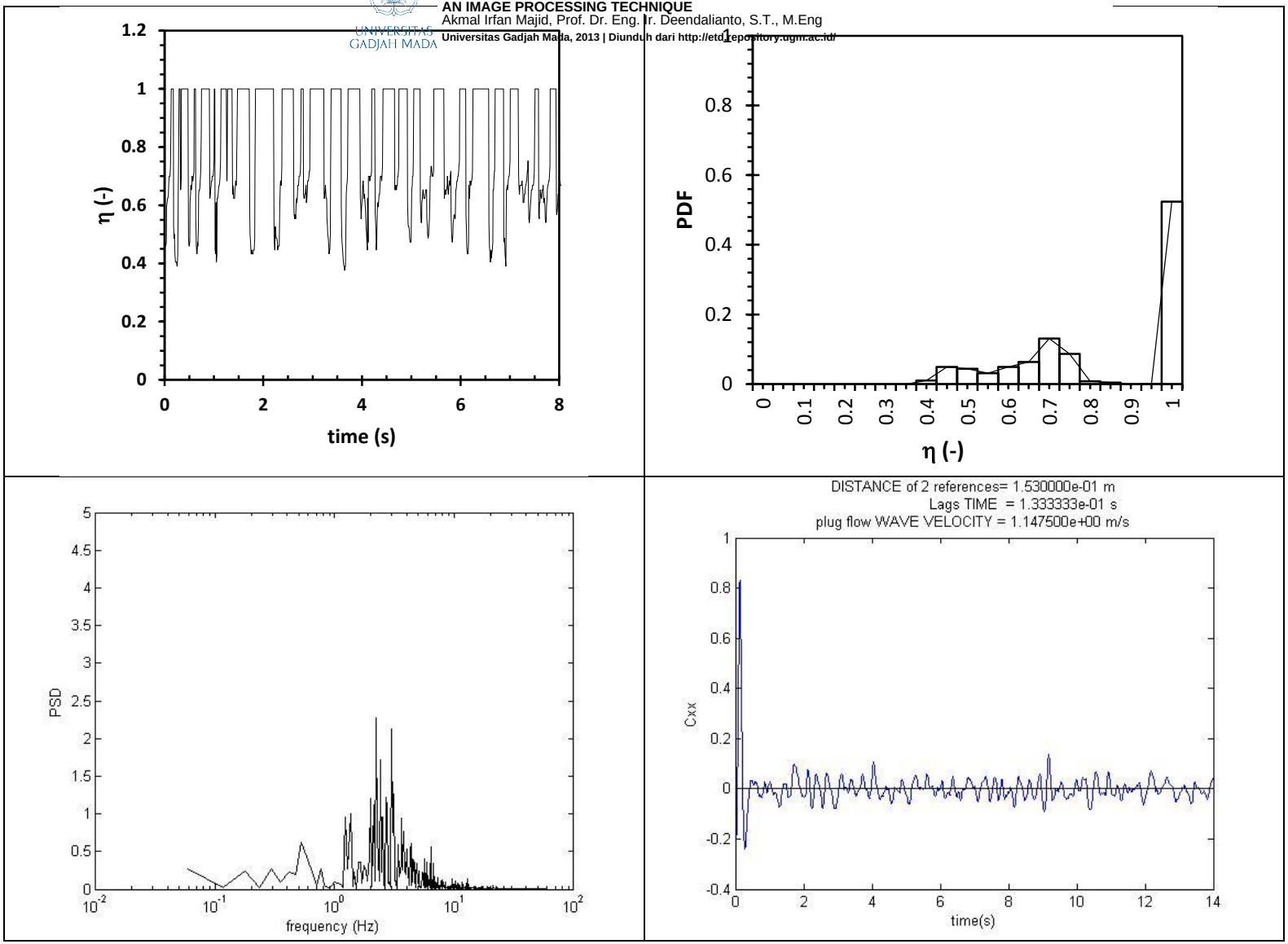
Data no : 61			
J_G	=	0.12	m/s
J_L	=	1.13	m/s

