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Dissolution Of Ferrous Into Molten Of Aluminum-Copper:A Proposed Dissolution Rate Constant

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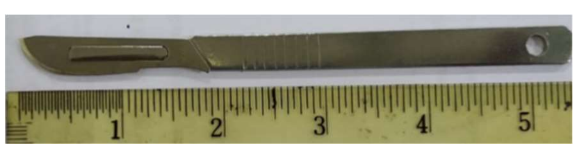
Abstract – In the previous research, a surgical blade was immersing into a molten aluminum-copper alloy and then destroy. A conventional corrosion rate equation is not used directly to predict a need time for the surgical blade to destroy. A corrosion rate constant should be corrected to become a dissolution rate constant. The aim of research is to propose a dissolution rate constant. Method. The molten of aluminum-copper was melted at 750 ^{0}C for 30 minutes. The samples were 4 steel-cutters. Next the sample was weighed firstly. Second, the half part of sample was immersed into molten aluminum-copper alloy for a certain time (10; 20; 30 and 60 minutes). Next the sample was pull out and a sticked aluminum was removed from the sample surface. Finally, the sample was weighed again. The thickness of sample was measured. The experimental results. The thickness of steel-cutter becomes thinner with increasing the dipping time. The K (dissolution rate constant) is 2.34.

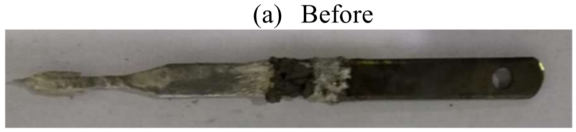
INTRODUCTION

The dissolution of ferrous alloy into molten a non-ferrous alloy is an interesting field to study [1, 2, 3, 4, 5, 6]. In the previous research, a surgical blade was immersing into a molten aluminum-copper alloy and then destroy as shown in Figure 1 [7, 8, 9]. A conventional corrosion rate equation is not applied directly to predict a need time for the surgical blade to destroy. A corrosion rate constant should be corrected to become a dissolution rate constant.

Immersing into molten metal alloy reduces the diameter of sample. Increasing dipping time increase rectifying diameter of sample as shown in Figure 2. [10]. Corrosion is defined as the destructive and unintentional attack of a metal; it is electrochemical and ordinarily begins at the surface [10, 11]. A rate of corrosion is the speed at which any given metal deteriorates in a specific environment (examples: water and sea water) [12].



(a) Before



(b) after

FIGURE 1. a surgical blade was immersed into a aluminum-copper alloy

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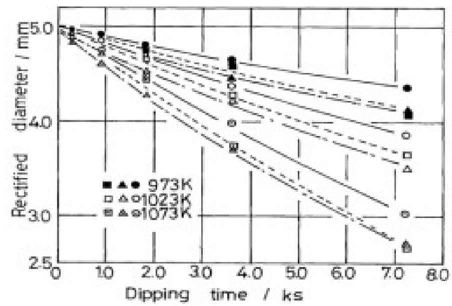


FIGURE 2. Relation between rectified diameter and dipping time (● ○ ● —Fe-3Ni, ▲ △ ▲ ~-~Fe2C, ■ □ ■---- Fe-3C). is distributed in Al bath homogeneously. [2]

The Corrosion rate equation is shown in Equation (1)

$$CR = (W.\,K) / (\rho.\,A.\,t) \tag{1}$$

Where:

CR	:	corrosion rate	ρ	:	density	*K*	:	constant of corrosion rate
W	:	weight	*A*	:	area	*t*	:	time

In order to predict a need time for the surgical blade to destroy the Equation (1) is used after the corrosion rate constant should be corrected to become a dissolution rate constant. The aim of research is to propose a dissolution rate constant.

METHOD

Figure 3 shows the research flowchart, an copper wire is weight for 40 gram and an aluminum is for 60 gram. The alloy is melted by a heating furnace. Then the Al-Cu Alloy molten was mixed by a stick at 800 ^{0}C and then hold for 30 minutes. Then the molten was ready. Second step the samples (4 steel-cutters) were washed, dried and then weighted. Next the half of length of each sample was immersed into the molten aluminum-copper alloy for a certain time (10; 20; 30 and 60 minutes). Then the furnace door was closed. Next the dipped sample was picked out. the sample surface was cleaned from a sticked metal. The thickness, width and length of dipped area were measured. Next each sample was reweighted. Finally, some calculation was done to find a dissolution rate constant.

