Evaluation method of drinking ease for aluminum beverage bottles

著者	Yamazaki Koetsu, Chihara Takanori, Itoh Ryoichi, Han Jing, Nishiyama Sadao
journal or publication title	2007 Proceedings of the ASME International Design Engineering Technical Conferences and Computers and Information in Engineering Conference, DETC2007
volume	6 PART A
page range	405-411
year	2008-01-01
URL	http://hdl.handle.net/2297/9987

Proceedings of IDETC/DAC 2007
ASME 2007 International Design Engineering Technical Conferences
& Design Automation Conference
September 4-7, 2007, Las Vegas, Nevada, USA

DETC2007-35637

EVALUATION METHOD OF DRINKING EASE FOR ALUMINUM BEVERAGE BOTTLES

Koetsu Yamazaki
Kanazawa University
Kanazawa, Ishikawa, 920-1192
Japan

Takanori Chihara
Kanazawa University
Kanazawa, Ishikawa, 920-1192
Japan

Ryoichi Itoh
Universal Can Corporation
Sunto-gun, Shizuoka, 410-1392
Japan

Jing Han
Universal Can Corporation
Sunto-gun, Shizuoka, 410-1392
Japan

Sadao Nishiyama
Universal Can Corporation
Tokyo, 112-8525
Japan

ABSTRACT

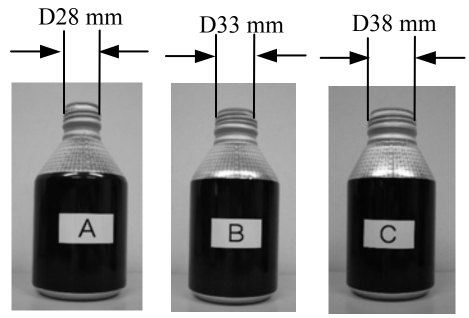
This paper has investigated effects of the bottle opening size on drinking feelings in order to improve the comfort level of consumers when drinking directly from the opening of aluminum bottle. A survey over 120 subjects has been performed based on a drinking test using three kinds of bottles with opening diameters of 28, 33 and 38 mm, respectively. Two questionnaires have been conducted. Statistical analysis results of Questionnaire 1 have shown that 33-mm opening is best for adult consumers with no matter the type of contents, gender and the mouth size. The factor analysis results of Questionnaire 2 based on Kansei Engineering have shown that drinking feeling is affected by two common factors, which considered as the flow from the bottle to the mouth and the flow adjustability. Moreover, the fluid-dynamics analysis model has been developed to simulate the bottled liquid in a drinking action consisting of survey results and experimental observations of consumers' drinking actions. Numerical simulations have been performed to understand how consumers control the flow during the drinking actions. It is found that the consumers usually try to realize the ideal and preferable condition by adjusting the inclination angle of the bottle.

INTRODUCTION

Structure optimization techniques based on the finite element analysis (FEA) have been applied in developing 2-piece aluminum beverage cans and bottles to get better performance and formability under various loading conditions, for example, light-weighting the lid of can subject to the constrains of the strength and maximizing the strength of the bottle bottom against the axial load and internal pressure [1-2]. Functions, performance and price of products are not only factors to affect customers' decisions on purchasing products, universal designs based on human factors are also expected in developing beverage containers for consumers' convenience [3-6]. Aluminum beverage bottles with a screw top of 28 mm and 38 mm in diameter have been launched on to the market recent years to meet new drinking custom trend of the consumers. However, some customers feel that the 28-mm opening is too small and feel 38-mm opening is too large. We need to develop a method to evaluate human feelings when drinking directly from the bottle opening and then to identify the opening size that is best for consumers' ease of drinking.

