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A DATABANK FOR THERMOPHYSICAL PROPERTIES OF LIGHT METAL ALLOYS

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The thermophysical properties of solid aluminium, magnesium and titanium alloys are extracted from literature and new measurements performed within a European concerted action (CONST 507D). In Marseille, heat capacity values for binary and ternary aluminium alloys as well as for industrial aluminium and titanium alloys are assessed between 20° and 600°C from DSC and heat content measurements using a drop method; enthalpies accompanying the precipitation and dissolution of metastable and stable phases are determined. All values are stored into the databank THERSYST together with detailed description of the materials and of the experimental conditions. Special modules enable the data selection, representation and manipulation according to the user's criteria.

Keywords: databank THERSYST, light metal alloys

Introduction

A European concerted action has been started in 1990 for three years in order to assess thermodynamic and thermophysical data on light metal alloys. The COST 507D project concentrates on Al- Mg- and Ti-based alloys which have already found a wide ranging application such as in aerospace and marine engineering but may still be improved and serve as matrix alloys in metal matrix composites reinforced by nonmetallic fibres, whiskers or particles. The variations of selected properties with respect to important parameters such as chemical composition, pretreatment of sample, structure and temperature are stored in the databank THERSYST. It contains already existing literature data as well as new experimental values where information is uncertain or lacking. Its aim is to provide experimental data for direct practical applications as well as for com-

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puter-aided engineering design, process simulation and control, and to test theoretical model assumptions on thermophysical properties.

Description of the databank

The databank THERSYST developed in Stuttgart [1, 2] is a combination of a factual data base for thermophysical properties of solids and a modular program system which handles the database content. The user may find in it a property for materials of his interest or, conversely, look for materials whose thermophysical property values cover a specified range.

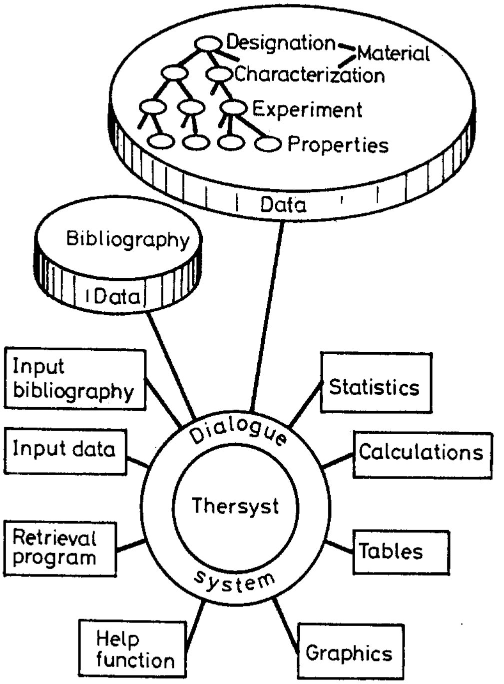

Fig. 1 Elements of modular system THERSYST for storage, handling and representation of thermophysical property data

The following properties are assessed within the COST project:
* thermal conductivity
* thermal diffusivity
* enthalpy
* heat capacity
* electrical resistivity

* linear thermal expansion
* density
* emissivity
* reflectivity

Figure 1 shows that each data-set contains four classes giving the material designation, the material characterization, the experiment description and the thermophysical property data. They are hierarchically structured so as to simplify the storage of different properties for the same material. The bibliographic information is linked to the corresponding data-set by a document number.

All information belonging to a set of experimental values is stored in a standardized form given by the THERSYST scheme of categories. In each data-set the original context between the data on a specific thermophysical property and the information on the sample material and experimental condition is preserved.

