Start of Microcracking in GRP

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Introduction - Basis of a strength calculation concerning the deformation, was the observation that material-specific indication of damage occur in glasslike amorphous thermoplastics (crazes) and semicristalline thermoplastics (microcracks) as well as in glassfiber reinforced plastics when predictable values of elongation are exceeded. Regarding the detaching of adhesive resp. cohesive bonds within the microzones of GRP this will be a criterion for permissible load.

State of Investigation up to now - Exerting for the interpretation of break machanism concerning glass/resin systems [2,3,4] state of multiaxial stresses were determined by experiments and were theoretically analyzed within the microrange of a comparable simple-to-treat uniaxial reinforced composite while variating the macroscopic state of stress. If stress distributions within the microranges (matrix, glass, interface, glass/resin) basing on simple assumptions (ideal geometry of fiber distribution, ideal coupling glass/resin, neglection of thermal stresses and internal stresses as a consequence of setting) were known, it could be detected - by knowing every single strength hypothesis of the above mentioned material ranges - at which macroscopic stress combinations - a cohesive break of glass fiber or resin resp. an adhesive break within the interface would appear. Following the state of knowledge, the single strength hypothesis valid for these respective microranges has to be determined empirically.
In unfavourable cases every single case has to be examined. The dependence of time and temperature of plastics should be regarded, too, as an important fact.

Limits of Permissible Material Load in Chopped Strands Mat Polyesters (CSM-UP)

One necessary precondition, namely the analytical description of multiaxial stresses within the microzones of the composite, at quasi isotropic mat laminates might hardly be obtained because of the irregular order of fibers. So dimensioning limits, measured by sensible testing methods [1] only can be found by experiments by coordination of macroscopic stress-respectively states of deformation and by material - specific strength limits. In mat laminates a damaging of cohesive resp. adhesive bonds is to be registrated, if critical states of stress within the microranges of the composite are obtained. The direct consequence is a detaching along such glass fibers which are aligned nearly perpendicular or just exactly normal to the maximum tensile elongation. There exists a critical tensile elongation limit as a universal material characteristic depending on the chosen matrix, respectively on the reinforcement (see Fig. 2). Fig. 1 shows that the start of detaching at the mentioned test temperatures ϑ is not depending on the glass content Ψ (10^{-2} %< $\dot{\varepsilon}$ < 10^{2}%) and on the deformation rate $\dot{\varepsilon}$. The elongation at break - up to now in connection with the strength values the basis of dimensioning plastics structures - do depend in comparison to this on Ψ and $\dot{\varepsilon}$. In addition to this they are differently influenced by temperature, depending on the glass content (Fig. 2). The critical tensile elongations at the start of detaching are independent of ϑ in wide ranges. At increased temperatures the field of application of mat laminates might be limited. Dropping the coupling agent (methacrylsilane) of the size of fibers, so there already will be observed detachings at very small elongations (Fig. 1). Admixing the resin additional methacrysilane (1 weight-%) by unchanged size of fibers (incl. methacrylsilane), so the critical elongation limit will be only little displaced to higher values. Long-term tests of uniaxial loaded laminates revealed that first detaching - independent of the glass content and the elongation values obtained during the creep test - could be noticed during a following continuous increase in load ($\dot{\varepsilon}$= 0,01 %/min). This detachment was also observed in the same deformation range (0,4 < ε < 0,5 %) as the one found in short-term tests (Fig. 1). There have also been registrated detachings - normal to the maximum tensile elongation - in momentary biaxial stressed thin-walled pipes as well as in long term biaxial loading (Fig. 4). This was found during direct as well as after finished creep tests with a following continuous increase

