APPLICATION OF SIMULATION SOFTWARE TO OPTIMIZE CONSTRUCTION NODES OF ULTRASONIC WELDING MACHINES

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Abstract
The whole lifecycle of a construction node and the whole technical system attempts to be optimized. An engineer decides whether the construction node or the whole technical system need optimization or when and by which optimization tools will be the optimization performed. Virtual simulation software belongs to the tools that help the engineer to make a decision. Within the virtual environment, there can be performed simulations that analyze the whole technical systems in detail. It is possible to proceed to such virtual simulations and analyzes during different stages of the technical system lifecycle and they may help us to reveal and precisely identify structural shortcomings, weak spots and elements. By means of such simulations, the engineer can solve a problem in the technical system construction in a faster, better and cheaper way.

Key words: *technical system; construction node; optimization; virtual simulation.*

INTRODUCTION

New kinds of software are being developed daily. They have to find and accurately identify possible construction deficiencies. Such software enables to simulate different impacts and loads on the construction elements, construction nodes or on the whole technical system and thereby save time and money. Such software analyzes enable to verify the selected parameters of the technical system at any time in the construction process, thus ensuring proper selection of optimization.

Thermoplastics are widely used due to their good mechanical and construction properties, mainly in the area of consumer goods, electrical engineering and automotive industry. Their great construction advantage is that they can be very reliably connected by means of welding. Ultrasonic welding belongs to effective welding methods of plastics. Practical application of ultrasonic welding for hard plastics was finished in year 1960. The patent for the ultrasonic method for welding rigid thermoplastic parts was awarded to Robert Soloff and Seymour Linsley in 1965 (Weber, 2007).

Success of the company depends primarily on the ability of meeting the requirements of the market respectively customer requirements. For this reason, customer satisfaction has become a measure of success (Žarnay, et al., 2000). Perspective future of automation of the ultrasonic welding of differently sized plastic parts leads the company CEIT Technical Innovation s.r.o. (Central European Institute of Technology s.r.o.) to optimize the already produced welding machines and to produce unified assembly units for incorporation into ultrasonic welding machines.

To perform a good welding joint, it is necessary to observe the main parameters of the ultrasonic welding. The values of the ultrasonic welding parameters vary according to the welded material.

The main parameters of the ultrasonic welding are: tip welding deflection amplitude A_o (mm), compressive force F_p (N), frequency f (Hz), welding time t (s) (Sobotová, 2005). Correct understanding of quintessence of physical phenomena and their effective use in technical systems also provides solid platform for innovation (Bultey, Yan, Zanni, 2015).

MATERIALS AND METHODS

The technical node for gripping the sonotrode shall ensure all the requirements coming from the ultrasonic welding technology. The technological procedure of ultrasonic welding involves the welding head supply to the welding joint. Transmission of ultrasonic vibrations into the welding joint is performed for the required time and under constant pressure and, if necessary, to ensure cooling of

the welding joint. The transfer of physical quantities necessary to carry out the ultrasonic welding has a negative impact on the whole construction node of welding heads or sonotrodes gripping.
When designing the construction nodes of sonotrode gripping, the greatest possible repeatability of these nodes was taken into account for the design of other technical systems for the ultrasonic welding. The following step was to create a database, including these construction nodes, for a faster production of technical systems. In this regard, the 3D design models of construction nodes for sonotrodes gripping were subjected to simulations in the virtual world. There were designed two gripping variants on Fig. 1. Both variants were subjected to simulations.

