EVALUATION OF THERMAL AND ACOUSTIC EMISSION OF COMPOSITES BY MEANS OF LOCAL STRAIN MEASUREMENTS

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The applicational behaviour of thermoplastic materials used for constructional purposes is essentially determined by changes of material caused by mechanical load. Insitu-experiments by means of acoustic and thermal and acoustic emission provides a possibility of monitoring damage processes of fibres, interface and matrix. For micromechanical evaluation of damage processes of composites the integral strain isn't suitable. Measurements of local deformation show that correlations to thermal and acoustic emission are existing. Early occurance of local deformation zones requires application of qualified techniques with a high resolution.

INTRODUCTION

The behaviour of constructional thermoplastic composites is essentially determined by changes of material resulting in mechanical load. These changes, well known as damaging or failure processes, affect the load capacity and service life of constructions. A suitable method for investigation such early occuraning damaging processes, determining causes of failure and monitoring of damage kinetics is, acoustic emission (AE) (1).
Coupling acoustic emission with videothermography provides the possibility of monitoring selectively the damage of matrix on surface, whereas acoustic emission characterizes the failure of the fibres and the interaction with the matrix (2). The evaluation and classification of damaging by means of critical strain measu-

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failure of the fibres and the interface (2). The strain related classification of critical states of deformation (3) or relevant duration of damage requires local deformation measurements (4). Because damage, mechanisms in composite materials are of various nature and different load conditions can initiate several dominant mechanisms, so elucidation of these processes, their kinetics and time of occurence is of special importance.

EXPERIMENTAL

Materials

For the investigations polyamid-6 with different contents of glass fibres (d_m ≈10 µm; l_m ≈320 µm; 5,10,20, 25,30,40,50 wt-%) was used. The tensile test samples prepared according to DIN 53455, Type 3 were produced by dilution and conditioned over saturated $NaNO_3$ solution for ten days. The insitu - experiments were carried out on notched (in the middle of specimen by razor blade) and unnotched samples. For realization of videothermography specimen were blackened on frontside and backwards gridded by silk-screen printing.

Techniques

The tensile testing experiments were carried out on a testing machine ZWICK 1464 with a crosshead speed of 1 mm/min. Acoustic emission measurements were performed using a BRÜEL&KJAER measuring device. The thermographic investigations were realized with a videothermography system AGEMA TV 782/TIC 8000. For local strain measurements a laserextensometer with a grid distance of 2 mm and 16 lines on sample surface (l_0 = 32 mm) was used.

RESULTS

Figure 1 and table 1 show that with increasing content of glass fibres tensile strength increases, fracture strain decreases and the intensity of AE is reduced. The critical values of strain (onset) for acoustic and thermal emission measured by integral strain of sample are absolutly shifted to lower values with increasing fibre content. Relating these onsets with fracture strain a relative constant onset of AE of about 10 wt-% of fibres is found, whereas relative thermal onset continuously increases. With the increasing filler content the maximum of temperature on the surface decreases and the thermally activated surface is reduced (Fig. 2).

TABLE 1 - Results of Measurements

content [WT-%]	R_Z [MPa]	ϵ_Z [%]	ϵ_{AE} [%]	ϵ_{TE} [%]	ϵ_{AE}/ϵ_Z [%]	ϵ_{TE}/ϵ_Z [%]	ΔT [K]
5	35.5	8.45	2.01	5.02	23.66	59.41	8.5
10	41.8	5.85	0.97	3.49	16.58	59.69	5.9
20	54.5	2.65	0.41	2.29	15.47	86.56	2.5
25	61.5	2.35	0.37	2.12	15.74	90.41	2.3
30	64.9	1.90	0.32	1.76	16.84	93.10	1.9
40	74.5	1.65	0.28	1.56	16.96	94.80	1.6
50	90.0	1.45	0.24	1.38	16.55	95.21	1.7

DISCUSSION

These investigations show that the thermal emission, independent of filler content, is recorded later than acoustic emission. The reason of this difference is caused in the selectivity of the two methods. Damage

of matrix (e.g. crazing) occurs after since delamination, pullout or fibre cracking eliminate coupling between fibre and matrix. These local plastic zones ahead of the crack tip are indicated by TE. Measurements of local strain (Fig.3) show the greatest deformation close to the notch as expected. Above the critical strain ϵ_{AE} the separated sectors of strain are more differentiated and show a good correlation to the measured temperature. Initial cooling of sample is caused by the thermoelastic effect. Characteristic for failure of composites is the varying rate of deformation above ϵ_{AE} (Fig.4), whereby local capability of relaxation in specimen is affected. As a result of these investigations micromechanical interpretation of TE and AE is only useful by knowing local deformation or closed-loop experiments using local strain.

SYMBOLS USED

ϵ_{AE}	= critical strain by acoustic emission	(%)
ϵ_{TE}	= critical strain by thermal emission	(%)
ϵ_Z	= fracture strain	(%)
R_Z	= tensile strength	(MPa)
l_0	= extensometer distance	(mm)
ΔT	= temperature difference	(K)

