D-LFT PROCESS: IN-LINE COMPOUNDING & COMPRESSION MOLDING OF LONG-GLASS-FIBER REINFORCED POLYMERS

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Abstract

Long fiber-reinforced thermoplastics have excellent mechanical properties and stiffness / weight ratio, which is of particular interest to the automotive industry. The new in-line compounding processes for long-fiber materials offers users more flexibility, as they are able to both compound and process such materials in accordance with their own formulation and also use ready-made compounds.

Preamble

Component parts from long-fiber-reinforced thermoplastics (LFT) are characterized by high stiffness at low weight, a flexural modulus as well as a high tensile strength and impact strength.

The reinforcing of plastics with glass or natural fibers (with a length up to 100 mm) has been experiencing a dynamic growth. The production of long-fiber-reinforced plastics was been more than tripled over the last 10 years. This development sould be stable over the next few years because of convincing economic efficiency and due to the high flexibility of the long-fiber technology. The most important market is the automotive sector with 95% of applications.

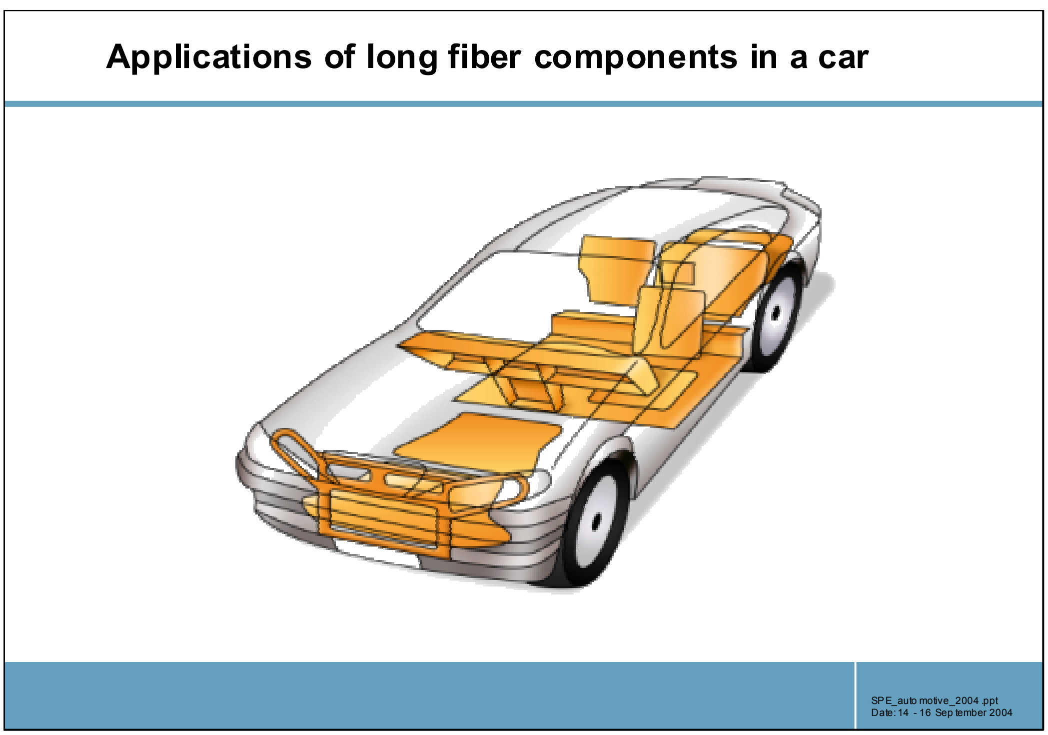

Figure 1: Applications of long-fiber components in a car

For the production of LFT components, the D-LFT process was established in the market over the last several years. The D-LFT[1] process is a direct process that bypasses the steps of semi-finished products. The parts are produced directly from the raw materials: glass fiber, polymer and additive. The In-line compounding and production of long-fiber-reinforced parts in a one-step process, opens great possibilities for rationalization without loss of quality. Parts made of long-fiber-reinforced thermoplastics combine design freedom of an impact part with high mechanical properties produced in an extruded fashion.