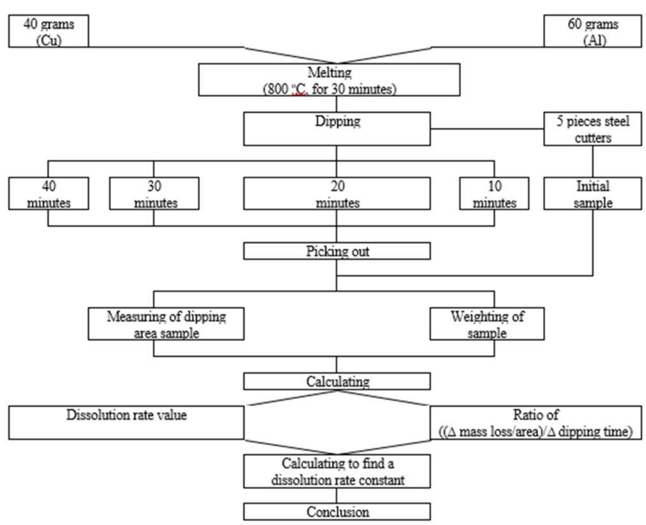
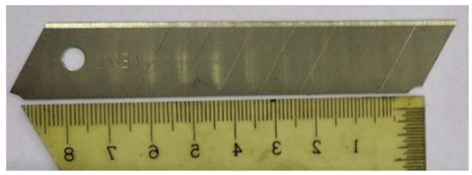


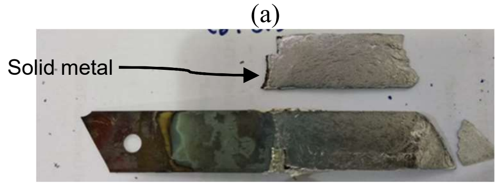
FIGURE 3. Research Flowchart

RESULTS AND DISCUSSION

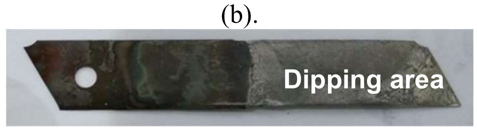
In this research, a half of length of sample was immersed into the molten of Aluminum-copper alloy with certain times. There was a thin metal (aluminum-copper alloy) stick on the surface. But it is easy to remove. (Figure 4). The dipping area of sample is location of dimension measuring (thickness, width and length).



(a)



(b).



(c)

FIGURE 4 The initial sample (a). A thin sticked metal is removed from the sample (b).
The sample (dipping area) was ready to thickness measuring (c)

Table 1 shows the results of thickness measuring. Table 2 shows the weight of the steel-cutter sample before (Wo) and after (W1) dipping into the molten aluminum-copper alloy. Table 3 shows the result of calculated dipping area.

TABLE 1. Thickness of Sample (mm)

No	Dipping time (minutes)				
	Initial sample	**10’**	**20’**	**30’**	**60’**
Average thickness	0.50 mm	0.381 mm	0.345 mm	0.271 mm	0.214 mm
Thickness loss	0	0.119 mm	0.155 mm	0.229 mm	0.286 mm

TABLE 2. Weight of sample before (Wo) and After (W1) dipping into molten

Dipping time		W0	W1	Mass Loss
Minutes	**(second)**	**(g)**	**(g)**	**(g)**
10	600	6,500	5,710	0,79
20	1200	6,503	5,388	1,115
30	1800	6,500	5,246	1,254
60	3600	6,476	4,671	1,805

TABLE 3. Mass Loss/Dipping Area

Dipping time		Mass Loss	Dipping area	Mass loss/dipping area
(Minutes)	**(Second)**	**(g)**	**(mm^2)**	**(g/mm^2)**
10	600	0,79	1914	0,00041
20	1200	1,115	1809,6	0,00062
30	1800	1,254	1660,8	0,00076
60	3600	1,805	1557	0,0012

The data in Table 1 are plot in a graphic as Figure 5. Based on the Figure 5 it can be shown that increasing in the dipping time reduce the thickness. For example, dipping times from 0 to 3600 second reduces the thickness from 0,5 mm to 0,21 mm. It is a proof that the sample dissolve into the molten. Phenomena of dissolution steel cutter into molten like as phenomena of “corrosion”.