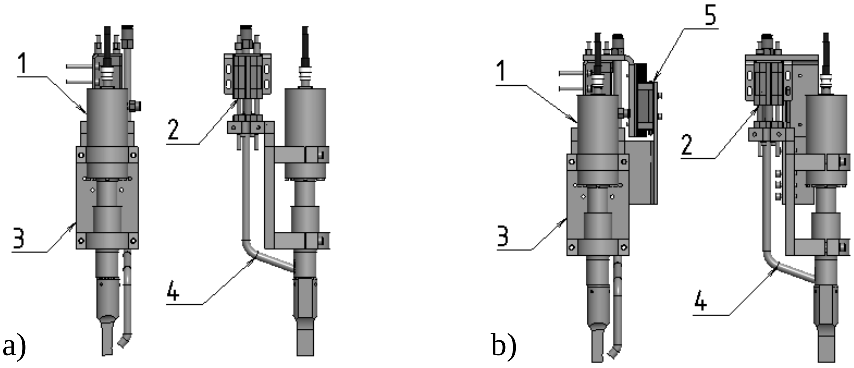

Fig. 1 a) Welding head gripping, Variant no.1; b) Welding head gripping, Variant no.2; (1) Sonotrode, (2) Linear conduct, (3) Pneumatic cylinder, (4) Cooling tube, (5) Gripping construction

For the purposes of the software in which the simulations were performed, both variants were simplified as much as possible and the 3D models were relieved of the excess elements that met only the secondary functions. Within the simulations, there were taken into account the gravitational force and the compressive force acting in the opposite direction as the gravitational force. The compressive forces during the ultrasonic welding range from 0,2 MPa to 10 MPa. They are selected according to the welded material properties and the type of material used. We will count with the greatest possible load of 3 MPa on the welded polymer.

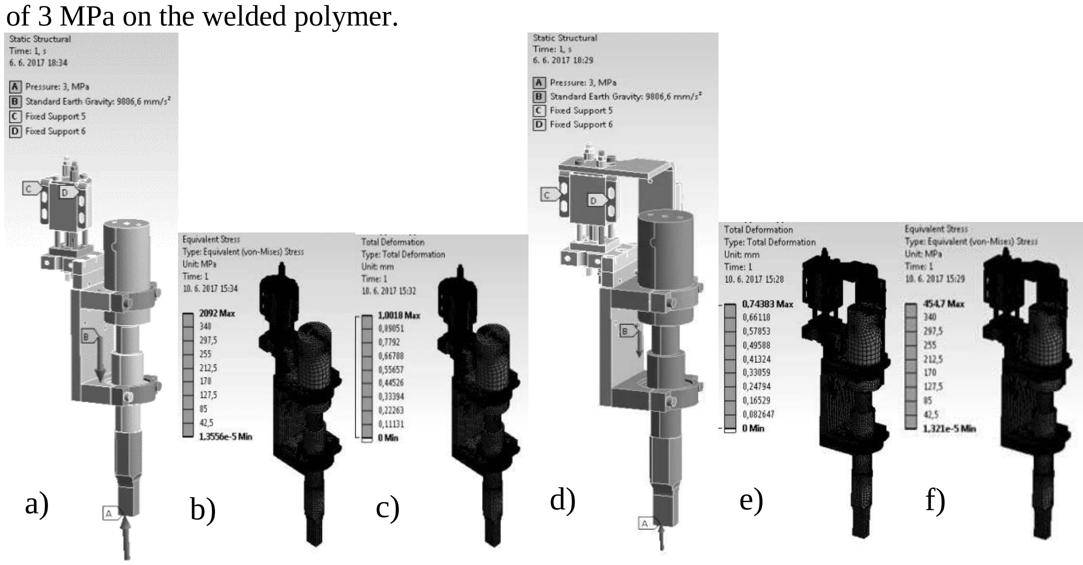

Fig. 2 a) Gripping and loadings, Variant no.1; b) Deflection of the sonotrode head, Variant no.1; c) Maximum stress in Variant no.1; d) Gripping and loadings, Variant no.2; e) Deflection of the sonotrode head, Variant no.2; f) Maximum stress in Variant no.2;

Variants have a similar construction type and some construction elements are repeated. Both variants are gripped to surfaces C, D, loaded by the gravitational force B and the compressive force A in the welding joint. These simulations show that the sonotrode has 1.0018 mm deflection of the welding head in the welding joint on the gripping, Variant no.1, and 0.744 mm deflection on the gripping,

