

Local Binary Pattern Texture Feature Extraction of Real Time Transformer Insulation Oil Images

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Abstract

Transformer is an electrostatic device operates under different voltage levels under constant frequency. Transformer oil is the extensively used as insulation as well as cooling liquid in all power transformers. The performance of insulation oil deteriorates with its operating temperature along with age. This paper aims to extract Local Binary Pattern (LBP) texture features of real time transformer oil images. An experiment conducted to investigate and characterize textural properties of insulation liquid. Transformer oil images are captured through digital camera at different operating conditions. These images are enhanced by noise eliminating filters. LBP features of the original as well as filtered transformer oil images extracted. The results of feature extraction illustrate the identification of considerable textures of the test images. The experimental results demonstrated that texture feature extraction derived from the LBP features realize a new technique in the analysis of transformer oil.

Keywords: Texture, LBP feature, Transformer oil, OSF, CSF, ICSF

1. Introduction

Texture is a significant visual perception in an image which is used in various computer vision systems. It can be defined as a repetitive pattern of local variations in image intensity which is difficult to describe [1]. Textures in the real world images are not uniform due to visual appearance, scale as well as variations in orientation. LBP algorithm originally proposed for the description of texture feature [2]. Later it was used in human face recognition, description as well as variation in facial expression [3-7]. Recently this algorithm used in many applications such as texture analysis of mammogram [8] and wood defect classification [9], texture classifications [10-11] and many more. LBP algorithm is uncomplicated by means of description of local texture features in an image. LBP is an

operator for texture pattern analysis.

It is based on the signs of differences between central and neighbor pixels [12-13]. LBP value computed according to the signs of the neighboring pixels. Transformer is a power transferring equipment. The life of a transformer depends on performance efficiency of cooling and insulation. Mineral oil serves for this function in all oil immersed transformers. The property of this oil varies under different operating conditions of the power transformer. This may result in under performance of the in service transformer [14-16]. Digital image processing techniques are used in the recent days to monitor the performance of the transformer instead of time consuming classical methods [17-18]. This paper proposes an image analysis technique to identify the LBP texture feature of a test image.

In general, transformer oil images acquired through digital camera combined with noise signal due to inappropriate lighting as well as convection or natural movement of oil. The image preprocessing filters were used to eliminate the noise in the digital images. In this paper wiener filter, non-local means (NLM) filter, original shock filter (OSF), complex shock filter (CSF) and improved complex shock filters (ICSF) are used for image enhancement of transformer oil images at different temperatures[19-21].

The objective of this paper is to explore the LBP texture features of real time transformer oil images at different temperatures. An experiment was conducted to acquire the transformer oil images using digital camera at 30°C, 60°C, 90°C as well as 120°C [22]. The maximum temperature limited to 120°C. These captured test images are improved using image filters. LBP texture features extracted from the original image as well as from the filtered transformer oil images.

This paper organized as follows: section 2 describes LBP features, section 3 demonstrates the comprehensive experimental results and discussions, and section 4 presents the conclusion of the paper.

2. Local Binary Pattern (LBP) Features

Local Binary Pattern (LBP) is one of the techniques to describe the texture feature of an image. Basically, LBP is an operator or code labels of the pixels of an image with decimal numbers that encodes the local structure around each pixel [23]. The basic LBP operator considers central pixel as threshold and compares this value with eight neighbors in 3 × 3 neighbor pixels. Binary pattern texture features created through threshold operation. Figure 1 illustrates the complete stages of LBP calculations. The basic equation of LBP expressed in decimal form can be represented as

$$LBP_C = \sum_{n=0}^7 2^n g(I_n - I_c) \quad (1)$$

Where LBPC is LBP value at central pixel c. I_c and I_n are the values of central as well as neighbor pixel respectively. Index n in the summation

represents index of neighbor pixel. The function $g(x)$ (where $x = I_n - I_c$) will be one if $x \geq 0$, otherwise equal to zero. This can be clearly explained by considering an example as shown in Fig.1. The central pixel 55 selected as threshold value. If the gray value of the threshold pixel is equal to or greater than the neighboring pixels, it marked as 1, otherwise 0. The LBP value evaluated with multiplying binary and weighted matrix. The sum of all multiplication results represents LBP value. Hence, LBP value of 3 × 3 matrix shown in Fig.1 is $20+25+26+27 = 1+32+64+128 = 225$.

