STUDY OF RESIDUAL STRESS PRODUCED IN METAL MATRIX COMPOSITE Al-SiCw BY SHOT PEENING.

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INTRODUCTION

Advanced composites show considerable promise for weight and volume critical applications, for instance, aircraft and space vehicules. Aluminum alloys reinforced with silicon carbide (SiC) whiskers and particulates are new potentially useful, structural materials with high strength and high modulus.

But the magnitude of residual stress and surface roughness in these materials have a very important effect on the yield stress and fatigue strength than in the conventionnals materials.

Shot peening treatment, hammering are known to increase materials fatigue behavior by inducing compressive residual stress.

Shot peening is an established surface treatment which produces both surface roughening and the development of compressive residual stresses in the surface. If the material is susceptible to work hardening, it also produces surface hardening since local plastic deformation occurs.

In this papers we have studied the effect of shot peening treatment on residual stress and surface roughness of MMC components. The incremental drilling method is used for residual stress determination. Parameters studied are : Almen intensity , bead diameter and density .

The previous investigation [1] about the influence of shot peening on MMC Al6061 + 20% SiCw and Al2024 + 15% SiCp shot peened have shown that shot peening treatment does not affect their fatigue strength significantly like on the unreinforced material, this may probably due to bad shot peening conditions.

The aim of this paper is to show the effects of shot peening treatment on residual stress field distribution , depth of compressive residual stress, microstructure and surface roughness of MMC.

A composite of 2024 and 15% volume fraction whiskers of SiC has been tested.

I EXPERIMENTAL CONDITIONS AND RESULTS

Experiments were carried out using shot peening conditions reported in table 1. The matrix chemistry composition was: in % Al(93,5), Si(0,8), Cu(4,4), Mn(0,8), Mg(0,5). The mechanical properties were as follows: ultimate strength UTS(616), yield stress σ_y(562), Young's modulus E(107400 MPa). This composite was manufactured by powder metallurgy method.

Residual stress and the depth of compressive residual stress were mesured by the incremental hole drilling method.

The hole drilling method involves monitoring the change in strains when a hole is drilled into a residually stressed component [2]. Measurement is made by means of a special three element strain gauge rosette. These strain measurements can then be related to the original stress in the analysed sample at the hole location.

To obtain the gradient of residual stress in depth, the hole is drilled in steps.

Surface roughness (Ra and Rt) was measured over a longitudinal distance of 15mm by a Talysurf 6

	Reference number of samples	Bead diameters (mm)	Almen intensity
Steel	1	0,60	F25-30A
	1B	0,60	F20-25A
bead	2	0,80	F33-40A
Glass	3	0,90	F15-20N
	4	1,00	F15-20A
bead	4B	1,00	F20-25A
Ceramic	5	0,75	F15-20N
	6	1,06	F25-30A
bead	6B	1,06	F20-25A

Table 1 Shot peening conditions and reference number of samples

RESULTS AND DISCUSSION

Table 2 shows the results

Reference number of samples	Roughness		Maximal residual stress	Depth of compressive residual stress
	Ra(µm)	Rt(µm)	(MPa)	(mm)
1	5,64	27,01	-358,4	0,70
1B	4,63	21,81	-388,4	0,45
2	6,82	31,83	-333,6	0,70
3	2,36	12,43	-354,9	0,18
4	3,83	19,84	-469,2	0,25
4B	4,56	21,48	-414,2	0,35
5	1,99	10,93	-391,2	0,14
6	6,32	31,61	-362,8	0,45
6B	4,94	24,43	-341,6	0,45
Casting	2,19	12,3	/	/
Machined	1,07	2,98	/	/

table 4 Mesured results : Roughness of peened surface, maximal residual stress and Depth of compressive residual stress change with shot peening conditions as the conventionnal materials

Shot peened MMC behaves like the matrix. Similar results were obtained on some MMC mechanicals properties.

