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Failure Analysis of Polymer Parts

Motivation

Quality management as well as failure and damage analysis increasingly grow in importance in the manufacturing of thermoplastic, duroplastic, elastomeric and fiber composite parts.
In consequence of the complex interactions between material properties, manufacturing process and design leading to the resulting part properties and their subsequent interaction with the loads during use, it is difficult to trace failures back to their causes. Typically this task is significantly more complex for polymers than it is for metals.
The aim of a failure analysis is to determine the type and magnitude of the existing deviations between the target state and their actual conditions as well as their causes. Deviations may occur from either a deficient design, the material, the manufacturing process or from the load during usage. The resulting failure causes can be either predictable or unpredictable, meaning they can either be comprehensible or unintentional. A predictable failure can be avoided at an early stage by a failure analysis within the design phase of a part or can be resolved by a precise reconstruction of all steps from part design to the moment of failure. However, the requirements for series production may differ from those for prototype manufacturing. Consequently, sufficient competence and experience are a prerequesite for a precise and efficient failure analysis. In many cases, random and/or unregarded factors are only revealed by failure analyses. These must then be proven with the correct investigation methods and assessed with regard to their contribution to failure development.

Fig. 1: Thermal overload of a polymer gear

Fig. 2: Chemical laboratory

Fig. 3: Thermal analysis

Test methods

The failure analysis requires procedures and test methods which take the specific characteristics of polymers into account. For these examinations, the Institute of Polymer Technology (LKT) offers a multitude of test equipment and methods for assessment. The available resources reach from simple determination methods to highly sophisticated measurement methods and state of the art equipment:

- Microscopy (e.g. stereo microscope, microtome, CT)
- Thermal analysis (e.g. DSC, TMA, DMA, TG)
Spektroscopy (FTIR)
- Chemical laboratory
- Rheology (e.g. RV, MVR, HKR, VZ)
- Mechanical analysis (static, dynamic)
- Stress crack analysis

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Approach

The successfull conduct of a failure analysis requires a highly structured planning regarding the type, scope and order of the utilized test methods as well as their thorough execution. It is not sufficient to concentrat on one influencing factor. Instead, it is required to investigate the entire environment of the damage event. Generally, the following three questions have to be answered within the scope of the failure analysis:

- Is the part faulty? (e.g. deficient material, deviations during manufacturing)
- Is the part unsuitable? (e.g. wrong material, unsuitable dimensioning)
- Is the handling not performed correctly? (e.g. transport or handling damage)
- The inventory phase also includes the determination of the available components and material samples. Good preconditions for a successfull failure analysis are, besides the availability of the faulty part, the availablity of:

Pellet material or other raw material of which the faulty part and possibly also good parts have been manufactured
- Unused parts of the same material batch as the faulty part
- Unused parts from the same manufacturing batch (retained sample)
- Serveral faulty parts
- Unfaulty parts which have been in use and do not show any damage
- Documentation of the actual production parameters during manufacturing

A systematic approach in the analysis differentiates failure causes and isolates them successively. The LKT conducts the required material inspections for every failure case, such as microscopy, spectroscopy, thermal analysis, chemical analysis, static and dynamic test as well as practical and laboratory test and calculations. In addition to that, the LKT can also be consulted during part design, even before a damage occurs. The LKT offers a wide range of experiences in the processing of all types of polymer materials as well as in designing with plastics, which both is essential for a successful failure analysis.

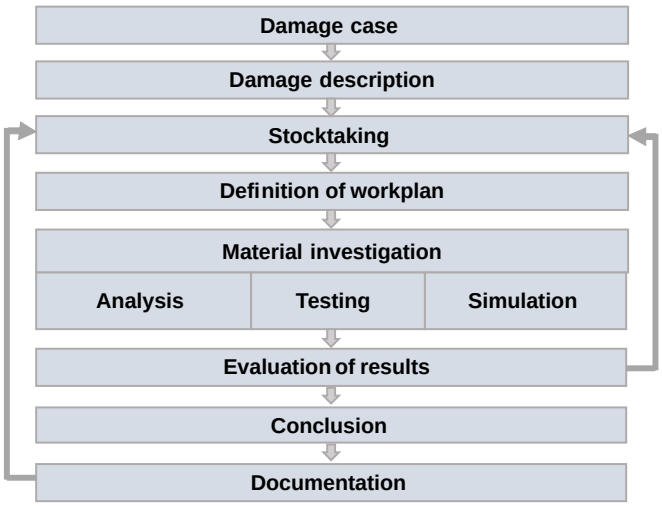

Fig. 4: Flow chart of a failure analyses

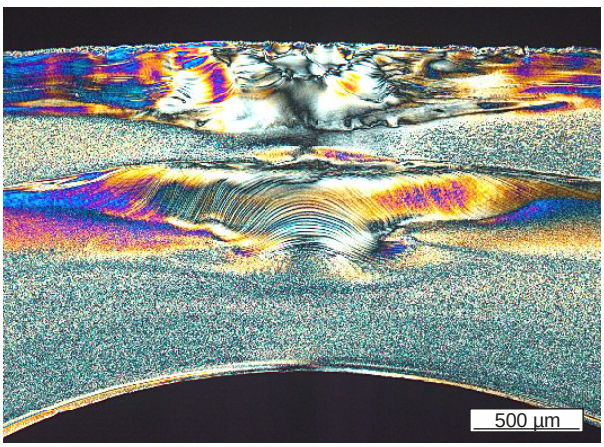

Fig. 5: „Cold plug“ in the gate section of a POM-part

Further Education Offers

The LKT hosts a yearly seminar dealing with using damage and failure analysis for polymers. Topic of this event ist both the theoretical and practical presentation of the primary test methods which allow for a qualified assessment of materials and parts. In addition, several failure relevant topics are discussed on the base of practical examples within the scope of the seminar.

In small groups, a failure analysis is then conducted in the laboratory based on specific examples. This is supposed to teach the seminar participants the procedure and selection of suitable test methods for the validation of an existing failure case.

Fig. 6: Seminars and conferences for practice-oriented further education

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