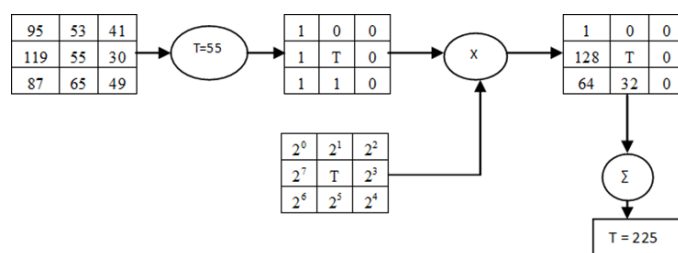


Figure 1 The complete stages of LBP calculations

The extended version of LBP [24] can be created by varying the number of involved pixel and neighbor location. The LBP8 operator produces 256 (2^8) different output values. Consequently, the 256 different binary patterns that can be formed by the eight pixels in the neighborhood pixel set. The LBP rotated with an order and bitwise 0/1 changes to achieve rotation invariant LBP textures [25-26]. The rotation invariant LBP defined as

$$LBP_8^{ri36} = \min\{ROR(LBP_8, i)\}, (i = 0, 1, \dots, 7) \quad (2)$$

Where $ROR(LBP_8, i)$ performs a bit-wise circular rotation right on the 8-bit number x for i times. It can be observed that LBP_8^{ri36} will be having 36 different values, corresponding to the 36 unique rotation invariant local binary patterns [27].

In this paper 36 unique rotation invariant LBP values are evaluated for each test image. The test images are real-time transformer oil images captured at specific defined temperatures (30°C, 60°C, 90°C and 120°C) as well as enhanced images.

Figure 2 demonstrates the LBP texture feature extraction methodology for real time insulation oil images. The test images are acquiring through digital camera. Then the images were cropped as well as resized to 200 x 200 pixels. The pixel data were normalized and enhanced through various linear and nonlinear filters such as wiener, NLM, OSF, CSF and ICSF before texture feature extraction. The uniform rotation invariant LBP texture features are extracted for all the test images.

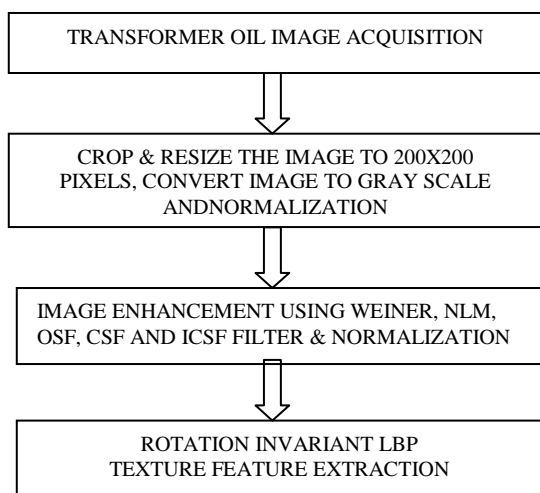


Figure.2 LBP feature extraction methodology

3. Experimental Results

In this section, the numerical results of real time transformer oil LBP texture features are presented. An experiment was conducted to capture the real time images of the transformer oil through digital camera at different desired temperatures such as 30⁰ C, 60⁰ C, 90⁰ C and 120⁰ C. The images are captured under three different cases. Firstly, unused or fresh transformer oil images taken at different predefined temperature. Secondly the transformer oil images are captured with metal nails Lastly the test images captured with metal nails as well as conductor coil in it. Further images were cropped and resized to 200 x 200 pixels. All the test images are preprocessed through noise eliminating filters. In this paper wiener, non-local means (NLM), original shock filter (OSF), Complex Shock Filter CSF) and Improved Complex Shock Filters (ICSF) are used for image enhancement.