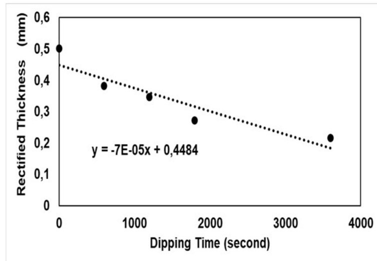


FIGURE 5. Relationship between dipping time and thickness

The dissolution rate equation can be analog with the corrosion rate equation [1] as follows:

$$DR = (W_1 . K_1) / (\rho . A_1 . T_1) \quad (2)$$

Where:

DR	:	Dissolution rate (mm/second)	K_1	:	Constant of dissolution rate	A_1	:	Dipping area (mm^2)
W_1	:	Mass loss (g)	ρ	:	density of ferrous (g/mm^3)	t_1	:	Dipping time (second)

The equation (2) can be rewritten as

$$DR = \left((W_1 / A_1)/t\right) \times (K_1 / \rho) \quad (3)$$

The dissolution rate constant can be calculated as an equation (4)

$$(K_1 / \rho) = DR \;/\; \left((W_1 / A_1)/t\right) \quad (4)$$

The value of Dissolution Rate (DR) can be found as an equation (5).

$$DR = (\text{Thickness loss / Dipping Time}) \quad (5)$$

The value “$((W_1/A_1)/t)$” is shown as an equation (6).

$$((W_1/A_1)/t) = ((\Delta \text{ mass loss/area})/ \text{ dipping time} \quad (6)$$

Finding dissolution rate value (*DR*)

The thickness loss increases with increasing dipping time as shown in Table 1 and Figure 6. The equation (7) is a linear regression for relationship between thickness loss with dipping time

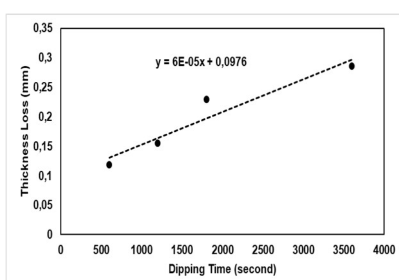


FIGURE6. Relationship between dipping time and thickness loss

$$y = 6.10^{-5}\, x + 0{,}0976 \quad (7)$$

where y = thickness loss (mm)

x = dipping time (sec)

According to equation (7), the ratio of (thickness loss/dipping time) is nearly to 6.10^{-5} mm/sec. Thus the dissolution rate value (DR) (equation (5)) can be wrote as:

$$DR \approx 6.10^{-5} \text{ mm/second} \tag{8}$$

Finding Ratio of ((Δ mass loss/area)/Δ dipping time)

Based on Table 2 and Table 3, a graph ((Δ mass loss/area) versus dipping time) is made and shown in Fig. 7. Their relationship is illustrated by equation (9).

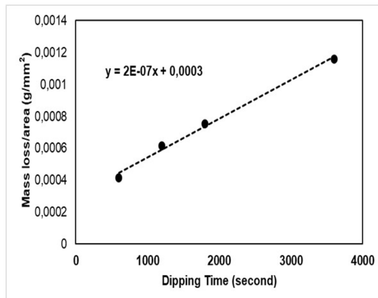


FIGURE 7. Relationship between dipping time and mass loss/area

$$y = 2.\ 10^{-7}\ x + 0.0003 \tag{9}$$

where
y is ratio of mass loss with area or (W_1/A_1) and x is time (t).