On the other hand, to get data for determining consumers' preference, a survey of trained panelists or consumers is usually carried out using trial products. The semantic differential (SD) method [7] and the factor analysis (FA) [8, 9] are typical techniques used in questionnaires. Kansei Engineering is initially proposed by Japanese researchers and now used internationally by designers as a design methodology [10-12]. While in the product designing stage before making lots kinds of trial products, the numerical simulation is a cost and time effective tool used to estimate whether a particular design will be loved by consumers or not.

Figure 1 Drinking test



(a) 28-mm (b) 33-mm (c) 38-mm

Figure 2 Experimental bottles

This paper studies effects of the bottle opening size on ease of drinking when consumers drink directly from the bottle opening. A survey over 120 subjects based on a drinking test is conducted using three kinds of experimental bottles with opening diameters of 28 mm, 33 mm and 38 mm. Two questionnaires based on the drinking test are performed. Questionnaire 1 is designed to get data for determining the consumers' preference of the opening size. Questionnaire 2 based on Kansei engineering is performed to investigate factors that influence consumers' drinking feelings and to identify main factors using the technique of FA. Moreover, a fluid-dynamics analysis model has been developed to simulate the flow of bottled liquid in a drinking action. The factors influencing the drinking feeling are evaluated numerically consisting of survey results and experimental observations of consumers' drinking actions.

SURVEY BASED ON DRINKING TEST

Drinking Test Method

The survey on consumers' ease of drinking has been conducted over 120 volunteers, 60 males and 60 females. All of them are Japanese college or university students, and are between the ages of 20-26 yr. As shown in Fig. 1(a), all subjects have sat while drinking and then have filled out questionnaire on the drinking feeling.

Figure 2 shows three kinds of experimental bottles with opening diameters of 28 mm, 33 mm and 38 mm. Among them, the 28-mm and 38-mm openings are familiar to the consumers, while 33-mm openings are not on the market yet. The bottles of a capacity of 300ml filled with 200 ml liquid have been tested. All subjects have been asked to have two mouthfuls of drinks from each kind of bottles, respectively. Six drinking orders of three opening sizes, 28-mm, 33-mm and 38-mm, have been set for each 20 subjects in order to avoid any influence of the drinking order. Green tea and carbonated beverage have been selected as test liquid.

Questionnaire 1 and Statistic Results

Table1 Ranking results of drinking ease.

Sample No.	The number of subjects			Scores
	Primary	2nd	3rd	
(1) 28-mm	16	36	68	188
(2) 33-mm	71	40	9	302
(3) 38-mm	33	44	43	230

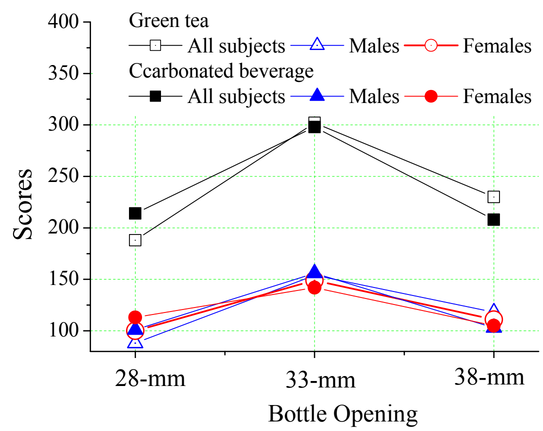
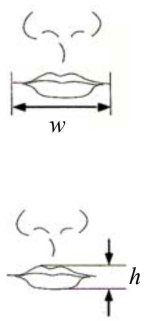
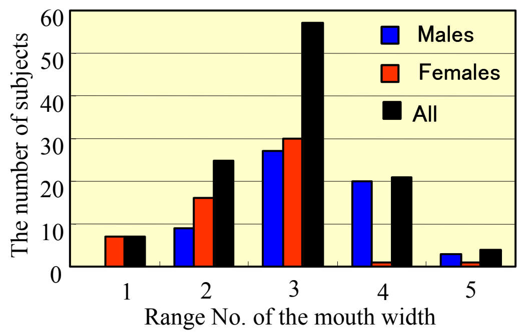


Figure 3 Ranking results of drinking ease.

