Gradient Ejection Melt Spinning and Puddle-less Melt Spinning Process for Aluminum Alloy Foil Rapid Solidification

Toshio HAGA , Kazuo MATSUOKA , Shin TAKEUCHI
Daiei UEJIM and Yuichiro ISHIBASHI

Dept. of Mechanical Engineering, Osaka Institute of Technology
5-16-1 Omiya, Asahi-ku, Osaka city 535-8585, Japan

ABSTRACT To make rapidly solidified foil with sound free solidified surface, two types of single roll processes were developed. To reduce the size of puddle is necessary for making free solidified surface sound. So, influence of some casting factors which weren't investigated before was tested in this study. One is ejection angle of melt and the other is back break of puddle. As a result of this study, foils cast by developed processes are better than that cast by conventional single roll rapid solidification process PFC (Planar Flow Casting).

Keywords: *rapid solidification, single roll, foil, melt spinning, planar flow casting*

1. INTRODUCTION

PFC(Planar Flow Casting[1]) is used to make rapidly solidified foil. In casting of aluminum alloy foil by PFC, free solidified surface doesn't necessarily become sound. The cause of defect on the free solidified surface is interference between front flow of puddle and front tip of nozzle[2]. To make free solidified surface sound, factors which affect front flow of puddle must be investigated. In this paper, effect of ejection angle of molten metal, nozzle shape, and back break[2] on the front flow of puddle and free solidified surface of the foil are shown.

2. EFFECT OF HOLDING OF THE PUDDLE

Schematic illustration of melt around the nozzle is shown in Fig.1. The holding of puddle has the effect of making the front flow of puddle small, and preventing the back break of puddle. The front flow and back break of puddle is controlled by the Nozzle-roll gap. The front flow becomes big and back break happens when nozzle-roll gap becomes wide.

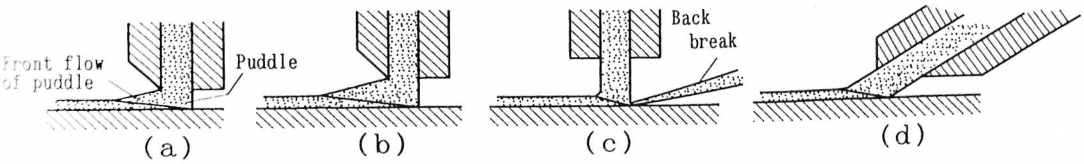

Fig.1 Relation between nozzle and molten metal ejected from nozzle.

3. EXPERIMENTAL METHOD AND EQUIPMENT

Experimental apparatus is shown in Fig.2. The size of copper roll is ϕ 300 × 100m. A rectangular slit nozzle is 0.5 × 20mm. The roll speed is set at 40m/s. This speed is higher than that of usual single roll rapid solidification. The aluminum alloy foil with fine surface can be made at the speed more than 40m/s by single roll method. Specimen is Al-12mass%Si. Ejection angle is set at the range of 15~90 degrees. Nozzle type is shown in Fig.3. Type (a)~(b) were used at the ejection angle of 90 degrees and type (d) and (e) were used at the ejection angle of 15~60 degrees. Type (f) was used at the condition of α=40 degrees, G=0.1mm and foil was cast with back break.

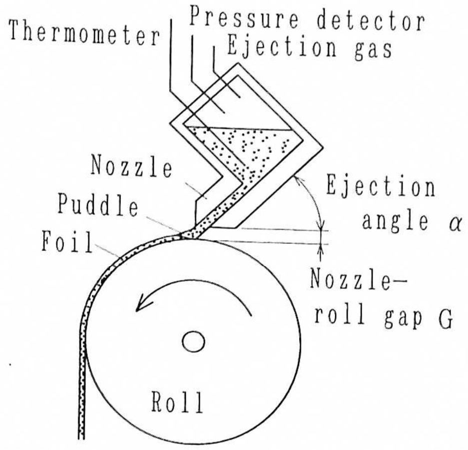

Fig.2 Experimental apparatus.

