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To cite this version:


HAL Id: jpa-00226532
https://hal.archives-ouvertes.fr/jpa-00226532
Submitted on 1 Jan 1987

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RECYCLING OF ALUMINIUM-LITHIUM PROCESS SCRAP

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Abstract

The yield of finished aluminium-lithium product from suppliers' semi-fabrication facilities varies with the product form but is generally quite low. The yield of finished aircraft parts in the aircraft manufacturers' fabrication processes is even lower. Of their scrap, some is heavy, relatively easily segregated and might be taken back by semi-fabrication plants for direct recycling. However, the bulk is in the form of machining swarf which will be unsuitable for direct recycling due to mixing with other aluminium alloys and other aircraft materials such as stainless steel and titanium. For conventional 2XXX and 7XXX aircraft alloys, swarf is sold off to scrap dealers and secondary aluminium smelters for conversion to aluminium-silicon foundry alloys.

The paper seeks to quantify the material flows for the industry as a whole, identify the problem areas and indicate a range of potential short and medium term solutions requiring R & D.

In particular, results will be presented on mechanical property measurements on laboratory cast samples of two aluminium-silicon alloys containing up to 8000 ppm of lithium. While modification of the microstructure occurred in the region 200-400 ppm, no significant effects on UTS were observed. Further work on a wider range of alloys and properties (including electrochemical properties) is planned.

Introduction

Although Al-Li alloys have been under intensive worldwide development for the past 5-10 years, very little has been published on the subject of recycling process scrap from the manufacturing operations of primary metal suppliers or aircraft manufacturers. As a logical step in the development of this new alloy range, the time is now ripe for public discussion, particularly as concerns have been expressed by the secondary aluminium industry about lithium contamination and by aircraft manufacturers as to the means of disposal of their scrap. However, primary producers have long recognised their responsibilities in what is an area of major unresolved issues (1) in terms of scrap segregation and handling, lithium recovery and lithium contamination of standard alloys.

For conventional aircraft aluminium alloys of the 2XXX and 7XXX series, the recycling of process scrap from both metal suppliers and aircraft manufacturers is a well established, worldwide industry. For the most part primary aluminium suppliers internally recycle their own scrap back into aircraft products. Their customers sell off their scrap to secondary aluminium smelters, which convert it into aluminium-silicon foundry alloys.
The introduction of Aluminium-Lithium alloys will not eliminate these activities, even if total alloy substitution is achieved. However, additional processing steps will have to be introduced and commercial arrangements modified against a background of the existing industry. The reasons for these changes stem from three properties of lithium metal: its high price, its high reactivity, its absence from the specifications of all registered alloys (2)(3) other than the currently rather limited number of alloys based on Al-Cu-Li (2090 etc) and Al-Li-Cu-Mg (8090 etc):

1. At around £50000/tonne of Lithium, the lithium content costs more than the aluminium base for each of the present generation of Al-Li alloys. Means must be found for recycling the value of that lithium. (4).

2. Both lithium metal and molten Al-Li alloys are highly reactive with humid atmospheres. Molten Al-Li is aggressive to conventional refractories and direct chill casting of ingot is particularly hazardous unless carried out with appropriate equipment, controls and personnel.

3. Until proven otherwise, man's innate fear of the unknown will prevent the acceptance of lithium as a contaminant in conventional wrought alloys or Al-Si foundry alloys.

The consumption of aluminium by the western world aircraft manufacturing industry ranges between 100000 and 200000 tonne/annum. While the total may reduce due to improvements in manufacturing methods and materials, by 1995 two thirds (5) of the aluminium may be Al-Li alloys, perhaps 100000 tonne/annum.

The yield of finished product from suppliers' semi-fabrication facilities varies with the product form but is generally quite low, even for conventional alloys. The yield of finished product from aircraft manufacturers' fabrication processes is even lower (4). A very simple model of this is illustrated in Fig 1. Of the aircraft manufacturers' scrap, some is heavy, relatively easily segregated and might be taken back by semi-fabrication plants for direct recycling. However, the bulk is in the form of machining swarf, see Fig 2, which will be unsuitable for direct recycling due to mixing with other aluminium alloys and other aircraft materials such as stainless steel and titanium. Even if metal suppliers are totally successful in recycling their own internal scrap and their customers' heavy scrap, aircraft manufacturers can be expected to supply the secondary market with 60000 tonne/annum of Al-Li swarf, not including tramp materials.

Scrap Strategy

In the light of the properties itemised above, it is clear that the recycling of such large tonnages can only proceed on the basis of new process technology. Such processes will not happen by chance, they will be arrived at only by extensive R & D based on appropriate technical and commercial strategy encompassing all the steps from scrap generation, through transport, storage, preparation, melting and lithium removal to alloying and end product application. The strategy must also recognise the R & D and market growth timescales.

Various strategies have been considered for short and medium term, see Fig 3. However, the alloy composition restrictions on Al-Si foundry alloys, conventional aircraft alloys and Al-Li aircraft alloys, together with the economic and environmental considerations, suggest that the only viable strategy is one where:
1. In the short term, while the market volumes are small, only the aluminium present in the scrap is recycled. After lithium removal, the remaining metal is absorbed into Al-Si foundry alloys.

