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Experimental Study of Yellowing Index Comparison between 430 Stainless Steel and 441 Stainless Steel Burner Plates on Domestic Gas Hobs

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Abstract: For the household appliances, one the critical design parameter is esthetic. On the surface of the domestic gas hob burner plates, yellowness problem is seen with the high temperature flame effect. When the burner plate surface is getting higher yellowness, esthetical problem is occurred. In this study, for evaluating yellowness period and comparing the yellowness ratio, 6 hobs are tested and measured yellowing index by using colorimetry method in Haier Europe Quality Reliability Laboratory. 3 of the 6 hobs have the 430SS burner plate, other 3 hobs have the 441SS burner plate. During 360 cycles of hob working, 4 times yellowness is measured in the beginning (cycle 0), then end of the 120,240 and 360. cycles. Each measurement is repeated 2 times on one area to increase accuracy of measurement. In the end of the study, results show that 441SS material has lower yellow color changing than 430SS material as a burner plate in the same conditions.

Keywords: Colorimetry, Gas hobs, Yellowness

Introduction

Color is one of the basis esthetical design parameters on domestic appliances. During usage, metal surfaces of hobs are exposed to high temperature and oxidation happens (Wang & Duh, 1995, Naylor, 1950). By thermal oxidation, yellowness and redness occur in the course of time. In the standard, there is not any specific rule to esthetical design point of view for yellowness and redness rate. To create design guide, yellowness characterization is needed. One of the good methods to measure yellowness is colorimetry method (Muduroglu et al., 2018, Maskan, 2001, Taskin, 2018).

CIE L*a*b* remarked 4 colors as a basis color which they are red, green, yellow and blue (Colorimetry, 1986). With the white and black hues, there are mainly 6 colors. Other colors are derived from these 6 main colors (Gilchrist & Nobbs, 2017).

In this study, 6 hobs are tested to measure yellowing ratio by using colorimetry method in Haier Europe Quality Reliability Laboratory. 3 of the 6 hobs have the 430SS burner plate, other 3 hobs have the 441SS burner plate. During 360 cycles of hob working, 4 times yellowness is measured in the beginning (cycle 0), then end of the 120,240 and 360. cycles. Each measurement is repeated 2 times on one area to increase accuracy of measurement.

Materials and Methods

In this experimental study, Haier Europe 60cm gas hob model is used. As a burner plate of hob, 2 different sheet metals are used. As a total 12 hobs are tested. 3 of them with 430SS sheet, other 3 with 441SS sheet for the burner plate of hob. Figure 1 shows the Haier Europe 60cm hob model to use for experimental study.

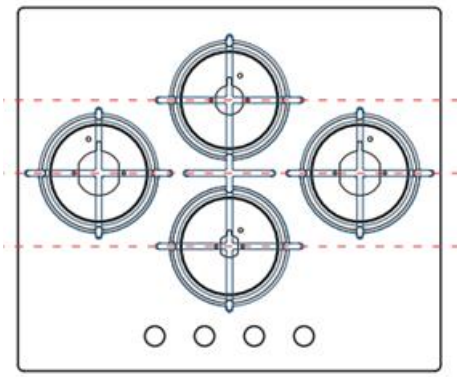

Figure 1**.** Haier Europe 60cm gas hob

Table 1. Test classification

Hob Model / Burner Plate	430 Stainless Steel Sheet	441 Stainless Steel Sheet
60cm Gas Hob	3 Samples	3 Samples

Table 1 shows the test classifications to measure Yellowness ratio above. For hob models, 8 critical areas are determined to measure yellowing ratio as shown Figure 2 below. Each measurement is repeated 2 times to increase the accuracy of values. Each measurement is indicated as a M1 and M2 as a first measurement and second measurement respectively. Apart from beginning, 3 different times (twice for each) measurement are taken at end of cycle 120, cycle 240 and cycle 360. 1 working cycle means; maximum power working for 20 minutes, minimum power working for 40 minutes and cooling (hob is off) for 30 minutes for gas hobs during QRL tests. Working cycle logic is shown Figure 3 below.