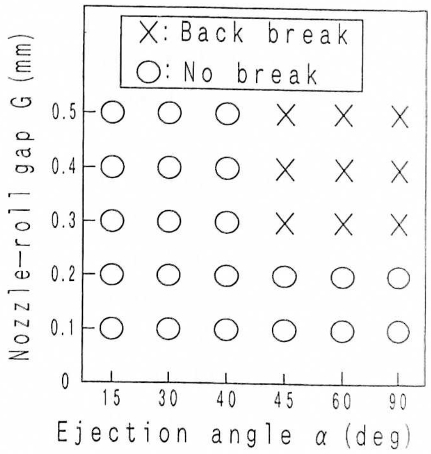

Fig.4 Relation among nozzle-roll gap, ejection angle and back break.

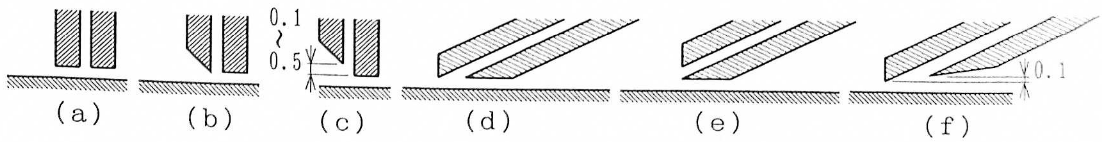

Fig.3 Schematic illustration of nozzles used in this study.

5. BACK BREAK OF METAL(BREAKING OF PUDDLE)

Effect of ejection angle and nozzle-roll gap on back break is shown in Fig.4. Ejection angle and nozzle-roll gap has significant influence on back break. Back break doesn't happen at the gap narrower than 0.3mm. And back break doesn't happen if ejection angle is less than 40 degrees. So holding of puddle isn't need at the ejection angle of less than 40 degrees.

6. Nozzle shape and surface condition of foil (angle=90degrees)

Relation between nozzle shape and foil surface at ejection angle α=90 degrees is shown in Fig.5. When ejection angle is 90 degrees, method is same as PFC. There are defects like scratch on the free solidified surface by using nozzle type (a) which tip is flat. Line pattern defect is formed by semisolid small puddle which is between the foil and nozzle. Front of type(b) nozzle is sharp, so there is less semisolid small puddle than type(a). When nozzle-roll gap of type(b) is 0.2 mm and 0.6mm of type(c), there are line pattern and wave pattern defect on the free solidified surface. The stretch of front flow of puddle causes wave pattern defect. As nozzle-roll gap becomes wide, front flow becomes big and front edge of puddle vibrates. When nozzle-roll gap is 0.5mm, there isn't line pattern defect. It seems likely that when nozzle-roll gap is wider than 0.5mm, nozzle doesn't interfere with puddle. Interference between nozzle and puddle has an significant influence on the free solidified surface. To make free solidified surface sound, the size of puddle must be restricted.

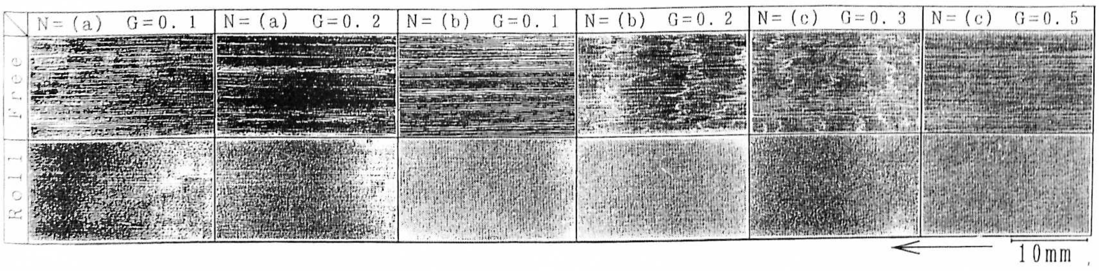

Fig.5 Surface of the foil. N : nozzle, G :nozzle-roll gap, ejection angle=90degrees

