

REDUSCTION OF ADHESION OF GRILLED FISH PROTEIN AGAINST STEEL PLATE COATED WITH ULTRA-HYDROPHOBIC DLC

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ABSTRACT

There is a problem of the fish adhering to the metal grids of grill strongly during grilling the fish. We suggested the evaluation method for the measuring of adhesion force between grilled fish protein and metal grids, we suggested two kinds of metal grids of grill which were micro-patterned not to adhere the fish. We considered that these micro-patterned metal grids of grills and fish soup decreased adhesion area. And these patterns were radial and circular for each rod axial. Furthermore in order to avoid the invasion of the fish soup, we introduced an ultra-hydrophobic DLC (UH-DLC)⁽²⁾ coating on both radial and circular for each rod micro-patterned metal grids of grills because the fish soup are included about 90% water. By using the micro-patterned metal grids coated with the UH-DLC, the fish soup did not enter to the grooves. Also we decreased the adhesion force between the micro-patterned metal rod (length of 30 mm) with the UH-DLC and heated fish soup drastically. Furthermore we made micro-patterned grids of grill (length of 188 mm) with the UH-DLC, and actually grilled a fish with it and measured its adhesion force with a push-pull gage. The adhesion force of radial-patterned grids of grill with SH-DLC coating was 40% lower than that of no-patterned grids of grill.

1. INTRODUCTION

During the grilling fish, the fish is stuck to metal plate and grid. This is still unsolved issue on the adhesion of the denatured fish body by heat. Usual Fluorine resin that surface energy is low could be denatured at high temperature more than 300 degree C. Therefore we should find anti-stick surface treatment against denatured protein and/or oil from fish for heat-resistant material. So we suggested two kinds of metal grids of grill. And we evaluated these specimens with our experimental method and confirmed with the experiment of grilling fish in a grillroom.

2. EXPERIMENTAL APPARATUS AND PROCEDURE

2.1 Our experiment method

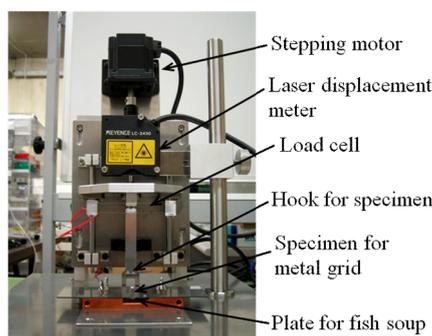


Figure 1 Experimental apparatus for the pulling load F and the displacement d

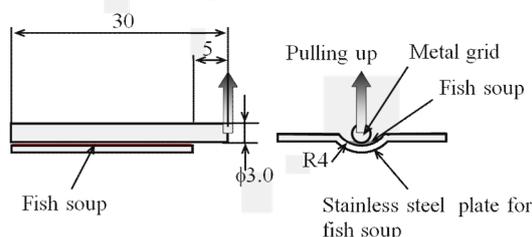


Figure 2 The schematic of a bar specimen and a dish specimen

Figure 1 shows the experimental apparatus to measure the relationship between load and displacement during the pulling off of a bar specimen against denatured fish protein in a shallow groove on a dish specimen after heating. The bar specimen and a dish specimen were shown in Figure 2. The radius and length of the bar specimen is 3.0 mm and 30mm, respectively. The radius of the groove of the dish specimen is 4 mm. After put the 0.3 μ l of fish protein on the groove of the dish specimen, the bar specimen was put on the groove. Both specimens were in an electric furnace to heat at certain temperature for the denaturing of the fish protein. After cooling off of both specimens, the both specimen was on the holder in the measurement apparatus of the adhesion.

2.2 The experiment of grilling fish in a grillroom

We need to confirm the adhesion force in case of pulling up real fish. So we prepared a Gas-grill-table. The Gas-grill-table has a grillroom usually. We put a fish on the center of grids of grill in the grillroom. And we heat them for 9 minutes. After that, we put them out in the

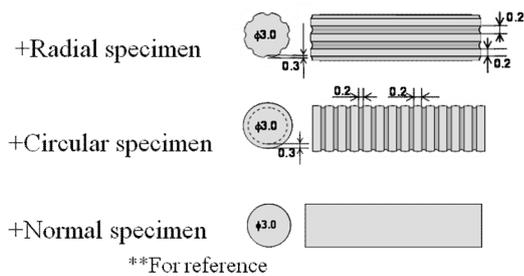


Figure 3 The schematic of patterned specimen which we suggested

grillroom, and leave them for 1 minute. And we pull the fish up for measured its adhesion force.