The D-LFT Process in the Part Production Process

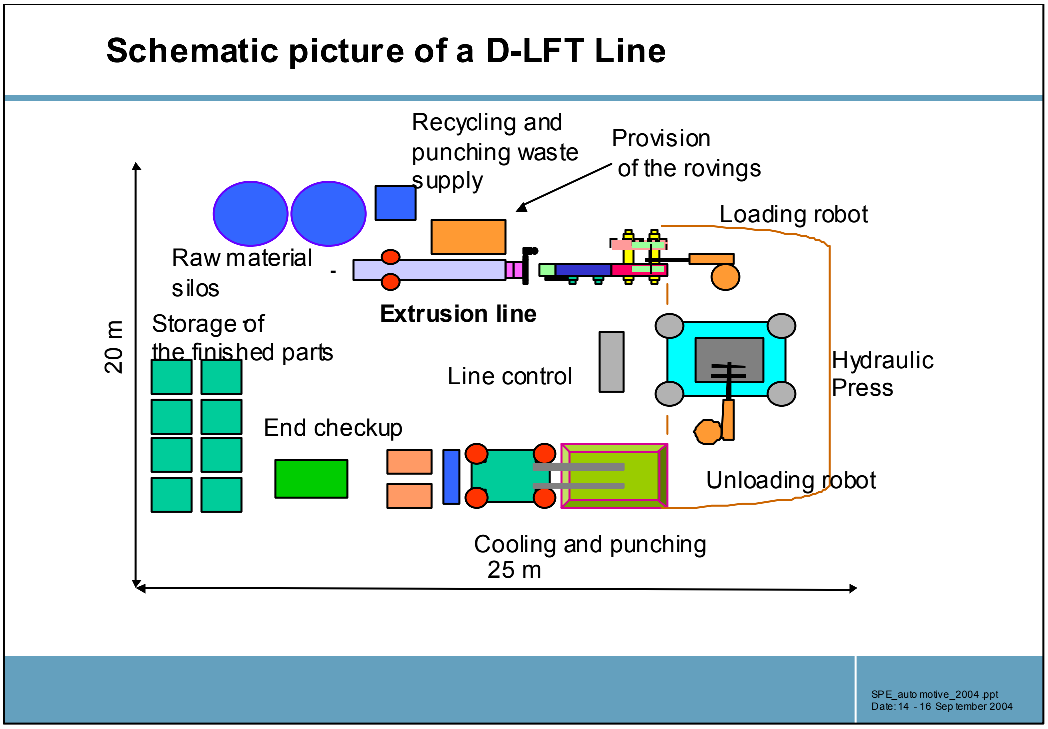

Figure 2: Scheme of a D-LFT Line

The D-LFT process is characterized by the following advantages:

- Low material costs in reason of the saving of semi-finished parts;
- High flexibility for part production;
- A high degree of automation is possible (one worker is adequate for the control and maintenance of the system);
- High productivity because of very-short cycle times;
- High availability of the system;
- Low factory rejects;
- 100% recyclability of the scrap and the factory rejects; and
- Low space requirements of the system.

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[1] **D-LFT** = In-line compounding and **D**irect compression molding of **L**ong-**F**iber-reinforced **T**hermoplastics.

The Core of the D-LFT Process: the Twin-Screw Extruder (ZSK)

The ZSK used for compounding is modular in design and consists of the following main sub-assemblies:

- Main drive;
- Gear box with axial bearing and oil recalculating oil-lubrication system;
- Processing section; and
- Discharge parts.

The processing section of the ZSK is built of several barrel modules, in which the co-rotating screws are arranged. Several standard barrels are used as well as a great variety of conveying, kneading and mixing elements, which are assembled on multi-spline shafts. Barrels and screw elements are specifically configured for their respective processing tasks.