Based on equation (9) it is found that

$$((W_1/A_1)/t) \approx 2.10^{-7}\ (\text{g} / (\text{mm}^2.\text{second})) \tag{10}$$

Finding Dissolution Rate constant (K_1)

The equation (4) can be written since the equation (8) and the equation (10) are substituted

$$(K_1/\rho) = (6.10^{-5}) / (2.10^{-7}). \tag{11}$$

Since $\rho = 7.8\ 10^{-3}$ (gram/mm^3), the equation (11) becomes

$$K_1 = (6.10^{-5} \times 7.8\ 10^{-3}) / (2\ 10^{-7}) \tag{12}$$

$$K_1 = 2.34 \tag{13}$$

CONCLUSIONS

The conclusion are as follows:

1. Since the steel cutter was immersed into molten aluminum-copper, the thickness of steel cutter becomes thinner.
2. Increasing the dipping time reduced the thickness of steel cutter.
3. $DR = (W_1 . K_1 .) / (\rho . A_1 . t_1)$

Where:

DR	:	Dissolution rate (mm/second)	ρ	:	density of sample (gram/mm^3)
$W1$	:	Mass loss (gram)	A_1	:	Dipping area (mm^2)
K_1	:	Constant of dissolution rate =2.34	t_1	:	Dipping time (second)

ACKNOWLEDGMENT

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Dissolution Of Ferrous Into Molten Of Aluminum-Copper:A Proposed Dissolution Rate Constant

by Rosalina Tjandrawinata FKG

AIP Conference Proceedings

RESEARCH ARTICLE | MAY 03 2023

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Dissolution Of Ferrous Into Molten Of Aluminum-Copper:A Proposed Dissolution Rate Constant

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[2)] *Department of Electrical, Faculty of Industrial Engineering, Universitas Trisakti Jalan Kyai Tapa No 1, Jakarta 11440, Indonesia*
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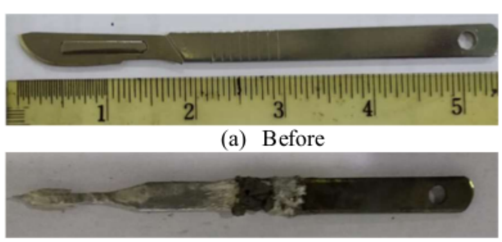
Abstract – In the previous research, a surgical blade was immersing into a molten aluminum-copper alloy and then destroy. A conventional corrosion rate equation is not used directly to predict a need time for the surgical blade to destroy. A corrosion rate constant should be corrected to become a dissolution rate constant. The aim of research is to propose a dissolution rate constant. Method. The molten of aluminum-copper was melted at 750 ^{0}C for 30 minutes. The samples were 4 steel-cutters. Next the sample was weighed firstly. Second, the half part of sample was immersed into molten aluminum-copper alloy for a certain time (10; 20; 30 and 60 minutes). Next the sample was pull out and a sticked aluminum was removed from the sample surface. Finally, the sample was weighed again. The thickness of sample was measured. The experimental results. The thickness of steel-cutter becomes thinner with increasing the dipping time. The K (dissolution rate constant) is 2.34.

INTRODUCTION

The dissolution of ferrous alloy into molten a non-ferrous alloy is an interesting field to study [1, 2, 3, 4, 5, 6]. In the previous research, a surgical blade was immersing into a molten aluminum-copper alloy and then destroy as shown in Figure 1 [7, 8, 9]. A conventional corrosion rate equation is not applied directly to predict a need time for the surgical blade to destroy. A corrosion rate constant should be corrected to become a dissolution rate constant.

Immersing into molten metal alloy reduces the diameter of sample. Increasing dipping time increase rectifying diameter of sample as shown in Figure 2. [10]. Corrosion is defined as the destructive and unintentional attack of a metal; it is electrochemical and ordinarily begins at the surface [10, 11]. A rate of corrosion is the speed at which any given metal deteriorates in a specific environment (examples: water and sea water) [12].