The LBP texture features are evaluated for the original test image as well as for enhanced images. Table 1 to Table 6 illustrates the tabulated values of computed LBP texture features of unused/normal transformer oil (represented as N-Table 1 and Table 2), transformer oil with metal nails(represented as WM-Table 3 and Table 4) as well as transformer oil with metal nails along with conductor coil in it(represented as WMC-Table 5 and Table 6). It can be observed from all the tables that the LBP values of enhanced images will be either less or more than the original acquired images depending upon the accuracy of the brightness enhancement of the test image. The rotation invariant uniform LBP textures represent the exact patterns of the images. These patterns recognitions are not possible through the visualization of these images. Hence LBP texture features identify the texture patterns of real time transformer oil images captured at desired temperatures.

4. Conclusion

The LBP texture evaluation is greatly unifying method when compared to traditional texture analysis. Textures are expressed in terms their patterns of statistical placement regulations. The LBP operator is comparatively invariant about changes in illumination along with image rotation. In this paper, the numerical results of uniform rotation invariant LBP texture features evaluated towards in recognition of the significant features to identify and discriminate the textures of the transformer oil images under different temperatures. The results indicate that the features estimated were extensively differs between the normal and enhanced test images at different temperatures. This paper concludes that the presentation of 36 uniform rotation invariant texture features quantify the essential features of test images with and without noise eliminating filters. The extension of this research may be utilized in condition monitoring of transformer oil working under different ages and temperatures.

Table1.LBP features of unused/normal transformer oil at 30⁰and 60⁰C temperatures.

Sl. No.	LBP Texture Features	30 ⁰ CN	30 ⁰ CN - Weiner filter	30 ⁰ C N-NL M filter	30 ⁰ CN-OSF filter	30 ⁰ CN-CSF filter	30 ⁰ CN-ICS F filter	60 ⁰ CN	60 ⁰ CN - Weiner filter	60 ⁰ C N-NL M filter	60 ⁰ CN-OSF filter	60 ⁰ CN-CSF filter	60 ⁰ CN-ICS F filter
1	LBP-1	640	271	51	1006	1385	1025	887	406	51	1459	1721	1293
2	LBP-2	1801	1112	244	2964	2488	1723	2172	1379	254	3587	2676	1968
3	LBP-3	1216	884	337	1934	3640	3790	1522	1129	344	2214	3922	4130
4	LBP-4	416	276	143	540	152	53	472	332	124	635	143	64
5	LBP-5	3008	3130	2347	3065	5872	6933	2970	3275	2299	2947	5534	6561
6	LBP-6	137	65	9	233	220	154	163	77	2	266	237	115
7	LBP-7	232	167	77	318	209	132	275	174	41	338	215	153
8	LBP-8	241	163	63	277	218	127	237	168	47	323	213	143
9	LBP-9	3819	4200	3603	3026	7805	8841	3692	4109	3638	2626	6571	7691
10	LBP-10	735	468	60	792	195	125	684	448	68	716	221	140
11	LBP-11	311	227	41	357	278	192	379	260	38	394	360	271
12	LBP-12	243	100	50	217	12	1	211	112	71	215	8	1
13	LBP-13	768	686	428	674	200	148	691	665	300	610	197	168
14	LBP-14	344	228	37	353	276	229	364	242	39	408	301	236
15	LBP-15	164	92	30	207	252	195	239	112	20	271	331	245
16	LBP-16	721	670	319	666	211	141	747	649	325	655	245	143
17	LBP-17	6478	8165	7728	4740	5885	6782	5551	7474	8198	3888	5107	6071
18	LBP18	21	2	1	32	7	0	28	6	0	35	21	3
19	LBP-19	230	135	21	275	290	192	350	203	22	389	341	268
20	LBP-20	39	12	16	49	5	2	75	35	11	83	9	1
21	LBP-21	16	1	0	21	7	1	20	0	0	34	7	7
22	LBP-22	357	237	120	374	159	109	412	275	108	377	177	113
23	LBP-23	66	60	14	80	109	116	90	87	16	113	153	159
24	LBP-24	49	19	5	55	5	3	71	31	7	82	15	1
25	LBP-25	298	218	56	268	255	224	401	249	54	333	336	253
26	LBP-26	264	204	86	282	213	189	346	226	61	323	352	286
27	LBP-27	378	218	111	356	150	97	400	270	95	400	194	126
28	LBP-28	4348	4929	3384	4071	3516	3849	4095	4717	3364	3670	3604	4080
29	LBP-29	10	3	1	6	0	1	10	4	5	10	0	0
30	LBP-30	148	86	78	137	5	2	136	88	77	117	9	1
31	LBP-31	13	4	0	17	5	5	30	5	0	28	4	1
32	LBP-32	847	577	786	705	105	31	868	651	1124	676	126	40
33	LBP-33	167	66	10	168	149	110	277	96	17	288	221	121
34	LBP-34	272	297	180	244	174	94	312	297	144	249	225	155
35	LBP-35	4308	4656	6228	4479	2446	1710	4086	4640	6096	4445	2732	2062
36	LBP-36	5311	5788	11752	5428	1518	1090	5153	5525	11356	5212	1888	1346