of load, independent of the type of the multiaxial load and also independent of the elongation values (ranges of 0,35 % < ε < 0,5 %) determined during creep tests. A plurality of creep tests under cyclic load showed that the start of detaching after a continuous increase of load (Fig. 5) again could be assigned to the known elongation range, independent of the type of cycle and its endurance. There were also analogous results for oszillating uniaxial load as well as for multiaxial load. Detaching will also start here, if the constant critical strain will be obtained. Tensile elongations at the start of detaching marks the transition between reversible and irreversible deformation behaviour. If laminates obtain elongation values above this limit, the deformations are no more reversible. Deformations of the unreinforced matrix are even reversible after extreme tensile elongations. In general, such a dimensioning towards strain limit (independent of the discussed influences) enables neglecting the still remaining big "deformation reserves up-to-break" to reduce effectively the until now used safety coefficients. The conventional safety factors have been connected with an incomparably immense uncertainty concerning the break behaviour. First investigations show that there are also detachings all along the fibers within the glass cloth and within the unidirectional reinforced laminates. These also time-independent and laminate - specific elongations at the start of detaching are the smaller the bigger the angle (in the range 0°-90°) between loading and fibre direction is (Fig.7). For multiaxial reinforced laminates first detachments appear along such fibers which are preferred orientated normal to the maximum tensile elongation.

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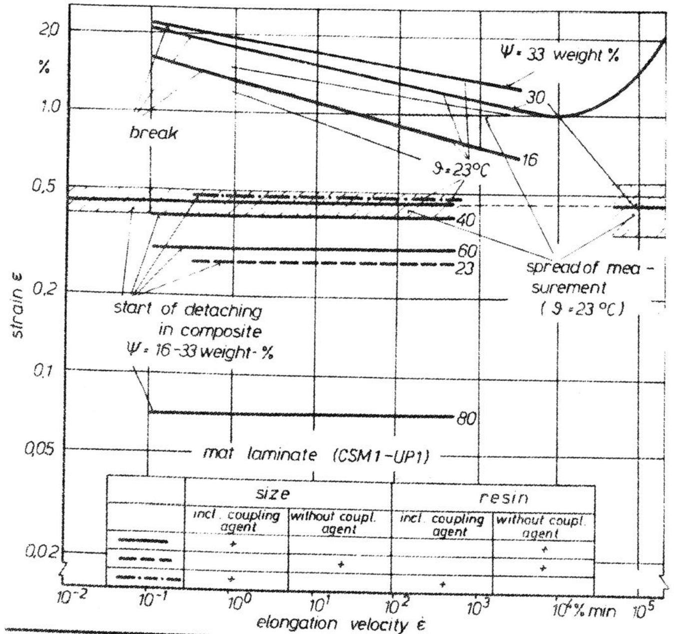
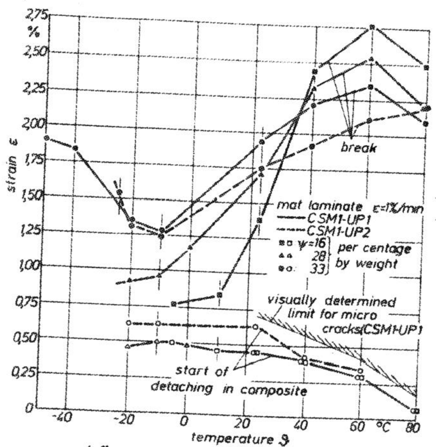
[2] Puck, A., Schneider, W., Plastics and Polymers,Bd.37, Nr. 127, 1969, S. 33-44
[3] Hackett, R.M., Polymer Engineering and Science Bd.11 (1971) Nr.3, S. 220-225
[4] Roth, S., Kunststoffe (1969) H.12, S. 967-974



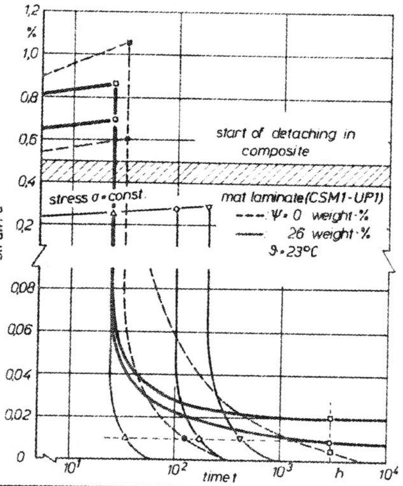
Elongation at break and at start of detaching as a function of elongation velocity, uniaxial tensile load