(a) Before

(b) after

FIGURE 1. a surgical blade was immersed into a aluminum-copper alloy

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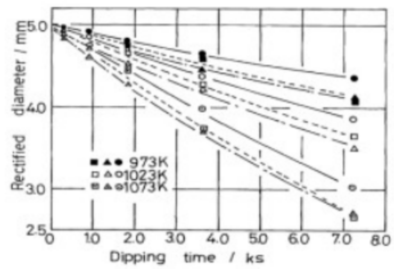

FIGURE 2. Relation between rectified diameter and dipping time (● ○ ● —Fe-3Ni, ▲ △ ▲ ~-~Fe2C, ■ □ ■---- Fe-3C). is distributed in Al bath homogeneously. [2]

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Where:

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METHOD

Figure 3 shows the research flowchart, an copper wire is weight for 40 gram and an aluminum is for 60 gram. The alloy is melted by a heating furnace. Then the Al-Cu Alloy molten was mixed by a stick at 800 ^{0}C and then hold for 30 minutes. Then the molten was ready. Second step the samples (4 steel-cutters) were washed, dried and then weighted. Next the half of length of each sample was immersed into the molten aluminum-copper alloy for a certain time (10; 20; 30 and 60 minutes). Then the furnace door was closed. Next the dipped sample was picked out. the sample surface was cleaned from a sticked metal. The thickness, width and length of dipped area were measured. Next each sample was reweighted. Finally, some calculation was done to find a dissolution rate constant.

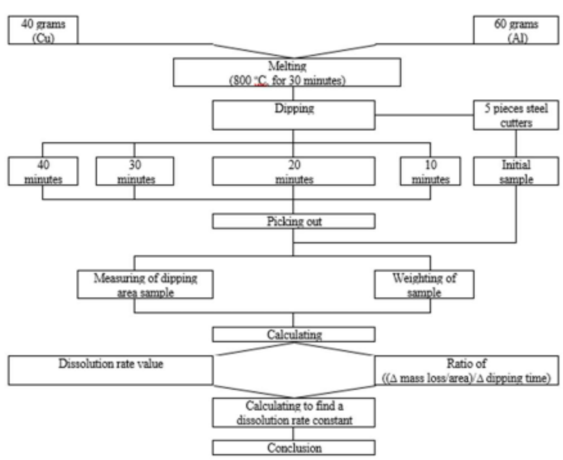
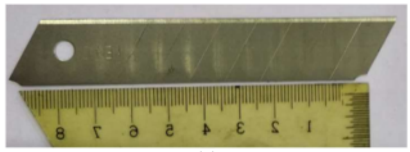


FIGURE 3. Research Flowchart

RESULTS AND DISCUSSION

In this research, a half of length of sample was immersed into the molten of Aluminum-copper alloy with certain times. There was a thin metal (aluminum-copper alloy) stick on the surface. But it is easy to remove. (Figure 4). The dipping area of sample is location of dimension measuring (thickness, width and length).



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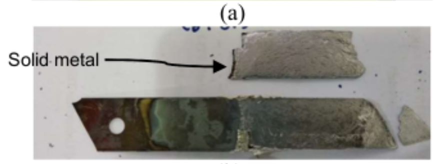

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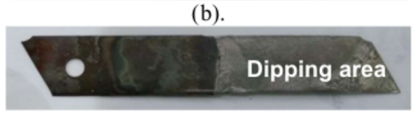

(c)

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The sample (dipping area) was ready to thickness measuring (c)

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TABLE 1. Thickness of Sample (mm)

No	Dipping time (minutes)				
	Initial sample	**10'**	**20'**	**30'**	**60'**
Average thickness	0.50 mm	0.381 mm	0.345 mm	0.271 mm	0.214 mm
Thickness loss	0	0.119 mm	0.155 mm	0.229 mm	0.286 mm

TABLE 2. Weight of sample before (Wo) and After (W1) dipping into molten

Dipping time		W0	W1	Mass Loss
Minutes	**(second)**	**(g)**	**(g)**	**(g)**
10	600	6,500	5,710	0,79
20	1200	6,503	5,388	1,115
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TABLE 3. Mass Loss/Dipping Area

Dipping time		Mass Loss	Dipping area	Mass loss/dipping area
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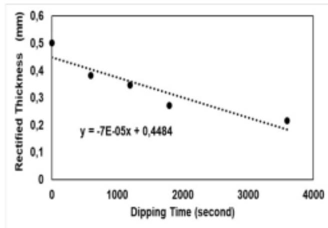

