廃蜜糖のレオロジー常数と比熱についての研究

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STUDY ON THE RHEOLOGICAL CONSTANTS AND SPECIFIC HEATS FOR MOLASSES

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ABSTRACT

Molasses is the by-product of sugar industry in Okinawa, the following rheological constants and specific heats are obtained by using BL-type viscometer and infrared lamps at 25°C.

Molasses	Plasticity (poise)	Pseudo-molecular weight	Constant "n"	Specific heat
KDT	4.15×10^3	25,220	2.31	0.22
IBU	4.46×10^3	26,590	2.34	0.23
IGK	6.00×10^3	31,800	2.47	0.23
MKO	8.11×10^3	37,080	2.08	0.22
MTA	9.05×10^3	39,050	2.62	0.22
KMA	12.0×10^3	44,100	2.67	0.22

Table 1

where,

KDT : Kita-Daitoh Seitoh K. K.
IBU : Irabu-Seitoh K. K.
IGK : Ishigaki-Jima Seitoh K. K.
MKO : Miyako-Seitoh K. K.
MTA : Miyata-Seitoh K. K.
KMA : Kumejima-Seitoh K. K.

1. INTRODUCTION

Molasses is the main by-product of sugar plants which is the top industry in Okinawa.

This investigation has tried to determine the rheological constants, pseudo-molecular weight and specific heat of specimen of molasses taken from a number of sugar sources, by means of a BL-type viscometer i),ii) and infrared lamps iii).

This is the report which tried to make the rheological constants and specific heat of molasses to be clear.

2. BASIC THEORY

The sample was poured in a small beaker or a cyiinder and fixed the handle to the stand, then hanged the viscometer. i),iv) Plasticity was obtained through readings on the scale of the viscometer.

For the very high plastic viscus flow, v),vi)

$$dw/dr = (1/\phi)(s - s_y)\, g_c^{r-1} \qquad (1)$$

where,

r : radius of particular layer under consideration. (m)
w : angular velocity of particular layer under consideration. (1/sec)
s : shearing stress at r. (Kg/m)
s_y: yield value of the high viscus materials. (Kg/m)
ϕ : Plasticity. (Kg/m·sec)
g_c: Conversion factos. (Kg·m/Kg·sec$_2$)

Let,

D_i: radius of inner cylinder. (m)
D_o: radius of outer cylinder. (m)
h : depth of immersion of inner cylinder. (m)
M: Moment due to external force. (Kg·m)

Then,

$$dw/dr = M \cdot g_c \,(1/r^3 - r_y^2/r)\,(2\pi h\phi)^{-1} \quad \cdots\cdots(2)$$

Actualy the moment is not a constant number in case of moment is changed, then s_{max} and s_{min} are also changed.[i),ii),vii),viii)] On the other hand s_y is the constant which depend on the sample.[ix)] Therefore the relationship among s_{max}, s_{min} and s_y are ;

(A) In case of no slip in construction, $s_{max} \geqq s_y$, slipping is never happened in every parts of the liquid. This kind of fluid showes the property of solid.[i),ii),x)]

(B) Under condition of $s_{min} \geqq s_y$ slipping will be occured in case of $D_i \geqq r \geqq r_y$.

Let, $r = D_i$, $r = r_y$, $w = 0$, $w = Q$

$$\int_{w=0}^{w=Q} dw \doteqdot \int_{r=D_i}^{r=r} M \cdot g_c \,(2h\phi)^{-1}\,(r^{-3} - r_y^2/r)\,dr$$
$$Q = M \cdot g_c \,[D_i^{-2} + (\mathrm{In} D_i - \mathrm{In}\, r_y^2) - r_y^{-2} - \ln r_y^2/r_y]\,(4\pi h\phi)^{-1} \quad \cdots\cdots(3)$$

(c) In case of $0 \leqq s_y \leqq s_{min}$' the following condition is obtained ;

$$\int_{w=0}^{w=Q} dw = \int_{r=D_i}^{r=D_o} (M \cdot g_c)\,(2h\phi)^{-1}\,(r^{-3} - r_y^2/r)\,dr$$
$$Q = M \cdot g_c \,[D_i^{-2} + \ln D_i/r_y^2 - D_o^{-2} - \ln D_o^2/r_y^2]\,(4\pi h\phi)^{-1} \quad \cdots\cdots(4)$$

then, several dimensionless terms were applied ;