BUBBLE-NOSE CONTOURS	
Original	
Binary	
Perimeter	

BUBBLE-TAIL CONTOURS	
Original	
Binary	
Perimeter	

THE INTERFACIAL CHARACTERISTICS OF GAS-LIQUID PLUG TWO-PHASE FLOW IN A HORIZONTAL PIPE BY USING
AN IMAGE PROCESSING TECHNIQUE
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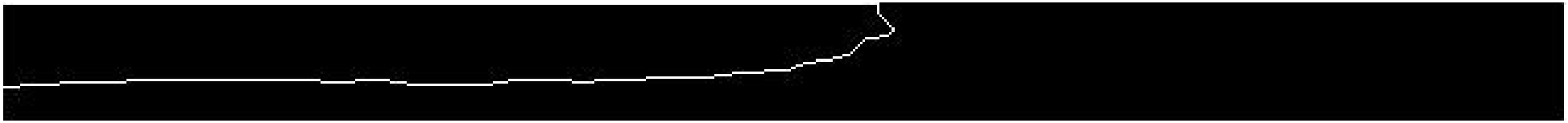


Important flow parameters

Average liquid hold-up	0.812	
Wave velocity	1.148	m/s
Wave frequency	2.227	Hz
Plug wavelength	3.814	m

Data no : 62			
J_G	=	0.18	m/s
J_L	=	1.13	m/s

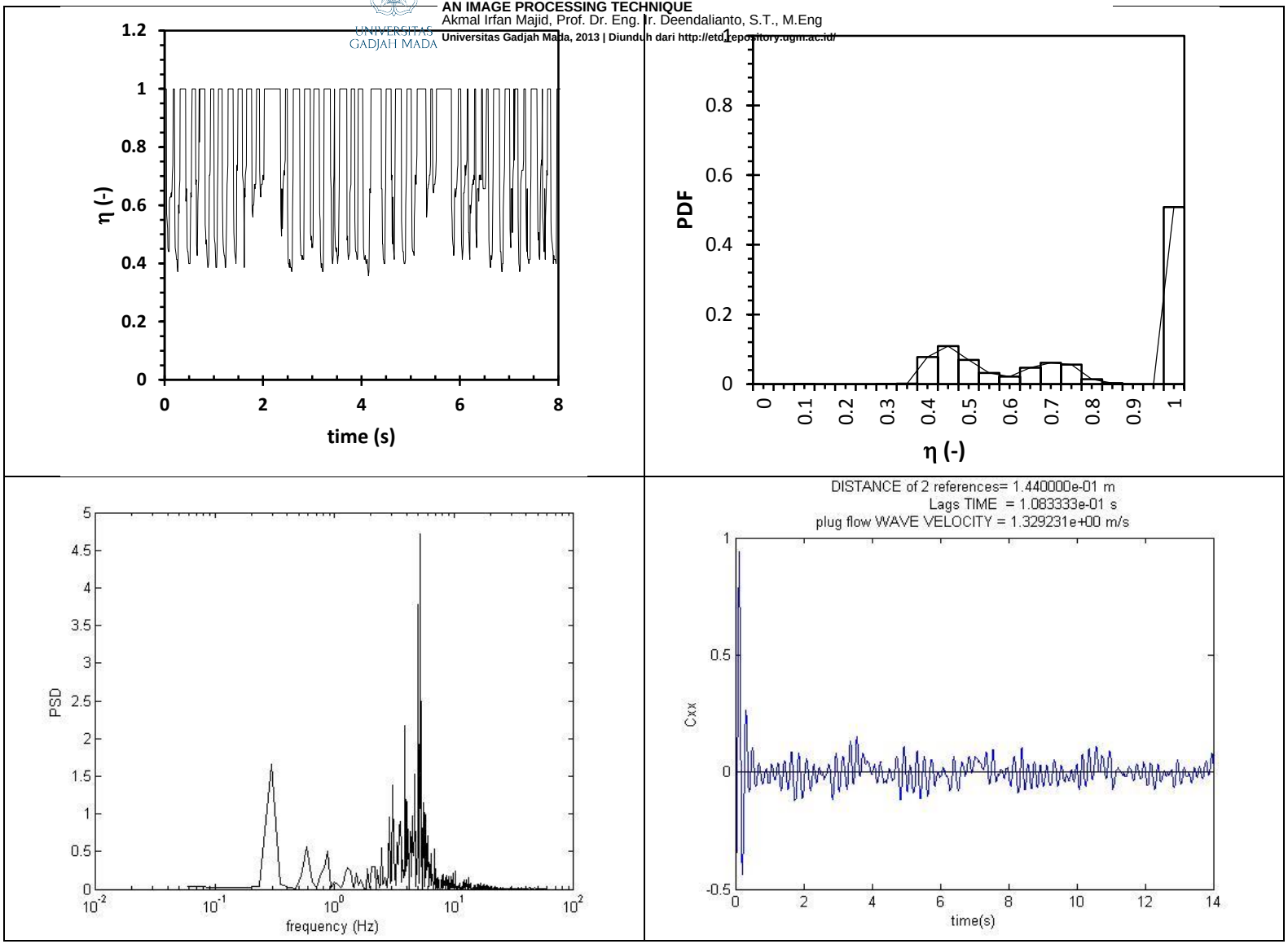
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BUBBLE-NOSE CONTOURS	
Original	
Binary	
Perimeter	

