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RECYCLING OF SEMI- SOLID- PROCESSING RESIDUES[*]

T. R. Noll [1], C. H. Kiehne [2], J. Krüger [3], B. Friedrich [4] (Authors)
Process Metallurgy and Metal Recycling
Department and Chair of RWTH Aachen

[1]Speaker, research metallurgist
[2]research metallurgist, now with Norddeutsche Affinerie AG Hamburg
[3]Head of the project raw material production and recycling
[4]Head of the department of Process Metallurgy and Metal Recycling

ABSTRACT: Thixoforming has passed the step from laboratory and process development to industrial application. Producers offer different alloys with various dimensions. Nevertheless some detailed aspects which belong to process development have not yet been discussed sufficiently. Recycling is one of these aspects. The influence of recycling on the process and the product quality is not known. For this reason, the amount of residues in different process steps is discussed and the chemical composition of such residues is analysed. The accumulation of certain impurities can be seen as well as the application of suitable melt treatments.

KEYWORDS: Recycling, amount and composition of residues, accumulation of impurities, melt treatment

1 INTRODUCTION

Semi-Solid-Processing gains great importance for the semi finished production. The most important application of this processing is the series production of great batches at the automotive sector. Although all semi-solid-processes have the same principle, –forming of a semi-solid slurry- processing industries and research departments attempt to reduce the number of process steps from feed stock to product. For example UBE New Rheocasting process (UBE Industries Ltd.) and Vexocast® (Ritter Aluminium Giesserei GmbH) produce semi-solid slurry including globular crystals directly from molten metal. Nevertheless which process- variants are going to gain acceptance there exists a considerable amount of semi-solid-processing residues.

The first aim of this work is stock taking. The amount and chemical composition of residues is determined. Moreover metallurgical aspects are discussed for each process step and suggestion for improvements are examined.

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2 AMOUNT AND CHEMICAL COMPOSITION OF RESIDUES

The amount and chemical composition of the residues depend on the chemical composition of the raw material. This flow chart (**Fig. 1)** is discussed for the most common thixoforming alloy AlSi7Mg (A356).

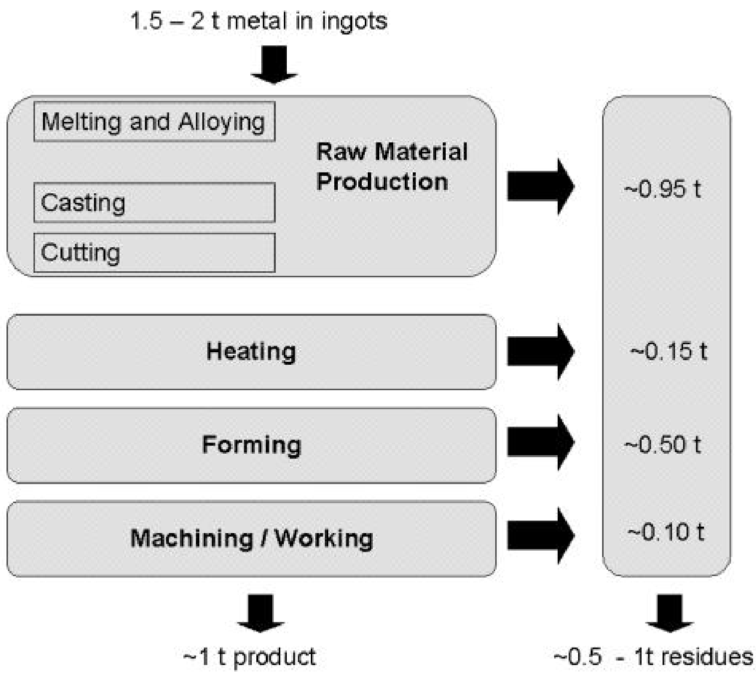

Fig. 1: Amount of residues in different process steps of A356 processing

The amount of residues is nearly the same as the amount of product in order to have a closer look to the reasons for metal loss, each process step has to be discussed metallurgically.