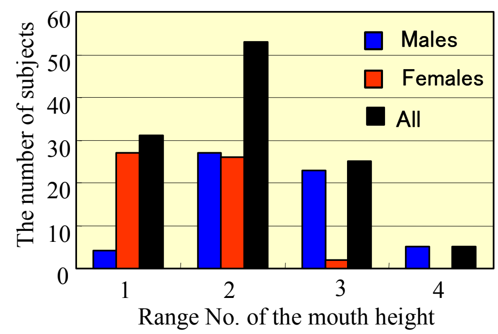
Questionnaire 1 is designed to determine the consumers' preference of opening size. All subjects have been asked to rank three kinds of bottles in the order of ease of drinking. As one example, the ranking result of green tea by all subjects is shown Table 1. If 3 scores is given to the first rank, 2 scores to the second rank and 1 score to the third rank, the total ranking scores of three kinds of bottles are then calculated as shown in the last column of Table 1. It is clear that the score of 33-mm opening is the highest followed by the 38-mm opening and then 28-mm opening.



(a) Measurement method [13]

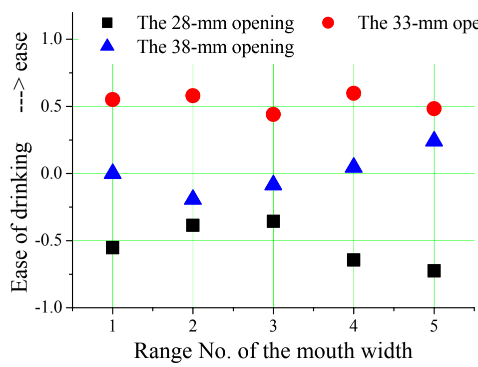


(b) Distribution of the mouth width

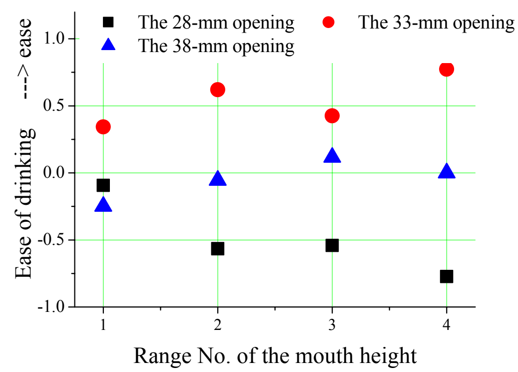


(c) Distribution of the mouth height

Figure 4 Dimension distributions of the mouth.



(a) Influence of the mouth width



(b) Influence of the mouth height

Figure 5 Influence of the mouth dimensions to drinking ease.

The ranking scores are plotted in Fig.3 to investigate the influence of the beverage type and gender to the ease of drinking. It has found that the first rank is kept by the 33-mm opening in both drinking tests of green tea and carbonated beverage, no matter gender. Comparing the ranking results of the 28-mm and 38-mm opening, it is observed that the consumers prefer to drink green tea from the bottle of a relatively large opening and to drink carbonated beverage from the bottle of a relatively small opening, however, differences in scores are small as compared with those of the 33-mm opening.

To investigate the influence of the subjects' mouth size to the ease of drinking, the width *w* and height *h* of mouth were measured for all subjects while closing the mouth naturally as illustrated in Fig. 4(a) [13], and the number of subjects in five ranges of the mouth width: (1) 35mm - 40mm, (2) 41mm - 45mm, (3) 46 mm - 50mm, (4) 51 mm – 55 mm, (5) 56 mm – 60 mm, and four ranges of the mouth height: (1) 9 mm – 15 mm, (2) 16 mm – 20 mm, (3) 21 mm – 25 mm, (4) 26 mm – 30 mm, are shown in Fig.4(b), (c). The ease of drinking are rated as shown in Fig.5(a),(b). It has found that the 33-mm opening always stayed at the first rank no matter with the mouth size. It is concluded that the 33-mm opening is best for Japanese adult consumers' ease of drinking.