BUBBLE-TAIL CONTOURS	
Original	
Binary	
Perimeter	

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Statistical analysis



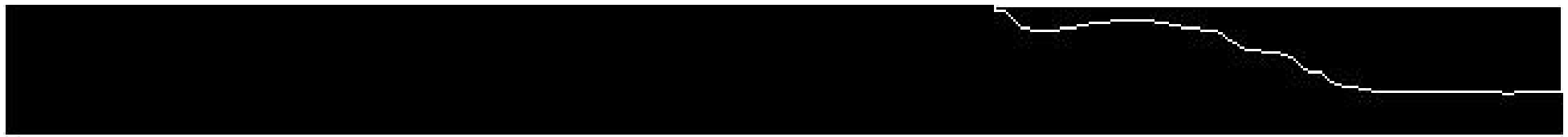
Important flow parameters

Average liquid hold-up	0.785	
Wave velocity	1.329	m/s
Wave frequency	5.215	Hz
Plug wavelength	2.953	m

Data no : 63			
J_G	=	0.24	m/s
J_L	=	1.13	m/s

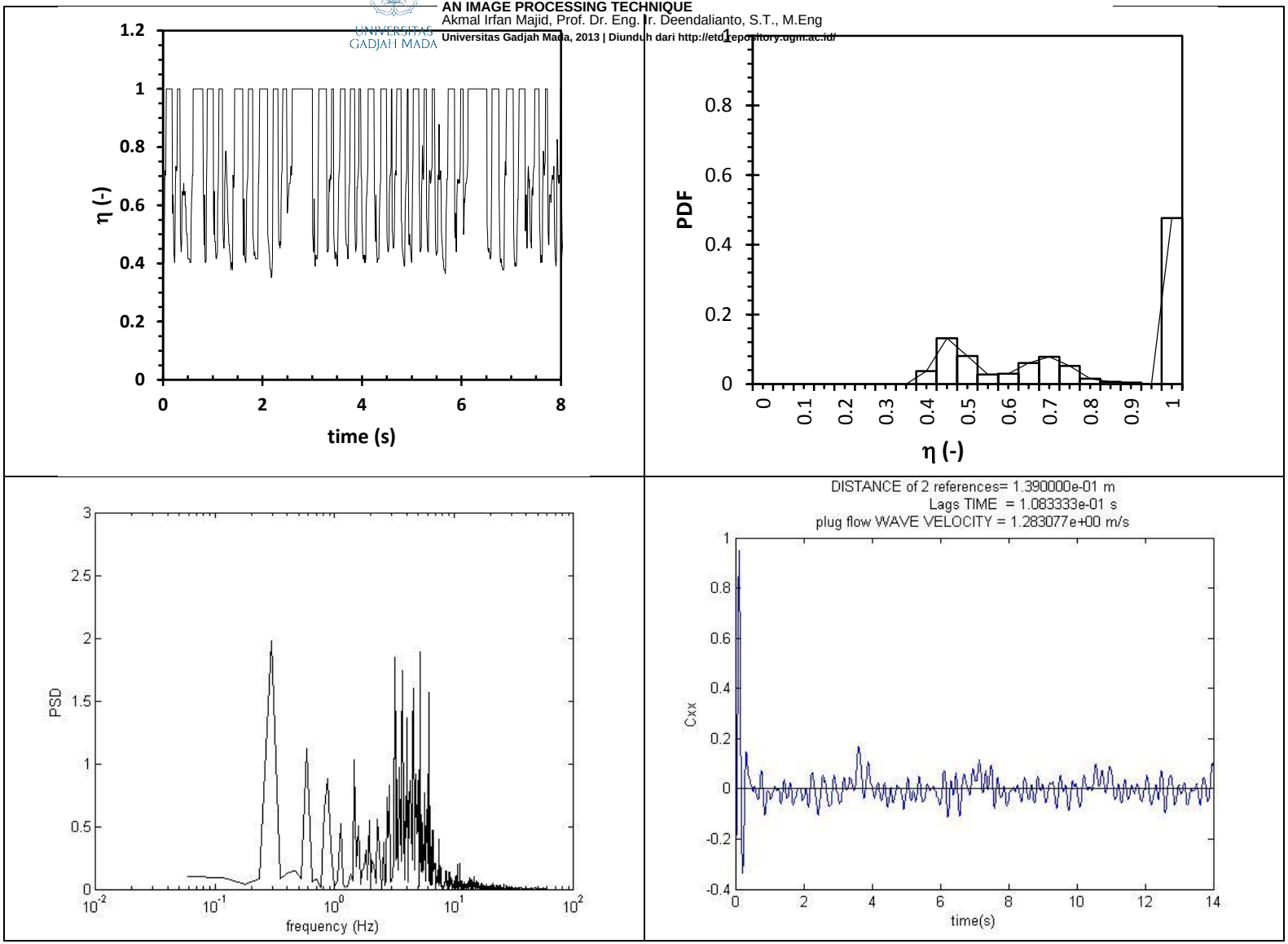
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Original	
Binary	
Perimeter	

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Original	
Binary	
Perimeter	

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Important flow parameters

Average liquid hold-up	0.765	
Wave velocity	1.283	m/s
Wave frequency	3.164	Hz
Plug wavelength	1.032	m