$D_i^2/r_y^2 = a$ and $D_i^2/D_o^2 = d$

Therefore, the equation (3) is shown as the following ;

$$Q = M \cdot g_c \,(4\pi D_i^2 h\phi)^{-1}\,(1 + a \cdot \ln a - a) \quad \cdots\cdots(5)$$

and the equation (4) is expressed as ;

$$Q = M \cdot g_c \,(4\pi D_1^2 h\phi)^{-1}\,(1 + a \cdot \ln d - d) \quad \cdots\cdots(6)$$

hence,

$0 \leqq s_y \leqq s_{min}$ is renoted as $0 \leqq a \leqq d$ if conditions are,

$d \leqq a \leqq 1$ $\quad L = 1 + a \cdot \ln a - a$
$0 \leqq a \leqq d$ $\quad L = 1 + a \cdot \ln d - d$

therefore the equation (5) and (6) are shown,xiii)

$$Q = (M\cdot g_c)(L)(4\pi D_i^2 h\phi)^{-1} \tag{7}$$

Let N is revolution of outer cylinder per minute

$$Q = \pi N/30$$

the equation (7) is written as

$$N = (15\cdot M\cdot g_c)(L)(2\pi^2 h D_i^2 \phi)^{-1} \tag{8}$$

and

$$s_y = (a\cdot M)(2\pi D_i^2 h) \tag{9}$$

On the experimentation to measure plasticity ϕ, for the two pairs of M and N the following equations are obtained ;

$$N_1/N_2 = M_1L_1/M_2L_2$$

then,

$$M_1N_2/M_2N_1 = K$$

hence,

$$L_2 = L_1K$$

where k is the dimensionless constant, and from the equation (9)

$$a_1M_1 = a_2M_2$$

and

$$a_1 = a_2 j$$

also j is the dimensionless constant too.

If a_1 and L_1 are known,

$$\phi = (15\cdot M_1 g_c L_1)(2\pi^2 D_i^2 h N_1)^{-1} \tag{10}$$

and

$$s_y = a_1M_1/2\, D_i^2\, h \tag{11}$$

s_y is obtained, under the condition of

$$0 \leqq a_1 \leqq d \qquad \text{and} \qquad 0 \leqq a_2 \leqq d$$

and

$$L_1 = 1 + a_1 \ln d - d$$

$$L_2 = 1 + a_2 \ln d - d$$

$$a_1 = (1 - d)(1 - k)([k - (j)^{-1}] \ln d)^{-1} \tag{12}$$

$$a_2 = (1 - d)(1 - k)[(kj - 1) \ln d] \tag{13}$$

$$L_1 = (1 - d)[1 - j^{-1}] \text{ x } [k - j^{-1}] \tag{14}$$

from equation (12), (13) and, (14)

$$a_1 = (1 - d)(M_2N_1 - M_1N_2)[M_1(N_2 - N_1) \ln d]^{-1} \tag{15}$$

$$a_2 = (1 - d)(M_2N_1 - M_1N_2)[M_1(N_2 - N_1) \ln d]^{-1} \tag{16}$$

$$L_1 = N_1(M_2 - M_1)(1 - d)[M_1(N_2 - N_1)] \tag{17}$$

From the equation (10) and (17)

$$\phi = 15(M_2 - M_1)(1 - d)[2\pi^2 D_i^2 h (N_2 - N_1)]^{-1} \tag{18}$$

and

$$s_y = (1 - d)(M_2N_1 - M_1M_2)[2\pi^2 D_i^2 h (N_2 - N_1) \ln d]^{-1} \tag{19}$$

i),ii),v),vi)

This is the method to solve ϕ and s_y without using the trial and error method.

As the special case, for Newtonian-liquid,

$$a_1 = a_2 = 0$$

and

$$L_1 = L_2 = 1 - d$$

also

$$M_1N_2 = M_2N_2 = 1$$

then

$$\phi = (15 \cdot M_1 \cdot g_c)(1 - d)(2\pi^2 D_i^2 h N_1)^{-1}$$

and

$$s_y = 0$$

3. EXPERIMENTAL DATA

Samples of molasses were taken from Kita-Daitoh Seitoh K. K., Irabu-Seitoh K. K., Ishigaki-Jima Seitoh K. K., Miyako-Jima Seitoh K. K., Miyata-Seitoh K. K. and Kumejima-Seitoh K. K., the following datas were obtained.