Variant no.2. In both designed constructions, too much stress is formed in the same construction unit and exceeds the used material´s strength limit of R_m 340 MPa. In Variant no.1, there is the stress of 2092 MPa and 454,7 MPa (Figure 2) in Variant no.2.
We need the construction node to ensure that deflection of the sonotrode head in the welding joint is at maximum 1 mm and the mechanical stress in the construction does not exceed 340 MPa. An analysis of the impacts of forces necessary during the ultrasonic welding technological process on the technical node has revealed the technical node construction deficiencies that prevent to repeatedly perform welding joints of the required quality. The simulations performed have exactly determined the unsatisfactory construction unit and also the specific place in which the unsatisfactory unit is overloaded on Fig. 3.

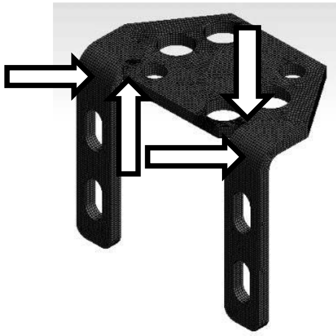

Fig. 3 Unsatisfactory construction unit (unsatisfactory construction places are marked with arrows).

This construction unit occurs in both original variants of the sonotrode gripping and proved to be unsatisfactory in both variants during simulations. When considering strength, both variants are unacceptable and the construction needs to be modified.

RESULTS AND DISCUSSION

The simulation results led to the design of Variant no.3 in which all the shortocomings of the previous variants should have been removed. The same simulations were performed also on the construction of this variant. When designing the construction node, Variant no.3, we tried to use as many construction units as possible from the previous variants, which complied with the requirements of the ultrasonic welding technological process when considering strength and functionality.

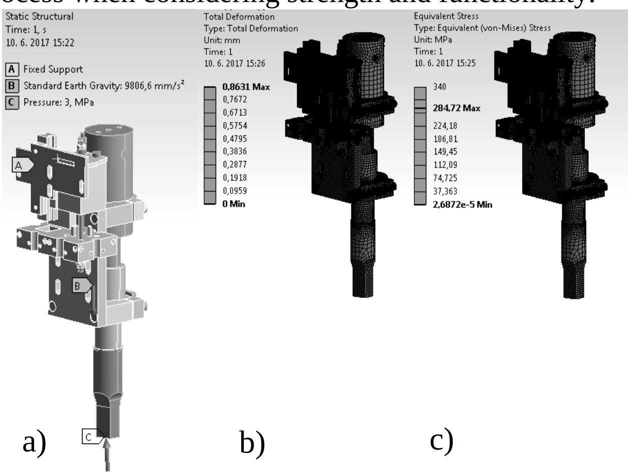

Fig. 4 a) Gripping and loadings, Variant no. 3; b) Deflection of the sonotrode head, Variant no.3; c) Maximum strength in Variant no. 3;

The construction node is gripped to surface A, loaded by the gravitational force B and compressive force A in the welding joint. The gripping area, the strength and the direction of their action are shown in the figure Fig. 4. The simulation shows that on the gripping, Variant no.3, the sonotrode has 0.863

mm deflection in the welding joint and the maximum voltage of 284.72 MPa is being formed in the construction with 3 MPa load.
When considering the forces used during the ultrasonic welding technological process, this construction node fully complies with the construction requirements for the use in the technical systems of the ultrasonic welding machines.

Tab. 1 Gripping analysis

Gripping	Deflection mm	Stress MPa	R_m MPa	Satisfactory Yes/No
Variant no.1	1,0018	2092	340	No
Variant no.2	0,744	454,7	340	No
Variant no.3	0,863	284,74	340	Yes

CONCLUSIONS

The biggest problem with the designed technical systems of the ultrasonic welding machines has been to design a sufficiently stiff, but also the most variable sonotrode gripping. The simulation software helped us to identify the unsatisfactory element and its deficiencies in the construction node in a relatively short time. This led us more effectively towards design of a new, suitable construction node. This saved us time and money that can be saved or used within the optimization process.

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