7. PUDDLE ISN'T HELD BY NOZZLE

Nozzle type (c) and (d) was used. Nozzle-roll rasp was set at 0.5mm, so puddle wasn't held by the nozzle. When foil was cast by type (c) nozzle, gap between roll and back side of nozzle was set at 0.1mm. There isn't remarkable difference in the condition of roll contacting surface of the foils as shown in Fig.6. Free solidified surface of the foil cast at the condition of α=15 degrees is best . As ejection angle becomes narrow, slit open width become wide and front flow of puddle becomes small, so significant wave pattern defect isn't formed on the free solidified surface.

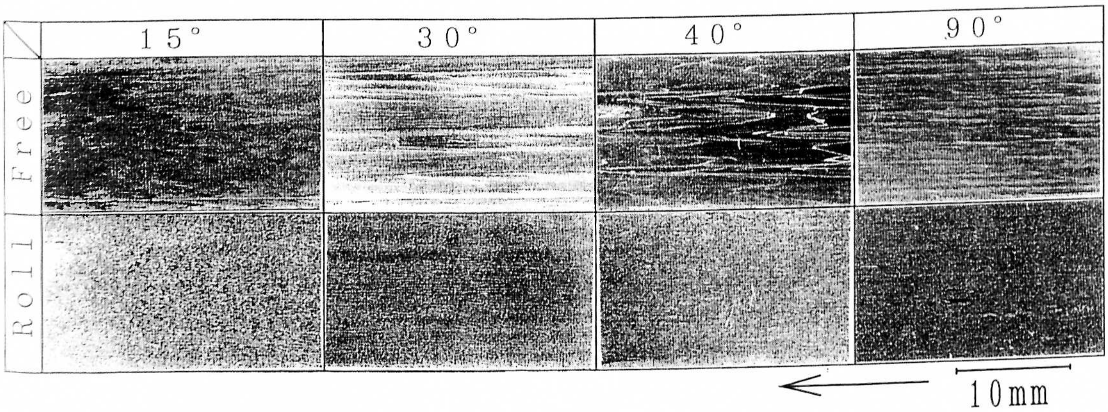

Fig.6 Surface of the foil. G=0.5mm, (α=90° , N= (c)), (α=15,30,40° , N= (d))

8. BACK SIDE OF PUDDLE IS HELD BY NOZZLE

Type (c) and (e) nozzle were used. Gap between back side of nozzle and roll was set at 0.1mm. In case where α=15,30 and 90degrees, wave pattern defect is formed as shown in Fig.7. When α is 90 degrees, front flow of puddle becomes big , and melt flows to the rotating direction between the nozzle and roll. In this condition, nozzle-roll gap is too narrow. As ejection angle becomes narrow, the component of rotating direction of velocity becomes big and front flow becomes big. Free solidified condition at α=15,30 degrees is better than that of α=90degrees. At the condition of α

=40degrees, free solidified surface is excellent. But, periodical defect exists on the roll contacting surface. It's clear that free solidified can be made sound without holding the puddle.