Table 2. LBP features of unused/normal transformer oil at 90⁰ and 120⁰ C temperatures.

Sl. No.	LBP Texture Features	90 ⁰ C N	90 ⁰ CN - Weiner filter	90 ⁰ C N-NL M filter	90 ⁰ CN-OS F filter	90 ⁰ CN-CSF filter	90 ⁰ CN-ICS F filter	120 ⁰ C N	120 ⁰ C N-Weiner filter	120 ⁰ CN-NLM filter	120 ⁰ CN-OSF filter	120 ⁰ CN-CSF filter	120 ⁰ CN-ICSF filter
1	LBP-1	581	278	69	894	1361	1078	548	228	50	828	1289	1088
2	LBP-2	1665	1061	257	2901	2182	1595	1532	977	281	2414	2347	1649
3	LBP-3	1339	962	336	2104	3694	3698	1077	883	338	1646	3558	3694
4	LBP-4	315	229	72	452	129	44	342	236	84	454	134	55
5	LBP-5	3308	3319	2390	3378	6241	7081	3066	3066	2161	3162	6375	7017
6	LBP-6	112	36	3	195	173	125	102	26	4	161	190	126
7	LBP-7	134	83	26	193	167	109	169	109	50	243	196	121
8	LBP-8	201	151	44	251	191	113	195	134	33	256	200	122
9	LBP-9	4211	4516	3792	3375	8057	8912	3531	3843	3139	3120	7978	9009
10	LBP-10	540	339	84	575	209	157	560	360	66	572	203	136
11	LBP-11	281	210	37	300	276	218	309	177	37	331	296	214
12	LBP-12	124	56	19	123	8	4	143	49	16	145	11	6
13	LBP-13	633	550	206	564	185	156	736	608	243	680	200	153
14	LBP-14	301	250	46	333	271	235	315	203	37	306	291	240
15	LBP-15	155	99	14	203	278	222	128	104	25	163	250	238
16	LBP-16	681	641	231	629	186	171	763	621	232	739	214	168
17	LBP-17	7173	8623	8250	5304	6195	7030	6766	8105	6954	5258	6036	6677
18	LBP18	15	3	1	29	4	2	20	2	0	21	5	2
19	LBP-19	258	139	19	289	268	212	253	131	26	291	294	245
20	LBP-20	46	18	5	49	6	1	44	19	6	46	6	4
21	LBP-21	5	0	0	15	5	1	5	0	0	14	2	4
22	LBP-22	290	222	54	303	146	104	352	229	97	347	159	107
23	LBP-23	87	65	16	89	134	145	80	65	11	99	121	142
24	LBP-24	58	11	1	52	5	1	31	13	5	40	3	4
25	LBP-25	240	250	60	235	216	205	331	218	68	294	229	225
26	LBP-26	293	270	51	307	229	209	296	236	66	290	262	240
27	LBP-27	378	216	67	339	141	72	324	221	84	315	127	95
28	LBP-28	4445	4907	3601	4125	3470	3709	4359	4944	3187	4201	3344	3665
29	LBP-29	5	3	1	5	0	0	3	2	4	2	0	0
30	LBP-30	99	46	31	91	3	0	121	54	39	112	9	2
31	LBP-31	18	4	1	26	3	3	22	4	0	23	10	3
32	LBP-32	672	414	446	556	98	24	815	528	551	723	91	34
33	LBP-33	155	78	9	167	109	86	149	50	14	152	117	91
34	LBP-34	277	320	99	230	138	101	346	301	127	291	150	112
35	LBP-35	3883	4378	5769	4228	2223	1470	4603	4836	6277	4639	2245	1572
36	LBP-36	5438	5669	12309	5507	1415	1123	5980	6834	14104	6038	1474	1156