Questionnaire 2 and Statistic Results

Questionnaire 2 based on Kansei engineering is designed to investigate factors that influence consumers' drinking feeling. In general, it is considered that consumers' drinking feeling may be related to containers (such as opening size, shape and material), beverage (such as temperature and taste), people (such as age, gender and drinking way) and environment (such as drinking place and time). Under the engineering consideration, the drinking feeling may be affected by the volume and rate of flow while drinks flowing into the mouth, adjustability and stability while drinking. Eleven evaluation items are selected to study drinking feelings based on Kansei words. As one example, the questionnaire of the 28-mm bottle opening for green tea is shown in Fig.6. Evaluation items are the same for all kinds of drinks and bottle

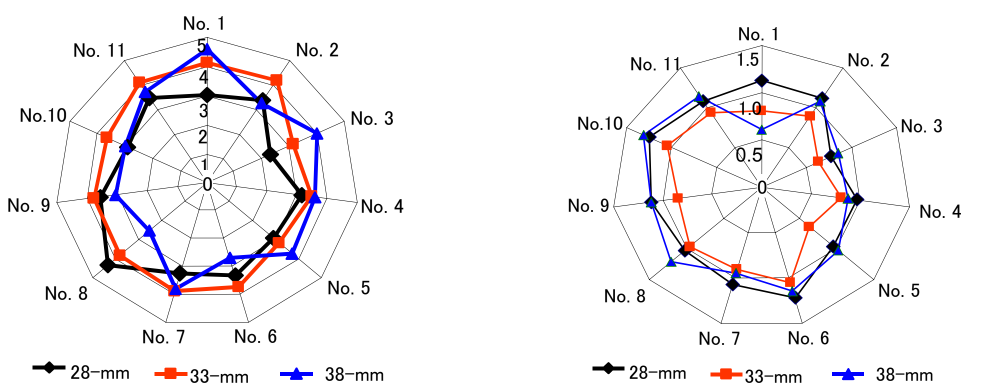
Figure 7 shows questionnaire results based on the drinking test using the bottles filled with green tea. The mean values and standard deviations are calculated for eleven evaluation items. It's found that mean values of the 33-mm opening are high in general. The 38-mm opening bottle shows the highest mean values in Item 1 (Liquid can easily flow out of the bottle), Item 3 (The flow volume through the opening is large) and Item 5 (The flow into the mouth is fast), while the 28-mm opening

(1) Bottle of 28-mm opening

Mark the number with ○

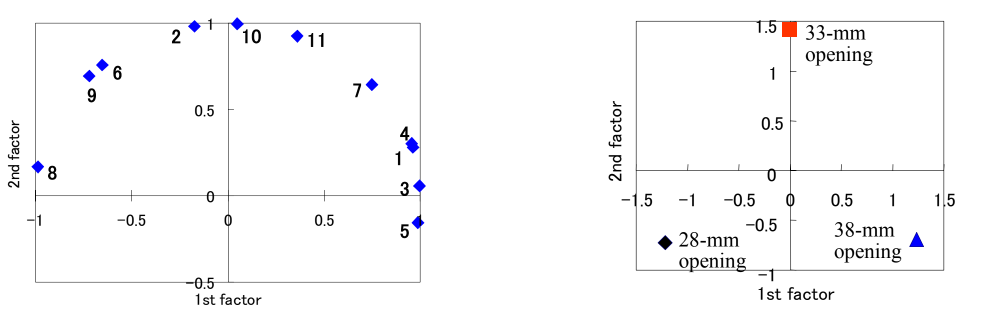
Evaluation items:	**Level:**					
1. Liquid can easily flow out from the bottle	5	4	3	2	1	Liquid can hardly flow out from the bottle
2. The flow volume through the opening is appropriate	5	4	3	2	1	The flow volume through the opening is inappropriate
3. The flow volume through the opening is large	5	4	3	2	1	The flow volume through the opening is small
4. Feel comfortable in throat	5	4	3	2	1	Feel uncomfortable in throat
5. The flow into the mouth is fast	5	4	3	2	1	The flow into the mouth is slow
6. The flow volume can be easily controlled	5	4	3	2	1	The flow volume can be hardly controlled
7. Liquid flows into the mouth smoothly	5	4	3	2	1	Liquid flows into the mouth not smoothly
8. Liquid hardly spills from corners of the mouth	5	4	3	2	1	Liquid easily spills from corners of the mouth
9. The bottle can be easily inclined	5	4	3	2	1	The bottle can be hardly inclined
10. The bottle opening is fit with the mouth	5	4	3	2	1	The bottle opening is unfit with the mouth
11. Drinking ease of bottles is better than that of cans	5	4	3	2	1	Drinking ease of bottles is worse than that of cans