Besides the representation of data in the form of graphs or tables, the mod-

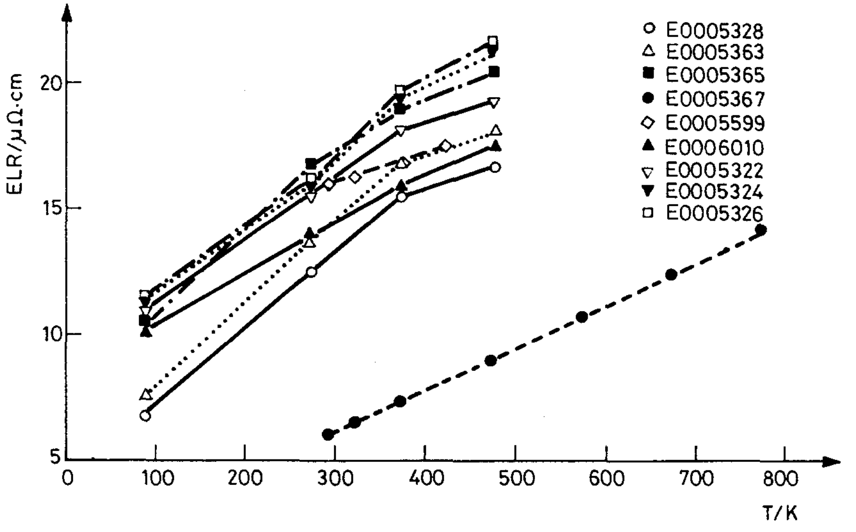

Fig. 2 Electrical resistivity of Mg-Al-based alloys

ules attached to the databank enable data selection corresponding to the criteria defined by the user, as well as data manipulation (e.g. conversion of units, variable transformation, regression of data, calculation of a new property from stored data on other properties).

Up to now, approximately 400 data-sets on light metal alloys exist. They cover Al–Cu, Al–Li, Al–Mg, Al–Si, Al–Ti, Mg–Al and Ti–Al based alloys.

Figure 2 shows as an example the temperature variation of the electrical resistivity for the Mg-Al alloys enumerated in Table 1.

Contribution of C.T.M.

Heat capacities are being determined by two different techniques depending on the material investigated. As for Ti based alloys the C_p-variation with temperature is rather smooth up to 600°C, heat content measurements are carried out in steps of 50°C using a drop method in conjunction with an isothermal Tian-Calvet calorimeter [3]. The mass range of the samples is 40–80 mg. The heat content determinations are performed under pure argon atmosphere.

Table 1 Mg-Al-based alloys: electrical resistivity

Data-set number	Chemical composition	Amount of element wt%	Author(s)
E0005363	Mg	94	Mannchen
	Al	6	
E0005365	Mg	92	Mannchen
	Al	8	
E0005567	Mg	88	Mannchen
	Al	12	
E0005599	Mg	99	Powell
	Al	1	
E0006010*	Mg	90.2	Powell
	Al	9.0	
	Zn	0.5	
	Mn	0.3	
E0005322	Mg	92	Mannchen
	Al	6	
	Si	2	
E0005324	Mg	90	Mannchen
	Al	8	
	Si	2	
E0005326	Mg	88	Mannchen
	Al	10	
	Si	2	
E0005328	Mg	86	Mannchen
	Al	12	
	Si	2	

additional information : B (balance)
*solution heat treatment

For each temperature the measurements are repeated about ten times. The overall error on the heat content data is about 2%. Figure 3 shows the heat content of a titanium alloy containing 6 mass-% aluminium and 4 mass-% vanadium (Ti-Al6-V4) in the 298-875 K temperature range. The corresponding C_P-variation obtained by derivation of ΔH with respect to temperature is given on Fig. 4.

