# Influence of Cooling Speed during Melt Spinning Process on Properties of Al-Fe-Mm-Si-Mg Bulk Materials Prepared by SPS

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**This work is devoted to description of microstructure of bulk Al-Fe-Mm-Si-Mg alloys and their thermal stability. The alloy was prepared at different cooling rates (600, 1000 and 1400 RPM) during melt spinning process and sintered at the same conditions by SPS. The aim of this work was to prove if change in melt spinning conditions influence the behaviour of bulk material. It was proven that independently on cooling rate precipitation occurs during sintering process. All materials exhibited heterogenous microstructure composed of fine and coarse areas – residue of melt spinning process. During annealing of bulk materials prepared by powder metallurgy, no precipitation of new phase was observed. It is an evidence that precipitation mechanism of self-healing is not possible for these alloys.**

**Keywords:** Al alloys, melt spinning, SPS, self- healing

## 1 Introduction

Aluminium alloys are widely used in automotive and aerospace industry. Although they have been studied for a long time, still new horizont of their utilization can be found. One of them are self-healing Al alloys. In case of rapidly solidified Al-Fe-Mm-Si-Mg alloy, the precititation self-healing mechanism might be possible. Precipitates forming at elevated temperature are closing crack in the material. This mechanism was proved in underaged commercial alloy [1].

Processing of Al alloy by melt spinning lead to formation of heterogenous structure. Ultrafine area that was close to the cooling wheel is formed be supersaturated solid solution [2]. The other parts of ribbon have coarser microstructure. Rapidly solidified ribbons can be chopped and sintered by spark plasma sintering [3, 4]. Short sintering times by SPS may support presence of supersaturated solid solution into bulk material, which can provide material self- healing properties. The higher cooling rate during melt spinning process the higher amount of metastable phases including supersaturated solid solution can be formed. The aim of this article is to describe the influence of cooling rate during metl spinning on properties of bulk material.

## 2 Experimental

The alloy with composition of Al- 5 wt. %Fe-5 wt. Mm-3 wt. Si-3 wt. Mg was prepared by melting appropriate amount of pure metals. Subsequently the alloy was processed by melt spinning technique at speeds of cooling wheel of 600, 1000 and 1400 RPM. The rapidly solidified ribbons were milled in ice bath and sintered by SPS (FCT HP D10 ) at 500 °C with duration of 15 min. Bulk samples were observed by SEM (TESCAN VEGA 3 LMU), TEM (Jeol 2200 FS), phase composition was measured by XRD (PANanalytical X´Pert PRO, Co lamp).

## 3 Results and Discussion

Microstructure of bulk material sintered from rapidly solidified ribbons prepared at 600 RPM is shown in Fig. 1.

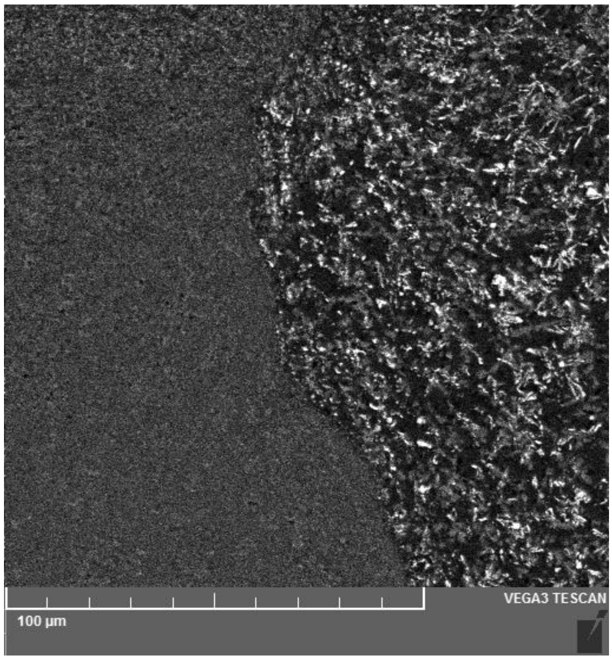


***Fig. 1*** *Microstructure of bulk SPS material sintered from rapidly solidified ribbons prepared at 600 RPM (SEM)*

Fig. 2 llustrates detailed microstructure of the material sintered from rapidly solidified ribbons prepared at 600 RPM. The elemental maps prove inhomogeneous distribution of alloying elements and prove presence of intermetallic phases in the material. The alloy is composed of Al matrix, Fe rich parts ($Al_5Fe_2$ phase), parts rich in Ce and Si (CeAlSi phase) and areas rich in Mg and Si ($Mg_2Si$ phase).

