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CONSIDERATIONS REGARDING SEMISOLID MATERIALS AND THEIR DEFORMATION BEHAVIOR

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ABSTRACT
The work presents some reflections on semisolid state processing of metal alloys and it highlights the behavioural regimes, which occur at the semisolid state deformation. The two regimes that show the deformation behaviour in semisolid state are steady-state regime and transitory regime.
Finally the paper presents the variation of the deformation resistance following the hot compression tests.
Keywords: semisolid, thixotropic, steady-state regime, deformation degree.

1. INTRODUCTION
Semisolid processing technologies are gaining atention both from scientist and from engineers due to their high potential to produce parts in almost final state. [1] Certain kinds of paint, honey, and mascara are all tixotropic. When they are shared they flow, wend allowed to stand they thicken up again, so their viscosity is shear rate and time dependent.
This phenomenon has been noticed for the first time by David Spencer, a student at the Massachusetts Institute of Technology (MIT) in the year 1972 and has lead to the development of a new technology for the processing of metal alloys.
If the material is stirred continuously during cooling from the fully liquid state to the semisolid state the viscosity was significantly lower then if the material was cooled into the semisolid state without stirring. Stirring breaks up the dendrites, which would normally by present so that the microstructure in semisolid state consists of spheroids of solid surrounded by liquid (figure 1).
The key to semisolid processing is to obtain a forerunning alloy with a spherical, nondendritic structure. This globular structure is completely different from the dendritic structure typical for casted alloys and its role is to share thixotropic properties to the semisolid alloys. Thixotropic alloys behave just as solids do, they have a butterish consistency (they are malleable), but under the action of shearing they act similarly to motor oils.
Spheric structure semi products may get to a semisolid status if heated and by die-forging or casting we obtain parts with a complex geometry, a finite shape and an excellent surface quality.
Two relatively new classes of the processing technologies, which allow obtaining parts with superior mechanical characteristics at low costs are thixoforming and rheocasting, processing techniques for semisolid metals and metal alloys. *Thixo* comes from thixotropy, a term introduced by H. Freundlich in 1935 to define the property of solutions and suspension to gelatinate when they are in repose and to become fluid when they are shaken up.

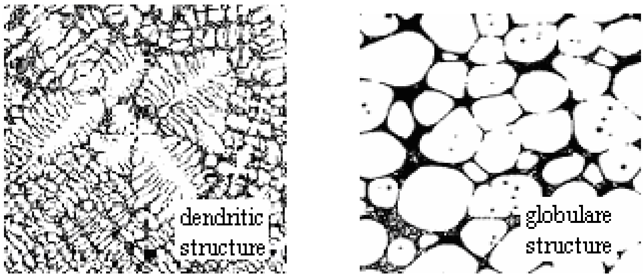

Figure 1. Semisolid alloy with dendritic structure and globular structure [2]

Semisolid processing rivals other technologies used for making spare parts for the aerospace industry, the military industry and especially the car industry. In Europe they produce aluminum spare parts for the car industry; in the USA they produce mostly bicycle spare parts while in Asia they produce electronic components used for the home appliances.

2. THE STEADY-STATE REGIME AND THE TRANSITORY REGIME

To exploit all the advantages of semisolid state processing we must understand the flowing behaviour of semisolid alloys. Although research was conducted on the optimization of the semisolid state processing technologies and on the globular microstructure specific to the precursory material, fewer are known on the way in which the deformation behaviour of semisolid suspensions influences the quality of the spare parts produced.

The constitutive model and the knowledge related to the materials characteristic properties as well as the agglomeration degree of the primary particles, the specific heat, the liquid fraction or the thermal conductivity in the semisolid temperature interval allow the optimization of the processing technologies.

The behaviour of thixotropic alloys in the semisolid temperature interval depends on the following factors: temperature, deformation degree, variation of temperature in time and the degree of deformation between the primary particles.