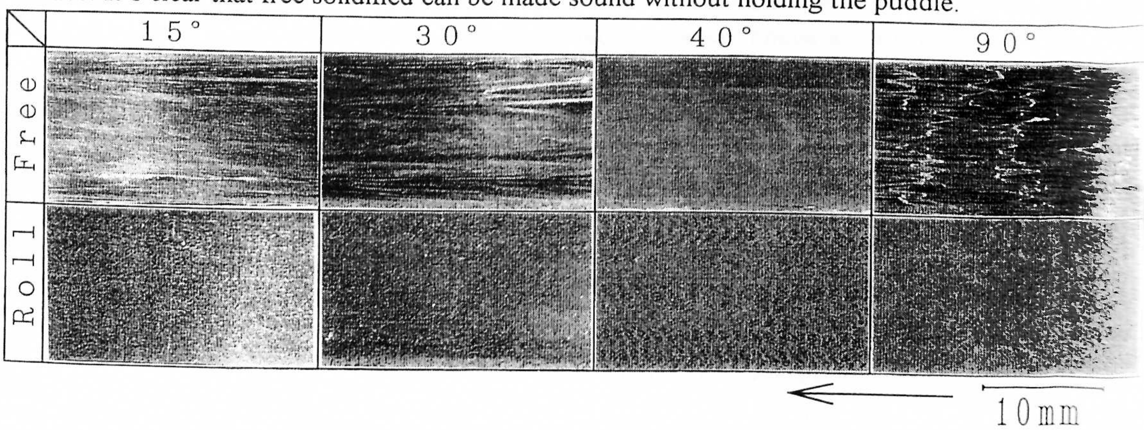

Fig.7 Surface of the foil. G=0.1mm, (α=90° , N= (c)), (α=15,30,40° , N= (e))

9. PUDDLE IS HELD BY NOZZLE

Type(b) and (f) nozzle were used. When ejection angle is 40 and 90 degrees, there is line defect on the free solidified surface (ref.Fig.8). Front flow is held by nozzle and its size becomes small, so wave pattern defect isn't formed. When α=15 degrees, there isn't line pattern defect but wave pattern defect is. As ejection angle becomes smaller, height of front flow becomes low and length becomes long. So, nozzle doesn't interfere with puddle. When ejection angle is 30 degrees, there isn't line and wave pattern defect. Front flow of puddle is considered to be optimum size at this condition.

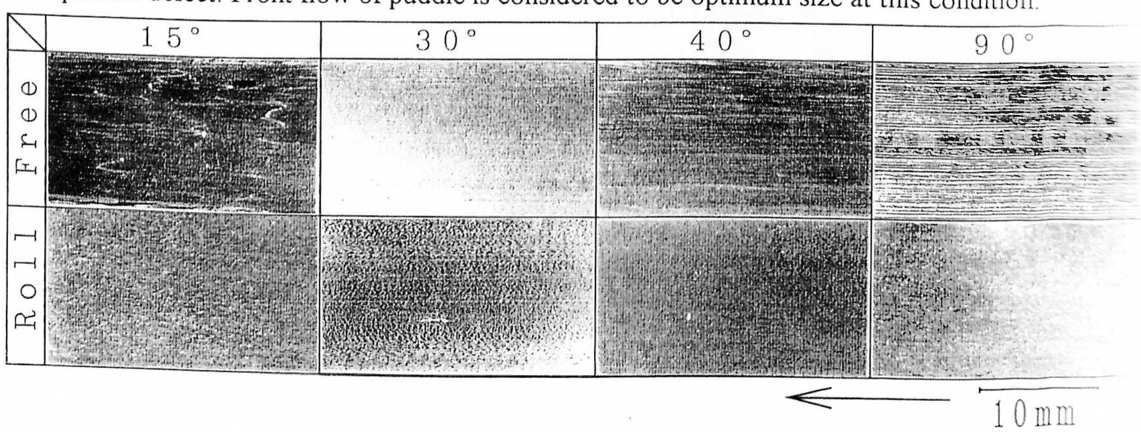

Fig.8 Surface of the foil. G=0.1mm, (α=90° , N= (c)), (α=15,30,40° , N= (d))

10. EXELENT FOIL OF EACH PROCESSES

Excellent foils made by four types of processes are shown in Fig.9. The foils made by these conditions that back side of puddle is held (α=40degrees, gap=0.1mm) and puddle is held by nozzle(α=30degrees, gap=0.1mm) are the most excellent. Gradient ejection is useful for making free solidified surface sound. It isn't always necessary to hold puddle in casting foil by single roll.

