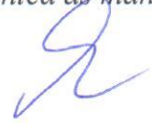


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DEVELOPMENT OF A TECHNOLOGICAL PROCESS AND ECONOMIC  
EFFICIENCY OF PROCESSING OF AK12 METAL CHIPS INTO SEMI-  
FINISHED PRODUCTS BY METHODS OF PRESSURE PROCESSING

Master's Program Metal and Alloys Forming under pressure

The abstract of Master's Thesis

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## **Background**

When metal products are manufactured, considerable amounts of waste in the form of chips and discards are produced. Recycling of scrap becomes a very economical method for producing materials because of the low cost of recycled materials. The secondary aluminum stream is becoming an even more important component of aluminum production and is attractive because of its economic and environmental benefits. The global demand for aluminum and aluminum products is increasing because aluminum alloys can offer excellent corrosion resistance with good strength and low density compared with steel.

## **Problem Statement and Research Target**

There are two primary methods of scrap recycling illustrated in Figure 1: conventional recycling and solid state recycling. The conventional technique requires melting of scrap. It involves high energy consumption, high operating costs, and a large number of operations. Usually the energy consumed in conventional recycling of aluminium is  $16\pm 19$  GJ/t, whereas direct conversion of aluminium chips into compact material requires only  $5\pm 6$  GJ per ton. By reducing the number of operations, the direct conversion method allows to reduce labor contribution to  $2.5\pm 6.5$  man-hours per ton of the product, whilst conventional recycling requires much higher labor contribution, ranging from 11 to 15 man-hours per ton. In the conventional recycling process, about 10% of material is lost due to burning and another 10% is lost due to mixing of the material with slag.

The solid state recycling process which involves compression and extrusion at room or moderate temperature results in significant energy savings. Compared with conventional recycling, solid state recycling of aluminum scrap may result in 40% material, 26–31% energy and 16–60% labor savings. Direct conversion of aluminum and aluminum-alloy chips into compact metal has a positive impact on the environment: less degradation of the natural environment because of reduced air-pollution emission. Moreover direct conversion includes a possible reduction in

the funds spend on environment protection as a result of the reduced consumption of ores and energy carriers.

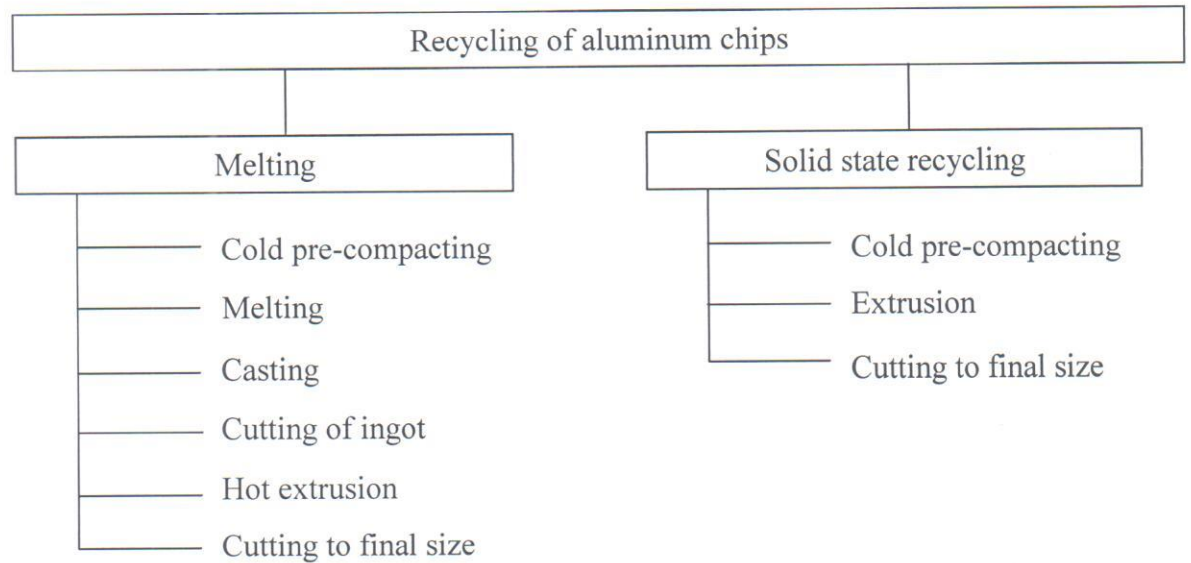


Fig.1 – Comparison of the conventional recycling of aluminum-alloy chips and their solid state recycling processes

The aim of the present research is to compare solid state recycling compression and extrusion at room or moderate temperature with conventional remelting and subsequent refinement and determine the optimal parameters of the process of the solid state recycling. Extra effort was made to assess the economic impact.

## Experiment

In this research, the effect of strain on deformation activation energy of an Al–Si eutectic alloy during compression was discovered and deformation behavior of Al–Si eutectic alloy was investigated. An extrusion test was used to optimize strain in Al–Si eutectic alloy. During extrusion tests, the billets cut from an Al–Si eutectic alloy bar were extruded with different reduction ratios that represented different strains. Then the elongation and strength values of the extruded specimens acquired by tensile tests were utilized to optimize the strain.