(A) Relationship between temperature and plasticity for molasses. from 20°C 40°C;

Temperature °C	KDT $x10^3$	IBU $x10^3$	IGK $x10^3$	MKO $x10^3$	MTA $x10^3$	KMA $x10^3$ (poise)
20	5.91	7.22	8.01	13.7	15.6	22.3
21	5.44	6.58	7.65	12.1	13.8	19.2
22	5.04	6.02	7.00	10.8	12.2	16.9
23	4.70	5.58	6.59	9.78	10.9	14.9
24	4.39	5.20	6.21	8.88	9.91	13.3
25	4.15	4.46	6.00	8.11	9.05	12.0
26	3.93	4.35	5.61	7.50	8.32	10.8
27	3.73	4.33	5.20	6.95	7.68	10.0
28	3.56	4.10	5.00	6.50	7.12	9.20
29	3.41	3.91	4.70	6.09	6.65	8.52
30	3.28	3.23	4.60	5.73	6.25	7.81
31	3.15	3.58	4.29	5.40	5.90	7.41
32	3.04	3.44	4.00	5.14	5.09	6.99
33	2.94	3.32	3.81	4.89	5.32	6.59
34	2.85	3.20	3.62	4.66	5.05	6.21
35	2.76	3.10	3.42	4.46	4.81	5.91
36	2.69	3.00	3.30	4.28	4.61	5.61
37	2.62	2.92	3.21	4.12	4.43	5.35
38	2.55	2.84	3.00	3.96	4.25	5.14
39	2.52	2.76	2.91	3.82	4.10	4.90
40	2.48	2.69	2.84	3.70	4.10	4.72

Table 2

On the table 2, abbreviations are used as follows :

KDT : Kita-Daitoh Seitoh K. K.

IBU : Irabu-Seitoh K. K.
IGK : Ishigaki-Jima Seitoh K. K.
MKO : Miyako-Seitoh K. K.
MTA : Miyata Seitoh K. K.
KMA : Kumejima-Seitoh K. K.

The relationship between temperature and plasticity is shown in Fig. 1.