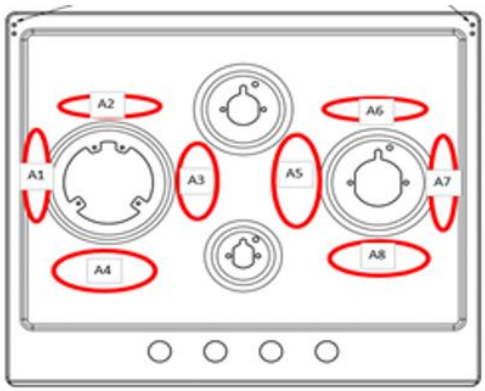

Figure 2. 60cm Hob measurement area

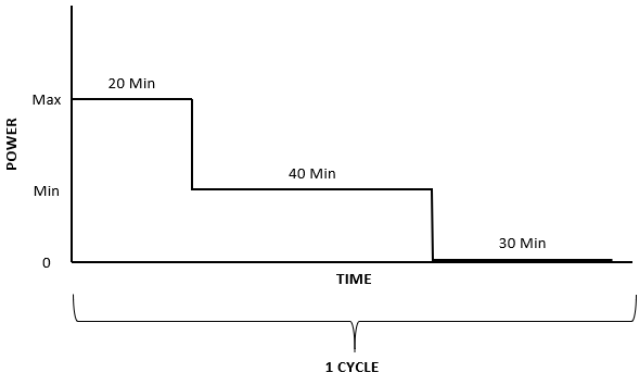

Figure 3. Hob 1 working cycle

During the measurement, Hunterlab MSEZ 4500L Colorimeter is used as shown Figure 4 below.

Figure 4. Colorimeter

Theory

Colorimetry measurement method is applied based on L*, a*, b* color space as shown Figure 5. L* represents lightness, a* represents redness and b* represents yellowness on positive side. On negative side, L* represents darkness, a* represents greenness and b* represents blueness (Onur et.al., 2017).

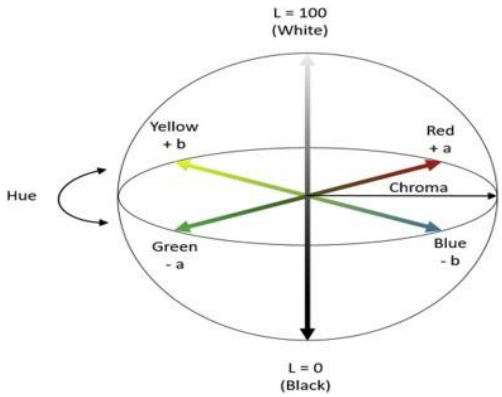

Figure 5. L* a* b* Color diagram

Color measurement is explained equation 1, 2 and 3 below. Total color change is shown in Equation 1. Chroma and Hue angle are shown are shown in Equation 3 and 4 respectively (Mask, 2001).

$$\Delta E = \sqrt{(L_0 - L)^2 + (a_0 - a) + (b_0 - b)} \quad [1]$$

$$C = (a^2 + b^2)^{1/2} \quad [2]$$

$$Hue\ Angle = tan^{-1}\left(\frac{b}{a}\right) \quad [3]$$

L, a and b values are color change, “o” index means color reading on materials (Stainless Steel Sheet).

Results

In this study, 6 hobs are tested to check yellowness measurements. 8 area are specified as a critical region as get effected by high temperatures during the working cycles. 3 hobs of test samples have 430SS burner plate, others have 441SS burner plate. Table 2, 3 and 4 shows yellowness measurements of 430SS hobs below. Table 5,6 and 7 shows yellowness measurements of 441SS hobs below.

Table 2. 430 stainless steel b* values at cycle 120

Cycle 120	Sample 1		Sample 2		Sample 3	
Area	M1	M2	M1	M2	M1	M2
A1	1,51	1,96	2,42	1,96	2,49	2,31
A2	1,26	1,74	2,21	1,47	1,95	2,11
A3	2,65	3,14	3,43	3,6	4,09	4,25
A4	1,26	1,72	1,92	1,79	2,07	2,15
A5	1,95	2,34	2,29	2,52	2,13	2,15
A6	1,56	1,64	1,39	1,82	1,7	1,61
A7	1,74	1,93	1,93	1,69	1,86	1,75
A8	1,52	1,45	1,42	1,79	1,87	1,67

Table 3. 430 stainless steel b* values at cycle 240

Cycle 240	Sample 1		Sample 2		Sample 3	
Area	M1	M2	M1	M2	M1	M2
A1	4,62	4,01	8,13	5,59	5,52	5,29
A2	2,44	2,48	3,46	6,17	3,12	3,75
A3	5,02	4,61	7,79	10,07	5,76	5,95
A4	1,43	1,43	2,74	4,28	2,21	1,88
A5	8,5	5,75	10,2	10,47	5,51	4,81
A6	3,33	2,78	10,12	4,48	1,58	1,19
A7	1,77	1,46	1,91	1,32	1,67	1,59
A8	0,86	0,95	1,36	5,6	0,89	1,13

Table 4. 430 stainless steel b* values at cycle 360

Cycle 360	Sample 1		Sample 2		Sample 3	
Area	M1	M2	M1	M2	M1	M2
A1	3,05	3,75	2,03	5,89	4,31	4,65
A2	3,18	4,04	6,66	8,75	3,77	4,8
A3	5,82	4,88	10,62	11,34	6,54	6,5
A4	1,95	2,36	5,92	2,40	3,93	3,14
A5	3,87	8,15	9,81	10,05	6,23	4,61
A6	4,21	1,88	10,70	3,81	1,9	1,72
A7	1,52	0,77	2,21	1,22	1,94	1,32
A8	1,17	1,35	1,48	7,93	1,13	1,38

