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Die design method for thin plates by indirect rheo-casting process and effect of die cavity friction and punch speed on microstructures and mechanical properties

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### Abstract

Thin plates with a thickness of 1.2 mm are fabricated from semi-solid A356 alloy through an indirect rheo-casting process both with and without an electromagnetic stirrer (EMS). The thin die cavity for forming is designed with the fluid analysis software MAGMA. A semi-solid slurry with a solid fraction of 40% is prepared and then injected into the die of a 200 ton hydraulic press. Forming tests are performed on the thin plates at two punch speeds (30 and 300 mm/s) and two cavity friction conditions ( $m_f = 0.4$  and  $m_f = 0.9$ ). The formability, mechanical properties, and microstructure are then evaluated. The semi-solid slurry obtained with an EMS contains fine and globular solid particles; the semi-solid slurry produced without an EMS reveals rosette particles and coarser globular solid particles. At high friction ( $m_f = 0.9$ ), the cavity is mainly filled with the liquid phase. At a higher punch rate, the thin plates show better formability and a microstructure with fine and even solid particles. The tensile strength and elongation of the thin plate formed with a punch speed of 300 mm/s in the cavity with graphite lubrication ( $m_f = 0.9$ ) are 216 MPa and 10%, respectively. These values are 57 MPa and 5.5% higher, respectively, than those of the thin plate formed at a punch speed of 30 mm/s.

*Keywords:* Semi-solid slurry, Indirect rheo-casting, Electromagnetic stirring, Thin plate, Filling simulation, A356 alloy

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