Figure 1 shows that the depth of compressive residual stress changes with bead density, Almen intensity and bead diameters. Steel beads with high density give a higher depth of compressive residual stress. This may probably be due to the high hammering and Hertz's pression which create plastic deformation on the surface layer. As in the conventional materials, maximal residual stress induced by shot peening seem not to be directly related to shot peening parameters (figure 2). Maximal residual stress which can be achieved by shot peening is considered as material intrinsic property. Niku Lari [3] has shown that, in conventionnal material, maximal residual stresses induced by shot peening is about 60% σ_y (yield stress). In those MMC, the maximal residual stress due to shot peening is about 62% σ_y. Shot peening seems to create more residual stresses in MMC components than in the matrix. This difference can be explained by the fact that MMC materials have higher mechanical properties than the matrix .

As in the conventional materials, shot peening treatment increases surface roughness in MMC. Figure 3 shows the Ra evolution with shot peening parameters. Increasing bead diameters, density and Almen intensity induces higher surface roughness.

Shot-peening parameters also have the same influence on residual stress evolution as in the conventional material (figure 4). It can be observed also that stresses in both directions x and y are the same after shot peening (figure 5), the opposite result is obtained after machining (figure 6). Shot peening can be interesting for MMC because it creates plane isotropic residual stresses on the surface layer.

On figure 7, 4 curves show residual stresses obtained with different manufacturing conditions. It is very difficult to apply superposition theorem in MMC components as in the unreinforced materials. In fact, the level of residual stresses on the machined and unmachined materials is different , but after shot peening the same materials, this difference becomes very small. Remember that superposition theorem is always used to predict the stress state in materials.

One of the aims of this study was to determine the shot peening effect on MMC surface layer microstructure. Investigations were carried out using an optical microscope at a magnification of 500X and Scanning Electron Microscope (SEM) for all the samples before and after shot peening. Figure 8 shows different results obtained. It can be observed that shot peening creates little change on surface layer, but it is very difficult to say whether it creates surface reinforts fracture or not .

On figure 9, we try to explain the mechanism of generation of residual stresses on MMC materials by shot peening. After shot peening, both reinforcement and matrix are in compression on the surface layer. We have assumed that, the compressive residual stresses are only created by the matrix's plastification, the presence of reinforcement in the matrix influences the residual stress level. Those results agreed with the numerical calculations obtained by an analytical model [4] and the experimental data obtained by X-ray diffraction method [5].

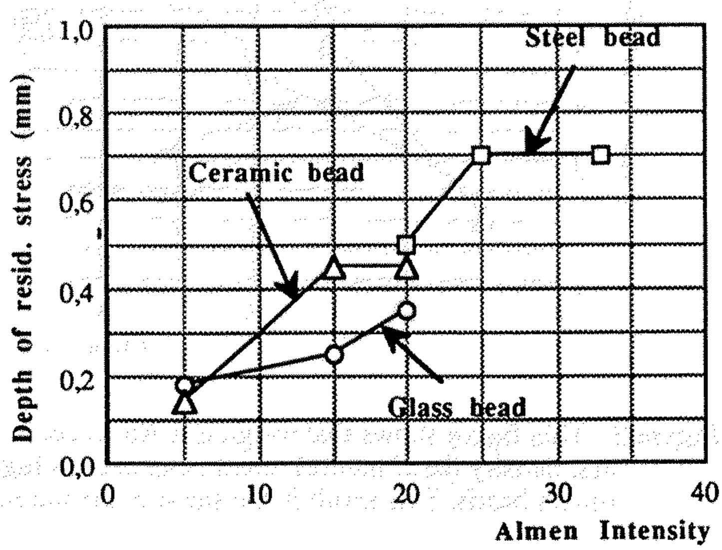

Figure 1 Depth of compressive residual stresses increases with Almen intensity and density of bead. High density bead gives high depth of compressive residual stresses as in the unreinforced material .