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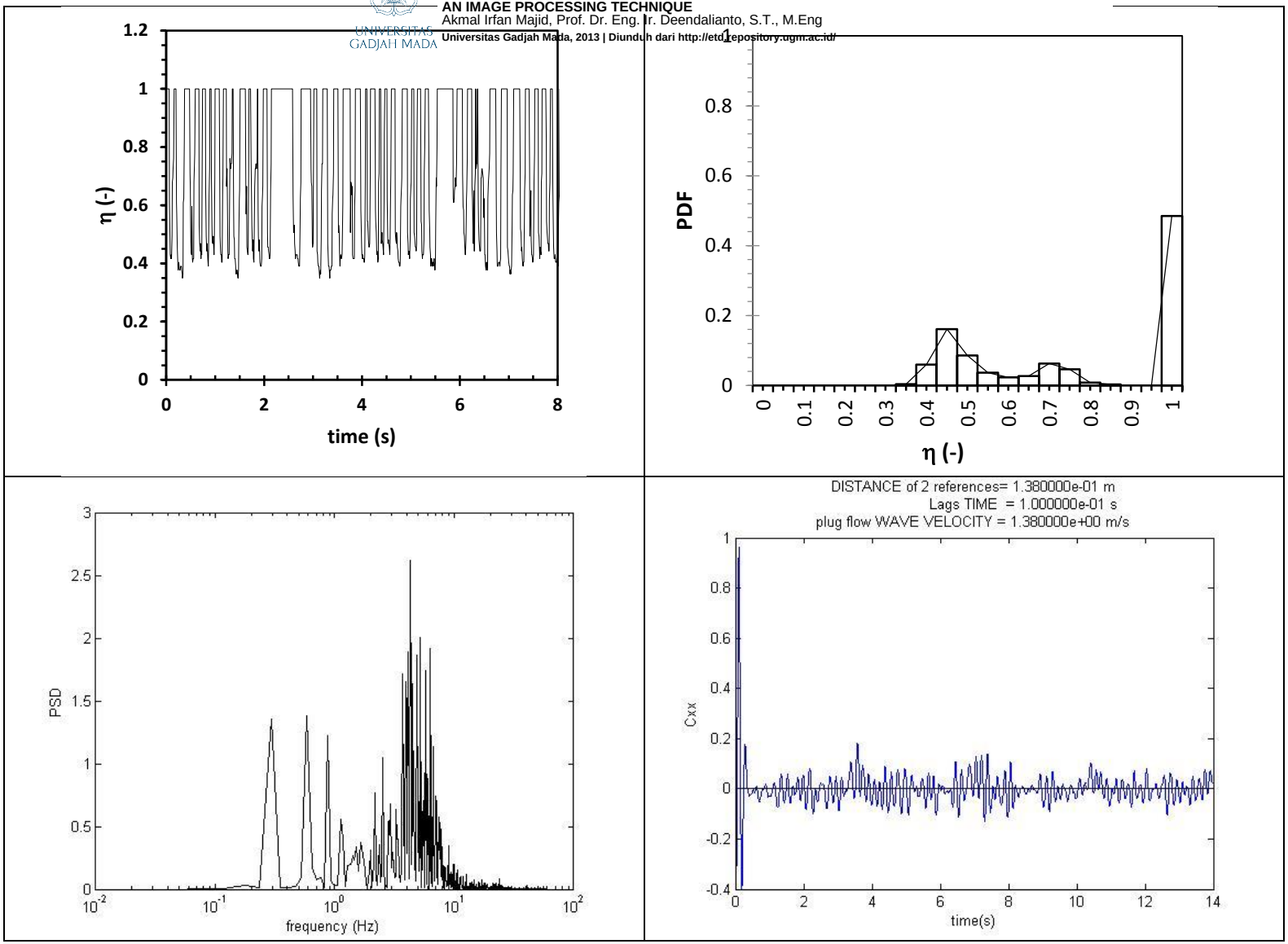
Data no : 64			
J_G	=	0.31	m/s
J_L	=	1.13	m/s

BUBBLE-NOSE CONTOURS	
Original	
Binary	
Perimeter	

BUBBLE-TAIL CONTOURS	
Original	
Binary	
Perimeter	

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Important flow parameters

Average liquid hold-up	0.750	
Wave velocity	1.380	m/s
Wave frequency	4.277	Hz
Plug wavelength	1.111	m