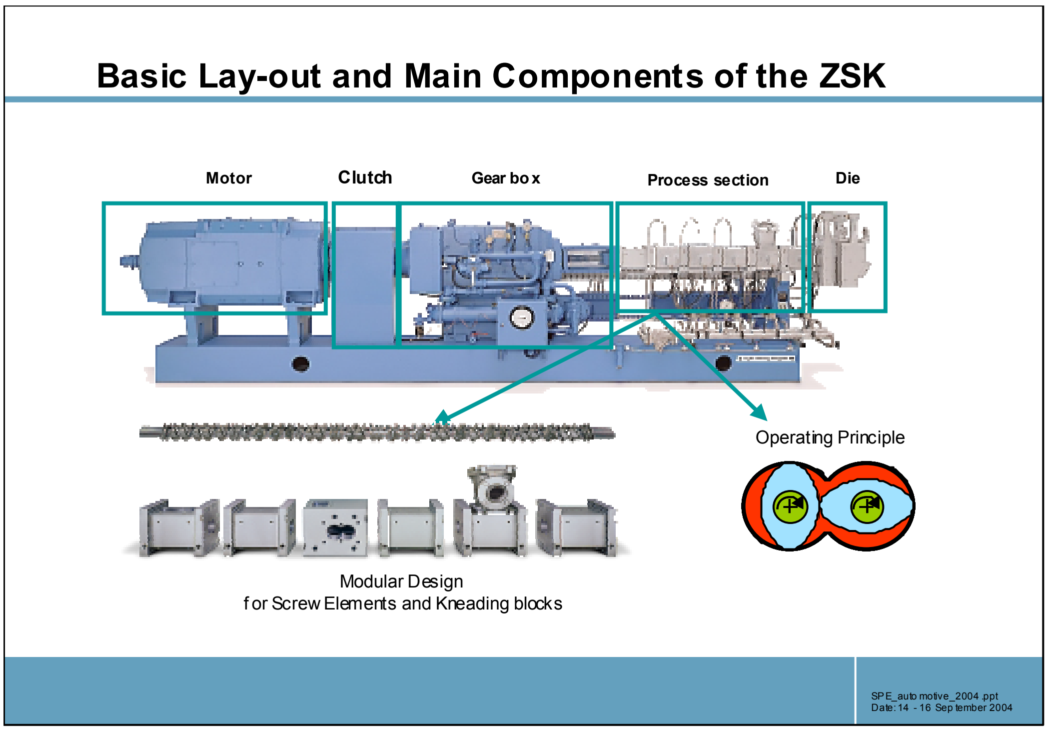

Figure 3: Modular design of the twin screw extruder

The Process Principle

Especially for the long-fiber technology, a special screw configuration was developed by which ensures the following:

- First the matrix polymer is melted;
- Then the melt is intensively mixed and homogenized stress-free;
- Finally, the continuous glass filaments are automatically taken in by the rotation of the screws, impregnated with the melt, cut to length and dispersed.

Upstream of the extruder, a gravimetric feeder for the matrix polymer is provided and, if necessary, gravimetric feeders for additives and pigments. The components of the formulation are fed in as a continuous stream with consistent accuracy so that the reproducibility of the formulation is always guaranteed.