3. OUR SUGGESTED SPECIMEN

We considered that it was important to decrease adhesion area between the metal grids of grill and fish. So, it is micro-structure work that we focused attention on⁽³⁾. And we applied our specimen to micro-structure. These structures were to pattern radial and circular direction for each rod axial into round bars of 3.0 mm in diameter, and these width of land and groove were 2.0 mm, and these depth of groove were 0.3 mm (figure 3). These grooves of micro-structure were worked by Wire-electrical Discharge Machine. We called them micro-patterned specimen collectively. Furthermore in order to avoid the invasion of the fish soup, we introduced an ultra-hydrophobic DLC (UH-DLC) coating on both micro-patterned specimen because the fish soup are included about 90% water. And we used SUS304 as the specimen material, because the heat temperature reached 300 degree C.

By the way, we prepared two kinds of specimens which were different with length -30 mm and 188 mm-. This reason was that the specimen of 30 mm was for our evaluation, and 188 mm was for grilling real fish in grillroom because of finally confirmation.

4. EXPERIMENTAL RESULT AND DISCUSSION

In order to avoid the intrusion of the fish soup, we introduced an UH-DLC coating on both radial and circular for each rod micro-structure metal grids of grills.

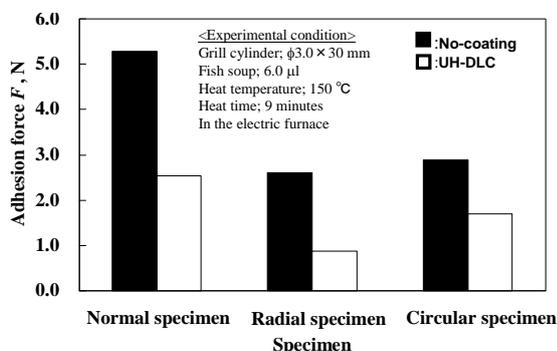


Figure 4 Adhesion force with our experiment method

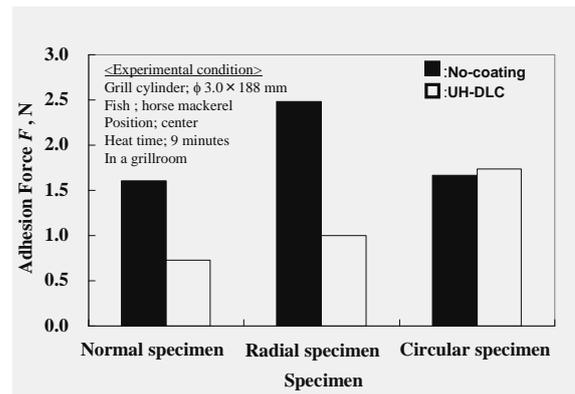


Figure 5 The result of adhesion force with the experiment of grilling fish in a grillroom

We tested two kinds of specimens which were length of 30 mm with our evaluation. Figure 4 shows result of this experiment. The adhesion force of radial and circular specimen was about 65% and 35% lower than that of normal specimen. Therefore we did the experiment of grilling fish in a grillroom with three kinds of specimen of 188 mm length. Figure 5 shows result of this experiment. The adhesion force of normal and radial specimen with UH-DLC coating was about 60% lower than that of each specimens with no UH-DLC coating but the adhesion force of circular specimen with UH-DLC coating was about 5% higher than that of its specimen with no UH-DLC coating.

We thought that the reduction of the adhesion force of normal and radial grooved specimen with UH-DLC coating was caused by the reduction of contact area. So adhesion force of normal and radial specimens are smaller than that of not groove specimen.

Normal and radial specimens had line contact for fish, but circular specimen contacts at points. However, adhesion force of circular specimen with UH-DLC coating did not improved well against no UH-DLC grid, because real adhesion area of its specimen did not change well.

5. CONCLUSION

We suggested new metal grids of grills with UH-DLC. Also they have micro-patterns that width of land and groove were 0.2 mm, and depth of groove was 0.3 mm. After the adhesion test against real fish in grill, a radial micro-patterned and a normal grid with UH-DLC coating showed 40% and 55% lower than that of no-patterned grids, respectively.

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