UNIVERSITAS GADJAH MADA
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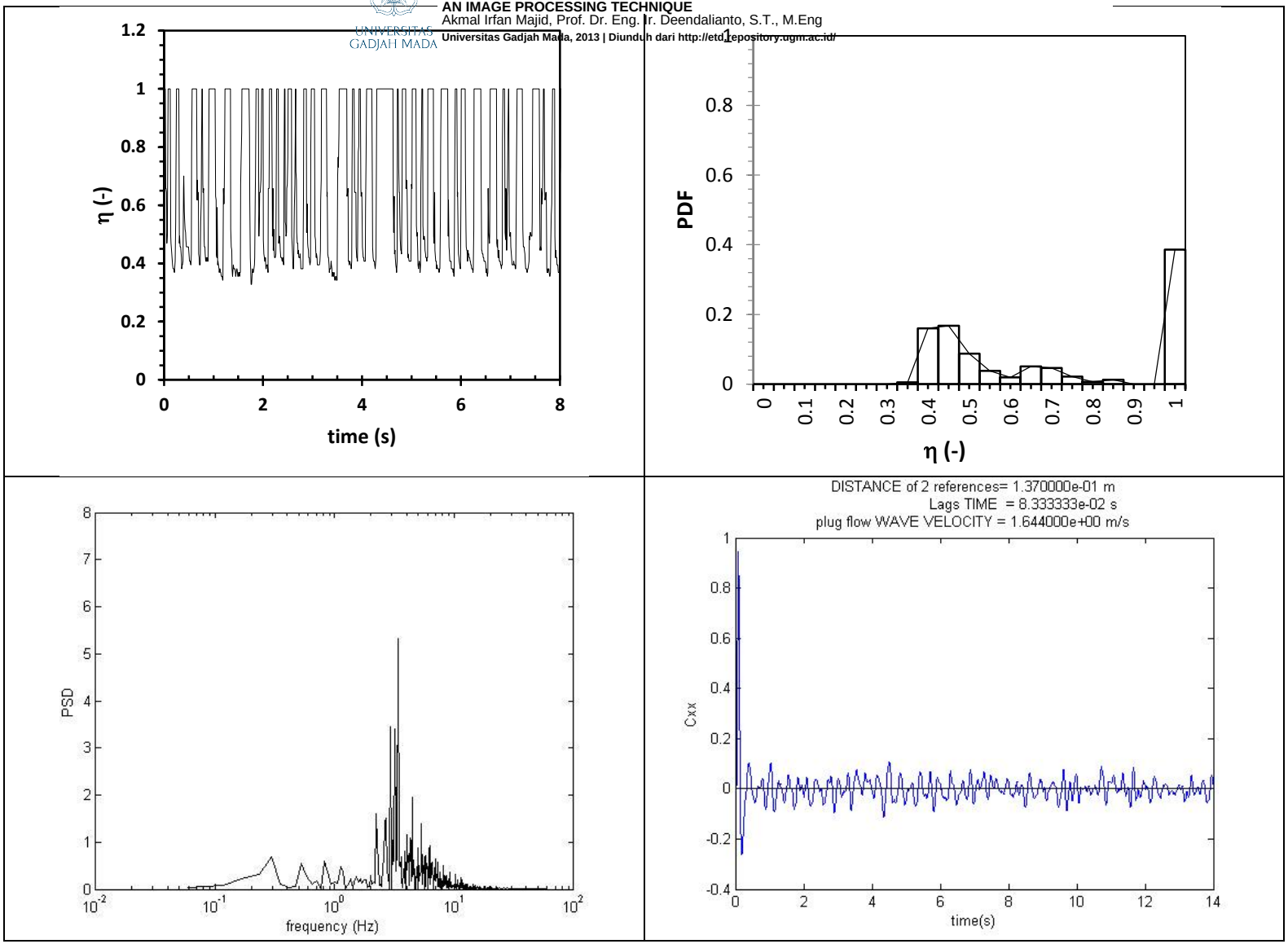
Data no : 65			
J_G	=	0.51	m/s
J_L	=	1.13	m/s

BUBBLE-NOSE CONTOURS	
Original	
Binary	
Perimeter	

BUBBLE-TAIL CONTOURS	
Original	
Binary	
Perimeter	

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AN IMAGE PROCESSING TECHNIQUE
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Statistical analysis



Important flow parameters

Average liquid hold-up	0.685	
Wave velocity	1.644	m/s
Wave frequency	3.398	Hz
Plug wavelength	0.484	m

Attachment 2 : Important flow parameters data

Average film thickness per each diameter (h_L/D)

J_L	J_G	Data number	hL/D
0.25	**0.12**	11	**0.732115**
0.25	**0.18**	12	**0.675152**
0.25	**0.24**	13	**0.646663**
0.25	**0.31**	14	**0.581679**
0.25	**0.51**	15	**0.493748**
0.31	**0.12**	21	**0.752391**
0.31	**0.18**	22	**0.701481**
0.31	**0.24**	23	**0.659688**
0.31	**0.31**	24	**0.60608**
0.31	**0.51**	25	**0.533307**
0.44	**0.12**	31	**0.779201**
0.44	**0.18**	32	**0.714787**
0.44	**0.24**	33	**0.668164**
0.44	**0.31**	34	**0.64387**
0.44	**0.51**	35	**0.558221**
0.77	**0.12**	51	**0.805704**
0.77	**0.18**	52	**0.757785**
0.77	**0.24**	53	**0.725891**
0.77	**0.31**	54	**0.679937**
0.77	**0.51**	55	**0.643419**
1.13	**0.12**	61	**0.732115**
1.13	**0.18**	62	**0.675152**
1.13	**0.24**	63	**0.646663**
1.13	**0.31**	64	**0.581679**
1.13	**0.51**	65	**0.493748**