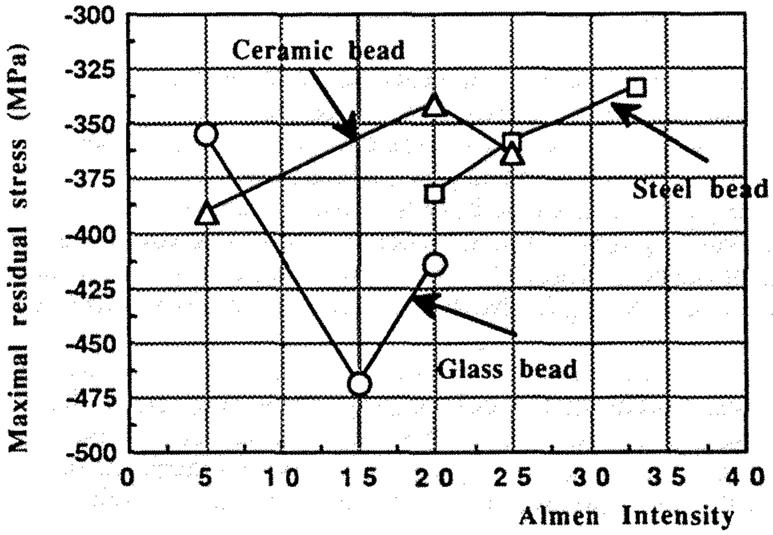

Figure 2 This figure shows little change of maximal residual stresses with Almen Intensity and bead density. Maximal residual stresses seem to be an intrinsic property of MMC like in the unreinforced materials. Maximal residual stress values are comparable to the matrix ones.

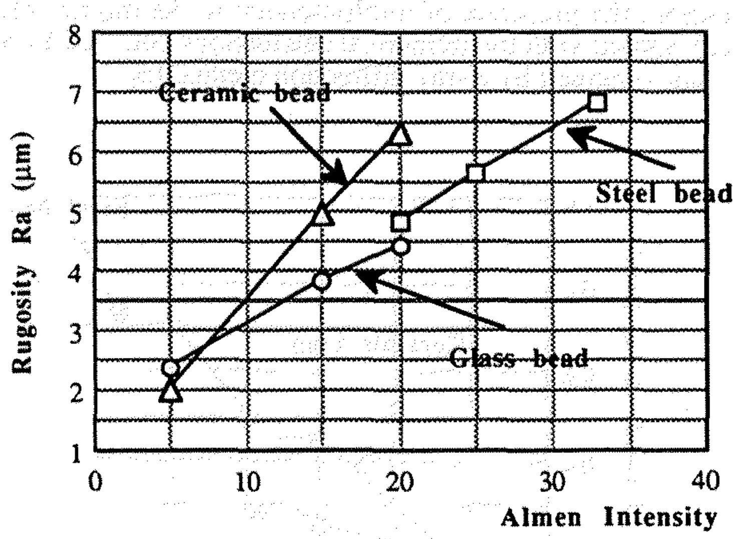

Figure 3 This figure shows that roughness Ra increase with Almen intensity and density (bead nature). Steel bead creates higher roughness than the two others beads. This result is the same in the unreinforced material.

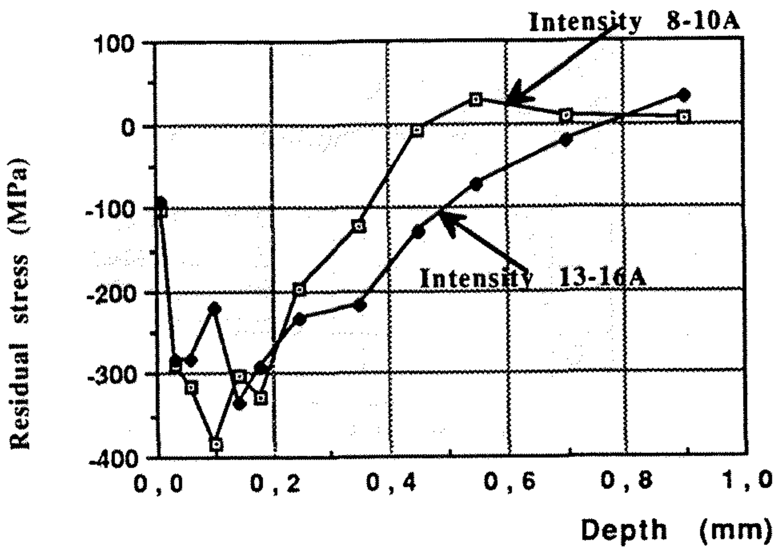

Figure 4 Both residual stress gradient and depth of compressive residual stresses change with Almen Intensity.

