History

J. Hirsch
Hydro Aluminium Deutschland GmbH – R&D, D53014 Bonn, Germany

During the last 50 years the volume of aluminium produced has increased significantly and now takes second place on the metal market and the number of applications is still growing. Especially within the mass transport, automotive and construction industry aluminium plays an increasing role in many applications because of its low weight and excellent specific mechanical and corrosion resistant properties.

Since many properties of aluminium semi products (like sheet, tubes and profiles) strongly depend on the process conditions also during early fabrication steps (i.e. casting, homogenization, hot and cold rolling or extrusion). This requires a sound knowledge about the underlying mechanisms and complex interactions between metallurgical and processing parameters which therefore need to be controlled. However, their relation to final properties can so far only be estimated, based on experience and generated mainly by trial and error. Therefore implementation of a new alloy and/or production route involves extensively industrial testing, which is usually very costly, time consuming and moreover, the required optimisation is often limited and therefore incomplete.

Major technical and scientific developments in recent years have lead to enormous improvement in computer power, fundamental physical know-how and models to quantitatively predict thermomechanical processes and related metallurgical effects and resulting material properties. Based on this time now is ready to apply these new methods and chances for the industrial application. In a combined effort of the main european aluminium producers and manufacturers of semifinished products these modern tools which are already well established in fundamental research have been evaluated, improved if necessary, adapted to the principal processes involved and combined to develop a new method of virtual manufacturing applicable to the complete process chain of semifinished products (e.g. sheet, extrusions) to predict the microstructure evolution and resulting material properties.

With this ambitious goal the European aluminium industry started a collective R&D initiative in 1999 composed of three separate projects **("Vir*": VIRCAST,**

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VIRFAB & VIRFORM ,cfr: http://europa.eu.int/comm/research/industrial_technologies/articles/article_371_en.html#1). The three projects were initiated by the **EAA** ("European Aluminium Association": "http://www.eaa.net") member companies combining their R&D forces with those of the leading European research centres and universities, organized in three independent research consortia, in a collaborative EU funded project (Fig. 1) under the 5th Framwork Program ("http://www.cordis.lu/fp5/home.html"), running from March 2000 until 2004.

The projects involved were the "VIR[*]" – cluster projects (Ref. [1–3]), composed of three individual projects "VIRCAST", "VIRFAB" and "VIRCAST" with the general objective is to develop a set of virtual tools (computer models and programs) to simulate microstructure evolution and related properties for the main conventional aluminium alloys for the complete process chain, e.g. DC ingot casting ("VIRCast"), hot and cold rolling or extrusion and annealing ("VIRFab"), and forming processes ("VIRForm"). A detailed overview of the three projects is given in [4] and chapter III.1.

With these computer programs it became possible to describe and analyze complex interactions of various process parameters and metallurgical reactions and their effects on final mechanical properties of aluminium semifinished products [4]. These have to be optimized to meet the ever increasing requirements for innovative and technically demanding applications for aluminium lightweight structures and safety components (e.g. for automotive and other traffic industries), as well as for conventional alloys and mass production (e.g. for packaging and building applications).

Although each of the three separate VIR* projects had its individual goals and independently defined deliverables, they were linked together to cover the complete process chain which can be achieved by correlating the critical output variables of each project with the critical input variables of any downstream project. The end product is an aluminium part with a well defined microstructure formed from a specifically processed semi finished product. Its microstructure and mechanical properties are characterized accordingly so that it's behaviour can be quantified and virtually tested in any adequate users simulation (e.g. in a forming or crash simulation).

A better understanding of material characteristics and quantitative physically based description of microstructure/property evolution during production processes (casting, hot/cold rolling and annealing of Aluminium alloys) and customer applications (e.g. forming operations) has been achieved and a new tool was developed that is able to describe the microstructure evolution of a well characterized small enough (local) material element as function of the thermo-mechanical parameters (i.e. temperature, time, strain and strain rate). This pre-competitive tool can be adapted to the specific parameters of any fabrication or processing route and applied to the many purposes, such as:

- Improvement of industrial production processes and product quality
- Improvement of R&D quality for process and product optimisation
- Design of microstructural states and resulting specific material properties
- Design most effective and efficient fabrication and processing routes

- Reduce significantly the number of expensive test runs in productive plants
- Reduce cost and time to market of new products and processes
- Standardize aluminium alloys for application and to enhance recyclebility.
- Support customer application by material data from the production line

The various simulation tools applied to the production of aluminium semi-finished products can be integrated to form a "Through Process Model" (TPM) that consists of a series of computer based models that are chained together to enable the modelling of the integral microstructural evolution. To create a TPM, it is necessary to develop a quantitative understanding and a set of software tools which can be used to capture and translate existing physical understanding and develop new quantitative descriptions and to apply it to real industrial Al alloys and to various fabrication processes and aluminium applications (e.g. sheet fabrication, extrusion, forming). In this approach any existing or newly developed model can be tested on its validity under production parameters and towards the specific properties required for the final product. It will help to identify any missing link and clarify the influence on upstream parameters on final properties. This joint modelling approach also enhances standardisation of the descriptions methods for microstructures and material properties throughout Europe.