Table 3.LBP features of transformer oil with metal nails at 30⁰ and 60⁰C temperatures.

Sl. No.	LBP Texture Features	30 ⁰ C WM	30 ⁰ CW M-Weiner filter	30 ⁰ CW M-NL M filter	30 ⁰ CW M-OSF filter	30 ⁰ CW M-CSF filter	30 ⁰ CW M-ICS F filter	60 ⁰ CW M	60 ⁰ CW M-Weiner filter	60 ⁰ CW M-NL M filter	60 ⁰ CW M-OSF filter	60 ⁰ CW M-CSF filter	60 ⁰ CW M-ICS F filter
1	LBP-1	459	208	33	691	1129	915	565	339	69	962	1345	1090
2	LBP-2	1337	850	231	2313	2043	1453	1992	1321	317	3328	2337	1775
3	LBP-3	1151	873	371	1850	3433	3486	1385	1021	387	2424	3701	3943
4	LBP-4	263	209	143	345	119	29	440	390	377	611	97	52
5	LBP-5	3245	3251	2521	3486	6477	7290	3616	3808	2933	3619	6267	6993
6	LBP-6	94	48	8	134	173	111	95	50	8	199	170	111
7	LBP-7	181	168	67	228	170	102	205	168	118	277	163	111
8	LBP-8	161	109	41	238	158	84	178	134	113	275	170	116
9	LBP-9	4427	4545	3602	3846	9163	9890	4580	4874	3662	3341	7878	8383
10	LBP-10	553	399	66	565	188	134	718	526	82	711	215	152
11	LBP-11	271	182	38	289	230	200	331	244	49	402	267	248
12	LBP-12	123	76	34	130	4	1	198	151	174	208	4	1
13	LBP-13	714	639	304	707	162	146	694	759	610	643	161	134
14	LBP-14	265	188	28	289	250	173	312	242	37	350	288	228
15	LBP-15	144	81	19	207	225	200	176	113	44	213	287	215
16	LBP-16	685	593	261	676	165	134	671	678	530	616	171	136
17	LBP-17	7928	9145	8134	5968	6432	7261	6947	8108	7957	4744	5980	6624
18	LBP18	7	1	0	9	5	4	15	3	1	25	2	1
19	LBP-19	190	150	22	219	212	190	265	196	18	285	273	228
20	LBP-20	44	13	6	45	6	2	51	34	26	54	4	0
21	LBP-21	7	1	0	13	4	1	10	1	0	20	3	1
22	LBP-22	329	190	70	313	151	102	330	278	158	316	134	101
23	LBP-23	53	50	14	64	100	105	62	69	7	79	138	157
24	LBP-24	25	17	4	23	2	1	57	42	25	61	4	3
25	LBP-25	261	184	47	249	185	148	291	252	82	278	221	221
26	LBP-26	248	167	56	246	193	151	282	230	89	258	245	221
27	LBP-27	356	197	93	336	144	92	357	258	156	333	156	81
28	LBP-28	4177	4788	3345	4055	3291	3483	4126	4621	3225	3940	3537	4025
29	LBP-29	6	2	5	5	0	0	9	14	17	11	0	0
30	LBP-30	95	64	42	101	1	1	106	99	221	105	2	0
31	LBP-31	10	2	0	14	3	2	14	5	1	28	2	2
32	LBP-32	826	545	578	684	78	31	690	539	1424	571	84	17
33	LBP-33	149	38	9	159	107	80	152	57	19	180	138	77
34	LBP-34	282	269	140	244	152	91	188	238	224	153	193	114
35	LBP-35	4074	4354	6753	4275	2092	1431	3806	3699	6371	4170	2365	1760
36	LBP-36	5276	5820	11331	5400	1169	892	4502	4855	8885	4626	1414	1095