Figure 6. An example of Questionnaire 2 based on the SD method.



(a) Mean values of 11 evaluation items (b) Standard deviations of 11 evaluation items

Figure 7 Evaluation results of Questionnaire.



(a) Factor loadings of 11 evaluation items (b) Factor scores of three kinds of bottles

Figure 8 Factor analysis results.

shows the highest mean value in Item 8 (Liquid hardly spills from corners of the mouth). It's also obvious that the standard deviations of the 33-mm opening bottle are generally lower than that of other two kind
opening sizes. The SD method is used, and five levels are set.

Since the 33-mm opening shows high mean values and low standard deviations in almost all evaluation items, it is considered that the 33-mm opening is highly evaluated by all subjects. In contrast, 28-mm and 38-mm opening bottles show relatively high standard deviations, so it is considered that subjects have different feelings while drinking from them. The 33-mm opening bottle shows a smaller value in Item 3 (The flow volume through the opening is large) but a higher value in Item 2 (The flow volume through the opening is appropriate) than 38-mm opening bottle does, hence, it' estimated that there is an appropriate flow of drinks for subjects feeling comfortable when drinking from the bottle.

The FA is performed to gain insight of the data obtained in Questionnaire 2. As one example, FA results of green tea are shown in Table 2 and Fig.8. Two common factors were identified. The contribution rate of the 1st factor (58.8%) is larger than that of the 2nd factor (41.2%), which indicates that the 1st factor affects ease of drinking more than the 2nd factor does. The communality of fluctuation rate of two factors is 99.6%, so the fluctuation in the drinking test results can be almost explained by these two factors. The transverse axes in Fig.8 (a), (b) indicate the 1st factor, and vertical axes indicate the 2nd factor. Item 3 (The flow volume through the opening is large), Item 5 (The flow into the mouth is fast) and Item 1 (Liquid can easily flow out from the bottle) give large loads and Item 8 (Liquid hardly spills from corners of the mouth)

Table2 Factor loadings obtained in the factor analysis.

Evaluation Item No.	Factor loadings		Communalit y
	1st factor	2nd factor	
1	0.97	0.24	1.00
2	-0.13	0.99	0.99
3	1.00	0.01	1.00
4	0.97	0.26	1.00
5	0.98	-0.20	1.00
6	-0.62	0.79	1.00
7	0.78	0.61	0.98
8	-0.98	0.21	1.00
9	-0.69	0.72	1.00
10	0.09	0.99	1.00
11	0.40	0.91	0.99
Contribution quantity	6.44	4.52	11.0
Contribution rate (%)	58.8	41.2	100
Fluctuation rate (%)	58.6	41.0	99.6

