VIBRATING MOLD FOR GRAIN REFINEMENT OF ALUMINUM ALLOY 4032

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Abstract – By physically shaking a metal mould during solidification, the effects of vibration on grain refinement in aluminium alloy were explored. The frequency and half amplitude both had an effect on grain refining, resulting in a smaller average grain size. We predicted that the excitation force consolidating the grains might be used to determine the average grain size. Experiments with varied vibration beginning times and varied vibration periods were undertaken to understand grain refining mechanisms. Mold vibration reduced both the equiaxed grain size and the columnar grain length before pouring, regardless of the vibration time. The columnar grain length increased when the mould was vibrated 15 seconds after pouring. Furthermore, the equiaxed particle size grew significantly. A vibrated mould consisting of aluminium alloy 4032 formed numerous crystals along the mould wall. These findings demonstrated the need of beginning vibration before solidification for grain refining.

Key Words: excitation force, grain refining, solidification, vibration, aluminium alloy

1. INTRODUCTION

Smaller-grained metallic materials have greater mechanical characteristics, according to the Hall–Petch law. Rolling and forging materials can have their grains refined throughout the production process. Cast materials, on the other hand, have poor mechanical characteristics because their grains coarsen throughout the production process. As a result, the development of fine grain castings has been pushed with zeal. Refiner addition, ultrasonic vibration, electromagnetic vibration, electromagnetic stirring, induction stirring, soaking the oscillator in molten metal, and vibrating or rotating the mould wall have all been investigated as techniques of refining grains of casting materials. Direct vibration and ultrasonic vibration have been investigated for a long time using these approaches. The refiner addition is now the most popular. However, grain refining with a refiner is disadvantageous since it includes contaminants from recycling. Ultrasonic vibration, electrical stirring, and immersing the oscillator in molten metal, on the other hand, have no effect on the alloy composition, making it simple to recycle. Grain refining has also been accomplished in research studying ultrasonic vibration, electrical stirring, and immersing the oscillator in molten metal. Ultrasonic vibration, in particular is recognized to be an effective aluminium processing method. The current study, on the other hand, looks at a simpler method: The grains of cast material are refined using the mould vibration device seen in Fig 1. This research is comparable to others that have looked into mould wall vibration. However, due of its basic form, the equipment utilised in this study can handle greater products than previous approaches. The effects of vibration on Al–4032 alloy grain refining were explored in this study. The grain refining mechanism of this equipment was also discussed.

Fig -1: vibrating mould with setup

2. Experimental procedures

The first step is to choose the base material, which is AA 4032. The qualities and selection of this non-ferrous alloy are completed, followed by the finalisation of the alloy's composition and the preparation of a charge calculation based on the raw materials available. The raw components are then weighed and stored in preparation for the production of AA 4032 aluminium alloy. The melting is done in an electric furnace at 670° C, where the aluminium begins to melt, then the charge which consist of 12.950% of Si, 0.729% of Fe, 0.779% of Cu, 1.042% of Mg, 0.106% of Cr, 0.655% of Ni, 0.193% of Zn is added and then allowed to heat up to 720° C, where the liquid molten metal is taken in a ladle and poured into an ingot mould, where it is allowed to solidify for about 15 minutes before being removed from the mould.

The room-temperature mould was vibrated before pouring under the vibration parameters shown in Table 1. After the molten metal hardened, the vibrations ceased. From 5 to 35 Hz, the frequency was altered. A signal generator was used to regulate the frequency. Before testing, the real amplitude was measured with a dial gauge.

To explore the effects of frequency and half amplitude on grain size, vibration conditions of (c) for a constant frequency or half amplitude experiment and (cef) for a constant excitation force determined from frequency and half amplitude experiment were used. After each test, each specimen was sliced in two directions: horizontally and vertically.