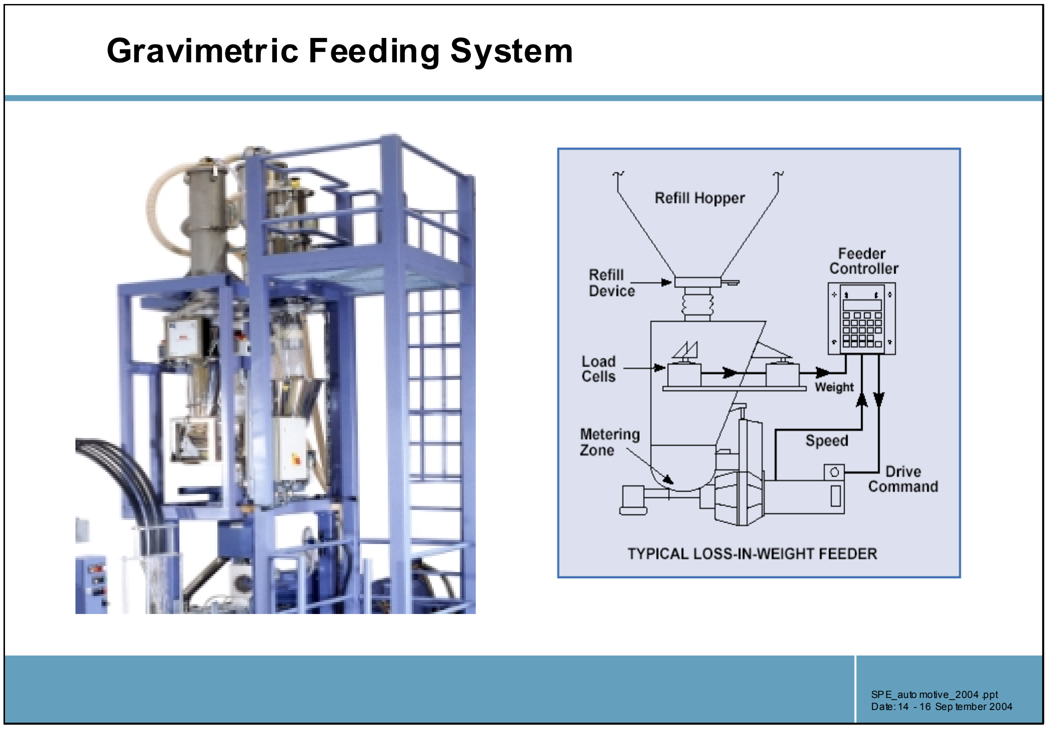

Figure 4: Gravimetric feeders

The glass fiber filaments are pulled from roving bobbins into the twin-screw extruder by the rotation of the screws. The screw design which has been especially matched to the viscosity of the polymer matrix and the roving, ensures uniform intake, sufficient impregnation and dispersion of the filaments as well as fiber length distribution in the plasticized material ready for molding.

Each roving is controlled separately so that a missing or stopping is detected immediately and alarmed on the line controls.