Table 5. 441 stainless steel b* values at cycle 120

Cycle 120	Sample 1		Sample 2		Sample 3	
Area	M1	M2	M1	M2	M1	M2
A1	1,11	1,10	0,76	0,79	1,26	1,26
A2	1,09	1,26	0,98	0,62	1,17	0,83
A3	2,07	1,47	0,93	0,62	1,00	0,68
A4	1,68	1,17	0,92	0,71	0,98	0,71
A5	1,17	0,93	0,67	0,59	0,62	0,50
A6	1,52	1,54	0,63	0,69	0,76	0,59
A7	1,30	1,10	0,82	0,47	0,80	0,54
A8	1,29	1,02	0,90	0,52	0,67	0,48

Table 6. 441 stainless steel b* values at cycle 240

Cycle 240	Sample 1		Sample 2		Sample 3	
Area	M1	M2	M1	M2	M1	M2
A1	4,98	2,43	4,08	3,01	2,91	3,02
A2	2,27	2,47	2,15	2,58	1,88	2,15
A3	3,57	3,39	3,52	3,31	3,71	3,15
A4	2,19	1,96	2,29	2,3	1,64	1,93
A5	3,25	2,82	4,03	4,71	2,72	2,43
A6	1,49	1,39	1,87	2,3	1,75	1,54
A7	2,28	2,19	2,36	3,06	1,78	1,44
A8	1,53	1,38	2	1,87	1,04	1,31

Table7. 441 stainless steel b* values at cycle 360

Cycle 360	Sample 1		Sample 2		Sample 3	
Area	M1	M2	M1	M2	M1	M2
A1	2,33	2,43	3,11	2,58	2,41	1,99
A2	2,08	3,78	2,45	2,89	2,35	2,14
A3	3,47	3,42	3,59	3,69	3,78	3,37
A4	2,53	2,1	2,28	2,79	1,41	1,14
A5	2,7	3,55	3,82	3,65	2,5	1,79
A6	1,47	1,47	2,29	2,39	2,12	1,4
A7	1,73	1,82	2,46	2,08	1,7	1,31
A8	1,44	2,09	2,1	2,36	1,07	1,46

Each measurement repeated to times to increase the accuracy of experimental study. There are 10% - 25% variation between measurements. Results showed that, 441SS material have better behavior than 430SS under high temperature conditions from yellowness perspective.

Table 8. Measurement of b* values for each sample/material comparison table

Material / Cycle	Sample 1			Sample 2			Sample 3		
	C120	C240	C360	C120	C240	C360	C120	C240	C360
430SS	1.84	3.50	3.25	2.10	5.86	6.30	2.26	3.24	3.62
441SS	1.30	2.40	2.47	0.73	2.78	2.84	0.80	2.00	2.15

Table 8 shows overall summary of the results, indicated each sample – materials values. In the Figure 6, results show prominently 441SS material have better behavior than 430SS material under high temperature condition from yellowness perspective. There are 45% - 55% differences between two materials.

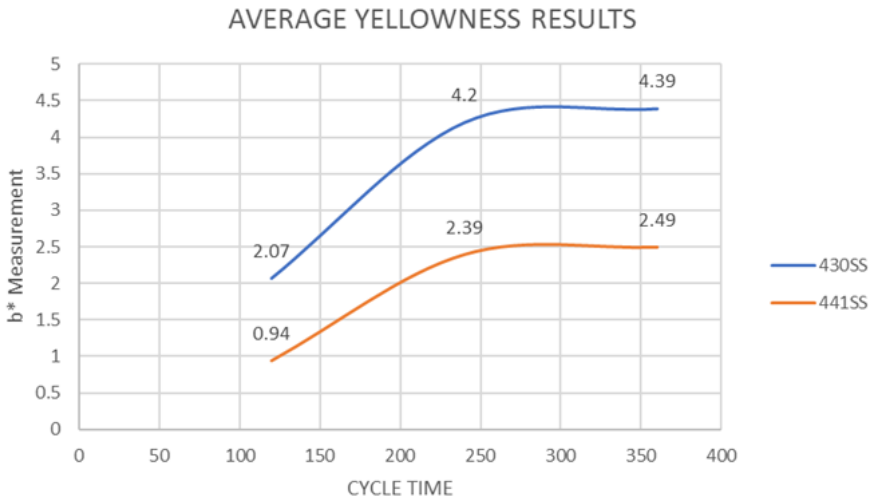

Figure 6. Average yellowness comparison

Conclusion

In this paper, yellowness measurement of materials as a hob burner plate has been investigated. As a total 6 hobs are tested for 6 months for each sample as a life test. In the end, results show that 441SS material is more qualified than 430SS material for the yellowness point of view. This is very effective on esthetical design, also for customer usage. After experimental evaluation, it is decided that 441SS will be used as a burner plate for the high segment products.

Scientific Ethics Declaration

The authors declare that the scientific ethical and legal responsibility of this article published in EPSTEM journal belong to authors.

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