gives a small load to the 1st factor, while Item 2 (The flow volume through the opening is appropriate) and Item 10 (The bottle opening is fit with the mouth) give large loads to the 2nd factor. Therefore, the flow may be considered as the 1st factor, and flow adjustability may be considered as the 2nd factor. The good flow adjustability means that the flow from the bottle opening can be adjusted easily and appropriately as expected by consumers. In Fig.8(b), the 38-mm opening shows a high factor score of the 1st factor followed by the 33-mm opening and then the 28-mm opening, in other word, subjects feel that the flow volume from the 38-mm opening is large followed by the 33-mm opening and 28-mm opening. Moreover, the factor score of the 2nd factor is higher for the 33-mm opening than other two bottles, which indicates that subjects feel that the flow adjustability of the 33-mm opening bottle is the best.

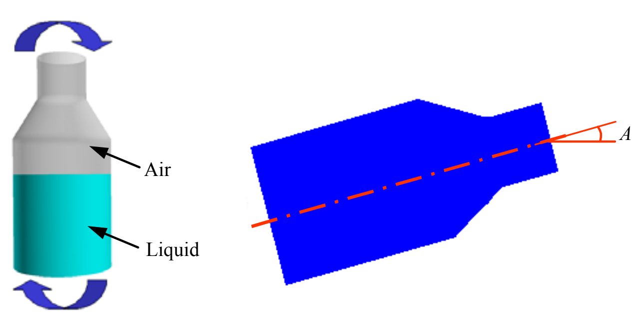
NUMERICAL SIMULATIONS

Flow-dynamic Analysis Model

Since the survey results based on the dinking test shows that the flow influences drinking ease obvious, it is necessary to develop a three-dimensional flow-dynamics analysis model to simulate the drinks flowing out of the bottle and to evaluate the ease of drinking numerically.

The analysis model is developed as shown in Fig.9. To simulate the drinking action, the bottle model is rotated from its initial position to the drinking position at a constant velocity during time T_0 and then kept stopping. The inclination angle (A) of the bottle is defined as the acute angle between the bottle's central axis and horizontal line.

The velocity boundary condition is applied to the wall and bottom of the bottle (Γ_1, Γ_2). There is no relative velocity of the fluid and the bottle. The distributed load boundary condition is applied to the opening of the bottle defined as the flow outlet (Γ_3). The bottle model is filled with 200ml water, and the water is assumed to flow out from the bottle without any external resistance. The water and air in the bottle are assumed as uncompressible fluid. The density of water and air are given as 998, 1.20 kg/m^3, respectively. And the viscosity of water and



(a) Model (b) Inclination angle

Figure 9 Three dimensional fluid-dynamics analysis model.

air are given as 1.00e-3, 1.82e-5 Pa-s, respectively. The computational fluid dynamics analysis code, FIDAP [14], is used to simulate the flow of fluid in the drinking action.

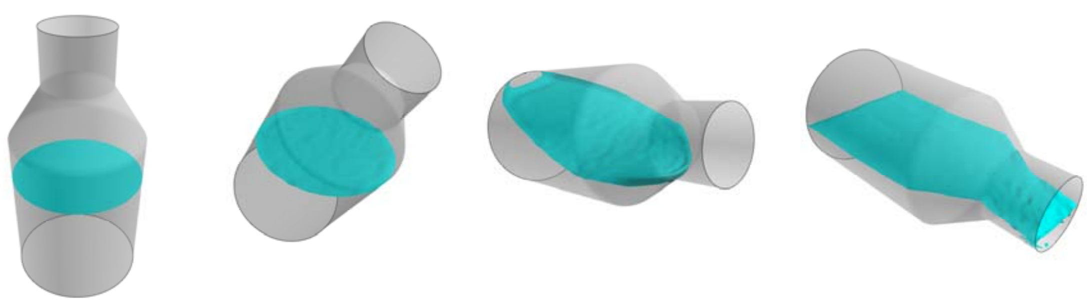
The drinking actions of several subjects have been recorded using the video recorder in order to measure the final inclination angle of the bottle while subjects drinking from the bottle. The average values of the final inclination angles are $A = 0.0^0$ for the 28-mm opening bottle, $A = 2.0^0$ for the 33-mm opening bottle and $A = 4.0^0$ for the 38-mm opening bottle. Five analysis models are considered as shown in Table 3. The inclination angles obtained experimentally are sent to Model 1 (28-mm opening), Model 2(33-mm opening), and Model 3 (38-mm opening), respectively. While, $A = 2.0^0$, the same as that of 33-mm opening bottle, is sent to Model 4 (28-mm opening) and 5 (38-mm opening). All models are rotated from $A = 90^0$.

