Since the discovery of quasicrystalline (QC) phases more than one hundred different quasicrystalline alloys have been observed and large efforts have been made in order to understand and apply the unique properties presented by these materials. Due to their structure, QC alloys have high hardness, high elastic modulus, low thermal and electric conductivity and good corrosion resistance. However, these alloys are brittle at room temperature and as consequence their application as structural component is limited. On the other hand, the use of such alloys as reinforcing phase in a metal-matrix composite is a potential field of application for the QC materials.

In the present work, hot extrusion was used to produce aluminum-based composites reinforced with Al$_{65}$Cu$_{20}$Fe$_{15}$ (at.%) QC alloy. The QC alloy was fabricated by arc melting, submitted to mechanical alloying (MA) and then to a subsequent heat treatment to obtain a single phase QC-powder. MA was also used to produce the mechanical mixture of Al and the QC alloy (10% of QC-phase in wt.%) where the mixed powders were ball milled during 5 h in a planetary high-energy mill with rotating speeds of 200 and 600 rpm, respectively. The powders were then hot extruded at 420 °C. The consolidated samples were analyzed by transmission electron microscopy (TEM) using a FEI TECNAI G2 F20.

X-ray diffraction patterns (not shown here) of the alloy powder that was used as the reinforcement phase in the composite confirmed that the single QC phases was obtained after the heat treatment at 700 °C. Figure 1 shows the selected area electron diffraction patterns (SAED) obtained from the particles in the hot extruded composite, confirming the icosahedral structure of the QC phase, which was stable during production of the Al-QC composite. Figure 2 shows bright field and dark field STEM micrographs of the composites fabricated with mixing velocity of 200 rpm. Such mixing condition did not produce a good dispersion of the QC phase, which remained mostly in the grain boundaries. Figure 3 shows bright field and dark field STEM micrographs of the composites fabricated with mixing velocity of 600 rpm. These micrographs reveal a much better and finer dispersion of the QC-phase in the Al matrix, with the particles distributed in the interior of the grains. Torsion tests for both composites indicated equivalent tensile strength of 130 MPa for the composite with the coarser distribution of the QC phase (Fig. 2) and 200 MPa for the composite with finer distribution of the QC phase (Fig. 3). Therefore the composite with finer particles presented a substantial increase on the mechanical strength, and the attractive values of tensile strength were associated with the uniform dispersions of the QC-phase inside the grains.

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Fig. 1: SAED pattern of the QC-phase in hot extruded composite, with 2, 3 and 5-fold symmetry, confirming the icosahedral symmetry of the reinforcement phase.

Fig. 2: STEM bright field and dark field images of the composite fabricated with powder mixing velocity of 200 rpm; the QC particles are coarse and preferentially located at the grain boundaries.

Fig. 3: STEM bright field and dark field images of the composite fabricated with powder mixing velocity of 600 rpm; the QC particles are finer, with a uniform dispersion preferentially located inside the grains.