With the help of these tools new alloys (e.g. more suitable for recycling) and new or optimised processing routes can be developed.

1 Zeitschrift Aluminium, Giesel Verlag Isernhagen/D, Vol.78/10 2002 and Vol.80, No.6 (2004), ISSN 0002-6689, (special editions "VIR* conferences):

VIR* publications:

Init.	*Name*	*Title of Publications*
Anne Lise	Dons	*Precipitation and dissolution of Mn-rich dispersoids during the heating of AA3XXX alloys*
Sebastien	Pellerin	*Industrial Application of Hot Tearing, Microstructure and Recrystalizaion Analysis Using the Vircast Software*
Olivier	Ludwig	*Rheological behaviour of partially solidified Al alloys, experiments and modelling*
Pierre-Daniel	Grasso	*Small scale experiments on coalescence and bridging in aluminium alloys*
Yanyun	Li	*Evolution of the microstructures in a DC-cast AA3003 alloy during heat treatment*
Quiang	Du	*Modelling microstructure formation during solidification of multi-component aluminium alloys*
Michel	Rappaz	VIRCAST Achievements: A view from the academic side
Asbjorn	Mo	*A European unified effort towards modelling of hot tearing – Summary of a sub-project in the European Project VIRCAST*
Mickael	Serriere	*Modelling of precipitation in multicomponent alloys*
Moukrane	Dehmas	*Evolution of primary precipitates in a AA3003 alloy during isothermal holdings*

Init.	Name	Title of Publications
Rene	Kieft	*The application of the Vircast hot tearing module on industrial castings*
Herve	Combeau	*Influence of convection on the solidification behaviour of continuous casting of Aluminium alloy*
Herve	Combeau	*Prediction of the macro and microstructures of solidification in DC casting of aluminium*
Erik Paul	van Klaveren	*Modeling of crystal solidification in a full scale ingot – prediction of grain size and morphology using the VIR[CAST] grain growth model*
Anne Lise	Dons	*Particle breakup during extrusion*
Rias	Lok	*Solute level determination in AA1200 and AA3103*
R.	Gärtner	*New Aluminium Radiation Thermometry*
Erica	Anselmino	*Size distributions and area fractions of dispersoids in hot and cold processed AA3103*
Lothar	Loechte	*Through-process modelling of microchemistry effects and application to AA5182 and AA3103*
Yuguo	An	*A comparison of yield loci derived from different approaches for aluminium alloys*
Stefan	Melzer	*High temperature X-ray diffraction: A new technique to study recrystallisation kinetics of aluminium*
Luc	Neumann	*Recursive Effect of Material Models on Process Simulation*
Alexis	Miroux	*Experimental measurement of microchemistry evolution during processing of AA3103*
Matthias	Goerdeler	*Modelling the Evolution of Texture, Microstructure and Mechanical Properties during Hot Rolling, Cold Rolling and Annealing of VIR[*] AA5182*
Jürgen	Hirsch	VIRFAB – What was achieved from an industrial perspective?
Paul	van Houtte	*Modelling deformation texture of aluminium using grain interaction models*
Olaf	Engler	*Correlation of crystallographic texture and anisotropy in the VIR(*) sheet alloys*
Ketill Olav	Pedersen	*The effect of pre-strain on the fatigue life properties of AA6063 and AA6082 alloys*
Eric	Maire	*Experimental characterisation of damage during cold forming of aluminium sheets by means of high resolution X ray tomography*
Shen	He	*Forming limits prediction using physics-based constitutive models*
Patrick	Franciosi	*Modelling particle induced damage during forming of aluminium alloys*
Knut	Marthinsen	*Modelling the Evolution of Microstructure and Mechanical Properties during Processing of AA3103*
Trond	Furu	*Through Process Modelling of Extrusion: Evolution in Microstructure, Texture and Mechanical Properties through the whole Process Chain from As Cast and Homogenized Condition to Forming of Profiles*
Bjørn	Holmedal	*Strain path changes in Aluminium alloys*
Øyvind	Ryen	*Work Hardening of Non-Heat Treatable Aluminium Alloys Towards Large Strains*
Gerd-Ulrich	Grün	The three VIR[*] projects and the final VIR[*]-conference