2.1 PRODUCTION OF RAW MATERIAL

2.1.1 Melting and Alloying

The chemical composition of the raw material –accomplished by alloying- is essential for the following processing of the raw material. In addition all further process steps are influenced by the chemical composition of the raw material.

By melting and alloying dross is produced. The amount of dross is about 0.5 to 1%. Due to oxidation melt-components e.g. Mg and Zn can be reduced. At the same time certain impurities like Fe, Cu, Cr, Ni, Zn and Sn are enriched. This effect is not significant, for the case of primary metal use. But if metal is recycled, this may become a problem. An influence on the process and the product quality has to be expected.

2.1.2 Casting

Today, the most common casting technology is Magneto-Hydro-Dynamic- casting (MHD) on horizontal or vertical continuous casting machines.

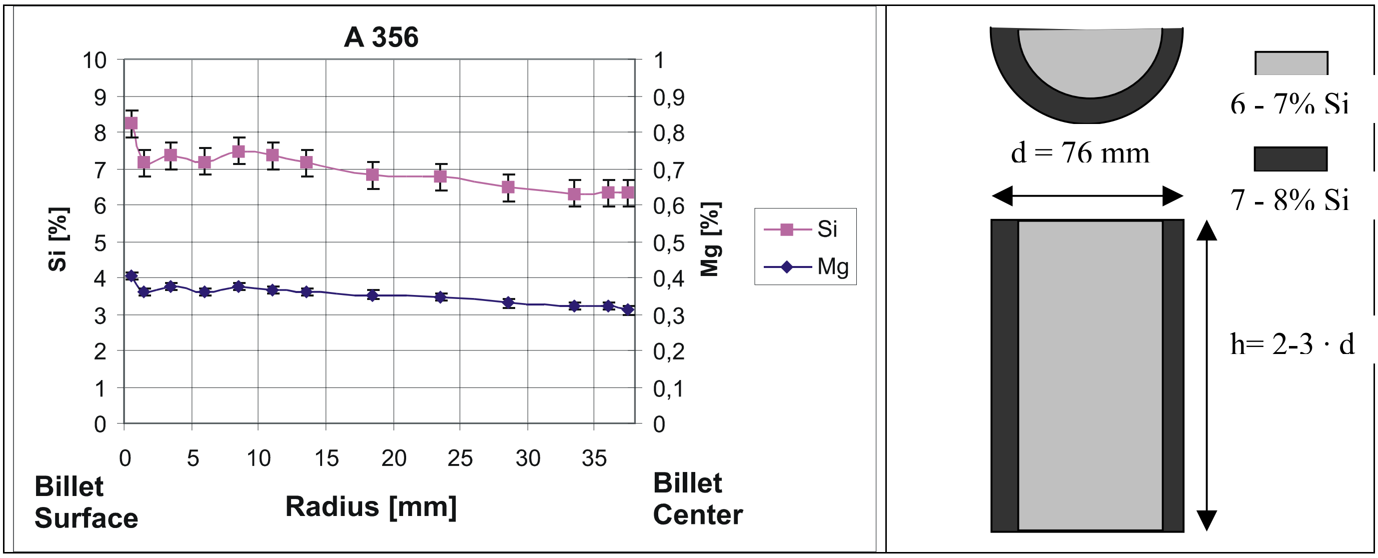

Fig 2: Typical thixoforming billet (AlSi7Mg –A356) and its chemical composition

Both ends of the bars are sawed off, so that the microstructure and the surface of the bars meet the demands. The composition of the casting-scrap is the same as the average composition of the bars. So such scrap may be returned directly to the melting process. The amount of casting scrap can be estimated to 2 – 6%.

2.1.3 Cutting

Cast-bars have to be cut into billets. The amount of saw shaving depends on the size of the bars. Usually direct casting bars are 3 – 6 m long. The amount of saw shavings for a 6 m bar is estimated to 2 %. Due to the high specific surface, oxidation cause a loss of metal and alloying elements. An enrichment of impurities takes place. Often shavings are mixed with cutting compounds like oil-water-suspensions. Special recycling methods and melt treatments have do be applied. They are discussed later. Saw shavings must not be recycled into thixoforming processing lines.