Table -1: mould vibration condition

Half amplitude (mm)	Frequency (Hz) 5	10	15	20	25	30	35
0.1	–	Cf	–	–	Cf	–	cef
0.5	–	Cf	–	–	–	cef	–
1.0	Cf	Cf	–	–	cef	–	–
1.5	–	–	–	cef	–	–	–
2.0	–	–	cef	–	–	–	–
2.5	–	Cf	–	–	–	–	–
3.0	–	Cf	–	–	Without vibration		
3.5	–	Cf	–	–	Cf		

cef: constant excitation force
Cf: constant frequency

Keller's solution was then used to polish and etch the specimen sections. Their macrostructures were then examined using an optical microscope (Eclipse LV150; Nikon Corp.). For grain size measurements, specimens were sliced in the horizontal direction. We calculated the average grain size (D_{avg}), which includes both columnar and equiaxed grains, as well as the average equiaxed grain size (D_{eq}) and average columnar grain length (L_{col}). The diameter determined from the average area of grains measured as a circle is used in this investigation. Columnar grains develop from the mold's wall to the centre.

The specimen comes in a variety of sizes. As a result, we measured their lengths 25 mm from the specimen's bottom. For the purposes of analysis, the average length was used. To clarify the mechanism of Al-4032 alloy grain refinement using mold vibration, some experiments were con- ducted with different vibration starting and stopping times, respectively, under conditions of 20 Hz frequency and 1.0 mm half amplitude.

Without vibration	10Hz, 0.1mm	10Hz, 0.5mm	40Hz, 0.1mm

Fig -2: macrostructure of specimen solidified under vibration condition

The macrostructures of castings solidified with varied frequencies and half amplitudes are shown in Fig 2. Columnar grains developed from the specimen's wall to the centre without vibration. In comparison to those created without vibration, 10 Hz frequency and mm half amplitude vibration induced relatively little macrostructural alterations. The columnar grain lengths decreased as half amplitude was raised to 0.5 mm. In the specimen centre, the equiaxed grains emerged. Furthermore, the columnar grains shrank when the frequency and half-amplitude were raised to 40 Hz and 0.1 mm, respectively. The equiaxed grains took up the entirety of the specimen.

Fig 3 depicts the relative relationships between the vibration pattern and L_{col} and D_{eq}. L_{col} was around 3 mm and D_{eq} was about 0.4 mm for the specimen vibrated from before pouring to the middle of solidification [patterns (3)–(5)], regardless of vibration duration. The grain refining impact was minor for the specimen vibrated 15 seconds after pouring [pattern (6)]: L_{col} and D_{eq} were 13.3 mm and 2.0 mm, respectively. These findings suggest that delaying the vibration onset time reduces the grain refining impact. Grain refining is more effective when the mould is vibrated before pouring.

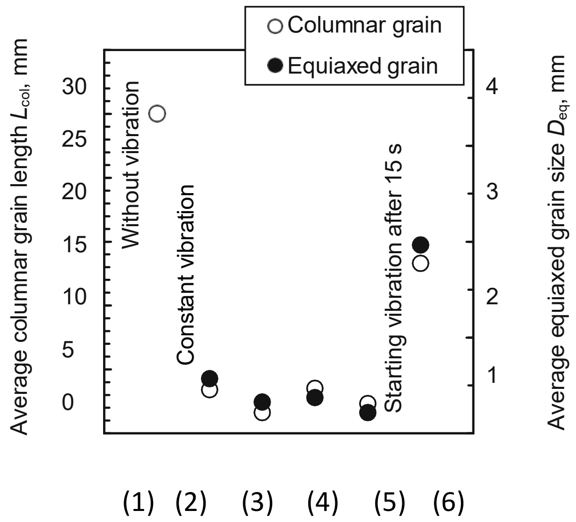

Fig -3: Average columnar grain length (L_{col}) and average equiaxed grain size were affected by the addition of vibration duration (D_{eq})

The Fig 4 shows the many macrostructures that may be created by altering the vibration pattern. The macrostructures of all specimens related to patterns (3), (4), and (5), for which vibration was stopped during solidification, were composed of small columnar grains on the specimen's wall and equiaxed grains in the centre. No noticeable variations were identified in macrostructures between the specimens by pattern (2), which vibrated continually, and by patterns (3)–(5). The columnar grains got longer in the pattern (6) specimen that began vibrating 15 seconds after pouring. The equiaxed grains grew coarser than the grains in the other vibration pattern specimens.