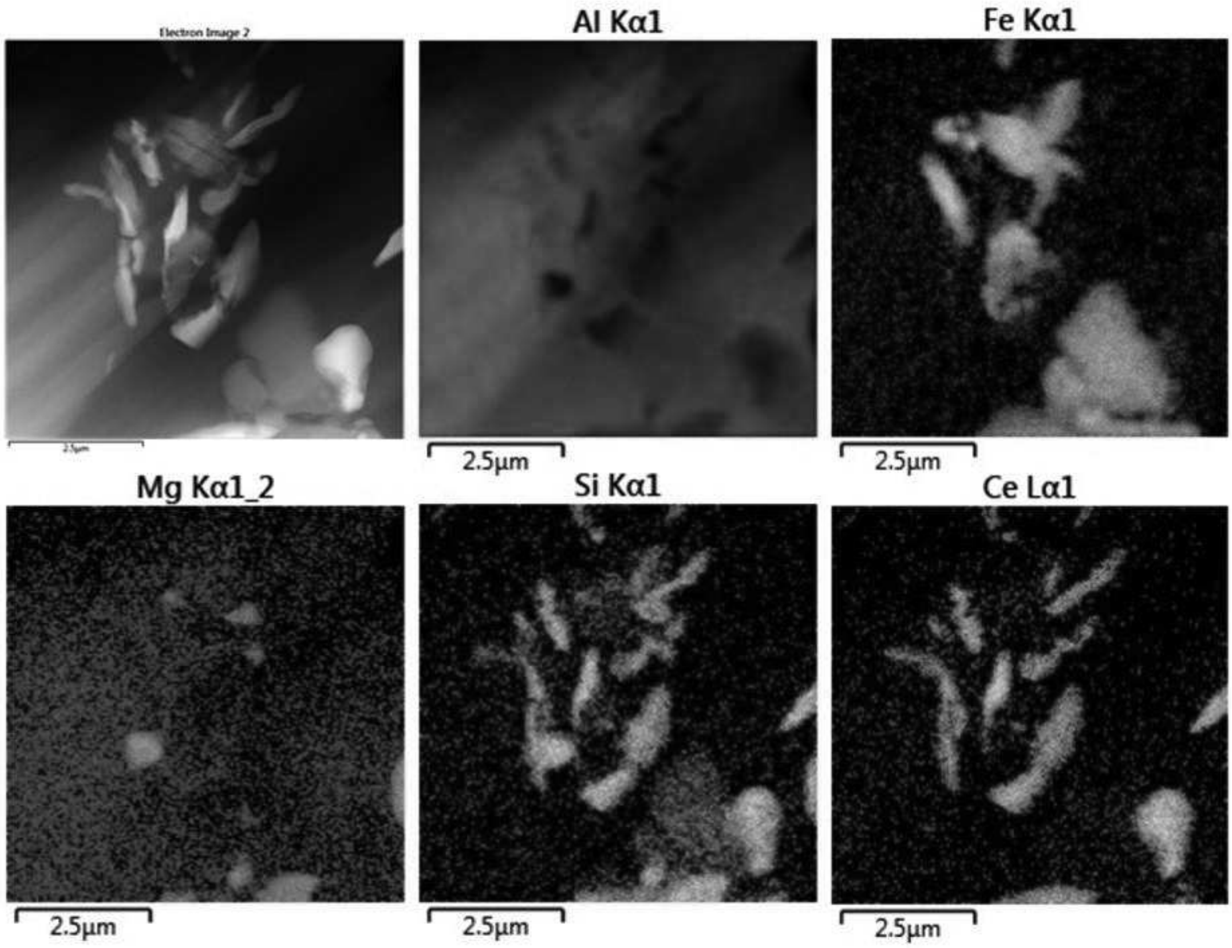


***Fig. 2** Detailed microstructure of bulk SPS material sintered from rapidly solidified ribbons prepared at 600 RPM (TEM/EDS)*