Flow-dynamics Analysis Result

Numerical simulation results of the 33-mm opening bottle (Model 2) when rotation time T_0 = 1 second are shown in Fig.10 as an example. It has been observed that the water flows out from the bottle smoothly. The similar flow can also be seen in the simulation for the bottle of the different opening size.

Figure 11 shows the history plots of the flow rate for five models when T_0 = 2 second. It's observed that two peaks appeared in the plot for all models, and that the starting time and the time period of two peaks are almost same in five models in spite of the difference in opening size, the final inclination angle as well as the amplitude of the peaks. The amplitude of the first peak is different in five models, so the flow rate at the first peak may be used to present ease of drinking as one of engineering variables. This agrees with the factor analysis results that the flow has an effect on ease of drinking.

The average rate of the flow during the first peak is scaled in Fig. 12 for each model by the flow rate of Model 2 (33-mm opening). If the final inclination angle is given as $A = 2.0^0$, the numerical analysis results of Model 2, 4, 5 shows that the average flow rate of the 33-mm opening bottle is smaller than that of the 38-mm opening but larger than that of the 28-mm opening. The range of difference is about 87%. While if the final inclination angles measured experimentally are given to each bottle respectively, the range of difference in the average flow rate becomes as narrow as bout 42%. If the flow of liquid from the 33-mm opening bottle is regarded as the appropriate flow, it is considered that consumers adjust the inclination angle of the bottle to achieve the appropriate flow for ease of



(a) $A = 90^0$ (b) $A = 55^0$ (c) $A = 20^0$ (d) $A = 0.0^0$

Figure 10 Fluid analysis results.

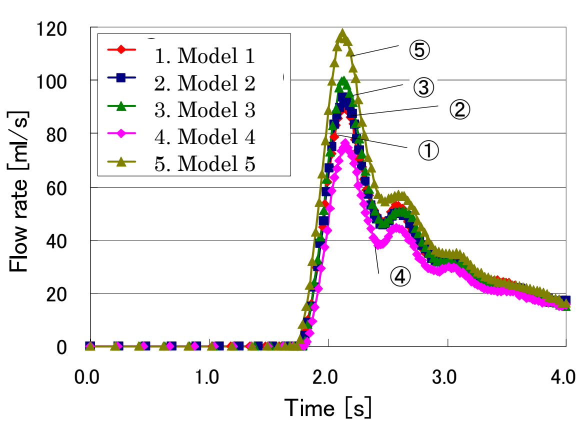


Figure 11 History plots of the flow rate.

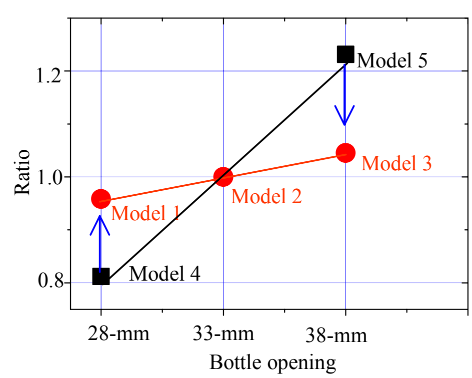


Figure 12 Average rate of the flow.

drinking. This agrees with the observation from the results of the drinking test and questionnaires.