THE INTERFACIAL CHARACTERISTICS OF GAS-LIQUID PLUG TWO-PHASE FLOW IN A HORIZONTAL PIPE BY USING
AN IMAGE PROCESSING TECHNIQUE
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Average Liquid Hold-up

Data number	J_G	J_L	Liquid Holdup	Xtt	Wallis
11	0.12	0.25	0.713	19.7887	0.607767
12	0.18	0.25	0.666	13.73837	0.566633
13	0.24	0.25	0.654	10.6045	0.535726
14	0.31	0.25	0.607	8.422768	0.507146
15	0.51	0.25	0.537	5.381052	0.449167
21	0.12	0.31	0.726	24.01578	0.628369
22	0.18	0.31	0.699	16.67303	0.588823
23	0.24	0.31	0.666	12.86974	0.558966
24	0.31	0.31	0.628	10.22196	0.531233
25	0.51	0.31	0.570	6.530504	0.47455
31	0.12	0.44	0.753	32.91385	0.660056
32	0.18	0.44	0.707	22.85054	0.623159
33	0.24	0.44	0.666	17.63809	0.595118
34	0.31	0.44	0.642	14.00929	0.568908
35	0.51	0.44	0.586	8.950115	0.514773
51	0.12	0.77	0.779	54.46442	0.705945
52	0.18	0.77	0.738	37.8121	0.673274
53	0.24	0.77	0.716	29.18676	0.648246
54	0.31	0.77	0.681	23.18198	0.624673
55	0.51	0.77	0.658	14.81027	0.575341
61	0.12	1.13	0.812	76.92045	0.734141
62	0.18	1.13	0.785	53.40227	0.704259
63	0.24	1.13	0.765	41.22065	0.681274
64	0.31	1.13	0.750	32.74006	0.659543
65	0.51	1.13	0.685	20.91663	0.613754

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WAVE VELOCITY

J_L	J_G	Data number	J_m	This work result	Franca & Lahey (1992)	Deviation from Franca & Lahey (1992)	
0.25	**0.12**	11	0.37	0.538182	0.52	**2.98**	%
0.25	**0.18**	12	0.43	0.609231	0.58	**4.79**	%
0.25	**0.24**	13	0.49	0.66	0.64	**3.09**	%
0.25	**0.31**	14	0.56	0.74	0.71	**4.40**	%
0.25	**0.51**	15	0.76	0.894	0.90	**(1.19)**	%
0.31	**0.12**	21	0.43	0.604444	0.58	**3.96**	%
0.31	**0.18**	22	0.49	0.648	0.64	**1.22**	%
0.31	**0.24**	23	0.55	0.709565	0.70	**1.51**	%
0.31	**0.31**	24	0.62	0.816	0.77	**6.31**	%
0.31	**0.51**	25	0.82	0.865263	0.96	**(10.21)**	%
0.44	**0.12**	31	0.56	0.714783	0.71	**0.84**	%
0.44	**0.18**	32	0.62	0.777143	0.77	**1.24**	%
0.44	**0.24**	33	0.68	0.806667	0.83	**(2.39)**	%
0.44	**0.31**	34	0.75	0.871579	0.90	**(2.62)**	%
0.44	**0.51**	35	0.95	1.088	1.09	**(0.27)**	%
0.77	**0.12**	51	0.89	0.873333	1.03	**(15.39)**	%
0.77	**0.18**	52	0.95	1.0425	1.09	**(4.45)**	%
0.77	**0.24**	53	1.01	1.112	1.15	**(3.29)**	%
0.77	**0.31**	54	1.08	1.191429	1.22	**(2.21)**	%
0.77	**0.51**	55	1.28	1.301538	1.41	**(7.98)**	%
1.13	**0.12**	61	1.25	1.1475	1.39	**(17.15)**	%
1.13	**0.18**	62	1.31	1.329231	1.44	**(7.94)**	%
1.13	**0.24**	63	1.37	1.283077	1.50	**(14.61)**	%
1.13	**0.31**	64	1.44	1.38	1.57	**(12.17)**	%
1.13	**0.51**	65	1.64	1.644	1.77	**(6.97)**	%

