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CONTROL LOOP INJECTION MOULDING PARAMETERS

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Technical task:
The task of the developed method is to control the injection moulding parameters for radomes and lidomes.

Initial situation:
Radar sensors in motor vehicles are frequently and increasingly hidden behind plastic body parts. The generic term for these body parts is "add-on part". In high-frequency technology, any plastic is also called a substrate, or radome, especially in radar applications, in order to express a cover or privacy screen. In analogy such covers are called Lidom with the laser scanner, also called Lidar. The radar must penetrate these attachments (= radomes) before it can perform its actual function. The actual function is to locate objects more or less far away (1-200 m).

These attachments made of plastic are only qualitatively examined to a very limited extent after production by injection moulding, mostly only for dimensional accuracy (width, length, height) and surface smoothness as well as sink marks. In total, only parameters under the generic term "mechanical parameters" are checked, but not the electrotechnical or even high-frequency properties. In addition, plastics today are provided with an abundance of additives and modifiers, so that these can be different from source of supply, manufacturer and processing methods. These differences in the material, however, influence the plastic component as a radome and consequently also the behaviour and accuracy of a radar, lidar or other radio communication device installed behind it, which must penetrate through this material.

It has been established from series of investigations that various parameters of the injection moulding technique have repercussions on the radome properties. In order to keep these in the optimum range, the parameters have to be permanently checked from shot to shot and adjusted if necessary. At present, there is no fast procedure for determining the influences on such systems. In addition, there is no fast and inexpensive method of comparing the measured variables of the high-frequency requirements with the injection moulding parameters of the machine on a running injection moulding machine for the production of thermoplastic plastic parts. This becomes a problem with increasing penetration on the way to autonomous driving and must be counteracted at an early stage.

These partly painted attachments have a damping effect on the high-frequency characteristics of a radar, but also of a lidar (also called laser scanner) as well as all radio communication devices installed behind them, so that they cannot develop their full efficiency. In addition, these attachments influence the locating accuracy in the case of radar and lidar. The variance of the components produced from an injection moulding machine is considerable in some cases, so that a high proportion of non-material parts can slip through during a pure random sample inspection. This is unacceptable for radar-based, highly automatic driving systems and safety-relevant requirements (e.g. emergency brake assistant). A further complicating factor is that modern plastics consist of a mixture of polymers, additives and additives to improve material properties (e.g. more impact-resistant, flame-retardant, acid-resistant, etc.). In addition, recyclate (products from the recycling process), i.e. hexed waste from plastics production, is added in sometimes considerable quantities without precise control in order to reduce costs. All this changes the plastic and its material properties. As there is currently no control and little restriction in the automotive industry by means of specifications, the material parameters become uncontrollable and, as experience has shown, uncontrollable. For modern vehicles with safety-relevant functionality, however, a high repetition rate of the manufactured components is necessary.

Solution:
The task must therefore be formulated in such a way that the influencing injection moulding parameters are checked after each manufacture of one or more components, the produced component is checked promptly for compliance with the high-frequency parameters and, if necessary, adapted to the manipulated variables. According to the invention, a control loop is to be set up between the manufactured component from an injection moulding machine with its setting parameters and the result of a high-frequency technical evaluation of the component or a material sample to determine and determine the material influences on the electromagnetic wave.

The radar of an automobile in the 76-81 GHz band should be used as an example, even if all other frequency spectra, explicitly also light as lidar or other radio communication devices, would be possible.

It is known from investigations with the radar of an automobile that injection temperature, mould temperature and sustained pressure as well as heating time and temperature of the granulate up to the melt in the extruder of a thermoplastic injection moulding machine influence the density and the structure of the molecules of the plastic.
For example, a cooler mould is helpful for rapid cooling of the melt after the injection process, as the material becomes more amorphous on the surface, even if it is a crystalline plastic. In addition, a higher injection temperature allows the melt to flow more quickly into the mold because the viscosity is higher. In addition, a higher injection force can be used. To avoid sink marks or blowholes (areas without material), a high sustained force is required, in which the residual melt is pushed into the component. If the plastic is heated for too long or kept in a molten state, its additives can gas out, making them less effective or even ineffective.

All these variances, which are good for the optical appearance and the compliance with mechanical requirements, change the density, the material structure and the material properties, which in turn have repercussions on the electromagnetic wave to be penetrated.

This development report is intended to control the high-frequency properties of a manufactured component by means of injection moulding parameters. For this purpose, a measurement of the high-frequency properties is necessary after the creation of a component or sample part and a definition of the action parameter spaces within which a mechanically as well as high-frequency technically perfect component is manufactured. This results in a control loop which, depending on the time delay of the measurement and setting of the parameters and their effect on the melt, causes a change in the manufactured component and thus leads to scrap-free production. This also applies in particular to high-frequency parameters such as reflection and damping.