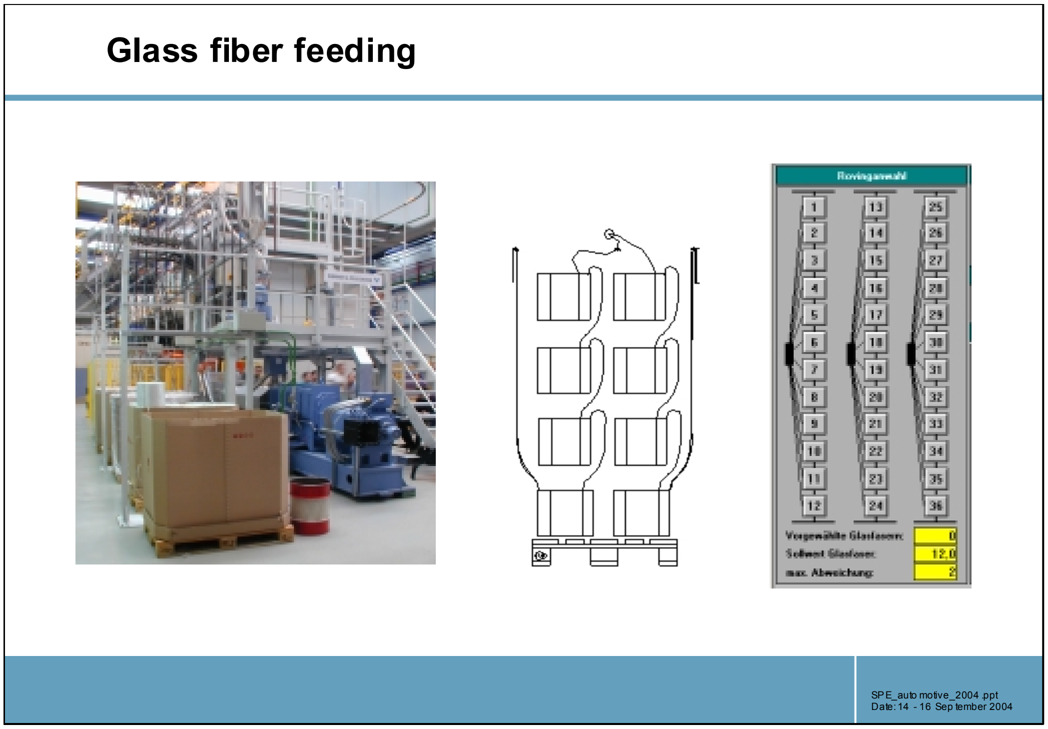

Figure 5: glass fiber supply

The shutdown level could be adjusted at the control system, so that the quality is ensured at any time.

The roving supply is designed in a way that no plant stop is required for the change from one bobbin to another. At each roving supply station there is one active and one passive palette.

Process Scheme

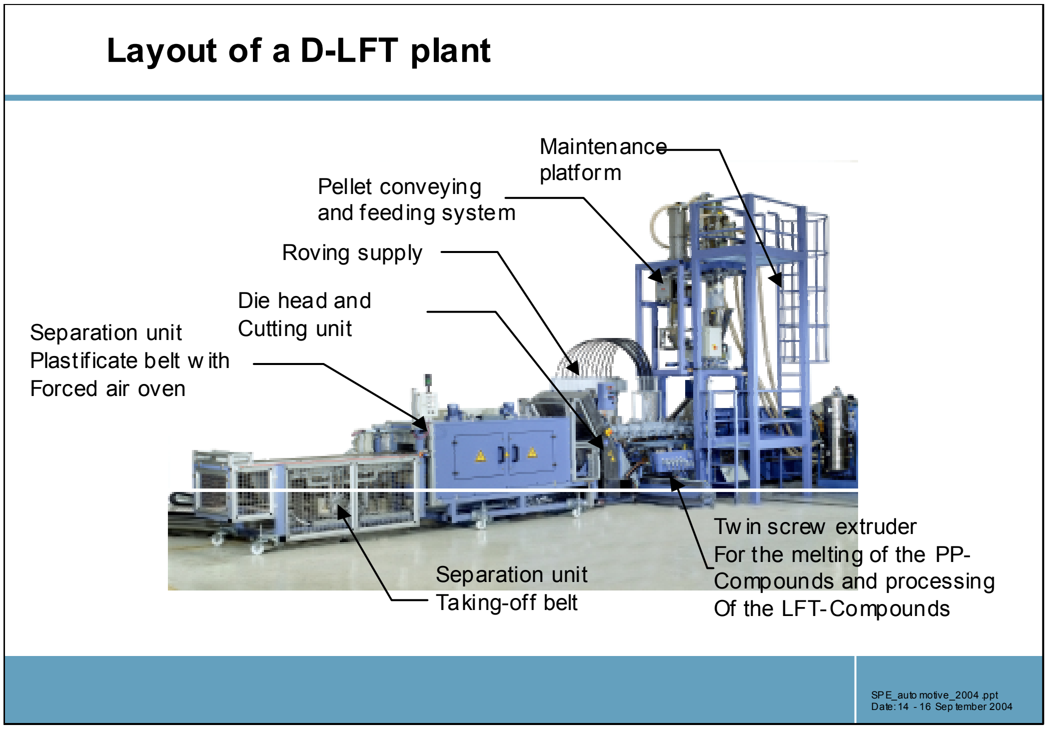

Figure 6: Layout of D-LFT plant

After the compounding step, the compounded LFT material is continuously extruded through a die head. The interface of the continuous compounding process with a discontinuous working press is sophisticated and technological challenging. First, the compounded material is cut into the required length directly at the die head. The band-shaped LFT compound is extruded onto a belt system. On this belt system, the extrudates are stockpiled and kept at a sufficient temperature level until the last individual blank has been extruded and cut. Then the complete stack of blanks is discharged onto a feeding belt. Immediately before the molding operation, the blank is picked up by a robot with gripping needles and placed in the press mold.