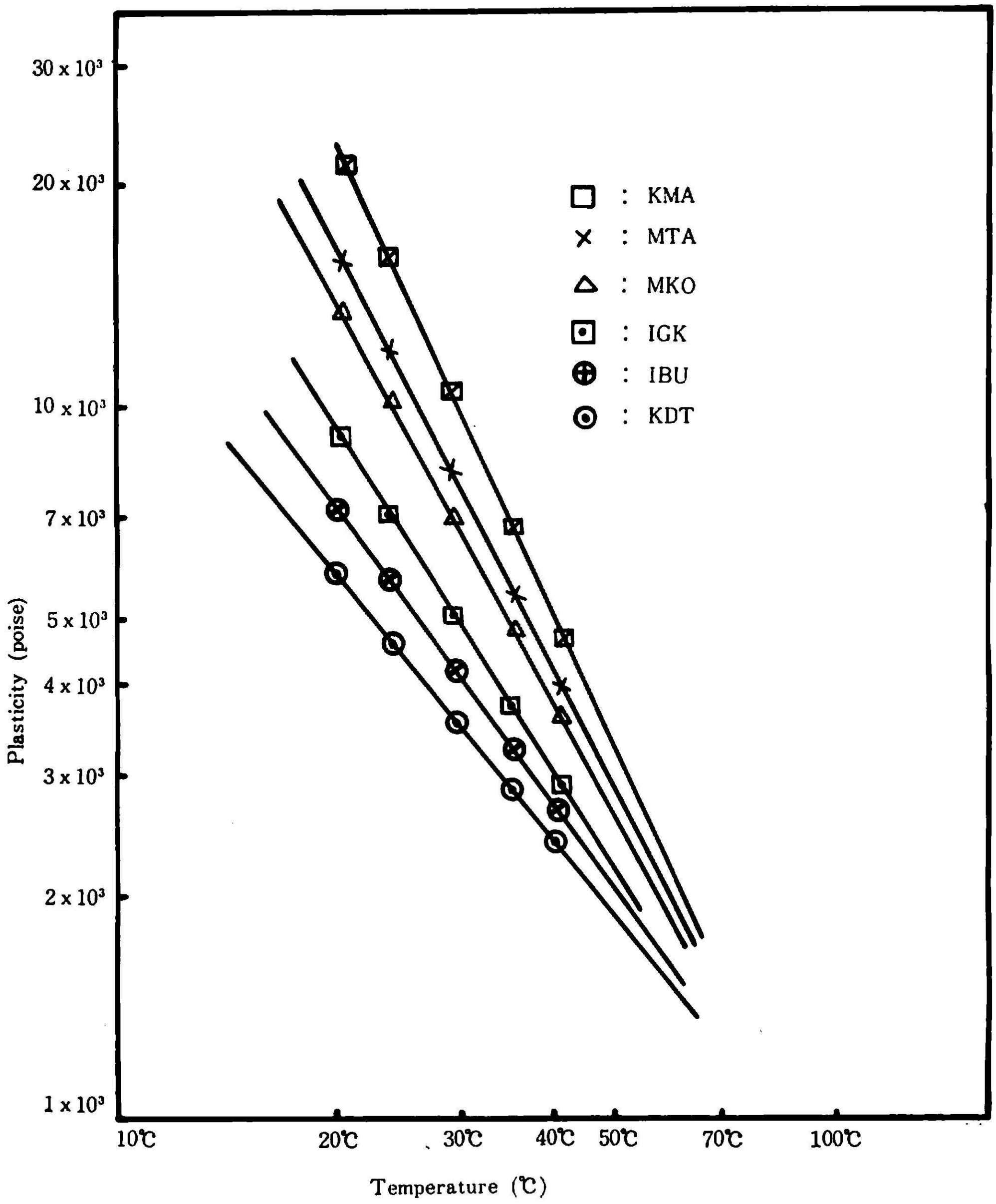

Fig. 1 The relationship between temperature and plasticity.

The following equations were obtained :

$$\text{KDT} : \phi = 3.91 \times 10^{5} \times \theta^{-1.73} \cdots\cdots (20)$$

$$\text{IBU} : \phi = 7.66 \times 10^{4} \times \theta^{-1.95} \cdots\cdots (21)$$

$$\text{IGK} : \phi = 7.45 \times 10^{4} \times \theta^{-2.03} \cdots\cdots (22)$$

$$\text{MKO} : \phi = 2.06 \times 10^{5} \times \theta^{-2.65} \cdots\cdots (23)$$

$$\text{MTA} : \phi = 4.62 \times 10^{5} \times \theta^{-3.02} \cdots\cdots (24)$$

$$\text{KMA} : \phi = 5.41 \times 10^{5} \times \theta^{-2.91} \cdots\cdots (25)$$

where,

ϕ : Plasticity
θ : Temperature in °C.

(B) Pseudc-molecular weight of molasses and plasticity relathionship were obtained by mesuring osmotic pressure of molasses, as in the following table[viii),ix),x)] ;

Molasses	Plasticity	Pseudo-molecular weight
KDT	4.15×10^{3}	25,220 at 25°C.
IBU	4.46×10^{3}	26,590
IGK	6.00×10^{3}	31,800
MKO	8.11×10^{3}	37,080
MTA	9.05×10^{3}	39,050
KMA	12.00×10^{3}	44,100

Table 3

These results depend on the plasticity at the temperature 25°C, and the relationship is expressed in the following equation :

$$\phi = 0.72 \times M_{p}^{1.98} \cdots\cdots (26)$$

where,

ϕ : Plasticity
M_p : Pseudo-molecular weight

The relationship between the plasticity and pseudo-molecular weight is shown in Fig. 2.

