Theses

of

The Behaviour of Polyurethane Foams During Robotic Handling

Ph.D. Dissertation

1. It was proven with theoretical calculations and experiments, that the force of pulling a fully inserted needle out of a soft open celled polyurethane foam can be calculated with appropriate precision using the Blatz-Ko strain energy functions and its different versions when concerning large deformations. The calculations were performed for a hyperelastic body assuming cylindrical symmetry. A test method was proposed and performed for verifying the calculations. The tests showed that the results can be appropriately approximated with the presented calculations. The method is suitable for calculating a technologically suitable maximal grasping force that can be transmitted by an ingressive (needle) gripper and can also be used for designing the arrangement of the needles in the gripper.

The thesis is based on Chapters 4.2, 4.4 and on [113] of dissertation.

2. A technologically suitable needle diameter was determined with experiments that causes the largest possible stress when is inserted in a flexible open celled polyurethane foam[1]. It can be shown that the needle diameter that produces the desired condition is dependant on the foam structure. The experiments were performed on commercial hypodermic needles (in the range of Ø0.5…Ø1.6 mm) and on soft open celled polyurethane foams[1] that has been produced with different mixing ratios. The needle diameter of Ø0.9 mm was determined to be generally usable for the examined foams.

The thesis is based on Chapter 4.1 and Appendix A.6 of dissertation.

3. With experiments it was proven, that the affect of the damage caused by the needles of an ingressive gripper is negligible to the quality parameters (geometry, hardness) of the examined polyurethane foams[1] during their long-term use. The result is valid for soft open-celled polyurethane foams, that were perforated with Ø9x60 mm needles with the needle densities of 0,04 and 0,16 needle/mm^2. The fatigue test was performed with 85000-cycle constant load pounding.

The thesis is based on Chapter 4.7 and Appendix A.6 of dissertation.

[1] The foams that were used in the tests are always soft open-celled polyurethane foams that were produce by 15 different mixing ratios from the base material: ICI W5691 "A", "B". The density of the foams were between ρ= 40…52 kg/m^3. These foams are soft flexible foams used in the automobile industry for seat cushioning. The examined foams cover the whole range of foams used in the automobile industry. Further definitions of foam properties can be found in Appendix A.6.

4. The compression curve of soft open celled polyurethane foams can be described with appropriate precision by the function $\sigma(\varepsilon) = a\,\varepsilon^{b} + c\ \tan(\frac{\pi}{2}\varepsilon)$ (0≤ε<1) when concerning large deformations. The parameters a, c have stress dimensions b is dimensionless σ is the compression stress and ε is the compression strain. A method was presented for the determination of the parameters of the function from experiments. A computer program performing the regression calculations, which is the base of the method, was also developed. With the above function, the force acting on an ingressive grasping during demoulding can be properly described in the case of cylindrical symmetry foams. The force calculations were performed on conical shaped foams. The results were verified with tests in which the difference of the measured and calculated values was less than 10%.

The thesis is based on Chapters 2.3.5.3, 5.3.1, Appendix A.6 and on [109] of dissertation.

5. When designing robot motion for ingressive grasping of soft open celled polyurethane foams the constant kinetic robot motion is the most favourable motion criterion. During ingressive grasping the friction surface on the needle is very small due to the porosity of the foam and it is important that sticking friction work between the foam and the needle during the entire motion. The condition for this is that during the motion there should not be large accelerations and large additional forces. The statement was proven with a computer simulation, by comparing time optimal and constant kinetic energy robot motion for a two degrees of freedom polar robot travelling on a circular path. With the comparison of the joint forces (torques) and joint accelerations (angular accelerations) of the motions made with the two criteria it can be clearly seen that the values of the constant kinetic energy motion are always smaller than the values of time optimal motion and the parameters (forces, accelerations) are much smoother for the constant kinetic energy motion than for the time optimal motion. The additional forces from the motion on the grasping will not be large, this way the reliability of the grasping is improved. The simulation was made in LabView graphical programming environment.

The thesis is based on Chapter 5.3.2 and on [114] of dissertation.

Peter Zentay
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