In the case of aluminium alloys, precipitation and dissolution of several metastable phases may occur when the alloy is taken to increasingly higher temperatures. As it would be too time consuming to attend the quasi-equilibrium

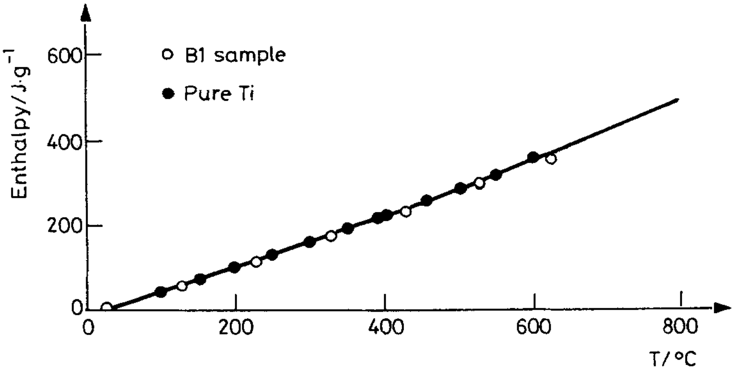

Fig. 3 Variation with respect to temperature of the heat content of a Ti-6%Al-4%V (B1) solid alloy (this work; crosses and solid line) and of pure titanium according to Hultgren *et al.* [5] (o)

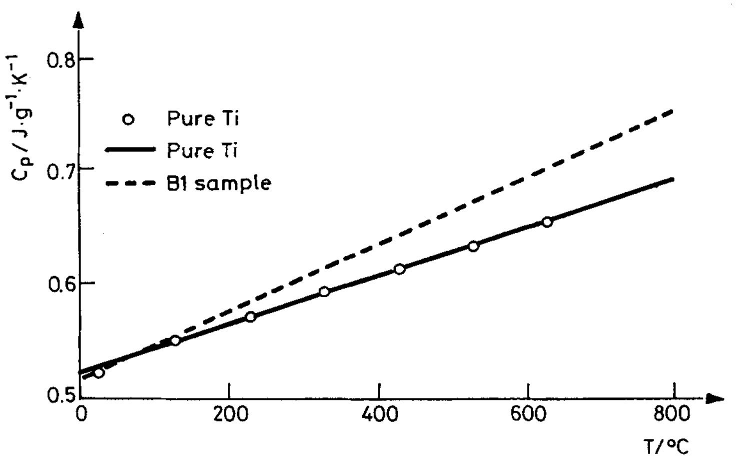

Fig. 4 Heat capacity of a Ti-6%Al-4%V (B1) solid alloy derived from heat content measurements (--) and of pure titanium (crosses and solid line). The crosses correspond to the C_P-data of [5]. The solid line is calculated by derivation with respect to temperature of the enthalpy data of [5]

states in isothermal calorimetric measurements, DSC investigations are preferred. A DuPont thermal analyser (model 990) is used at a heating rate of 20 deg·min^{-1}. The alloys are in the form of disks 6 mm in diameter and 1 mm thick. Their masses are about 70 mg. In order to increase the quality of the curves and to derive the enthalpy values which characterize the different processes, the scans are performed with respect to pure aluminium. The absolute C_p-value for a given temperature is obtained by adding the positive or negative ΔC_p-value to the corresponding C_p-value of pure aluminium given in the literature [4]. Three runs are performed in general; owing to sample inhomogeneities, the reproducibility of the ΔC_p and ΔH data is in general not better than ±5%. For each alloy investigated different heat treatments are carried out in order to study the influence of aging time and temperature on the ΔC_p evolution. All these specifications enter the databank.