Table4.LBP features of transformer oil with metal nails at 90⁰ and120⁰C temperatures.

Sl. No.	LBP Texture Features	90 ⁰ C WM	90 ⁰ CW M-Weiner filter	90 ⁰ C WM - NLM filter	90 ⁰ C WM -OSF filter	90 ⁰ C WM -CSF filter	90 ⁰ CW M-ICS F filter	120 ⁰ C WM	120 ⁰ C WM-Weiner filter	120 ⁰ CW M-NLM filter	120 ⁰ CW M-OSF filter	120 ⁰ CW M-CSF filter	120 ⁰ CW M-ICSF filter
1	LBP-1	709	311	63	1080	1410	1125	622	265	47	1053	1253	1018
2	LBP-2	1751	1111	266	2906	2327	1692	1742	934	297	2809	2092	1722
3	LBP-3	1291	1025	377	2002	3728	3806	1148	846	376	1662	3263	3404
4	LBP-4	468	386	267	604	131	67	428	172	84	511	133	59
5	LBP-5	3315	3412	2523	3301	6196	6946	3356	3638	2525	3040	6521	7142
6	LBP-6	131	62	4	202	210	143	59	26	9	101	128	105
7	LBP-7	222	201	122	278	182	126	139	61	28	184	169	113
8	LBP-8	176	178	136	245	162	131	104	66	41	167	170	104
9	LBP-9	3772	4141	3068	2997	7577	8522	3427	4596	3740	2938	8466	8911
10	LBP-10	601	417	55	596	203	142	508	304	102	535	167	132
11	LBP-11	263	223	43	321	270	223	220	156	42	253	208	175
12	LBP-12	195	123	84	192	11	5	187	39	29	170	6	2
13	LBP-13	820	707	538	734	194	143	551	369	196	464	204	147
14	LBP-14	308	229	35	350	303	238	236	173	58	245	227	214
15	LBP-15	159	103	45	192	296	228	155	67	37	179	274	214
16	LBP-16	784	759	582	722	188	155	568	396	244	511	202	153
17	LBP-17	6453	7727	7133	4780	5963	6730	6880	8999	8301	5552	6798	7523
18	LBP18	19	2	1	26	10	5	10	0	0	25	4	1
19	LBP-19	284	155	26	307	263	235	179	113	20	256	271	199
20	LBP-20	75	32	19	65	4	5	32	10	2	30	3	0
21	LBP-21	12	0	0	16	5	3	7	1	0	13	5	5
22	LBP-22	350	266	132	330	146	95	308	147	62	266	160	102
23	LBP-23	78	63	16	103	129	157	32	35	10	50	95	130
24	LBP-24	81	34	19	79	6	5	31	8	5	23	6	4
25	LBP-25	307	249	87	312	282	215	231	148	61	246	211	197
26	LBP-26	326	273	119	304	264	216	201	147	47	215	212	170
27	LBP-27	366	284	151	365	157	103	268	136	81	258	165	97
28	LBP-28	4191	4635	2993	4004	3610	3991	4375	4802	3768	4191	3310	3444
29	LBP-29	7	6	6	7	0	0	11	2	4	9	0	0
30	LBP-30	146	112	124	135	5	3	81	27	40	74	7	5
31	LBP-31	18	3	2	28	3	3	17	0	0	19	7	3
32	LBP-32	871	778	1311	766	106	46	612	356	400	520	113	31
33	LBP-33	184	80	27	206	123	97	135	33	7	145	80	76
34	LBP-34	313	356	263	254	152	90	196	206	102	187	184	137
35	LBP-35	4333	4724	8051	4458	2267	1566	4680	4270	5716	4815	2119	1710
36	LBP-36	5037	5249	9728	5149	1533	1159	6680	6868	11935	6700	1183	967

Table 5.LBP features of transformer oil with metal nails and conductor coil at 30⁰and60⁰C temperatures.