2.2 HEATING

There are two different heating philosophies. In some cases the billet is heated horizontally. But the most common practice is vertical heating. In this case the height / diameter-ratio of the billet is limited by the heating process to about three [1]. Otherwise, the billet would tilte or collapse.

Liquid metal forms first at the surface of the billets during the inductive heating, because of heat transfer to the surface and higher Si- content of the raw material at the surface, which leads to a lower melting point. Si-rich parts of the billet start to melt first. The oxide skin seems to protect the billet from bleeding. Because of the metallostatic pressure - which depends on the load- the drops start to flow out at the lower end of the billet. After bleeding the resulting billet is more homogenous than the original one (**Fig. 3**), but it has a lower Si-content. The consequence of this is the formation of another type of alloy. Often, this fact is not considered in practice or in publications.

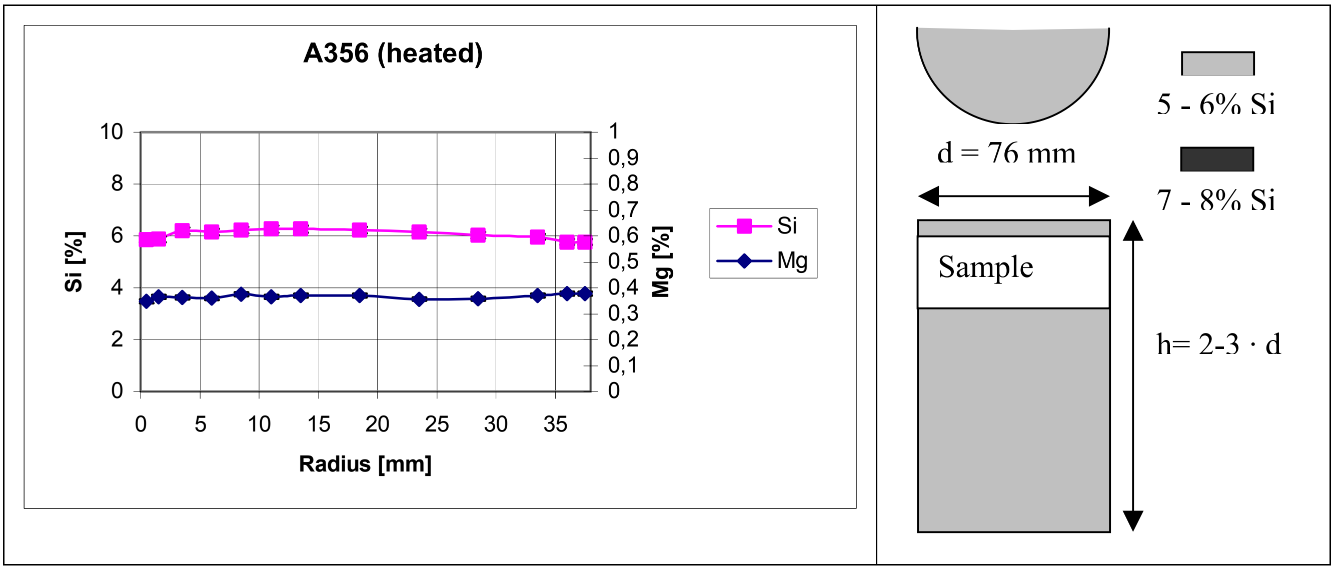

Fig 3: Chemical composition of a vertical heated billet at the top

The quantity of bleeding drops is between 5 % and 12 % of the metal used. The chemical analysis indicates a nearly eutectic composition for the drops, with 11.2 - 11.9 % Si and 0.51 - 0.72 % Mg. This is in correspondence to the Al-Si constitution. Because of the increased gas- and oxide-contents, direct recycling of the drops is not recommended. Like the shavings, the drops should be given to a secondary smelter. Perhaps the metal loss can be lowered by addition of elements with a higher surface tension. On the other hand the critical grain size grows by addition of these elements. These effects should be examined more extensively in raw material production projects.