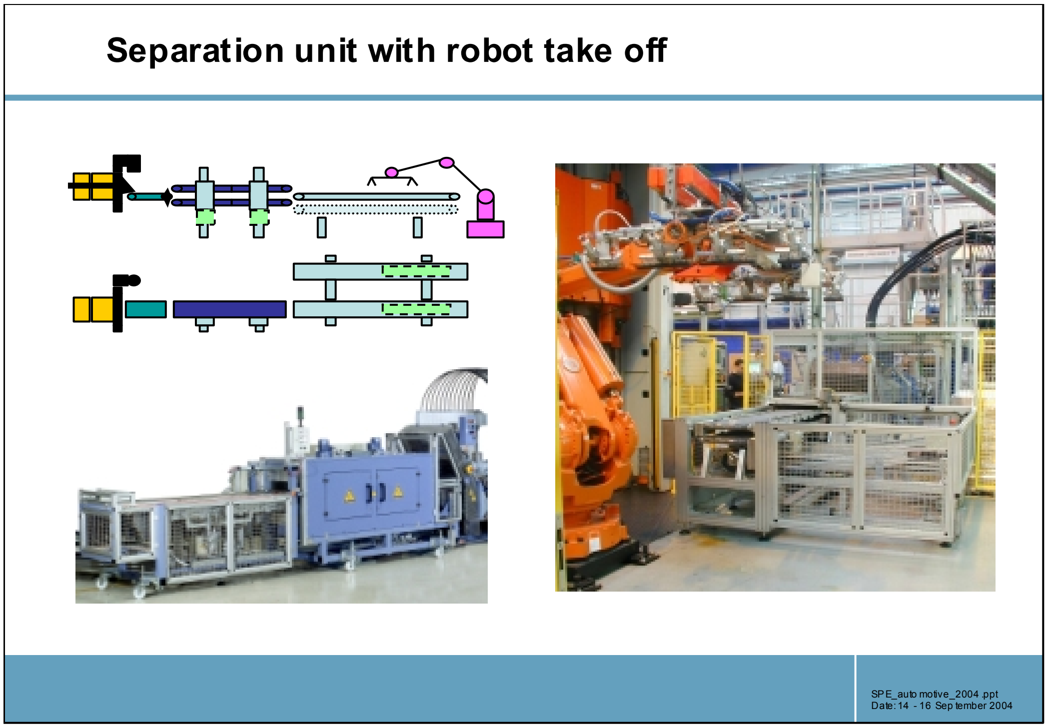

Figure 7: Separation unit with take off by a robot

Advantages of variable adjustable thickness

The necessary press capacity and the filling of the mold, the warpage and thickness tolerance of the part are all strongly influenced by the shape and the position of the extruded material in the mold.

Current state-of-the-art technology usually requires selecting double or triple layer press insertion schemes. These insertion schemes are also used in the production of GMT products. For the automation of such systems, very complex and heavy needle grippers with double lift cylinders are needed to accumulate the material.

Knowing about these difficulties, it was self-evident to equip the already manually adjustable die with a servo actuator and to change the height of the extruded material during the extrusion step. Special attention must be put here on interaction between extrusion, cutting unit and separation unit.