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AN IMAGE PROCESSING TECHNIQUE
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WAVE FREQUENCY

	J_L	J_G	Wave frequency
11	**0.25**	**0.12**	0.527344
12	**0.25**	**0.18**	0.234375
13	**0.25**	**0.24**	0.234375
14	**0.25**	**0.31**	0.234375
15	**0.25**	**0.51**	0.234375
21	**0.31**	**0.12**	0.820313
22	**0.31**	**0.18**	0.644531
23	**0.31**	**0.24**	0.292969
24	**0.31**	**0.31**	0.292969
25	**0.31**	**0.51**	0.292969
31	**0.44**	**0.12**	0.878906
32	**0.44**	**0.18**	1.640625
33	**0.44**	**0.24**	1.640625
34	**0.44**	**0.31**	2.167969
35	**0.44**	**0.51**	1.054688
51	**0.77**	**0.12**	2.402344
52	**0.77**	**0.18**	2.988281
53	**0.77**	**0.24**	0.292969
54	**0.77**	**0.31**	0.292969
55	**0.77**	**0.51**	0.292969
61	**1.13**	**0.12**	2.226563
62	**1.13**	**0.18**	5.214844
63	**1.13**	**0.24**	3.164063
64	**1.13**	**0.31**	4.277344
65	**1.13**	**0.51**	3.398438

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Plug wavelength

Data Number	J_L	J_G	WAVE FREQUENCY	WAVE VELOCITY	period	lamda
11	**0.25**	**0.12**	0.52734375	0.538181818	1.896296	1.020552
21	**0.31**	**0.12**	0.8203125	0.604444444	1.219048	0.736847
31	**0.44**	**0.12**	0.87890625	0.714782609	1.137778	0.813264
51	**0.77**	**0.12**	2.40234375	0.873333333	0.41626	0.363534
61	**1.13**	**0.12**	2.98828125	1.1475	0.334641	0.384
12	**0.25**	**0.18**	0.234375	0.609230769	4.266667	2.599385
22	**0.31**	**0.18**	0.64453125	0.648	1.551515	1.005382
32	**0.44**	**0.18**	1.640625	0.777142857	0.609524	0.473687
52	**0.77**	**0.18**	2.98828125	1.0425	0.334641	0.348863
62	**1.13**	**0.18**	5.21484375	1.329230769	0.19176	0.254894
13	**0.25**	**0.24**	0.234375	0.66	4.266667	2.816
23	**0.31**	**0.24**	0.29296875	0.709565217	3.413333	2.421983
33	**0.44**	**0.24**	1.640625	0.806666667	0.609524	0.491683
53	**0.77**	**0.24**	2.4609375	1.112	0.406349	0.45186
63	**1.13**	**0.24**	3.1640625	1.283076923	0.316049	0.405516
14	**0.25**	**0.31**	0.234375	0.74	4.266667	3.157333
24	**0.31**	**0.31**	0.29296875	0.816	3.413333	2.78528
34	**0.44**	**0.31**	2.16796875	0.871578947	0.461261	0.402026
54	**0.77**	**0.31**	2.34375	1.191428571	0.426667	0.508343
64	**1.13**	**0.31**	4.27734375	1.38	0.23379	0.32263
15	**0.25**	**0.51**	0.234375	0.894	4.266667	3.8144
25	**0.31**	**0.51**	0.29296875	0.865263158	3.413333	2.953432
35	**0.44**	**0.51**	1.0546875	1.088	0.948148	1.031585
55	**0.77**	**0.51**	1.171875	1.301538462	0.853333	1.110646
65	**1.13**	**0.51**	3.3984375	1.644	0.294253	0.483752