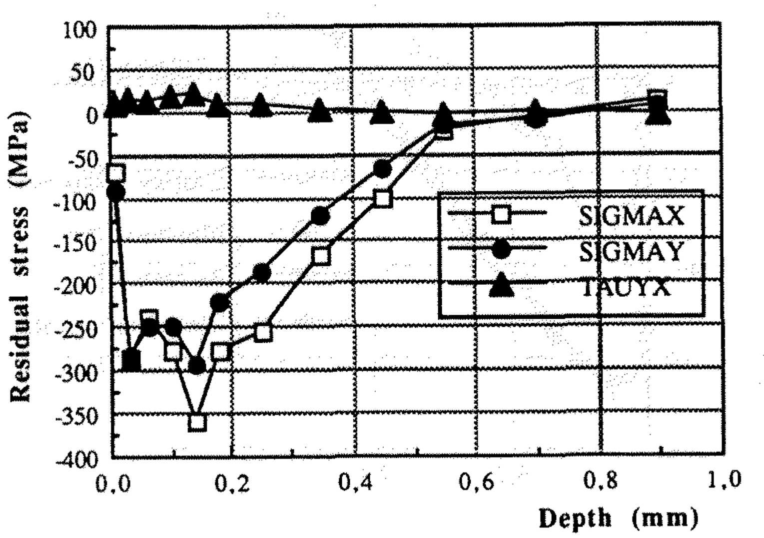

Figure 5 Isotropic residual stresses in both directions x and y after shot peening

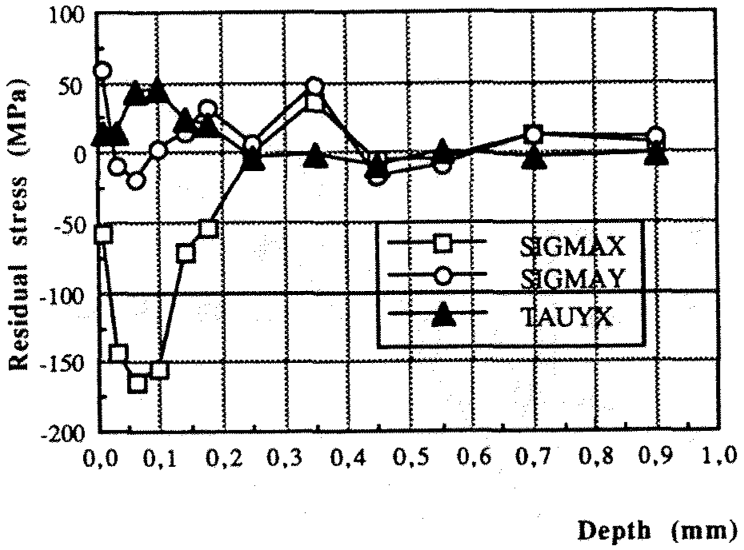

Figure 6 Non isotropic residual stresses in both directions x and y after machining