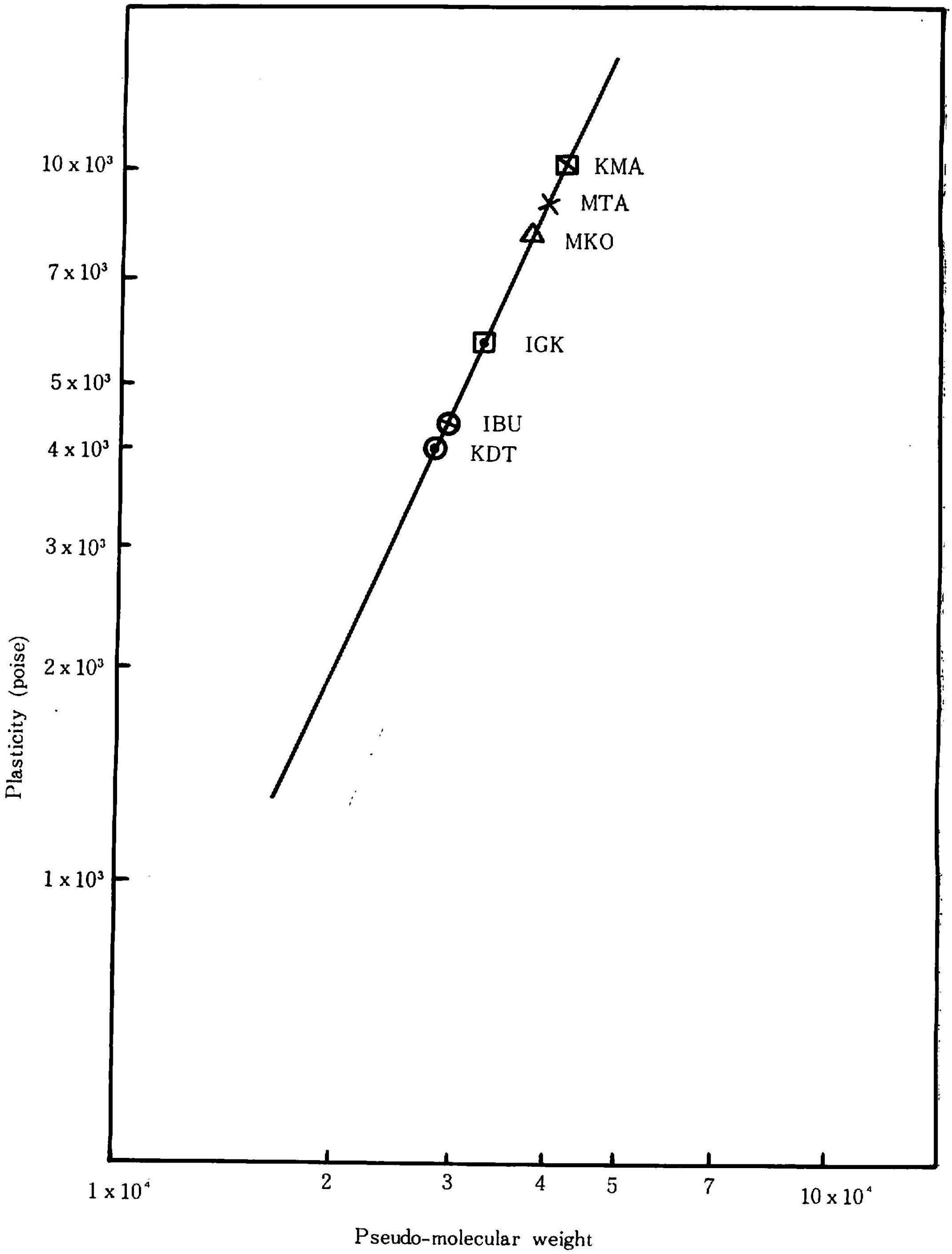

Fig. 2 The relation-ship between the plasticity and pseudo-molecular weight.

(c) Specific heat of molasses and the constant "n" are obtained by measuring radiation[iii)] and shearing stress[i),ii)] as in the following table[xi),xii),xiii)];

Molasses	Shearing stress	constants	Specific heat
KDT	0.235	2.31	0.22
IBU	0.599	2.34	0.23
IGK	0.599	2.47	0.23
MKO	0.573	2.08	0.22
MTA	0.615	2.62	0.22
KMA	0.835	2.67	0.22

Table 4

4. CONCLUSION

On this investigation, study on the rheological constants for the molassesin Okinawa, the following results were obtained.

Molasses	ϕ (poise)	Mp	n	Shearing stress	Specific heat
KDT	4.15×10^5	25,220	2.31	0.235	0.22
IBU	4.46×10^5	26,590	2.34	0.599	0.23
IGK	6.00×10^5	31,800	2.47	0.599	0.23
MKO	8.11×10^5	37,080	2.08	0.573	0.22
MTA	9.05×10^5	39,050	2.62	0.615	0.22
KMA	12.0×10^5	44,100	2.67	0.835	0.22

Table 5

For this experiment, there is a pattern, the plasticity and other rheological constants are difference from the molasses which produced in factories of Okinawa main island.

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