A STUDY ON DARCY'S LAW ANALYSIS AND PROCESS OF Al_2O_3 FIBER/AC8A COMPOSITE BY LOW PRESSURE INFILTRATION

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Introduction

Nowadays, many areas need high strength, low density and excellent material just like in aerospace and automobile industry. Lightness metal reinforced by high strength phase now is popular [1]. Metal Matrix Composite (MMC) be paid more and more attention to research. Manufacture MMC general method is squeeze casting, but this method needs high temperature and high pressure, then preform will be destroyed under the high-pressured situation, therefore many researches about low pressure infiltration method.[2,3] The most popular application of the Darcy's law is used to infiltrate. The law is formulated by H. Darcy, used for important physical property of porous systems. In this study we use Darcy's law to advance theoretical analysis relation between infiltration depth and time.

Experimental Method

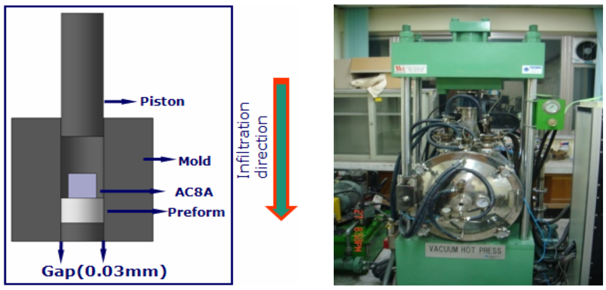
Low pressure infiltration process

The matrix material is AC8A.Table 1 shows the chemical composition. The reinforcement, we use porous preform with 10% and 20% volume fraction (V_f) of Al_2O_3/SiO_2 fiber.

Table 1. Chemical composition of the AC8A (wt %)

Cu	Si	Mg	Fe	Mn	Ni	Ti	Sn	Cr
0.99	12.2	1.05	0.38	0.12	1.02	0.06	0.05	0.04

The infiltration time is from we give pressure to piston and touch the surface of melting AC8A to pressure disappeared. The infiltrated depth is influenced not only by threshold of infiltration pressure, but also depends on the fiber volume fraction of the preform. Several sets of infiltration experiments were designed, with the applied pressure, and the fiber volume fraction of the preform, V_f maintained constant but actually they altered from one set of experimental runs to another. In our study heating speed is 10℃/min, hold point is 200℃, 400℃, 600℃ and holding time is 10min and then we increase until 650, 700, 750℃ holding 10min and infiltrate. We choose from 1 to 26s to check the infiltration depth, the reason why we didn't continue calculating is h_0=50 mm, the infiltration depth can not over h_0.



a b

Fig. 1 (a) mold of manufacture MMC, (b) vacuum hot press

Results and Discussions

Darcy's law analysis about processing

The equation as showing[4]:

$$U=\frac{k\rho}{n\mu}\times\frac{\Delta\varphi}{X} \Rightarrow X=\frac{\gamma_{lv}\cos\theta}{P_v-P_{th}-\rho g h_o}\left(\frac{P_a-P_{th}}{3\mu}\right)^{1/2}\times t^{1/2}$$

The left is original equation, right is deduced which is fit in our experiment. The parameters as showing: ***U*** *is infiltrated depth,* ***X*** *is infiltration depth,* ***k*** *is permeability,* ***n*** *is porosity,* ***ρ*** *is density,* ***μ*** *is viscosity.* ***Δφ*** *is energy loss per unit mass of liquid metal,* ***r*** *is effective capillary tube radius of the fiber preform.*

$\boldsymbol{P_a}$ *is external pressure applied to the liquid metal,* $\boldsymbol{P_c}$ *is capillary pressure at the infiltration front,* $\boldsymbol{P_v}$ *is pressure of the gas that occupies the inter fiber pores,* $\boldsymbol{\gamma_{lv}}$ *is surface tension of the liquid metal,* ***θ*** *is contact angle between the liquid metal and preform*

For the infiltration under 10% and 20% Al_2O_3/SiO_2 fiber preform and it is known from that the threshold of infiltration pressure P_{th} is 0.22 MPa with V_f=10% and is 0.35 MPa with V_f=20%. If taking h_0=50 mm, P_v=1 atm, θ=132^o, γ_{lv}=0.837-0.00013 (T=650^{o}C) Pa, ρ=2357 kg/m^3, and μ=1.39*10^{-3}Pa μs,

when P_a-P_{th}= 0.08 MPa, X= 0.020244393 * $t^{1/2}$ m=20.244393* $t^{1/2}$ mm

P_a-P_{th}= 0.15 MPa, X= 0.027720777 * $t^{1/2}$ m=27.720777* $t^{1/2}$ mm

when P_a-P_{th}= 0.08 MPa, X= 0.00976571741 * $t^{1/2}$ m= 9.76571741 * $t^{1/2}$ mm. P_a-P_{th}= 0.15 MPa, X= 0.013372259 * $t^{1/2}$ m= 13.372259 * $t^{1/2}$ mm

The theoretical relationship between the infiltrated depth and the infiltration time can be plotted as shown in Fig. 2. Table 2 is experimental and calculated data, as showing all calculated data are bigger, the reason is when we make MMC, some AC8A outflow from the mold.