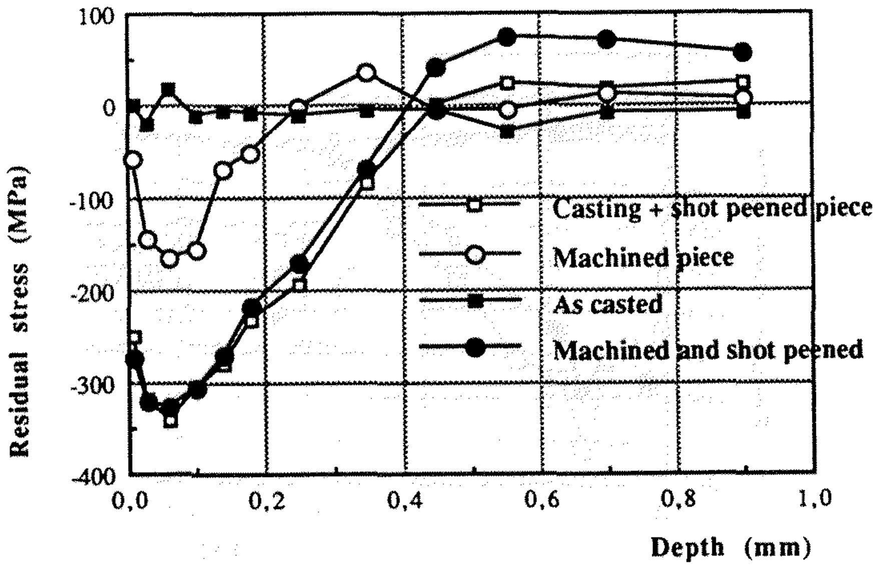

Figure 7 This figure shows the effect of machining and shot peening on residual stresses in metal matrix composite. Both treatments create compressive residual stress in MMC. Knowing residual stresses in machined piece and unmachined shot peened piece, it is not possible to apply superposition theorem to predict residual stresses in the machined and shot peened pieces.