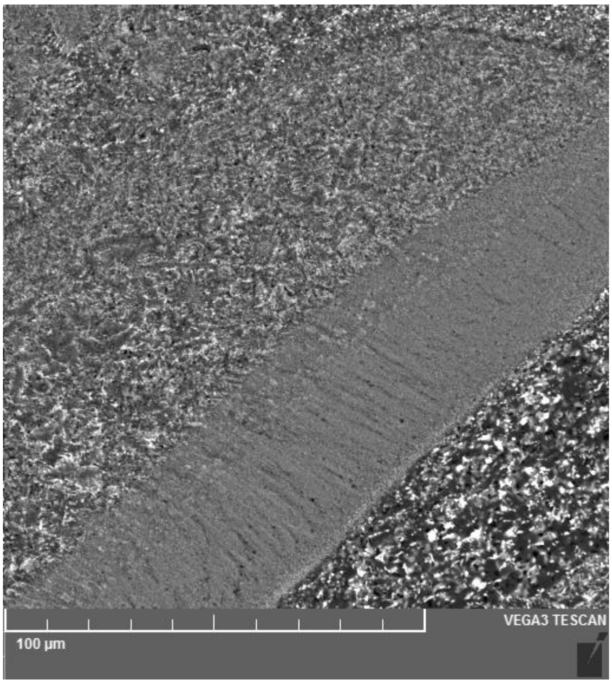


***Fig. 3** Microstructure of bulk SPS material sintered from rapidly solidified ribbons prepared at 1000 RPM (SEM)*

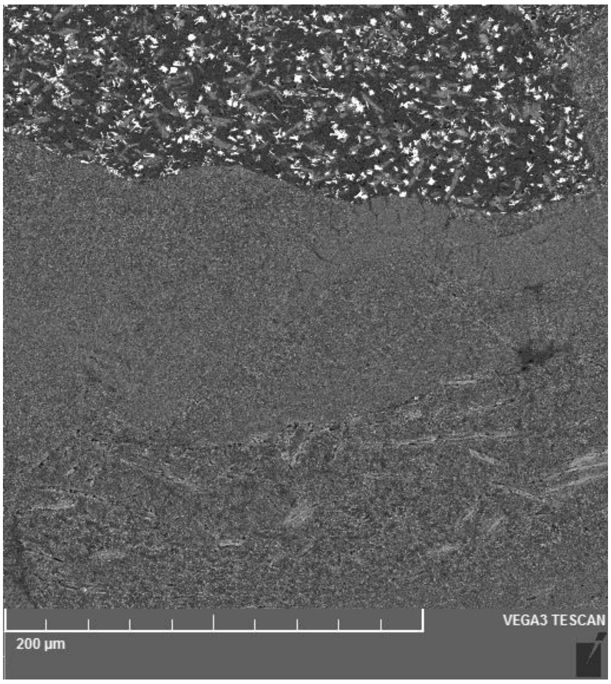


***Fig. 4** Microstructure of bulk SPS material sintered from rapidly solidified ribbons prepared at 1400 RPM (SEM)*

Fig. 3 shows microstructure of material sintered from rapidly solidified ribbons prepared at 1000 RPM. The microstructure is similar to the previous material with inhomogeneities resulting from melt spinning process.

Fig. 4 shows microstructure of material sintered from rapidly solidified ribbons prepared at 1400 RPM. The microstructure is similar to those shown in Fig. 1 and Fig. 3.

Bulk material sintered from rapidly solidified ribbons prepared at 600 RPM was formed by 1 – Al, 2 – CeAlSi, 3 – $Al_5Fe_2$, 4 – $Mg_2Si$, 5 - $Al_{167,8}Fe_{44,9}Si_{23,9}$ phases, as shown in diffraction patterns in Fig. 5. The main change in phase composition happened during SPS process. Subsequent heat treatment did not lead to observable changes in phase composition.