2.3 FORMING

During the forming process residues like remainders, rejects and overflow are also produced.

	Si	**Mg**	**Ti**	**Fe**	**Cu**	**Zn**	**Mn**
product:							
- finger probe	7.15	0.36	0.079	0.14	0.004	0.006	0.005
remainders:							
- finger part	6.01	0.33	0.091	0.091	0.002	0.005	0.005
overflow	10.6	0.39	0.089	0.2	0.009	0.008	0.006

Tab. 1: Analysis of residues and products

The chemical composition of the components differ greatly from the initial compositions of the heated billet. A certain separation of the components has taken place.

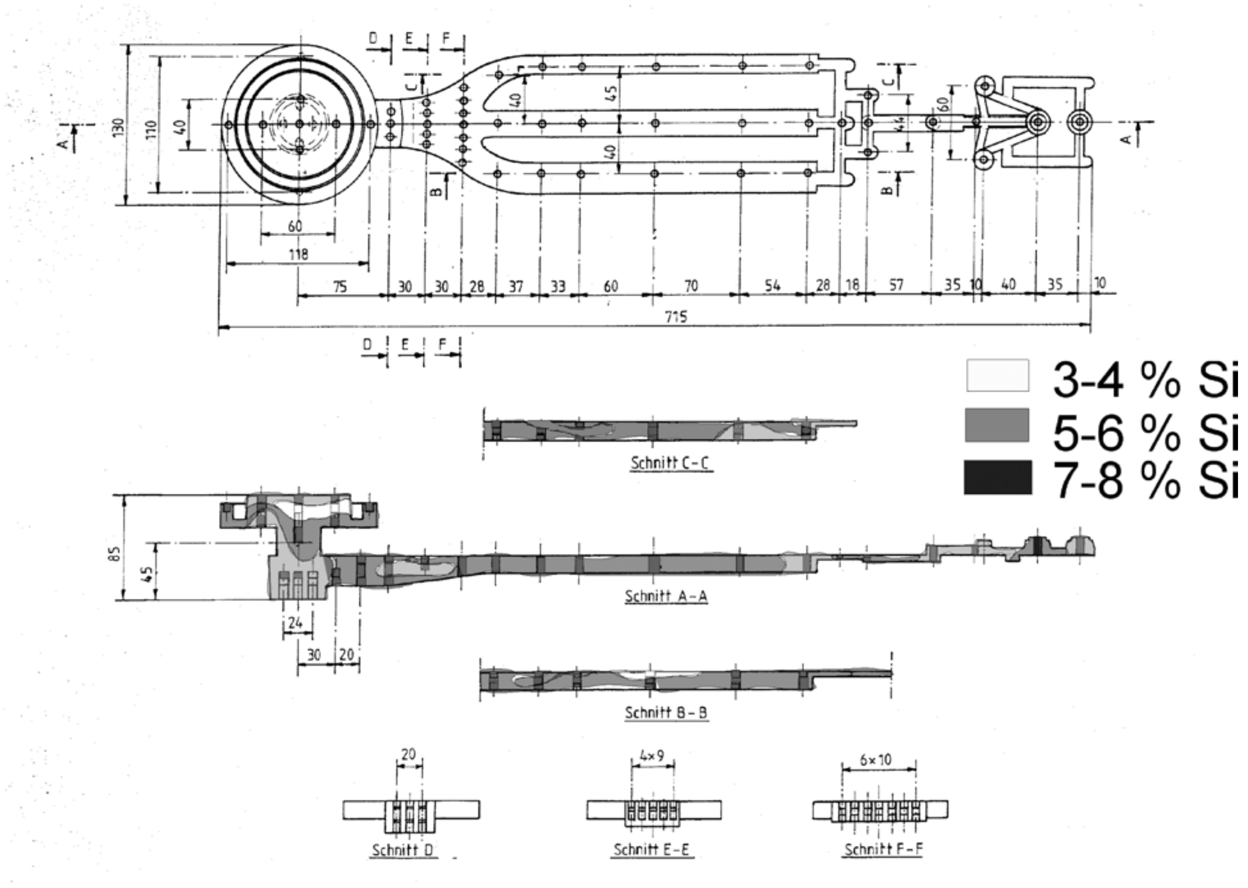

Fig 4: Sketch of a formed product and of the chemical distribution (GI Gießerei–Institut, RWTH department of foundry technology)

Due to the difference to the initial composition and the increased oxide content, the overflow should be recycled in a secondary smelter. The remainders could be remelted directly in the cast house since their oxide content is very low. But due to the reduced content of alloying elements a careful control of composition and realloying is necessary.

2.4 MACHINING AND WORKING

Swarf and turnings, which arise during machining and working in the range of up to 10% of the product [2], should be recycled in a secondary smelter like the saw shavings.

3 ACCUMULATION OF IMPURITIES

The distribution of minor elements and impurities e.g. Fe, Mn and Zn show the same behaviour as the main alloying elements like Si and Mg. These minor elements are enriched in the phases with a higher Si content, e.g. overflows and drops, but also in finished parts. This is in correspondence to the analyses of **Tab 1**.

Fe- rich components like overflows and drops contain about 0.2 % Fe. Therefore, these residues should not be recycled directly, because of their high Fe-concentrations.

Remainders however contain less than 0.1 % Fe and can be used for recycling with identical use..

4 RECYCLING METHODS AND MELT-TREATMENT

Depending on the characteristics of the residues different recycling methods are recommended (**Tab.2**).

Residues of semi-solid processing	**Specific Surface**	**Oxide-content**	**further impurities and enrichment of elements**		**Pre-Processing**	**Recycling**	**Re-commended Melting furnace**
	large / medium / small	**high / low**				**internally / externally**	