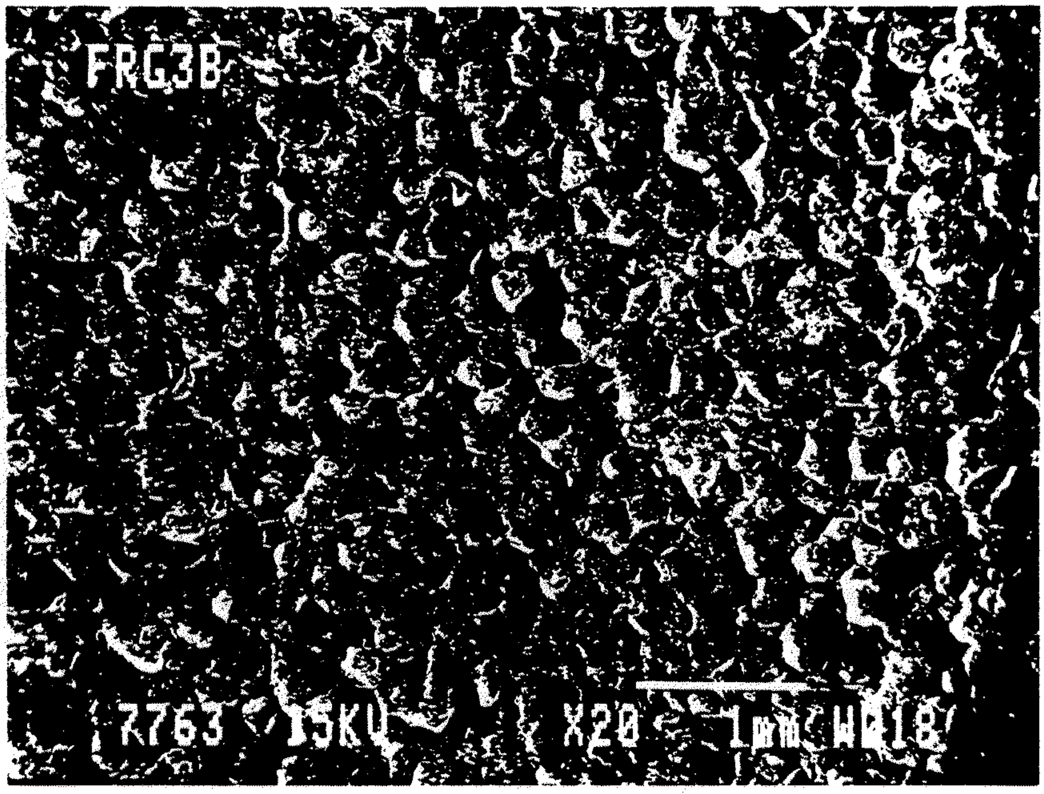

Figure 8 a Surface state of shot peened MMC

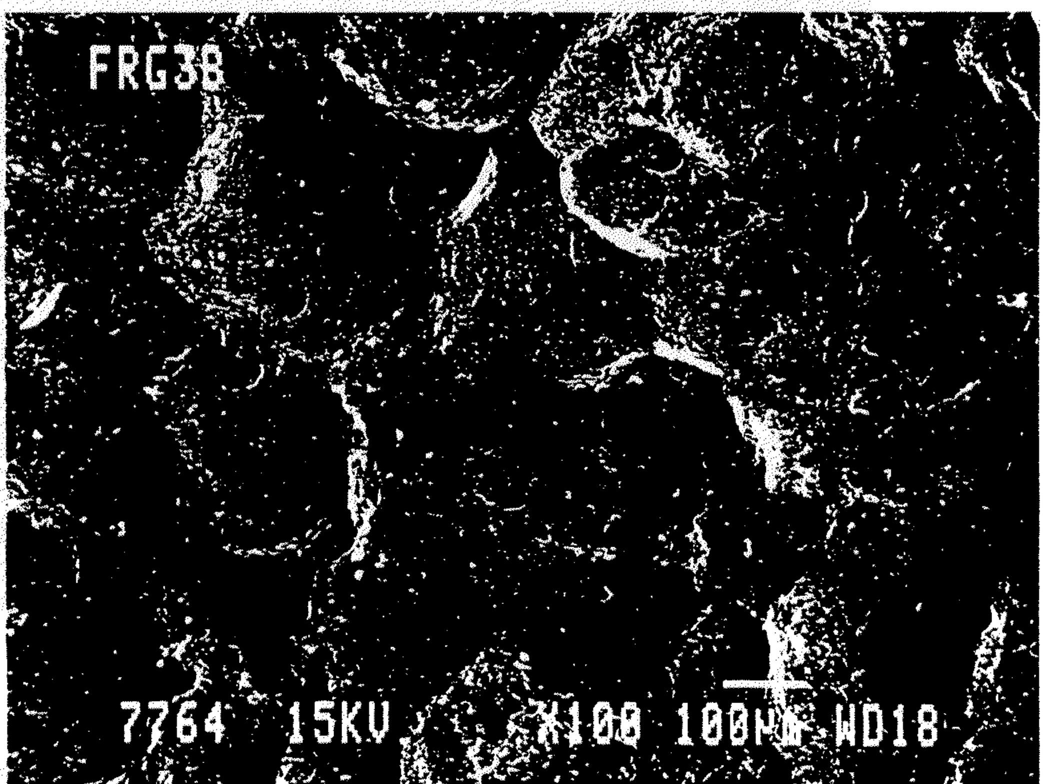

Figure 8 b Surface state of shot peened MMC : detail

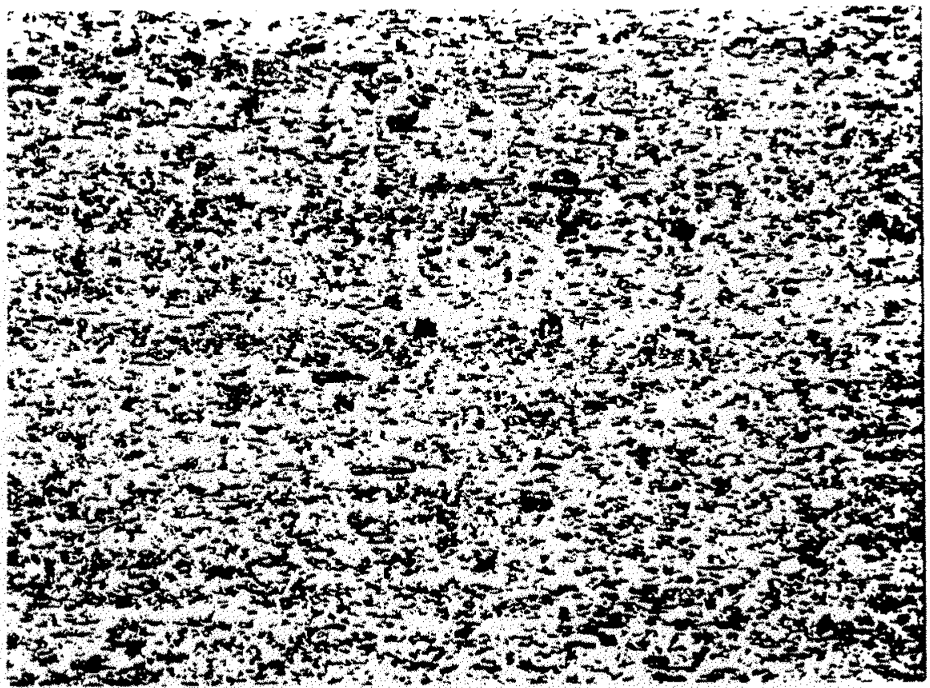

Figure 8 c Microstructure of MMC material before shot peening