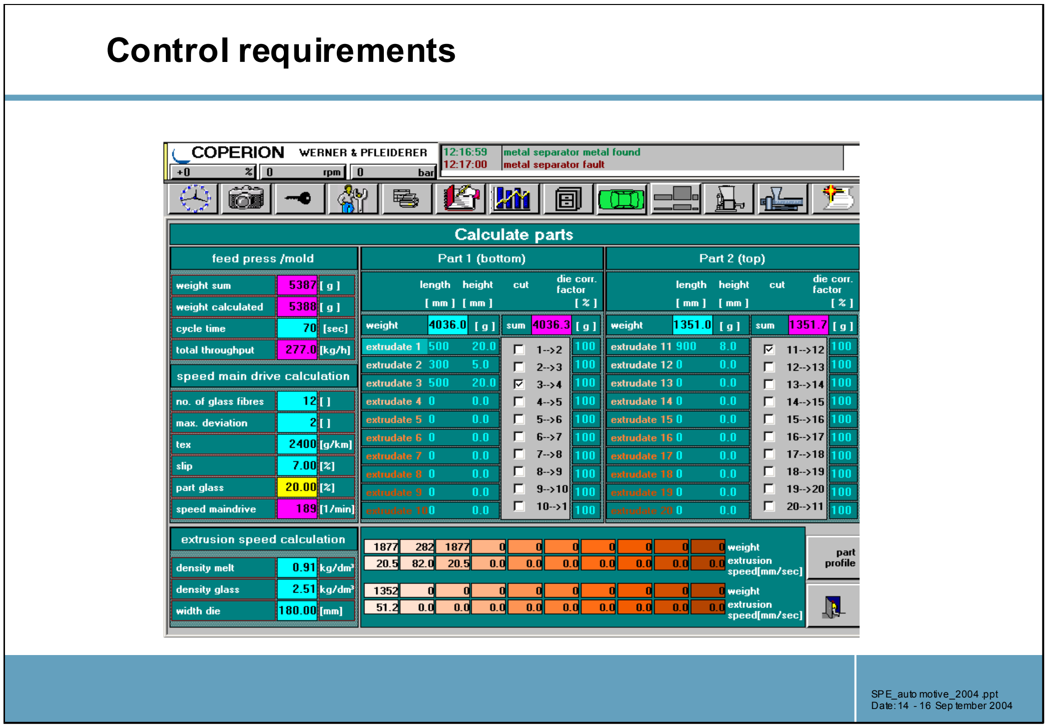

Figure 8: Requirements of the control

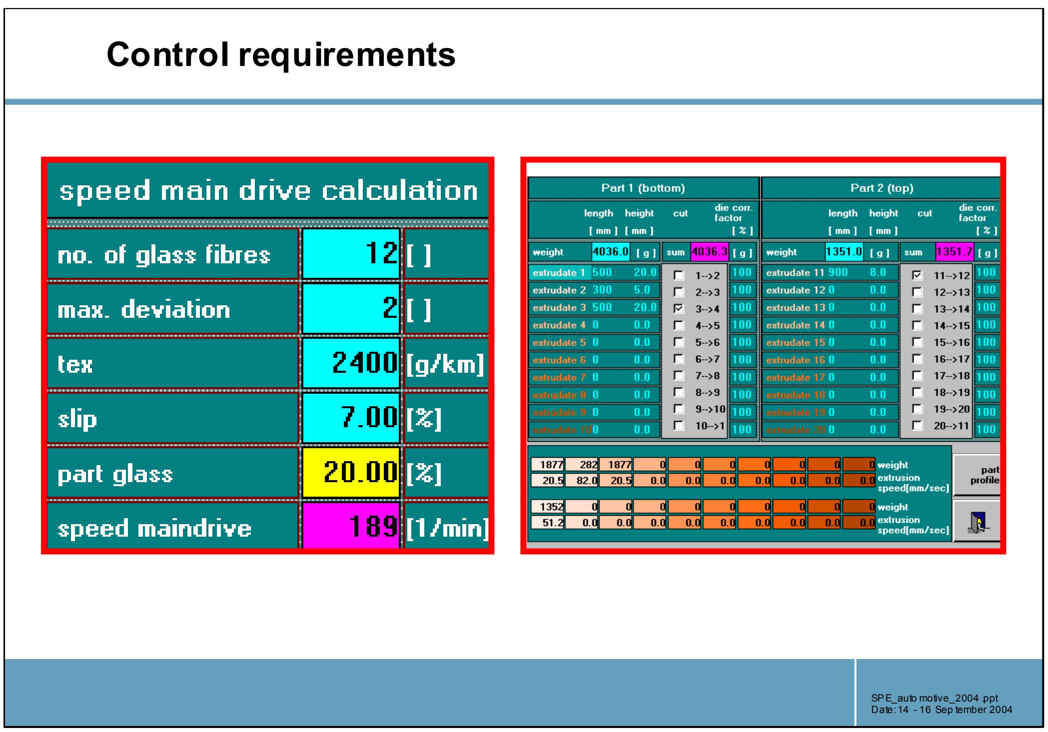

Figure 9: Requirements of the control

The belt speed of the separation unit has to be adjusted to the extrusion speed. When the thickness of the LFT compound is changed, the speed always has to be changed as well. Additionally, the suppressed material – respectively the fill material in the die – has to be corrected.