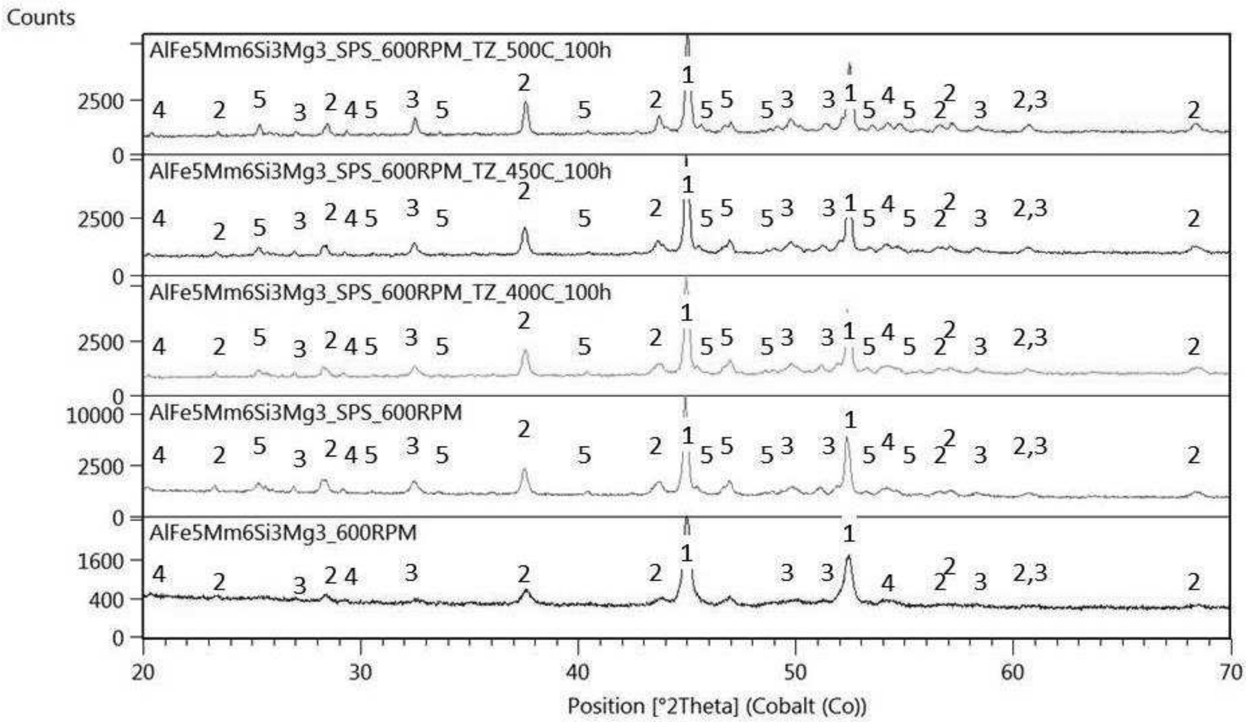


***Fig. 5*** *Phase composition of bulk SPS material sintered from rapidly solidified ribbons prepared at 600 RPM (XRD)*

Fig. 6 illustrates the situation for material sintered from rapidly solidified ribbons prepared at 1000 RPM that is similar to the one for material sintered from rapidly solidified ribbons prepared at 600 RPM.

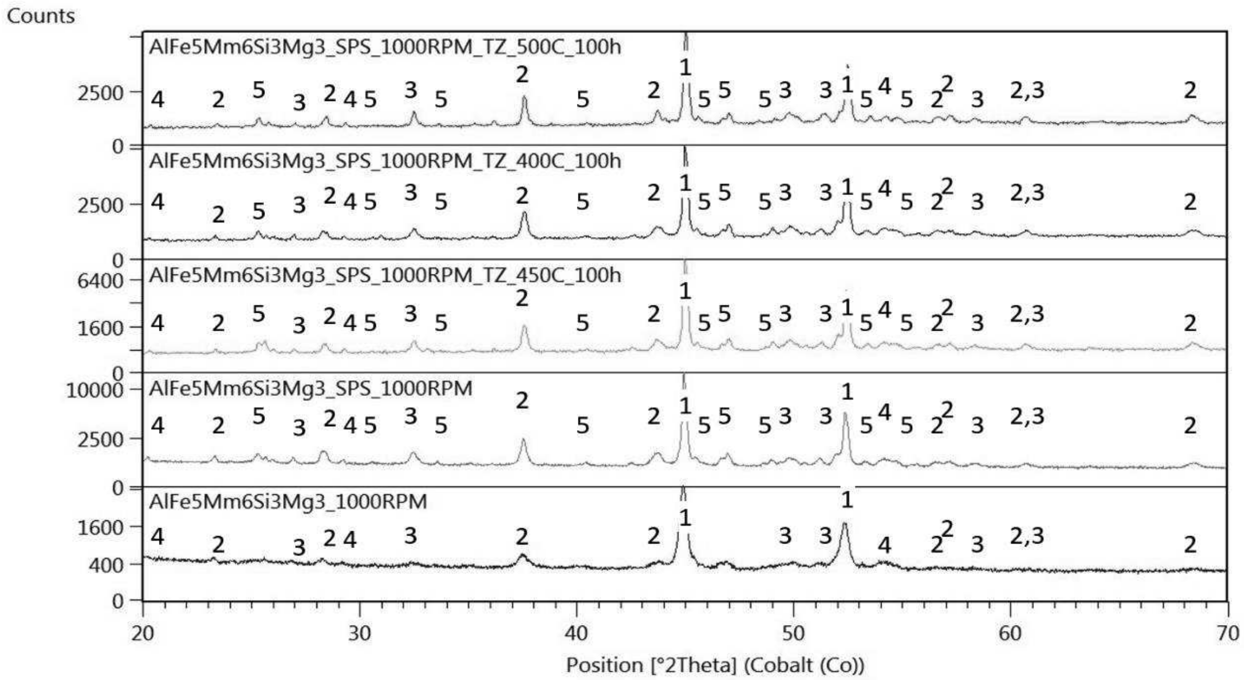


***Fig. 6*** *Phase composition of bulk SPS material sintered from rapidly solidified ribbons prepared at 1000 RPM (XRD)*