From the numerical simulation results, it has been judged that the flow-dynamic analysis model can explain the observations in the drinking test and questionnaires, and may be utilized in further development of containers to guarantee consumers' ease of drinking.

CONCLUSIONS

This paper has investigated effects of the bottle opening size on drinking feelings in order to improve the comfort level of consumers, when drinking directly from the bottle opening. The drinking tests have been performed using three kinds of bottles with opening diameters of 28, 33 and 38 mm, respectively. From the statistical analysis of the questionnaires, it is concluded that 33-mm opening is best for Japanese adult consumers with no matter the type of drinks, gender and the mouth size. Results of the factor analysis based on the data obtained in the questionnaire based on the SD method have shown that two factors contributing to the drinking feeling, the first factor corresponds to the flow and the second factor relates to the flow adjustability.

Moreover, the fluid-dynamics analysis model has been developed to simulate the bottled liquid in a drinking action consisting with survey results and experimental observations of consumers' drinking actions. Numerical simulations have been performed to understand how consumers control the flow during the drinking actions. It is found that the consumers usually try to realize the ideal condition by adjusting the inclination angle of the bottle.

In order to increase the comfort level of consumers when drinking directly from the bottle opening, the flow-dynamic analysis model developed in this paper may be used to investigate effects of the bottle shape, opening shape, material and so on. And the analysis model may be further developed, for example, including human mouth and hand into the analysis model, to investigate the influence of consumers' drinking actions.

REFERENCES

[1] Yamazaki, K., Itoh, R., Watanabe, M., Han, J. and Nishiyama, S., 2007, "Applications of structural optimization techniques in light weighting of aluminum beverage can ends", Journal of Food Engineering, **81**, pp.341–346.

[2] Han, J., Itoh, R., Nishiyama, S., and Yamazaki, K., 2005, "Application of Structure Optimization Technique to Aluminum Beverage Bottle Design", Structural and Multi-disciplinary Optimization, **29**(4), pp.304-311.

[3] Han, J., Yamazaki, K., Itoh R. and Nishiyama, S., 2006, "Multi-Objective Optimization of a Two-Piece Aluminum Beverage Bottle Considering Tactile Sensation of Heat and Embossing Formability", Structural and Multidisciplinary Optimization, **32**(2), pp.141-151.

[4] Nishiyama S., 2001, "Development and Future Subjects of Aluminum Beverage Cans", Packpia, **2**, pp.10-15 (in Japanese).

[5] Ueno, H., 2003, "Drinks Cans with Customer Convenience", Proc. the Canmaker Summit [CD-ROM], Singapore.

[6] Han, J., Yamazaki, K. and Nishiyama, S, 2004, "Optimization of the Crushing Characteristics of Triangulated Aluminum Beverage Cans", Structural and Multidisciplinary Optimization, **28**(1), pp. 47-54.

[7] Iwashita T., 1983, "Measurement of image by SD method", Kawashima Publishing (in Japanese).

[8] Richard L. Gorsuch, 1983, "Factor Analysis", 2nd Ed., Lawrence Erlbaum.

[9] Shiba, S., 1979, "Factor Analysis", University of Tokyo Press (in Japanese).

[10] Nagamachi, M. et al., 1974, "A study of emotion-technology", The Japanese Journal of Ergonomics, **10**(4), pp. 121-130.

[11] Nagamachi, M., 1995, "Kansei Engineering: A New Ergonomic Consumer-Oriented Technology for Product Development", International Journal of Industrial Ergonomics, **15**, pp.3-11.

[12] Nagamachi, M., 2000, "Kansei Engineering, Perspectives of Kansei Engineering", Technical Report of IEICE. OME, **100**(252), pp. 167-173.

[13] National Institute of Bioscience and Human-Technology, 1996, "Human Body Dimensions Data for Ergonomic Design", Japan Publication Service(in Japanese).

[14] FIDAP User's Manual, Fluent Incorporated.