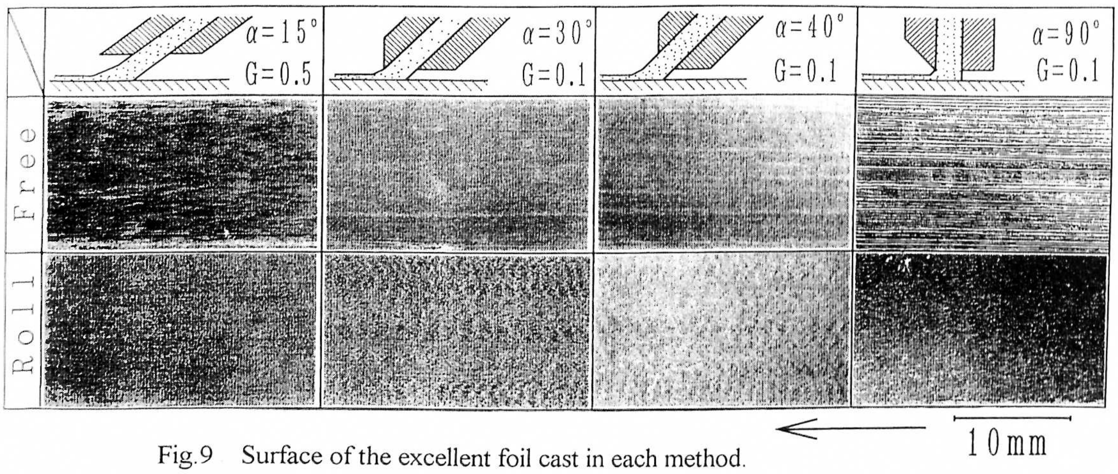

Fig.9 Surface of the excellent foil cast in each method.

11. WETTING PATTERN ON THE ROLL CONTUCTING SURFACE

Wetting pattern is shown in Fig.10. Ejection angle doesn't affect on the air pocket on roll contacting surface. Roll speed of this experiment is very high, so roll speed dominates primarily wetting pattern more than ejection angle of molten metal.

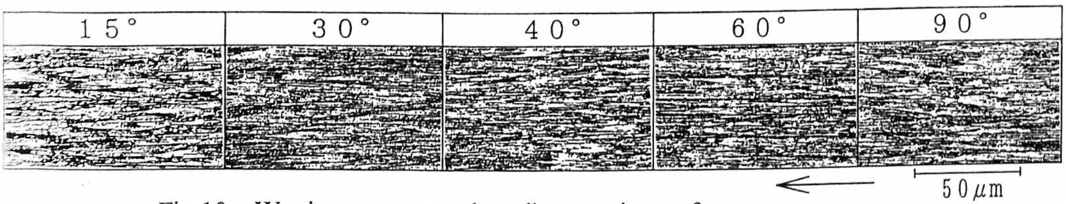

Fig.10 Wetting pattern on the roll contacting surface.

12. PUDDLE-LESS MELT SPINNING PROCESS

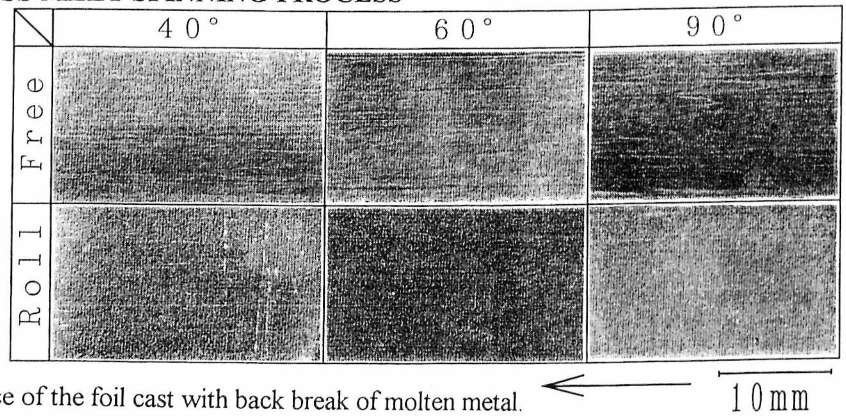

Fig.11 Surface of the foil cast with back break of molten metal.
(α=90°, N= (b), G=0.3mm), (α=60°, N=(d), G=0.3mm), (α=40°, N=(f), G=0.1mm)

Foil can be cast at the condition that puddle is broken and melt flies off toward backward. Fig.12 shows the surfaces of the foils cast with back break of melt. Roll contacting surface cast with back break isn't different from roll contacting surface cast without back break. Free solidified surface of the foil with back break is better than that without back break. This reason is thought that front flow of puddle with back break becomes smaller than without back break. Ejection angle of melt doesn't affect the surface condition of foil. The mass of back breaking melt becomes less as angle becomes small.