Sl. No.	LBP Texture Features	30 ⁰ C WMC	30 ⁰ C WMC - Weiner filter	30 ⁰ C WMC -NLM filter	30 ⁰ C WMC -OSF filter	30 ⁰ C WMC -CSF filter	30 ⁰ C WMC- ICSF filter	60 ⁰ C WMC	60 ⁰ C WMC - Weiner filter	60 ⁰ C WMC -NLM filter	60 ⁰ C WMC - OSF filter	60 ⁰ C WMC -CSF filter	60 ⁰ C WMC -ICSF filter
1	LBP-1	887	361	33	1334	1682	1157	501	121	40	979	942	716
2	LBP-2	1716	1008	176	3023	2216	1580	1296	745	214	2168	1704	1322
3	LBP-3	1421	1016	250	1957	3753	3625	1021	579	290	1402	3072	3492
4	LBP-4	434	321	70	547	162	75	551	116	50	525	132	43
5	LBP-5	3157	3290	2520	3004	5856	7059	3108	3386	2617	2858	7060	7757
6	LBP-6	127	50	2	195	208	140	33	10	1	67	76	62
7	LBP-7	243	146	32	281	231	141	81	38	24	97	134	76
8	LBP-8	281	187	42	336	237	152	110	36	25	130	166	102
9	LBP-9	3404	4002	4106	2724	7184	8796	2533	4748	4479	2260	9742	9770
10	LBP-10	435	272	54	467	181	129	365	289	84	455	113	82
11	LBP-11	347	193	30	413	349	234	182	109	47	240	175	123
12	LBP-12	155	79	13	157	8	1	220	47	11	201	11	6
13	LBP-13	718	532	165	660	237	189	717	286	220	625	201	114
14	LBP-14	311	186	31	349	295	221	176	100	35	244	153	124
15	LBP-15	212	115	21	263	347	230	191	48	20	247	289	212
16	LBP-16	663	582	262	613	254	155	744	273	217	668	173	137
17	LBP-17	5795	7500	7919	4325	5732	6827	6832	9721	9355	5799	7261	8074
18	LBP18	19	6	0	37	11	5	8	0	0	9	3	3
19	LBP-19	329	176	16	378	358	238	215	86	16	272	239	180
20	LBP-20	65	25	7	69	7	2	16	6	2	21	2	2
21	LBP-21	17	3	1	22	10	6	6	0	0	10	3	1
22	LBP-22	405	223	69	410	181	103	435	106	75	317	160	67
23	LBP-23	128	75	8	140	183	176	18	14	17	37	55	61
24	LBP-24	66	23	5	64	5	1	27	7	3	31	3	2
25	LBP-25	374	263	62	327	274	234	132	88	42	163	159	131
26	LBP-26	409	285	41	382	293	220	125	77	39	155	148	127
27	LBP-27	426	239	73	389	196	117	423	106	72	321	161	81
28	LBP-28	4373	4882	3307	4090	3564	3631	4108	4558	3802	3975	3205	3323
29	LBP-29	7	4	2	5	0	0	6	0	0	5	1	0
30	LBP-30	168	70	35	136	7	1	75	25	44	71	15	5
31	LBP-31	24	7	0	27	11	6	5	0	2	7	2	4
32	LBP-32	821	537	495	680	116	52	733	388	431	593	126	55
33	LBP-33	252	96	17	262	168	101	92	15	7	106	67	69
34	LBP-34	365	305	134	284	159	86	131	101	100	154	158	90
35	LBP-35	4483	5097	6588	4593	2186	1503	4651	4013	5629	4625	1591	1291
36	LBP-36	5379	6260	11830	5473	1755	1223	8549	8174	10406	8579	914	712

Table 6.LBP features of transformer oil with metal nails and conductor coil at 90⁰and120⁰C temperatures.