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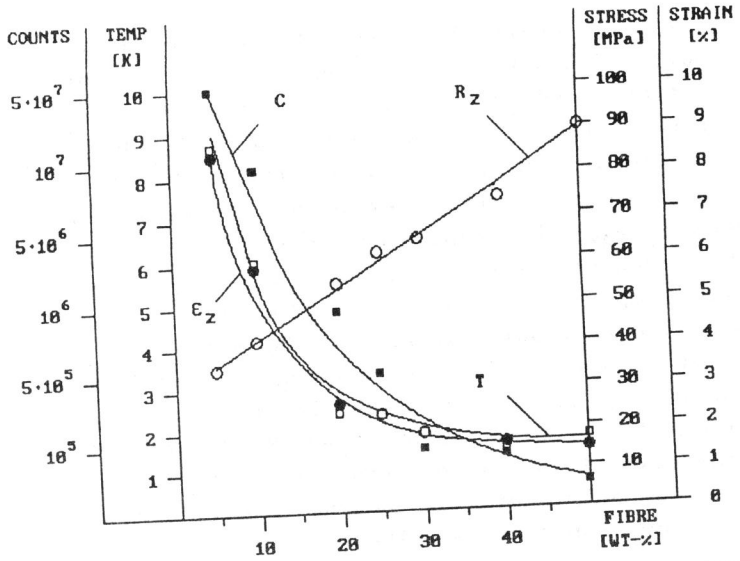

Figure 1 Mechanical values, counts and temperature in dependence of glass fibre content

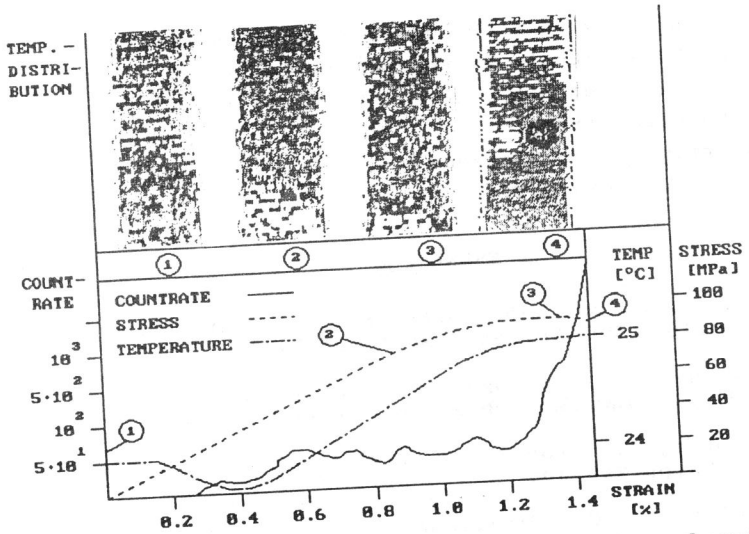

Figure 2 Acoustic and thermal emission for polyamid, 50 wt-% glass fibres

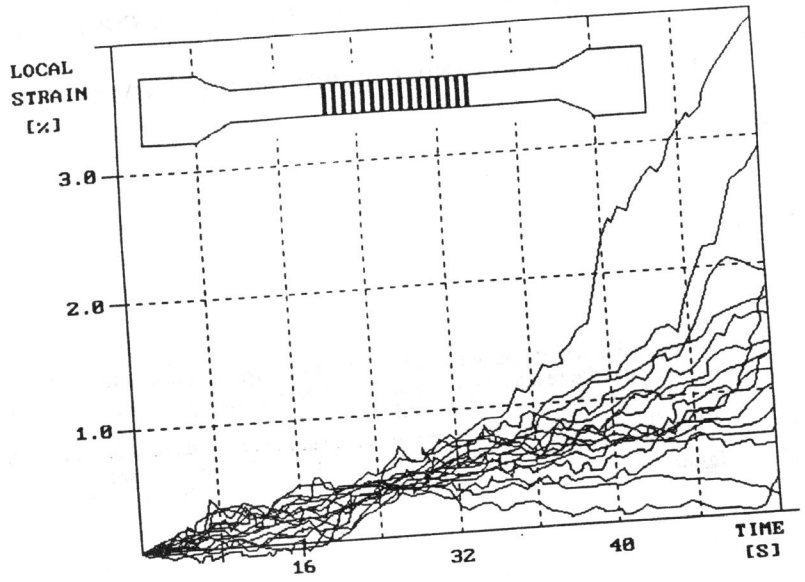

Figure 3 Distribution of local strain

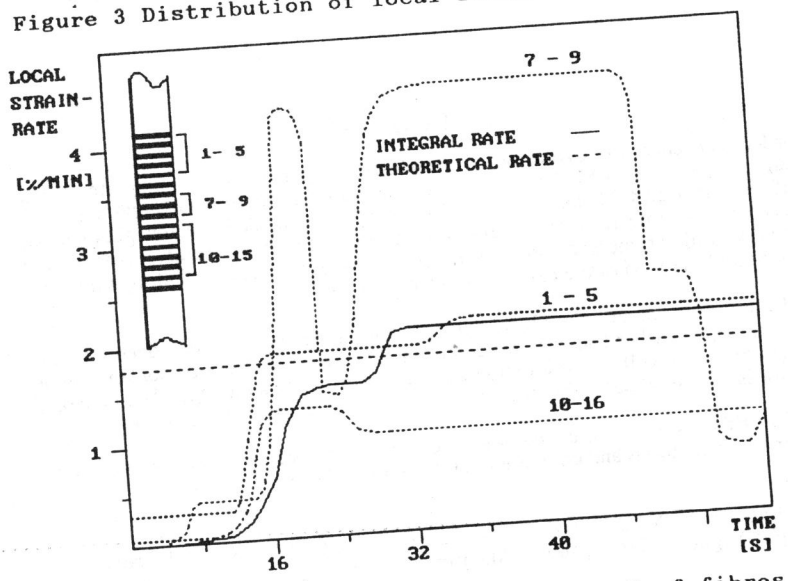

Figure 4 Strain rate for polyamid 50 wt-% of fibres