Phase composition of material sintered from rapidly solidified ribbons prepared at 1400 RPM is again similar to previous two materials, as shown in Fig. 7.

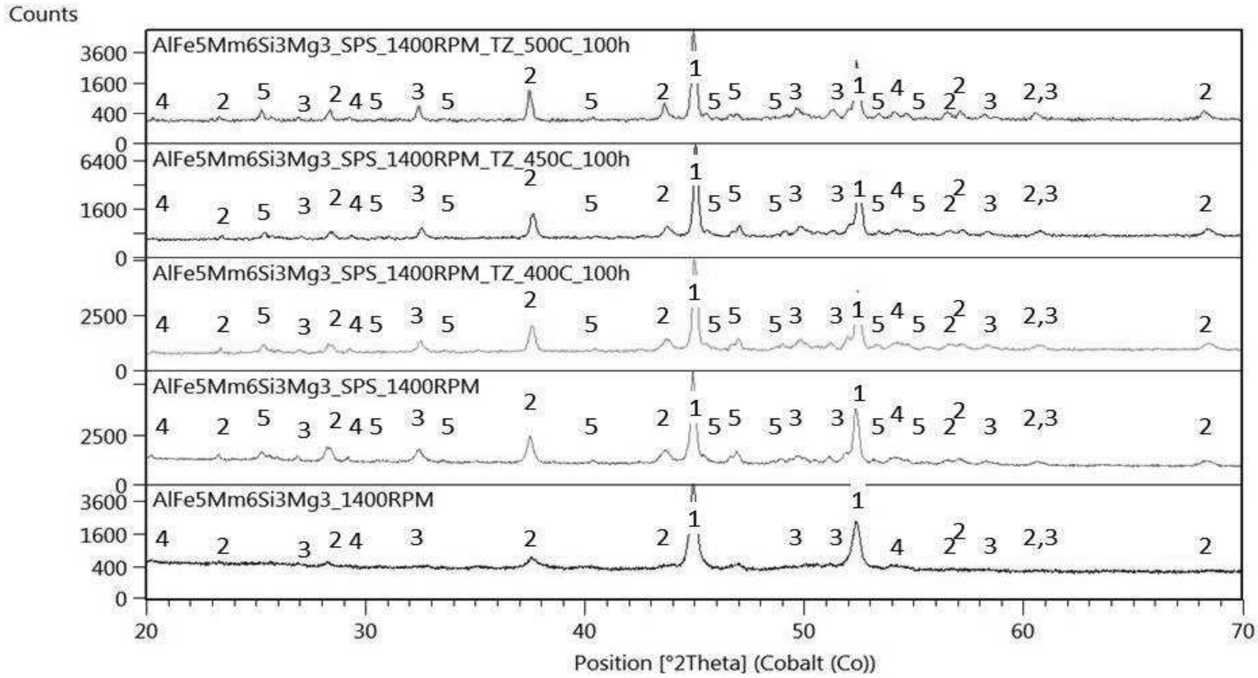


***Fig. 7*** *Phase composition of bulk SPS material sintered from rapidly solidified ribbons prepared at 1400 RPM (XRD)*

The precipitation took place fully during SPS process. Under subsequent heat treatment no change in phase composition was observe. This means that precipitation healing is not possible for bulk materials independently on cooling rates of rapidly solidified ribbons.

## 4 Conclusion

All prepared bulk materiáls exhibited very fine microstructure with residual porosity comming. As-sintered materials had heterogenous microstructure formed by areas with different cooling conditions during melt spinning proces. In all cases, supersaturated solid solution was fully decomposed during sintering of rapidly solidified ribbons and no changes in phase composition were observed during subsequent heat treatment. These results indicate that conditions of melt spinning proces do not influence significantly properties of bulk materials prepared by SPS. The fully precipitation of alloying elements from Al matrix during sintering also predects that this materiál would not exhibit the slef-healing properties as precipitation healing was the most probable self-healing mechanism in this case.

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