POLISH ACADEMY OF SCIENCES - MATERIALS SCIENCE COMMITTEE
SILESIAN UNIVERSITY OF TECHNOLOGY OF GLIWICE
INSTITUTE OF ENGINEERING MATERIALS AND BIOMATERIALS
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Conference Proceedings

11th INTERNATIONAL SCIENTIFIC CONFERENCE
ACHIEVEMENTS IN MECHANICAL & MATERIALS ENGINEERING

Thixoforming of laminate made from semisolid cast strips

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In order to reduce the cost of the feedstock, a laminate, in the form of a slug, made from roll cast strips has been used as feedstock for thixoforming. A high-speed twin roll caster was used to cast A356 strip from which the laminate was manufactured. The strip thickness varied from 3 mm to 2 mm, when the strip was cast at the speed from 30 m/min to 90 m/min. The strip was cast from semisolid slurry that was produced using a cooling slope. The primary crystal of the strip become spheroidal when heated up to semisolid condition. The ability of the laminate to flow, in the semisolid condition, was similar to that of conventional feedstock for thixoforming.

1. INTRODUCTION

Thixoforming has many advantages over casting, for example, better mechanical properties, less energy intensive process, longer die-life, to name a few. However, special feedstock, usually in the form of slugs (ingot), is needed for thixoforming. The special slugs (feedstock) used in thixoforming, must have spheroidal primary crystals as opposed to the dendritic structures associated with castings, therefore, slugs that are not made specifically for thixofrming, i.e. not possessing the appropriate microstructures, cannot be used.

On the other hand, the technique described here utilizes a twin roll caster that has the advantages of low running costs and rapid solidification. If the strip that is cast by the twin roll caster could be used as the feedstock for thixoforming, the costs associated with this produces would be substantially reduced. Ingots, cast from semisolid slurry, exhibited microstructures that contained spheroidal primary crystals in a liquid matrix, when re-heated up to the semisolid condition. In this present study, semisolid strip casting, using a cooling slope, has been experimentally investigated as a possible production route of thixoformable feedstock and the microstructures of the resulting products were assessed in the semi-solid state. Thixoforming of laminate slugs assembled from semisolid cast strip has been tried, and the mechanical properties of the products assessed.

2. EXPERIMENTAL PROCEDURE

2.1 Strip casting

A356 aluminum alloy was used. This casting alloy is commonly used for thixoforming applications. In order to produce the necessary spheroidal morphology in the feedstock, a vertical type twin roll caster [1] was used as shown in Fig. 1. Figure 1 shows in schematic flow-chart form the sequence of steps required to go from the roll casting to thixoforming. A cooling slope was attached to the twin roll caster in order to produce the semisolid slurry [2]. The cooling slope is simple water-cooled plate made from mild steel. Pouring the melt onto the cooling slope where it becomes the semisolid slurry by virtue of its flow on the cooling slope produces semisolid slurry. Solid fraction of the semisolid slurry was about from 3% to 10%.

