Solid State Upcycling of Aluminum Alloys

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ABSTRACT – Aluminum alloys are crucial materials in automotive and aerospace manufacturing sectors due to their high specific strength, corrosion resistance, and lightweight properties, which provide better fuel efficiency and mechanical performance. Extraction of Al from bauxite ore is an energy intensive process. Conventional aluminum recycling involves several steps: scrap collection, shredding, cleaning, melting, casting, and rolling. While this process helps reduce the need for raw materials and energy compared to ore extraction for producing primary aluminum, it still involves substantial energy consumption and has major environmental drawbacks. Particularly, melting and casting require significant energy inputs and produce significant greenhouse gas emissions. The International Aluminum Institute (IAI) estimates that the primary Al production is expected to reach a volume of 82 million tons by 2050 whereas Al recycling is expected to grow at a rather higher rate to hit 70 million tons, which is ~30% higher than the present primary Al to recycled Al ratio! Additionally, IAI also estimates the primary Al production to descent and reach today's rate of production whereas Al-recycling is expected to mount to 120 million tons by 2070. Such a future trend in Al-recycling tonnage demands exploration of novel approaches that align with the principles of circular economy and sustainability. One such alternative is to recycle Al without melting. Friction stir based processes are ideal for this. An overview of our upcycling effort using SolidStir extrusion and SolidStir additive manufacturing will be presented. Our analysis has shows that the energy requirement for Al-recycling using the SolidStir technology can be substantially reduced to 0.78 kWh/kg, which is mere 1.7% of energy required for primary aluminum extraction and only 28% of the energy required for conventional Al recycling. The results demonstrate substantial energy saving compared to the conventional recycling route (60% less), and mechanical properties exceeding the base alloy properties.