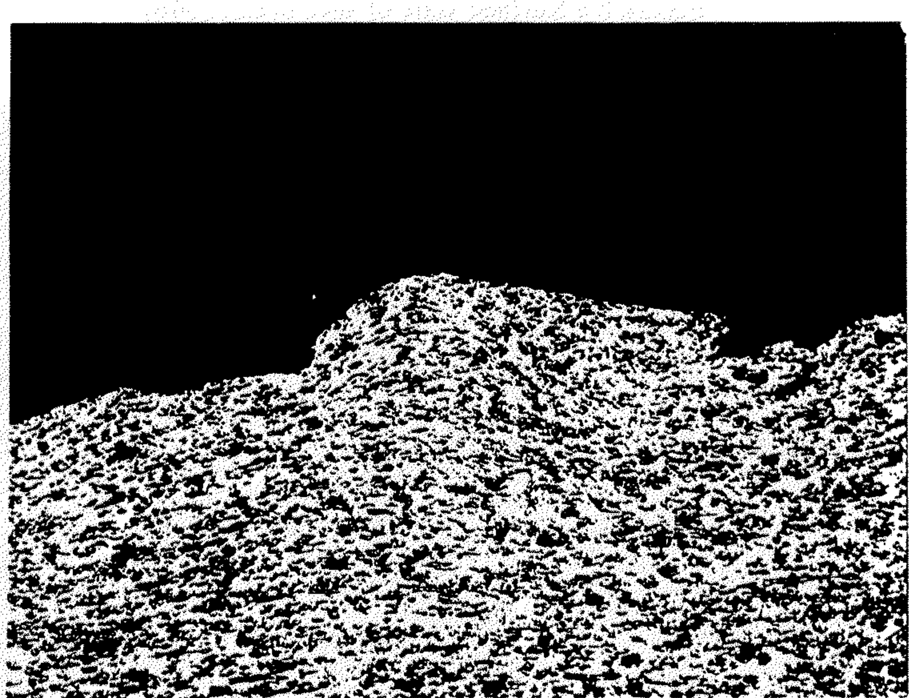

Figure 8 d Microstructure of MMC after shot peening

Figures 8 These figures show MMC microstructure before and after shot peening. There is no significant modifications after peening surface of MMC. No reinforcement fracture or delamination has been observed