Dross (0.5-1%)	large	high	--		Dross preparation (e.g. crushing and screening)	externally	Rotary drum (salt)
							Tilt type rotary
							Alurec™
Casting scrap (2-6%)	small if compact scrap	low	--		--	internally	Induction
							Hearth type
Saw swarf (~2%)	medium	low	Oil and water		Drying or washing	externally	Induction
			dry		--		
Drops (from heating) (5-12%)	medium	high	Water	Si, Mg, Fe	Drying	externally	Induction
			sand		screening		Hearth type
Remainder (~30%)	Small if compact scrap	low	lubricant (e.g. Boron-Nitride)		--	internally	Induction
Overflow	small to medium	low	--		--	externally	Induction
Swarf / Turnings (~10%)	medium to large	low	Oil and water		Drying or washing	externally	Channel induction

Tab. 2: Recommendation of different recycling methods depending on semi-solid processing residue type

At the end of the process chain 50% of the raw material arises as residue. The chemical composition of the different types of residues differ essentially and depends also on the chemical composition of the raw material. It is essential to reduce the amount of drops and remainders, which have to be recycled externally. One possibility to reduce the amount of residues is to modify the raw material. This practice will be discussed in our work e.g. in the raw material production project.

5 SUMMARY

The amount and chemical composition of semi-solid-processing residues are analysed. Nearly one half of the raw material becomes to residue. The residues have often different chemical compositions and depend on the chemical composition of the raw material.

The "history" of the materials is documented for all process steps. The accumulation of impurities is indicated. There is a correspondence between the enrichment of Si-rich components and the impurities (e.g. Iron). Special melt-treatment must be applied. Because of economical aspects residues with higher contents of impurities have to be recycled externally by secondary smelters.

For the future the operation of special recycling plants is discussed [4], [5]. Nevertheless the amount of residues e.g. remainders or drops have to be minimised. The optimisation of semi-solid-processing alloys by addition of elements with a higher surface tension could be one trail solution.

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