13. FRONT FLOW OF PUDDLE

Fig.12 shows observation in casting foil. Front flow of puddle can be observed. When wave pattern is exist on the free solidified surface, tip of the front flow is wave shape. Foil with sound free solidified surface is cast at the condition that puddle is very small or tip of the puddle isn't disturbed like wave shape.

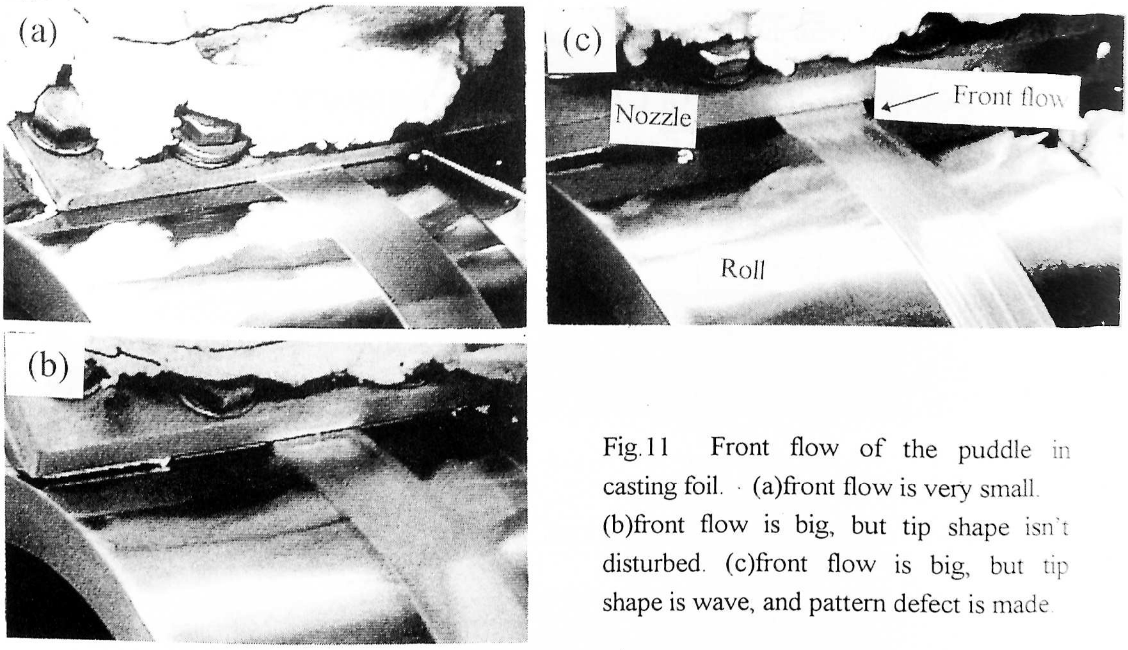

Fig.11 Front flow of the puddle in casting foil. (a)front flow is very small. (b)front flow is big, but tip shape isn't disturbed. (c)front flow is big, but tip shape is wave, and pattern defect is made.

14. CONCLUSION

Aluminum alloy foil with sound free solidified surface could be cast by Gradient Ejection Melt Spinning and Puddle-less Melt Spinning Process. Holding the puddle isn't always necessary to make free solidified surface sound. The smaller front flow of puddle becomes, the better free solidified surface becomes. Gradient ejection of melt and back break of melt useful for making front flow of puddle small.

REFERENCES

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