XVI Konferencja Naukowo-Techniczna
TKI2022
TECHNIKI KOMPUTEROWE W INŻYNIERII
18–21 października 2022

Design optimization of second-generation polymer overmolded IO-Link Splitter box using FEM analysis

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ABSTRACT: The scope of the investigation was to optimize, using FEM analysis, the design of a polymer overmolded IO-Link Splitter box. Based on the experience gained in earlier projects/ it was established, that the warping after pre and final overmolding and in effect the reliability of the device will be a great challenge for the second-generation IO-Link Splitter due to incised dimensions and material mass.

KEY WORDS: FEM simulation, electronic direct overmolding, shrinkage

1. Introduction: high pressure overmolded electronics

The possibility of direct overmolding with a polymeric material of printed circuit boards, equipped with M12 electric ports, was investigated by our development team based on a case study of a simple Y-Splitter. A robust housing concept which can guarantee a long-time persisting performance was required. Solutions already available on the market showed a number of weaknesses in the design and therefore was a need to find a solution for improving product properties. Based on the overmold concept of these Y Splitters, the design preconditions for an overmold process of a high complex electronic device like an IO-Link Master were investigated. A simulation of the cavity filling with wrapping and shrinking after the injection process was performed. [1]

The findings of numerical analysis were confronted with tests performed on a physical model, produced in a prototype overmolding tool. The concept of positioning the injection points at one level with the printed circuit board has been proofed to be not practical, due to production tolerances and therefore no uniform filling of the cavities below and above the circuit board. [1]

Based on the gained experience, a novel manufacturing technology for far more complex electronic devices was introduced. Key feature was a two-step high pressure overmolding process. In the first step a printed circuit board equipped with electronic components is overmolded with a relatively soft and compliant thermoplastic polyurethane PUR. In the second step the device gets its finish with the final overmold. The material chosen for this step is a hard and resistant to environmental factors polyamide PA12. The challenge of sealing the M12 electric ports was solved by utilizing a novel overmolding tool sealing technology, which is built around a flexible radial elastomeric sealing component. An example for such a device is shown on Fig. 1. We also introduced horizontal grooves on the top side to reduce the effects of wrapping after both overmolding steps. This provides additional compliance to the system and therefore makes it easier to further process the pre-overmolded device. [2]

Fig. 1. Example of a 1st gen. 1 IO-Link Box

While introducing to production the longer variants, the finished devices have shown an arc-like deformation, with the bending direction to the bottom side. This wrapping behavior was investigated by the project team. The key points, which were examined, were: the nonconform mass distribution of the first overmold material above and below the circuit board and the added shrinkage volume for the final overmold material after implementation of the horizontal grooves. The study has utilized thermal wrapping simulation, and also a measurement setup built into a climatic chamber. The samples included devices with different design approaches to the groove design. The measurement setup has shown that the least wrapping during the climatic cycles had exhibited the samples with an enlarged thickness of the preovermold material above the circuit board. On the other hand, the wrapping simulation have shown only an influence of the shrinkage coefficient of the used materials on the wrapping behavior. [3]

2. Motivation

The motivation of the actual study is the development of a second generation of the IO-Link Boxes. The key driver for this process is the market demand for more complex functionality and more computing power.

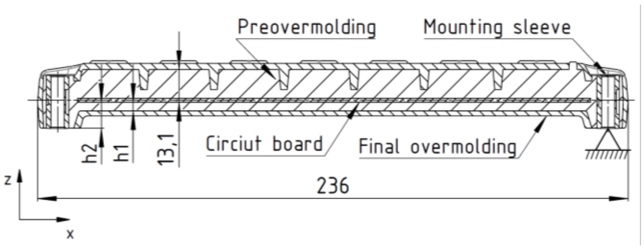

Fig. 2. Design proposal for 2nd gen. IO-Link Box.

3. Method

The optimization of the gen 2 design of IO-Link boxes was performed at first by numerical simulations of the bending behavior in a function of temperature. The optimization criterion was to find a design with the lowest value of deflection. The optimization parameters were the height h1 and h2 of the bottom volume of the preovermolding as shown in Fig. 2. An overview of the h1 and h2 parameter values is shown in Tab. 1.

