Development of molten flame-retardant magnesium alloys for die casting

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Magnesium is the lightest structural metal and is essential in the field where weight reduction is a critical requirement. There are several challenges to increasing the utilization of magnesium alloy components, and one of these is their “flammability.” Die casting is the most common production method for magnesium alloy automotive parts; developing new magnesium alloys with suppressed flammability during the melting process would provide an environment in which magnesium alloys can be used safely and at low cost. The concept of the alloy development is shown in Fig.1

In the Japan Magnesium Association’s “Automotive Magnesium Application Expansion Committee” (2014–2018), efforts were directed toward enhancing safety and eliminating the need for protective cover gases by developing molten flame-retardant magnesium alloys for die-casting, which exhibits significantly reduced flammability during the melting process. In the committee, it was considered that demand for EV components would increase in the future due to the electrification of automobiles, and therefore decided to focus its development efforts on the alloys not high heat resistance but with high toughness. Specifically, we set the following targets: no combustion or no significant oxidation during component processing (die casting); a failure elongation of more than 15%; and a Charpy absorbed energy of more than 30 J to ensure high toughness.

Using an AM alloy (Mg-Al-Mn alloy) as the base alloy, the contents of five elements (Al, Ca, Mn, Y, and C) were adjusted. Al and C were added to improve elongation and absorbed energy, while Ca, Mn, and Y were added to improve flammability resistance and heat resistance.

First, to understand the flammability resistance, the ignition temperature was investigated using a differential thermal analyzer (DTA). It was confirmed that adding more than 0.3% of Ca to AM alloys increased the ignition temperature. Furthermore, it was confirmed that the ignition temperature further increased with an addition of approximately 0.3% of Y in addition to Ca.

Next, various property evaluations were performed by using test specimens obtained by die casting. As representative results, Fig. 2 shows a summary of the absorbed energy obtained from Charpy impact tests. It was observed that the absorbed energy tended to decrease with increasing Ca content in AM alloys. In particular, alloys with a Ca content of more than 0.7% could not achieve the target values. It was found that adding Mm is effective in improving the absorbed energy, particularly in alloys with low Ca content.

Based on the results of the various evaluation tests described above, we selected the Mg-5.0%Al-0.3%Ca-0.3%Mm (AXE500) alloy as the candidate alloy. And, we then conducted the flammability resistant tests by using an actual die-casting process and determined that it is less flammable than conventional magnesium alloys and suitable for use as a molten flame-retardant magnesium alloys for die casting.

Finally, we produced prototype steering wheels by using die-casting with the newly developed AXE500 and AM50 alloys. And, we then conducted bending and drop weight tests, which are simple evaluation methods commonly used in production. As a result, it was determined that these alloys are suitable for use in automotive components.

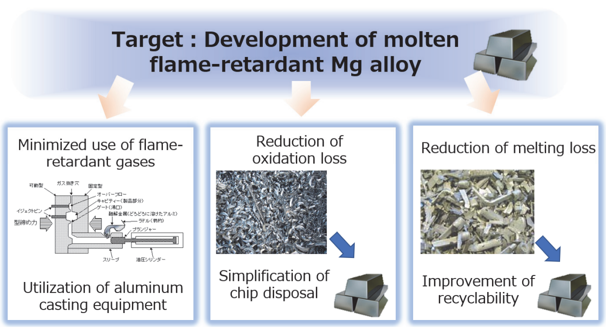

Fig.1 Concept of development of molten flame-retardant Mg alloy.

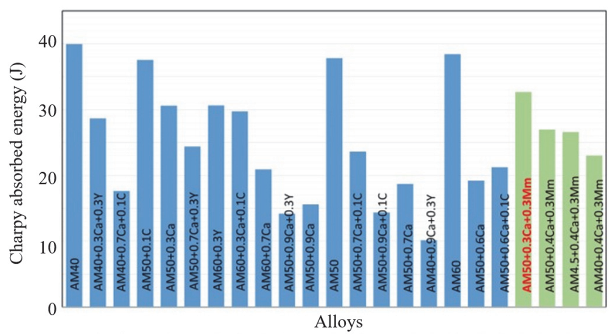

Fig.2 Charpy absorbed energy of the AM series magnesium alloys with Ca, Mm, Y, C addition.