2. In the medium term, say 3-5 years, processes are developed which permit the recovery of lithium for recycling back into aircraft quality Al-Li alloys. The remaining metal would continue to be absorbed into Al-Si alloys.

Clearly there are some process steps and some product requirements common to both timescales. Early results of studies fundamental to these common process steps will now be presented.

**Storage of Aluminium-Lithium Scrap**

While the market is small, Al-Li scrap is likely to be handled by secondary smelters on a batch or campaign basis. Consequently, extended storage times may have to be considered. Even with larger markets in the medium term, extended storage times may still be inevitable if expensive, central lithium extraction facilities are established. In view of the known reactivity of lithium, the corrosion susceptibility of samples of 8090 swarf was compared with samples of 2014/2024 and 7075 swarf.

The tests were designed to simulate the various conditions to which it was considered the swarf may be subjected during storage while awaiting recycling:

1. Corrosive atmosphere - High Acetic Acid Salt Spray Test (6)
2. Condensation - 95% humidity at 45°C - with and without steel swarf to simulate storage bin galvanic effects.

The Al-Li swarf had a corrosion resistance equal to or better than the conventional alloys in all of the tests, see Fig 4. - a conclusion which is generally consistent with testing of semi-fabricated products (7).

**Drying and De-oiling of Al-Li Scrap**

A precursor to most swarf melting operations is removal of oil and water by thermal drying in rotary kilns. In view of the surface oxidation observed in heat treatment operations (8), measurements were made of the weight gains of swarf when heated in air at various temperatures and for various items, see Fig 5. Because of the thin gauge of the swarf and high mobility of the lithium atoms within the aluminium matrix, diffusion rates are sufficient to enable total loss of lithium if time and temperature are not closely controlled. Process conditions of around 10 min below 400°C seem to be indicated.

**Aluminium Recovery : Secondary Smelting : Properties of Al-Si Alloys**

The response of the secondary industry, given an adequate economic incentive, will be to use existing plant and equipment to remove lithium from aluminium-lithium melts. Techniques currently used for magnesium removal can be expected e.g. chlorine gas, reactive salts. With appropriate environmental controls, such processes should be quite acceptable for recovering the aluminium content and value of the scrap but clearly the lithium value will be lost. Dilution with other aluminium base feedstocks will also be used to achieve a low residual lithium level in aluminium-silicon foundry alloys.
Investigations were made of the effects on the ultimate tensile strengths and microstructures of Al-Si alloys LM4 and LM27 of additions of Li up to 8000 ppm. No significant effects on UTS were observed (see Fig 6) and modification of the microstructure occurred in the region 200-400 ppm (see Fig 7) giving a structure comparable with that obtained with 120 ppm of sodium. Further work on a wider range of alloys and properties (including electrochemical properties) is planned.

**Lithium Recovery: Medium Term Processing**

Many potential processes have been identified for the recovery of lithium values by extraction of metallic lithium from mixed aircraft manufacturers' scrap, see Fig 8. Work is in progress within Alcan to identify the best options and establish design data for production units to be built to meet the needs of the expanding Al-Li business in the 1990's. However, it should be recognised that while some options are better than others, all necessitate heavy expenditures on R & D and capital investment. Moreover, operating costs will be high and recoveries are likely to be significantly less than 100%.

**Aircraft Manufacturing: Medium Term**

Contamination of aircraft manufacturers' Al-Li scrap to the extent of significant dilution will only serve to exacerbate the economic problems. Aircraft manufacturing methods and process control to minimise scrap mixing, maximise fly:buy ratio and enable scrap sorting must be developed in parallel with the efforts of the metal suppliers.

**Conclusions**

The successful exploitation of Al-Li aerospace alloys necessitates the definition of a viable scrap strategy. Such strategy includes both short and medium term business activities and supporting R & D and engineering programmes. Undoubtedly, the problems associated with scrap are solvable given adequate effort on the part of metal suppliers, aircraft manufacturers, the scientific community and governments. Work is already underway in Alcan and some early results have been reported here. An increased emphasis on recycling can be expected at future Al-Li conferences.

**Acknowledgements**

Alcan International Limited wishes to express its sincere thanks to all who have facilitated the work presented in this paper, particularly British Alcan plc, British Aerospace plc and North Western Metal Merchants Limited.

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Fig.1: MATERIAL FLOWS PER 1000 TONNE SEMI-FAB PRODUCT
Fig. 2: AIRCRAFT MACHINING SWARF: Of the aircraft manufacturers' scrap, some is heavy, relatively easily segregated and might be taken back by semi-fabrication plants for direct recycling. However, the bulk is in the form of swarf which will be unsuitable for direct recycling due to mixing with other Al alloys stainless steel and titanium.

Fig. 3: SCRAP STRATEGY OPTIONS
COMPARATIVE SWARF CORROSION TESTS: The tests were designed to simulate the various conditions to which it was considered the swarf may be subjected to during storage awaiting recycling. The Al-Li swarf had a corrosion resistance equal to or better than conventional aircraft alloys.

Fig. 4. WEIGHT GAIN OF Al-Li SWarf
Fig. 7, EFFECT OF Li AND Na ADDITIONS ON MICROSTRUCTURES OF LM4 AND LM27
Fig. 6. UTS v. Lithium Content for LM4 and LM27

Fig. 8. Lithium Recovery Options