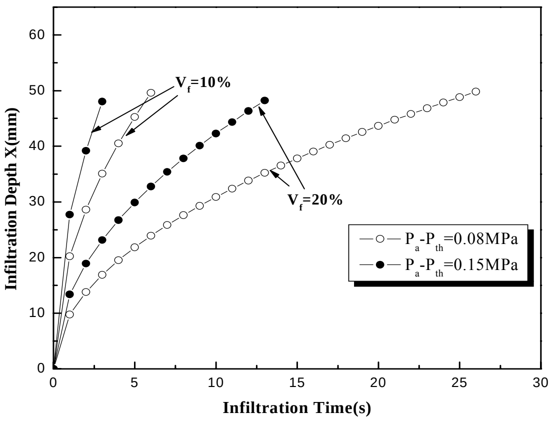


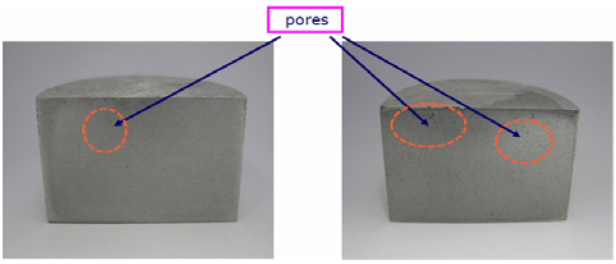
Fig. 2 Relation between infiltration depth and time.

Table 2 Values of t_0 and X in experimental and calculated

p	V_f	t_0	X(mm)	
			Calculated	Experimental
0.08	0.1	1.8	27.16	25.1
0.08	0.2	2.1	14.15	13.4
0.15	0.1	1.2	30.37	27.2
0.15	0.2	2.5	21.14	20.3

Porosity analysis

Fig. 3 shows the longitudinal section of MMC, quantity of pores inside MMC, V_f=10% is less than 20%



V_f=10% V_f=20%

Fig. 3 The longitudinal section of MMC

Relative density analysis

The cross section image can not determine the quality of MMC, because same MMC the different cross section porosity is different, so we use total MMC's specific density to check MMC's quality. Fig. 4 shows the full color icon is we using the equation to get the specific density, the virtual icon is we use optical microscope to check, both of theirs data all similar. V_f low, it means easily to enter AC8A into preform and if infiltration temperature is high the viscosity is low , easier to infiltration. And we count the specific density use the equation is:

$$Density\,\rho = \frac{MMC\,mass}{preform\,mass + (1 - V_f) \times MMC\,volume \times \rho_{AC8A}}$$

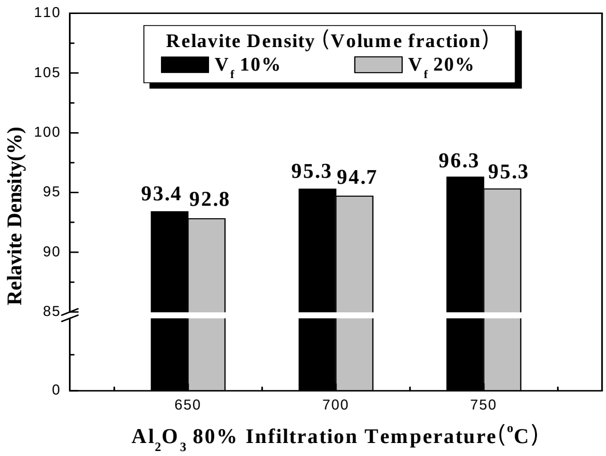


Fig.4 Relative density of MMC.

The viscosity coefficient of flowing mediator, increasing flows temperature, the relationship between both of them is proportional. According to continuity principle of flow, not only due to law of conservation of mass and Darcy's law, but also the density of 20% is higher than 10%, more difficult to infiltrate aluminum into the preform. So during manufacture, we need give higher pressure and infiltration temperature.

Conclusions

The experimental data are fit on the calculated by the equation. Infiltration depth and $t^{1/2}$ is pro portional. If V_f is high, need high pressure. Qua ntity of pores inside MMC, V_f=10% is less than 20%.

Acknowledgments

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