FIGURE 5. Relationship between dipping time and thickness

The dissolution rate equation can be analog with the corrosion rate equation [1] as follows:

$$DR = (W_1.\, K_1) / (\rho.\, A_1.\, T_1) \tag{2}$$

Where:

DR	:	Dissolution rate (mm/second)	K_1	:	Constant of dissolution rate	A_1	:	Dipping area (mm^2)
W_1	:	Mass loss (g)	ρ	:	density of ferrous (g/mm^3)	t_1	:	Dipping time (second)

The equation (2) can be rewritten as

$$DR = \left((W_1 / A_1)/t\right) \times (K_1 / \rho) \tag{3}$$

The dissolution rate constant can be calculated as an equation (4)

$$(K_1 / \rho) = DR \;/\; \left((W_1 / A_1)/t\right) \tag{4}$$

The value of Dissolution Rate (DR) can be found as an equation (5).

$$DR = (\text{Thickness loss / Dipping Time}) \tag{5}$$

The value "$((W_1/A_1)/t)$" is shown as an equation (6).

$$((W_1/A_1)/t) = ((\Delta \text{ mass loss/area})/ \text{ dipping time} \tag{6}$$

Finding dissolution rate value (*DR*)

The thickness loss increases with increasing dipping time as shown in Table 1 and Figure 6. The equation (7) is a linear regression for relationship between thickness loss with dipping time

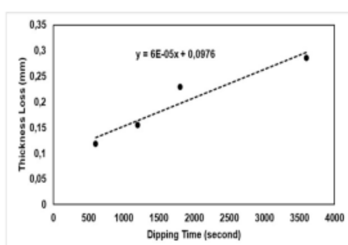

FIGURE6. Relationship between dipping time and thickness loss

$$y = 6.10^{-5}\, x + 0{,}0976 \tag{7}$$

where y = thickness loss (mm)

x = dipping time (sec)

According to equation (7), the ratio of (thickness loss/dipping time) is nearly to 6.10^{-5} mm/sec. Thus the dissolution rate value (DR) (equation (5)) can be wrote as:

$$DR \approx 6.10^{-5} \text{ mm/second} \quad (8)$$

Finding Ratio of ((Δ mass loss/area)/Δ dipping time)

Based on Table 2 and Table 3, a graph ((Δ mass loss/area) versus dipping time) is made and shown in Fig. 7. Their relationship is illustrated by equation (9).

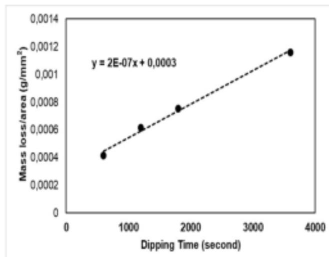

FIGURE 7. Relationship between dipping time and mass loss/area

$$y = 2.\ 10^{-7}\ x + 0.0003 \quad (9)$$

where
y is ratio of mass loss with area or (W_1/A_1) and x is time (t).

Based on equation (9) it is found that

$$((W_1/A_1)/t) \approx 2.10^{-7} \text{ (g / (mm}^2\text{.second))} \quad (10)$$

Finding Dissolution Rate constant (K₁)

The equation (4) can be written since the equation (8) and the equation (10) are substituted

$$(K_1/\rho) = (6.10^{-5}) / (2.10^{-7}). \quad (11)$$

Since $\rho = 7.8\ 10^{-3}$ (gram/mm³), the equation (11) becomes

$$K_1 = (6.10^{-5} \times 7.8\ 10^{-3)} / (2\ 10^{-7}) \quad (12)$$

$$K_1 = 2.34 \quad (13)$$

CONCLUSIONS

The conclusion are as follows:
1. Since the steel cutter was immersed into molten aluminum-copper, the thickness of steel cutter becomes thinner.
2. Increasing the dipping time reduced the thickness of steel cutter.
3. $DR = (W_1 . K_1 .) / (\rho . A_1 . t_1)$
Where:

DR	:	Dissolution rate (mm/second)	ρ	:	density of sample (gram/mm³)
$W1$	:	Mass loss (gram)	A_1	:	Dipping area (mm²)
K_1	:	Constant of dissolution rate =2.34	t_1	:	Dipping time (second)

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