Sl. No.	LBP Texture Features	90 ⁰ C WMC	90 ⁰ CWMC - Weiner filter	90 ⁰ C WMC - NLM filter	90 ⁰ C WMC - OSF filter	90 ⁰ C WMC -CSF filter	90 ⁰ C WMC -ICSF filter	120 ⁰ C WMC	120 ⁰ CWM C- Weiner filter	120 ⁰ CWM C- NLM filter	120 ⁰ CWM C- OSF filter	120 ⁰ CWM C- CSF filter	120 ⁰ CWM C- ICSF filter
1	LBP-1	339	189	37	551	887	705	172	11	1	348	550	508
2	LBP-2	1323	815	239	2460	1792	1206	488	56	53	814	1161	1081
3	LBP-3	1167	906	346	2203	3160	3237	310	150	45	428	1602	1899
4	LBP-4	220	143	51	354	91	41	263	79	63	232	204	84
5	LBP-5	3822	3768	3010	4222	7076	7903	1274	1704	1319	1333	5842	6512
6	LBP-6	67	28	5	103	113	73	5	0	0	13	48	63
7	LBP-7	153	88	18	213	138	86	31	16	30	30	172	111
8	LBP-8	127	86	24	209	131	79	40	17	35	35	146	95
9	LBP-9	5524	6013	5196	4200	10298	10641	1254	1856	3169	1247	15476	15141
10	LBP-10	466	357	87	468	112	100	423	18	42	561	137	123
11	LBP-11	210	156	34	216	164	139	78	11	13	100	94	82
12	LBP-12	84	32	8	95	2	0	306	47	9	289	25	11
13	LBP-13	552	463	183	520	126	107	547	353	273	525	145	138
14	LBP-14	185	141	24	209	197	127	73	7	8	102	99	83
15	LBP-15	141	76	20	159	182	165	52	3	0	61	163	88
16	LBP-16	455	433	196	458	136	124	554	401	170	557	137	120
17	LBP-17	8532	9768	10122	6195	6754	7479	7677	11133	11058	6859	6927	7059
18	LBP18	7	2	0	10	3	0	2	0	0	6	4	7
19	LBP-19	182	111	29	218	195	167	48	8	4	69	149	84
20	LBP-20	24	9	1	30	2	0	12	0	2	10	5	7
21	LBP-21	3	0	0	6	2	1	8	0	0	6	7	2
22	LBP-22	228	129	56	254	109	72	120	36	29	79	124	112
23	LBP-23	44	39	12	58	92	100	3	1	0	10	14	8
24	LBP-24	21	9	1	24	0	0	15	8	6	16	3	7
25	LBP-25	198	178	46	198	152	131	39	12	9	48	108	90
26	LBP-26	210	175	61	198	158	149	37	8	4	61	83	94
27	LBP-27	228	122	60	262	113	69	144	46	30	117	106	87
28	LBP-28	4507	4910	3993	4582	3221	3438	1691	2003	1972	1934	1632	1860
29	LBP-29	4	4	1	4	0	0	25	3	1	11	3	1
30	LBP-30	59	25	18	60	2	1	121	35	51	109	25	10
31	LBP-31	3	0	0	8	2	0	11	1	1	8	4	6
32	LBP-32	554	333	347	510	52	19	1112	539	605	943	160	90
33	LBP-33	100	30	5	124	92	67	59	3	2	55	59	60
34	LBP-34	233	245	90	196	134	74	73	21	25	92	119	76
35	LBP-35	3793	3474	5287	4086	1820	1187	4205	3011	4962	3993	1367	1147
36	LBP-36	4651	5159	8809	4753	908	729	17144	16819	14425	17315	1516	1470

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