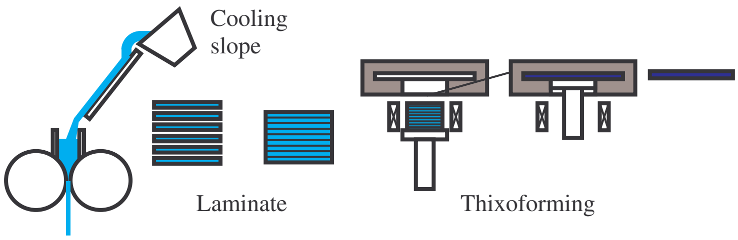

Fig. 1 Processing sequence of the present method

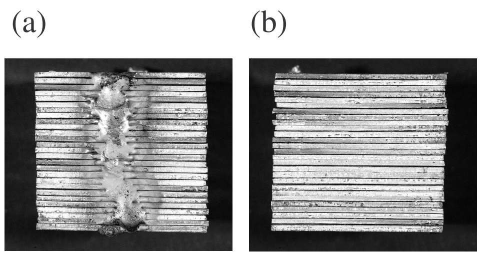

Fig. 2 Laminate made from strips
(a) welded surface. (b) non-welded

2.2 Microstructure at semisolid condition

The strips cast from the melt and the semisolid slurry were further cold rolled at a reduction of 20%. The microstructure of the strain-induced metal becomes globular when the metal is re-heated up to semisolid condition. The microstructures of both as-cast and cold rolled strips were investigated after being heated up to semisolid condition.

3. RESULTS

3.1 Microstructure of strip

Table 1
Spheroidicity of primary crystals in the semisolid condition

	30 m/min	60 m/min	90 m/min
SS	Yes	Yes	Yes
SS+CR	Yes	Yes	Yes
MM	No	No	No
MM+CR	Yes	Yes	Yes

SS: casting from semisolid slurry, SS+CR: semisolid casting and cold rolling,
MM: casting from molten metal, MM+CR: casting from molten metal and cold rolling,
30, 60, 90 m/min: roll speeds.

The primary crystals of the strip cast from the melt did not become spherical when heated up to semisolid condition. In contrast, the primary crystals of the strip cast from the semisolid slurry did spheroidise when re-heated to the semisolid state. The cold rolling was very useful in assisting the primary crystal development into spheroids. The roll speed did not appear to have affected the amount of spheroidisation of the primary crystals. The microstructure of the as cast strip after being heated up to semisolid condition is shown in Fig.3. The microstructure of the strip is a duplex structure. In the strip cast from the molten metal, the microstructure around the center of the thickness appears to be equiaxed, but the rest appears to be of acicular nature. The microstructure of the strip cast from the semisolid slurry was also duplex. The microstructure at the center of the cross section was a near spherical structure. The primary crystals of the strip cast from semisolid slurry were more spheroidal than the primary crystals of conventional slugs used for thixoforming. The morphology of the primary crystals of the semisolid cast strip was sufficiently spheroidal to allow them to be used as feedstock for thixorming.

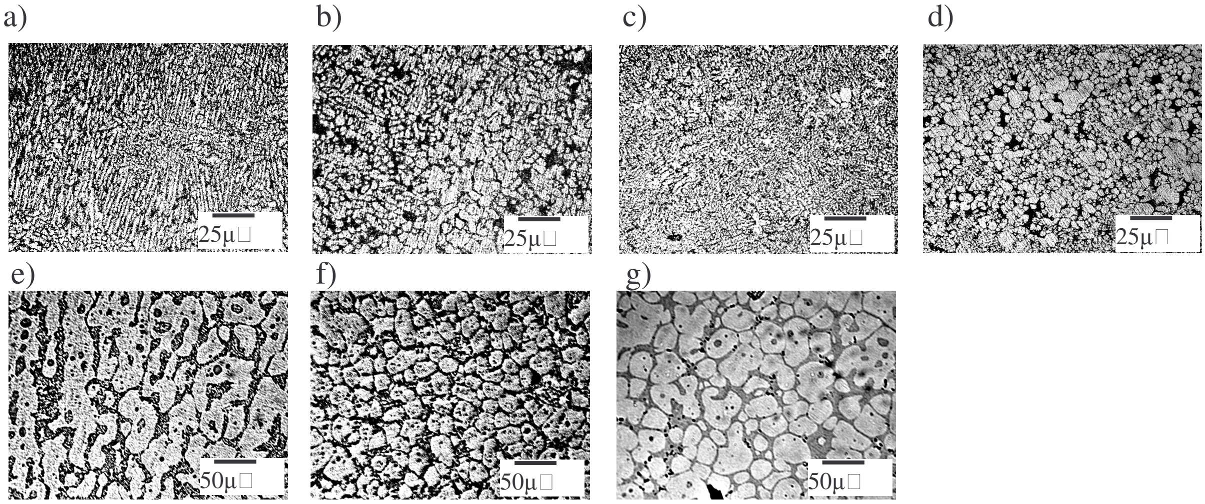

Fig. 3 Microstructure of as cast strip and in the semisolid condition
(a),(b) as cast strip from melt, (c),(d) as cast strip from semisolid slurry, (a),(c) inside, (b)(d) near surface, (e) semisolid of the strip cast from molten metal, (f) semisolid of the strip cast from molten metal, (g) conventional thixocasting