It is generally accepted that the semisolid alloys deformation stress is in accordance with the thixotropic behaviour shown in figure 2, due to the phenomenon of agglomeration and de-agglomeration during formation. The stress corresponding to the σ_∞ steady-state condition and the characteristic time τ depend on the agglomeration and de-agglomeration mechanisms. In figure 2 there are highlighted two behaviour conditions: the transitory condition and the steady-state condition.

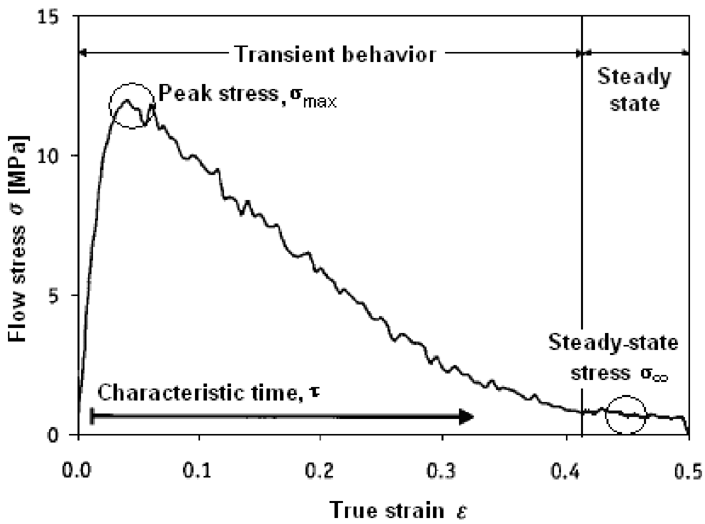

Figure 2. The curve of the dependency between stress and deformation at the compression test of a thixotropic behaviour aluminum alloy which highlights the steady state and transitory state behaviour [3]

In the transitory condition the semisolid material has a behaviour, which depends on the initial structure. What interests in this stage is the maximum deformation stress, σ_{max} because it determines the maximum value of the deformation force.
If we neglect the structure modifications during processing and we take a deformation degree independently of the deformation stress, which only varies with the deformation temperature and speed, we may consider a behaviour of the material in the steady-state regime. [3]

3. THE DEFORMATION BEHAVIOUR OF SEMISOLID MATERIALS

At the Tokyo-Japan institute – Institute of Industrial Science – they conducted some research on 304 stainless steel type; they also performed compression tests in order to obtain the stress-deformation curves. The chemical composition of this steel may be noticed in table 1. [4]

Table 1. The chemical composition of the 304 stainless steel [4]

C, [%]	Mn, [%]	Si, [%]	Cr, [%]	Ni, [%]	S, [%]	P, [%]
0,03	1,74	0,45	18,06	9,21	0,024	0,024

The temperature corresponding to the semisolid field characteristic to this steel varies between 1663K and 1723K. The test pieces were heated at temperatures around the solidus point and then they performed the hot compression test where they obtained data on the force applied, respectively the piston stroke. They also had several trials where the deformation speed varied between 0,5 – 10 s^{-1} (figure 3).
The stress-deformation curves show a maximum stress at small deformations and lower stress, corresponding to the steady-state condition, at high deformations. Thus, in order to obtain these curves the researchers of the Tokyo Institute have performed a series of hot compression tests.
At a temperature of 1688K steel is made up of liquid and ferrite δ. The deformation behaviour, at this temperature, consists in an increase in stress up to a maximum value considered the stress top, corresponding to a deformation of 10-15%; then, with the increase of the deformation degree the stress decreases to a certain minimum value. At deformation degrees exceeding 0,4 we consider that we are in a steady-state condition while at deformation degrees of up to 0,4 the condition is considered transitory.