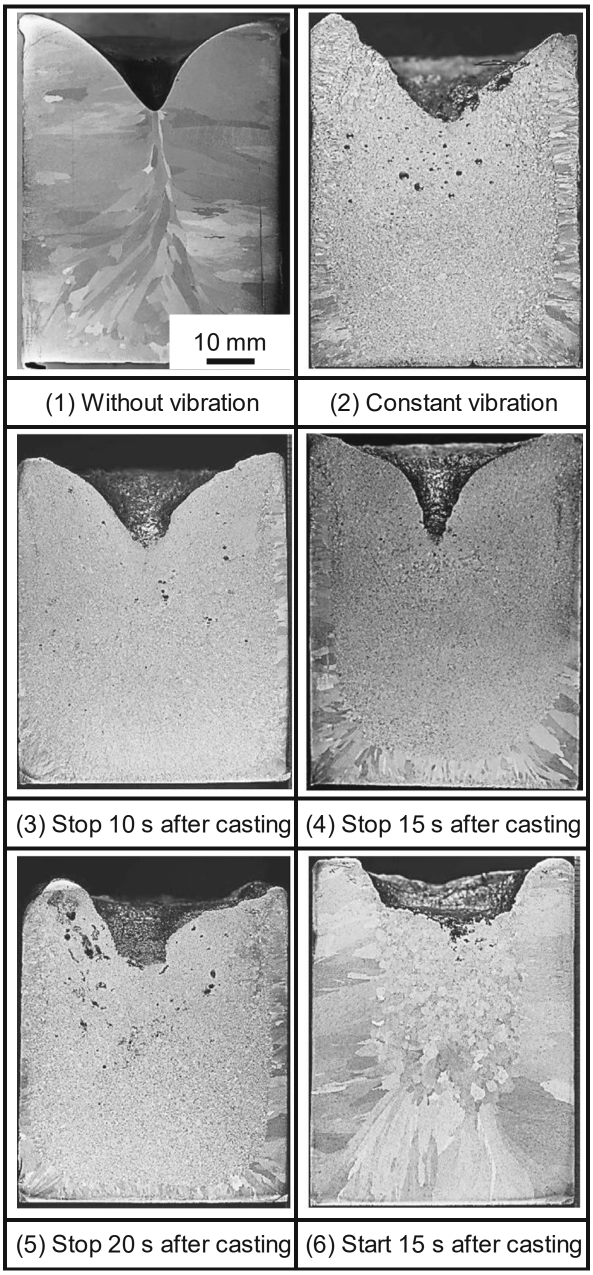

Fig -3: Average Macrostructures of specimens with different vibration patterns presented in Fig 2 (1.0 mm, 20 Hz)

3. CONCLUSIONS

The effects of vibration on the grain refinement of the AA-4032 alloy were explored. The following conclusions are drawn from the findings:

(1) The Al–2% Cu alloy grains are refined by vibrating the molten metal. With increasing amplitude and vibration frequency, the granules get smaller.

(2) The excitation force may be used to estimate the average particle size. Smaller particle size is connected with higher excitation force.

(3) When the excitation force is constant, changing the half amplitude is more efficient than changing the frequency for grain refining.

(4) It's critical to vibrate the mould early in the solidification process to efficiently refine the grains.

(5) The vibration mold's grain refining mechanism vibrates the created grains away from the mould wall and convectionally pushes them into the molten metal.

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