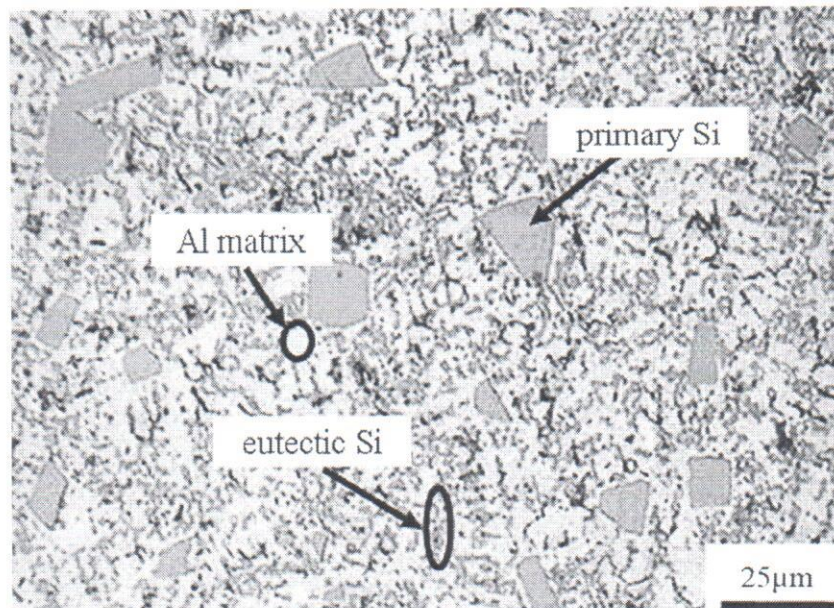


Fig 2. – The microstructure of the Al–Si eutectic alloy

A commercial Al–Si eutectic alloy bar of 40 mm in diameter was used in the research. The composition of alloy is Al–12 Si–0.8 Cu–1.1 Mg–0.7 Ni–0.5 Fe–0.2 (wt%). Fig. 2 is the optical micrograph showing the initial microstructures of the Al–Si eutectic alloy that consists of coarse massive primary Si, dendritic eutectic Si and Al matrix. Compression specimens were machined with the compression axis parallel to the extrusion direction.

Due to low relative filling density of the chips, the total amount of chips prepared for each specimen could not fit into the die at once. Therefore pre-compacting operations were needed.

Pre-compacted aluminum chips were poured into the bottom mould and the top mould was fixed accordingly. The top mould acted as a plunger to press the aluminum chips. The mould was then placed inside the hot press forging machine to execute the forging operation. The operation is called flashless forging because the raw workpiece (aluminum chips) is completely contained within the mould cavity during compression, and no flash is formed. Flashless forging minimizes waste associated with post-forging operations. Therefore, the final product needs little or no finishing. Low pressures were applied in pre-compacting operations in order to avoid formation of layered structures in specimens.



## **Results and Analysis**

Solid bonded material has similar mechanical performance to cast material, with only a small reduction in ultimate tensile strength and ductility. The microstructure of extruded chip-based billets differs from the microstructure of extruded cast billets in terms of shape and size of the grains, yield strength and ultimate tensile strength. Chip-based billets extruded through the flat-face die have a smaller grain size compared to cast billets extruded through the same die.

The deformation activation energy research results show that the deformation mechanism of Al–Si eutectic alloy changes with strain. The maximum deformation activation energy value of the Al–Si eutectic alloy is 178 kJ/mol with the strain of 0.1, which is higher than the diffusion of pure aluminum (142 kJ/mol). The deformation activation energy of Al–Si eutectic alloy during hot compression decreases with increasing strain when strain is lower than 0.4. Strain has slight effect on deformation activation energy value of 163–164 kJ/mol at higher strain than 0.4, which is more close to self-diffusion activation energy of pure aluminum. Deformation activation energy describes the activation barrier that transition of atom requires to overcome and represents the workability of alloy. There is other deformation mechanism rather than dislocation movement during high temperature deformation of the Al–Si eutectic alloy up to the strain of 0.1.

## **Concluding remarks**

Solid state recycling of aluminium chips into solid billets has a number of advantages over conventional recycling. This process enables material and energy savings and it is more environmentally friendly as no remelting takes place. However, solid state recycling has application only in such processes where no material mixing is performed and where cutting waste is simply sorted (the best example is in mass machining). This paper elaborates cold compression process of Al-alloy chips. Compression force of solid state recycling provide promising alternatives in aluminum scrap process to be very important factor in proper chips

solidification, as billets compressed with lower forces exhibited small final densities. Final experimental investigations (backward extrusion and free upsetting) proved that in order to obtain good mechanical properties of compressed billets further processing of the material is needed. Further research would consider employing severe plastic deformation methods probably to enhance material properties.

Compared with conventional remelting and subsequent refinement, solid state recycling utilizing compression and extrusion at room or moderate temperature results in significant energy savings and higher metal yield.