With these thickness-profiled extrudates, a number of advantages can be achieved [2]:

- Reduction of the press capacity up to 40% (depending on glass-fiber content and part design);
- Reduction of the warpage by reason of a lower fiber orientation;
- Achieving of a more regular part thickness;
- Simplification of the needle grippers, because simple grippers can be used.

Figure 10: Adjustable die head

Short Start-Up Time

Often existing GMT production plants are rebuilt for the D-LFT process. To minimize downtime of the existing press, the whole D-LFT system is modularized and designed to be plug and play. This concept allows for a start-up including test run within a two week time window.

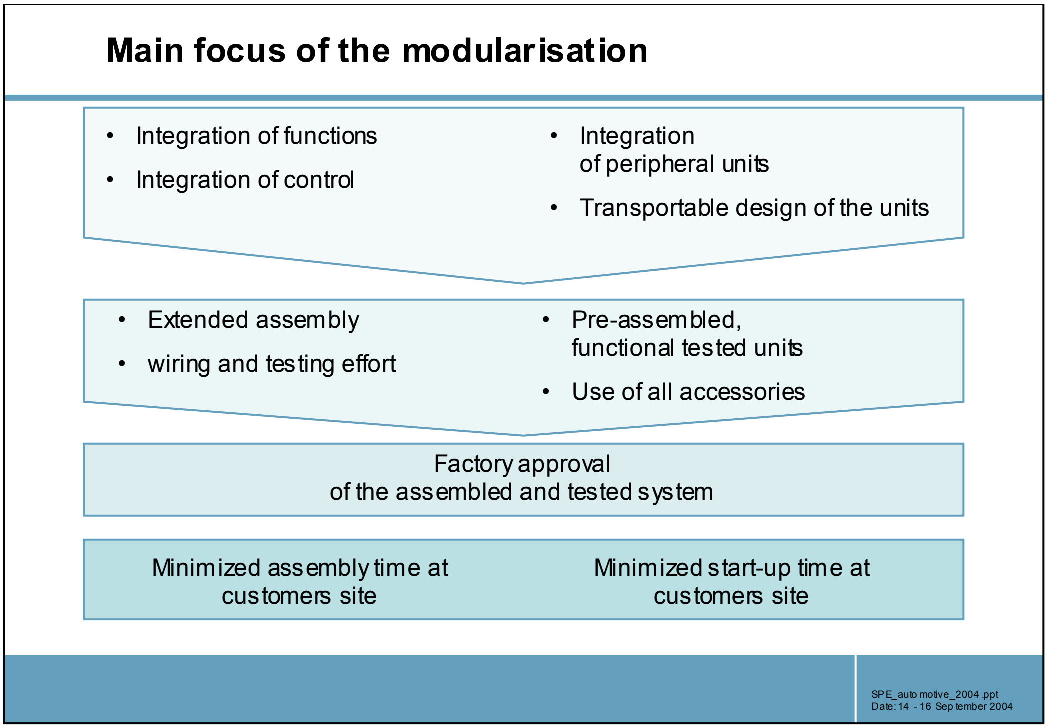

Figure 11: Main focus of the modularisation

References

1. Marroquin, I.: In-line Compounding and direct compression molding of long fiber reinforced thermoplastic parts for automotive industries; long-fiber molding/extrusion conference, Miami 2002
2. Meinert, H.-D.: Internal studies of the AKsys GmbH, Köngen 2003 and of the Coperion Werner & Pfleiderer GmbH & Co. KG