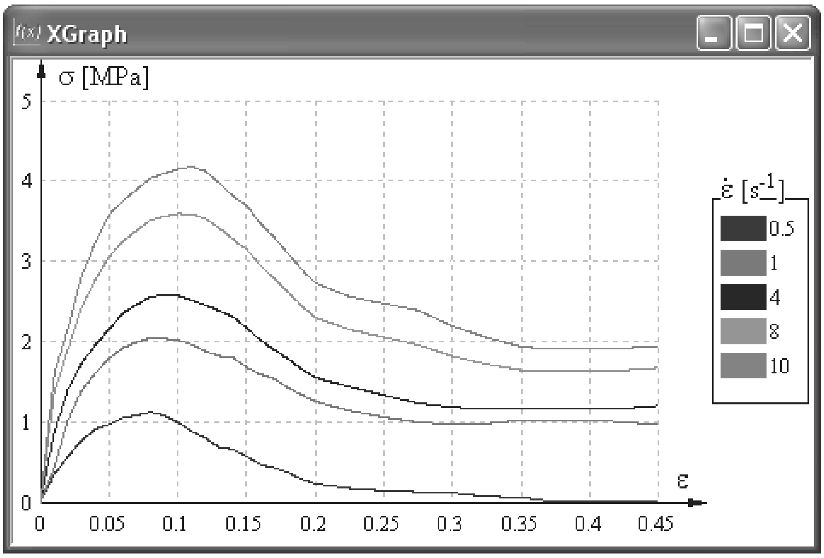

Figure 3. The stress-deformation curves at different deformation speeds

The hot compression tests were performed at different deformation speeds varying from 0.5 - 10s^{-1} and according to the trials they noticed that the maximum stress increases with the increase of the deformation speed (figure 4).

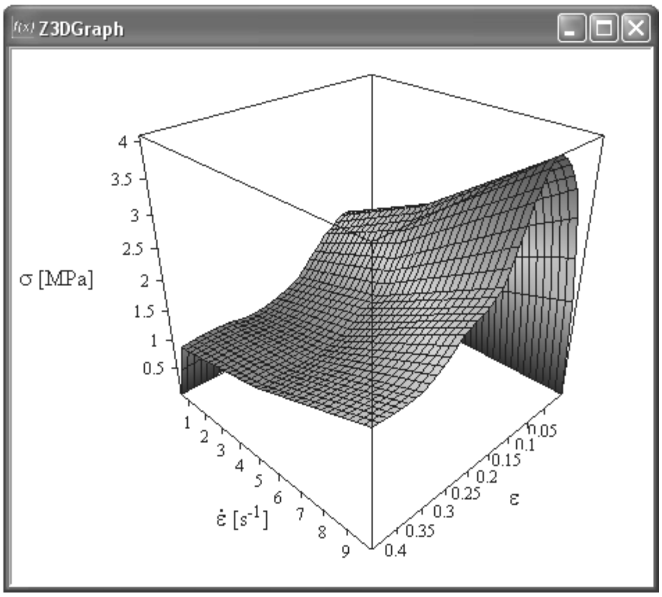

Figure 4. The stress – deformation – deformation speed dependency

4. CONCLUSIONS

A very important variable in the deformation processes of the semisolid state materials is the deformation i.e. flowing behaviour of the semisolid suspension.

The hot compression tests were performed at different deformation speeds varying from 0.5 – $10s^{-1}$ and according to the research we noticed that the maximum stress increases with the increase of the deformation speed. From the stress-deformation curves we notice that during low deformation degrees in the transitory regime the stress is maximum and during the steady-state condition, which corresponds to high deformations the stress is low.

The deformation behaviour at the temperature of 1688K consists in the increase of the stress to a maximum value, which is considered the stress top at a deformation degree of 10-15%. When the deformation degree increases, usually exceeding 0.4, the stress decreases up to a certain minimum value. Therefore the deformation degrees exceeding 0.4 show that we are in a steady-state condition while the deformation degrees of up to 0.4 show that the condition is transitory.

5. ACKNOWLEDGEMENTS

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