Advantages:
Only by the immediate measurement of a component after the production and evaluation of the high frequency characteristics, it can be evaluated whether the injection moulding parameters are optimally adjusted for the mechanical requirements and the high frequency technical requirements. If this is not the case, immediate correction is necessary and appropriate. This results in a loosely coupled control loop. In addition, there is an early quality control before the further processing of a manufactured component (sprue trimming, punching, painting, installation in other construction elements, etc.). Especially for highly sensitive radar and lidar applications, e.g. the emergency brake assistant in motor vehicles, permanent compliance and, if necessary, logging of the parameters is necessary.
Since the granulate supplied can also change during the manufacturing process of an injection moulding machine, permanent monitoring and control is necessary. If the high-frequency properties are measured immediately after creation and limits and parameter margins are defined, an optimum component can always be created within their limits, for example as a radome. The parameter limits can also be determined using this method. For this purpose, test series with one change each of the parameters with continuous measurement of the result after manufacture are carried out. Thus, the limits and the limits to be expected are determined. The task of the invention was thus completely fulfilled.

Possible application:
The invention method in an advantageous design form is implemented with a sample plate tool. With the help of this tool, the setting parameters and the expected measured values of the high-frequency test can be easily determined.

In the first step, material samples from the plastic of the later component are created and measured with only one change of the machine parameters (temperatures, compression forces, etc.). This includes at least one parameter set with optimum mechanical and electrical or high-frequency properties, which would be the starting point for manufacturing the component. In addition, limits for the machine parameters can be derived from the measurement series. Subsequently, the real components, starting with the start parameters, are manufactured.

According to the invention, the high-frequency parameters are determined by means of a network analysis, in which reflection and/or transmission of the sample plate for the adjustment parameter analysis or the real components are determined at a suitable location. It is irrelevant whether a scalar or vector network analysis of the scatter parameters (called S-parameters, determine reflection and transmission behavior) is performed. In a particularly favourable design, the application frequency range for the component is also to be used for testing. Even if an analogy and transposition of the measured values of another frequency range to the useful frequency range would be possible, direct measurement with the useful frequency band represents a significant simplification in the evaluation of delivery quality and product documentation. The testing of the S-parameters on the real component should take place at a location that would also be representative and comparable with the sample with regard to thickness and shape. In a preferred location, the specimen would be at least 10x10 mm^2 flat or with a slight curvature at the location to be examined.

Since the hot injection moulded parts are usually removed from the injection moulding machine by means of robots or mechanical grippers, the movement of the robot to the test station located near the manufacturing machine can be programmed in a preferred design. The positioning of the component and the transmitting and receiving antenna of the test system required for network analysis is aligned in such a way that the point to be examined is placed in front of the measuring unit and is held still for the duration of the measurement. The influence of the cooling components would have to be observed in the course of the parameter limit determination and, if necessary, taken into account in the evaluation good/bad.

The measurement of the S-parameters for a frequency point can be assumed with approx. 1 second. Modern measurement systems for high frequency network analysis are much faster. Depending on iteration, smoothing, number of measuring points, etc., a statement about the manufactured component can usually be made after a few seconds.
In the preferred design presented here, the measurement results and compliance with the limit values are transmitted to a computing unit which, in addition to database management of the components and associated injection moulding parameters and measurement results, also monitors and readjusts the injection moulding parameters. In a favourable

design, it can also initiate label printing or laser marking as well as packaging of the parts classified as good for dispatch or further processing. The control loop would then be closed.

In a very advantageous design, the series-produced parts already have a test structure at the edge or at a suitable point so that each component can be tested and sorted (good/bad) directly after the injection moulding process. This test structure can also be removed later with the removal of the sprue or can be integrated directly into this sprue. However, this would be disadvantageous, but conceivable, for subsequent inspection.

Figure 1 describes the principle arrangement of the control loop as a block diagram.

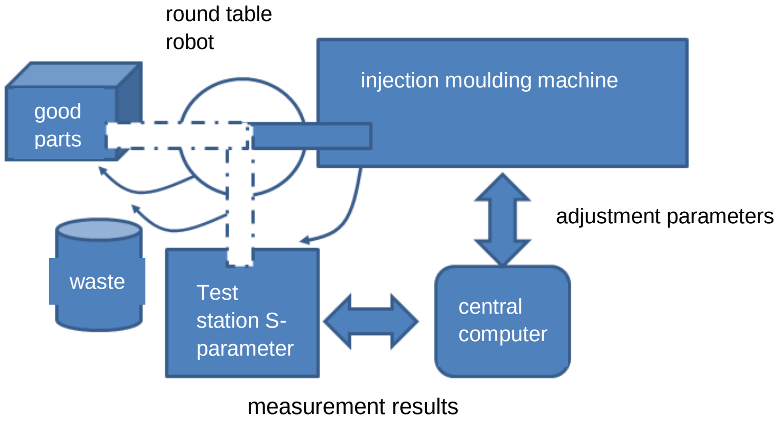

Figure 2 shows the detailed design proposals