3.2 The effect of direction in the laminate

Strip cast at 90m/min was used to assemble the laminate slugs to be thixoformed in the conventional manner. The effect of the direction of the laminate slug arrangement relative to the direction of the moving ram is shown at Table 2. The laminate shown in Fig. 2 was made up by welding strips in a horizontal arrangement. When the laminate slugs were made from the as cast strip cast from the melt, the metal did not fill the cavity of the die as shown in Fig. 4 (a). Laminate slugs made up from strips, arranged in both horizontal and vertical directions, could not fill the cavity. The reason for this is that the primary crystals were not spherical and the ability of the metal to flow into the die was impaired. Laminate slugs assembled from the strips produced under other conditions did fill the die cavity as shown in Fig. 3(b). The primary crystals became near spherical, and the ability of the semisolid slurry to flow was much improved. Naturally, oxide film existed at the free surfaces of the strips. The direction of assembly of the laminations did not affect the flow of semisolid metal at the conditions used in this the present study.

a) b)

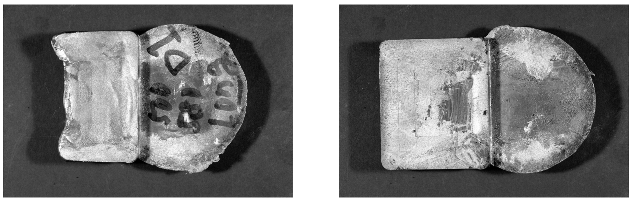

Fig.4 Thixoformed metal into the cavity
(a) die cavity is not filled by the metal.
(b) die avity is filled by the metal

Table 2
Forming of semisolid laminated slugs

	Horizontal	Vertical
SS	Yes	Yes
SS+CR	Yes	Yes
MM	No	No
MM+CR	Yes	Yes
SS, SS+CR, MM, MM+CR: refer to Table 1, Yes: Die cavity filled by slurry No: Die cavity not filled by slurry		

3.4 Mechanical properties

The mechanical properties of the thixogformed strip laminate after T6 were: Tensile strength of 315MPa, 253MPa 0.2%proof stress and 8% elongation. The tensile strength and 0.2% proof stress were better than the conventional thixoformed ingots. However, the elongation of the laminate was slightly lower than that of conventional thixoformed slugs. The primary crystals of the thixoformed ingot made from laminate were finer than the primary crystals of conventional thixoformed products. This may offer improved mechanical properties. The oxide film may have an effect on the elongation. Although most of the oxide film existing on the strip surfaces appears not to have flowed into the die cavity, some part of the oxide film may have been incorporated into the semisolid slurry. This oxide film may have contributed in the reduction in elongation recorded.

4. CONCLUSIONS

The use of laminate slugs for thixoforming was devised and demonstrated. The primary crystals of the strip cast from semisolid slurry become near spherical when the strip is heated up to semisolid condition. The ability of the semisolid slurry to flow when produced from a laminate slug appears to be very similar to that of slugs used in conventional thixoforming. The mechanical properties of thixoformed products using the laminate slugs as starting feedstock are very close to the mechanical properties of conventional thixoformed products.

REFERENCES

1. Toshio Haga, Proc.of Int. Conf. on Advanced Mater. & Processing Tech.,(2001), 191.
2. Toshio Haga, J. of Mter. Process. &Tech., (2001), 64.