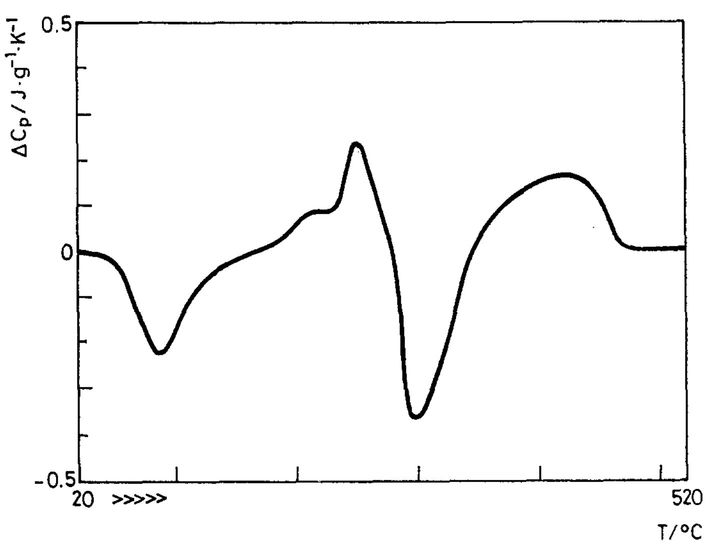

Fig. 5 Heat capacity evolution of an Al-2%Cu-1.3%Mg alloy with respect to pure Al, at a heating rate of 20 deg·min^{-1}

ΔC_p curves for two aluminium alloys transmitted by an Austrian COST-partner are given as further examples. Figure 5 shows the evolution of an Al-2% Cu-1.3% Mg alloy homogenised at 525°C for 20 minutes and quenched into water at 20°C. The low temperature GPB zone precipitation is accompanied by an enthalpy value of –11 J·g^{-1}, the metastable *S*' – and the stable *S*-precipitation around 300°C, by –14.5 J·g^{-1}.

The ΔC_p curves obtained on an industrial Al alloy 6060 containing 0.44% Si, 0.43% Mg and 0.17% Fe as main elements and having undergone two different heat treatments are given in Fig. 6.

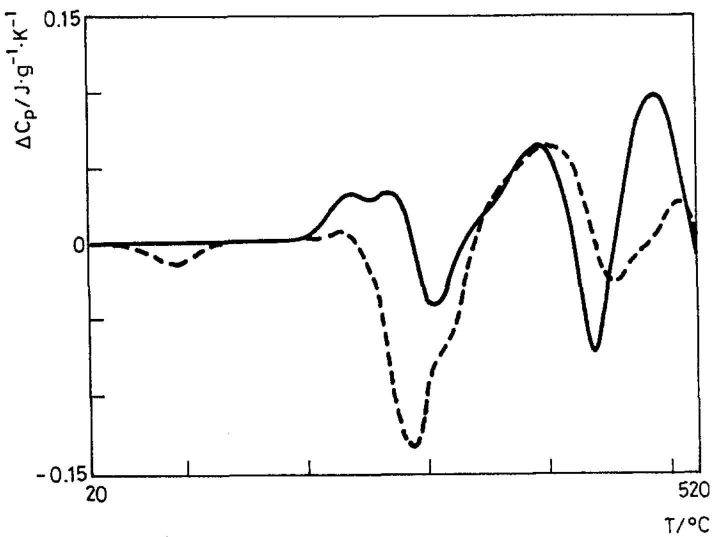

Fig. 6 Heat capacity evolution of an industrial alloy 6060 with respect to pure Al (heating rate : 20 deg·min^{-1}). Discontinuous curve: 2 h/550°C → 0°C. Continuous curve : Temper F22

It is hoped that all these results will contribute to the further development of light metal alloys and provide a basis for the development of metal matrix composites for extended industrial applications.

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Zusammenfassung — Die thermophysikalischen Eigenschaften fester Aluminium-, Magnesium- und Titanlegierungen werden aus der Literatur gesammelt und neue Messungen sind innerhalb eines europäischen Projekts (COST 507D) im Gange. In Marseille werden spezifische Wärme-kapazitäten für binäre und ternäre Aluminium- und Titanlegierungen zwischen 20° und 600°C aus dynamischer Differenzkalorimetrie und Wärmeinhaltsmessungen mit Hilfe einer Fallmethode bestimmt; daraus ergeben sich die Enthalpien, die Bildung und Auflösung metastabiler und stabiler Phasen begleiten. Alle Ergebnisse werden in die Datenbank THERSYST mit genauer Angabe der untersuchten Stoffe und der Versuchsbedingungen gespeichert. Spezielle Module erlauben die Datenauswahl, -wiedergabe und -manipulierung gemäss Verwenderkriterien.