Table 1. Values of h1 and h2 parameters

Geometry description	h1 [mm]	h2 [mm]
No.1 Standard bottom	3.5	10.4
No.2 Thick bottom	8.0	11.3
No.3 Medium bottom	5.8	10.3

The material properties used in the simulation were modeled based on values from the material data sheets available for the materials used for the 1st gen. IO-Link Boxes (Tab. 2). A linear elastic material model was utilized for the analysis.

Table 2. Material description and mechanical properties

Component	Thermal expansion coef.	Young modulus
Preovermolding	$12 \times 10^{-5} K^{-1}$	2620 MPa
Final overmolding	$9 \times 10^{-5} K^{-1}$	26200 MPa
Printed Circuit Board	$1{,}1 \times 10^{-5} K^{-1}$	220590 MPa

The model geometry used for the simulation was based on a simplified design of the 2nd gen. IO-Link Box concept. The simulation was performed in the Simulation module of the SolidWorks2020 CAD suite. The nodes on the bottom side around the right-hand mounting sleeve were fixed. The starting point of the simulation was an ambient temperature of about 20°C, where the box was modeled as a non-wrapped geometry. The bending of the model was induced by rising the ambient temperature up to 65°C, which corresponds with the ifm intern temperature cycle test for this product. The geometry wrapping due to ambient temperature change is visualized as a deflection map, painted on the surface of the model.

4. Results

The results of the simulation are showing the largest deflection value of approximately 0,41 mm for the geometry No.1 (Fig. 3). The geometry No.2 shows a deflection at the loose end of approximately 0,10 mm, which is the lowest value calculated in this analysis. The geometry No.3 shows a deflection value of about 0,20 mm.

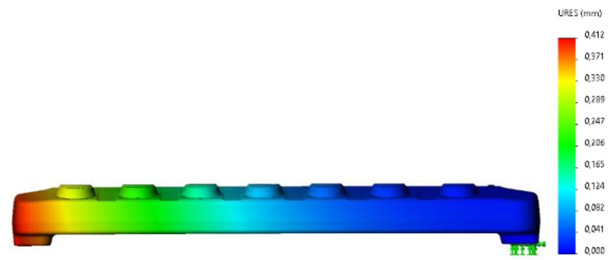

Fig. 3. Simulation results for Geometry No.1

5. Summary

The new design proposals exhibit a clear improvement in comparison to the Standard geometry: the geometry No.3 shows about 53% decrease in the deflection value. For the geometry No.2 even a 77% decrease can be reported.

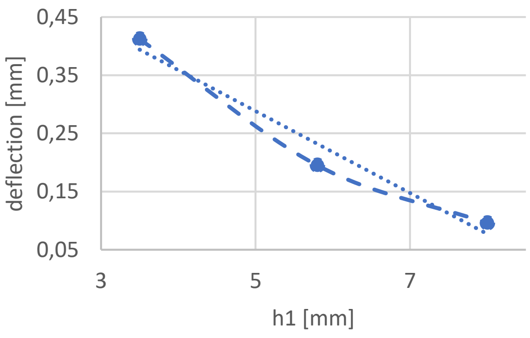

Fig. 4. Deflection in correspondence to value of h1.

1) In respect to the geometry defining parameters h1 and h2, it is visible that the greatest impact on the deflection imposes the parameter h1. With the rise of h1 a decrease of the deflection value is visible as shown in Fig. 4.
2) A similar dependency between the value of parameter h2 and the calculated deflection values is not visible.
3) The results obtained in this study are showing a dependency between the material thickness ratio below and above the circuit board and the calculated deflection value. The lowest value of deflection was calculated for a thickness ratio of 0.6.

Praca została wykonana w ramach Regionalnego Programu Operacyjnego Województwa Opolskiego 2014-2020 z dofinansowaniem z Europejskiego Funduszu Rozwoju Regionalnego.

References

[1] Konietzko M., Ryczaj W., *Wielkopunktowy wysokociśnieniowy wtrysk polimeru. Badania modelowe*, XXXIV Konferencja „Problemy Rozwoju Maszyn Roboczych" Bydgoszcz, 16.02.2021.
[2] Cammareri D., Mehnert W., *DE 10 2017 203 870 A1*, Deutsches Patent – und Markenamt 13.09.2018.
[3] Ryczaj W., Paluszek M., Urbaniec J., Miłkowski A., Konietzko M., *Analiza przyczyn odkształceń inteligentnego rozgałęźnika sygnałów*, XXX Sympozjon Podstaw Konstrukcji Maszyn Opole, 13.09.2021.