Fig. 1



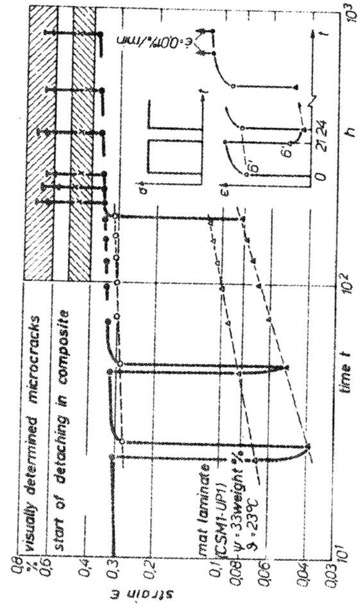
Influence of temperature on elongations at start of detaching and at break for chopped strands mat reinforced polyester, uniaxial tensile load

Fig 2



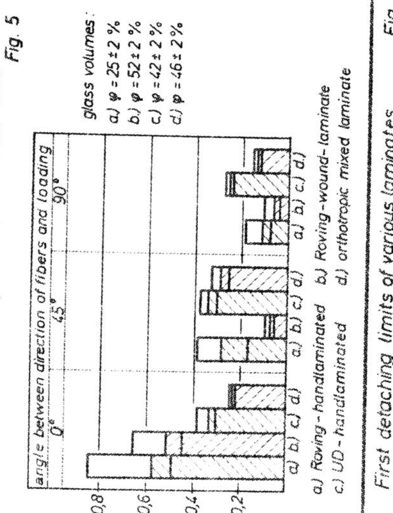
Reversible and irreversible deformation, behaviour unloading after finished creep test, uniaxial tensile load

Fig.6



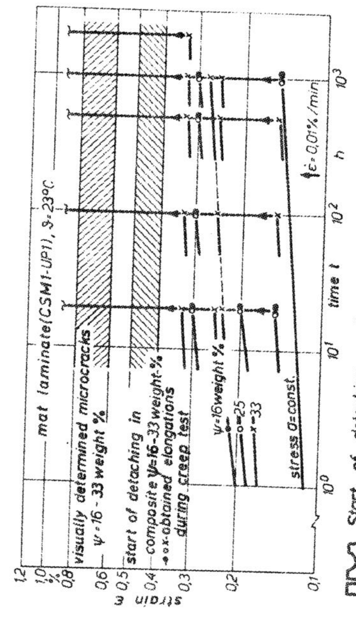
Start of detaching and visually determined microcracks after cyclic uniaxial tensile load

Fig. 5



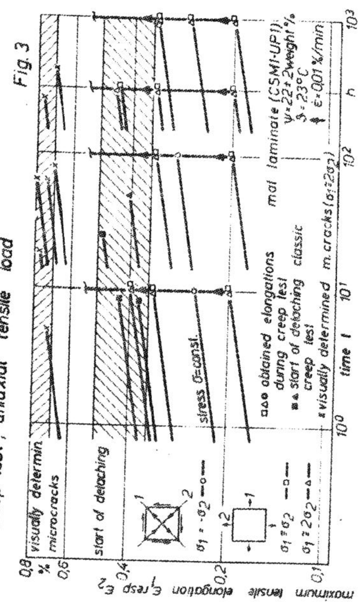
First detaching limits of various laminates refered to strain rates

Fig. 7



Start of detaching and visually determined microcracks during continuously increasing load after finished creep test, uniaxial tensile load

Fig. 3



Start of detaching and visually determined microcracks during multiaxial load

Fig.4