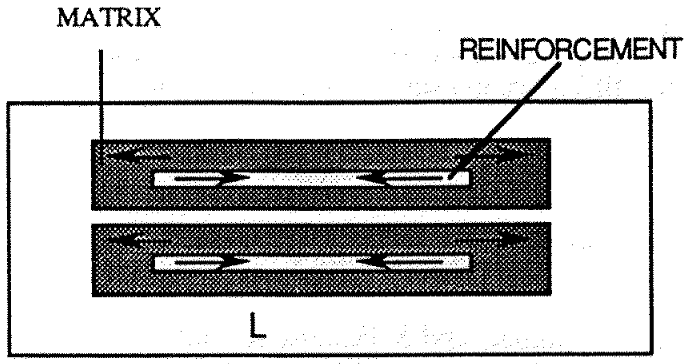

Figure 9 a Residual stresses in MMC before shot peening

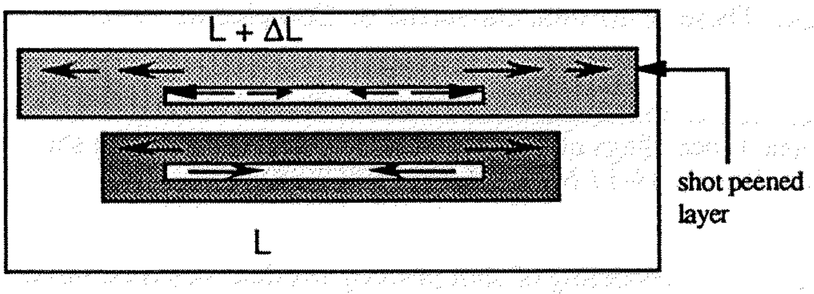

Figure 9 b Residual stresses in MMC during shot peening

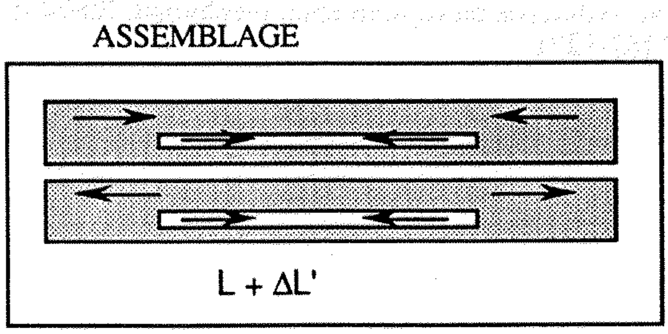

Figure 9 c Residual stresses in MMC after shot peening

CONCLUSION

Shot peening behavior of MMC materials is similar to the unreinforced materials; Ra and Rt roughness, the level of compressive residual stresses and the depth of the prestressed layer change with shot peening parameters. Shot peening creates more residual stresses, the depth of compressive residual stresses in MMC materials than in conventionnal materials. The shot peening parameters have little influence on the maximal residual stresses as in the unreinforced materials. The main difference between matrix and shot peened MMC materials is the surface microstructure layer. Shot peening can induce reinforcement fracture and delamination. But in this study no significantly microstructural modification of peened MMC materials has been observed This may probably be due to the difficuties to analyse the surface layer.

Bibliography

1 S. Tohriyama, M. Kumano and S. Hisamatsu . Influence of peening on fatigue life of SiC reinforced aluminum. Preceedings of the fourth international conference on shot peening Oct. 1990 pp. 307-316.

2 Jian Lu. La mesure de la répartition des contraintes résiduelles par la méthode du perçage pas à pas. Thèse de doctorat Université de Compiègne, 1986.

3 A. Niku-Lari, D. Gillereau. Contraintes résiduelles et fatigue des alliages d'aluminium grenaillés. Proceedings of second international conference on shot peening ICSP-2 Chicago, Illinois 14-17 May 1984 pp. 102-114.

4 C.Omam, J.Lu . Modeling of shot peening residual stress on MMC.To be published

5 J.Lu, B.Miège, J.F.Flavenot. Combination of two methods for measuring the residual stress gradient in SiC reinforced aluminium metal matrix composite. Preceedings of the 9th International conference on experimental mechanics. 20-24 August 1990 Copenhagen vol.3 pp. 1262-1271.