Method for Producing Models of Living Objects from Elastomers

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***Abstract* - This study uses the existing technology of casting plastic parts in silicone and develops a new method that allows replicating shapes of the living objects and produces their models from plastics and elastomers. The method offers way to replicate and investigate energy efficient movement mechanisms from animal world and transfer them to technology.**
Description of the method: a container is filled with 5 cm thick layer of liquid silicone which has been kept for 30 minutes in vacuum under pressure 10hPa, a living object is placed in it and covered with another layer of liquid silicone. After silicone has hardened (24 hours) acquired casting mold is cut in half, remains of the living object are removed, and the mold is washed under strong running water and dried. Holes are drilled in the mold – one on top with diameter 10mm for inflow of elastomer and few more with diameter 3mm in the middle and bottom parts for air to escape. Actuator leads are placed in the mold and carefully aligned parts of the mold are tied back together. The model is produced using 2-component elastomer, e.g., Altropol base Neukadur ProtoFlex 150-05N and hardener PTG8. The mold is placed in plastic casting vacuum chamber and filled with liquid elastomer. If a model with empty void in the middle is required, the mold has to be filled with elastomer only up to half, then taken out of the chamber and turned in different directions (for about 15 minutes) in order to spread liquid elastomer around the mold where it will stick to the walls and harden leaving middle of the mold empty where later actuator, electronic components and power supply can be placed.
Mechanical tests (bending and tension) of the acquired model of fish were performed.

***Keywords* - elastomer, bionics, model, prototype, living objects.**

1. INTRODUCTION

The use of the positive features of living organisms in technology increases constantly. Application of bionic solutions in practice has improved parts strength/weight ratio, reduced resistance forces of moving mechanisms in viscous environment, improved car tyres adherence to road surface, improves other parameters of technical equipment. For example, development of an object that moves in water in most efficient way would assume imitation of a shape and movement of a fish that through evolution has developed a form and moving mechanisms which enable it to move in water with minimal energy. [1] There is an increasing demand for finding quick methods to replicate living objects and produce models from materials that best reflect features of these objects. Elastomers can be considered as being one of such materials.

The objective of this study is to develop method for replicating shapes of living objects and producing their models from elastomers.

II. REPLICATION OF A LIVING OBJECT AND MAKING A MOULD

There is vast amount of literature available describing technologies of making parts from plastic and elastomers, e.g. [2] - [5]. However these sources do not offer detailed information on ways to replicate forms of the living objects and make their models from plastic and elastomers.

Literature and technological equipment available to authors lead to conclude that at least two methods can be used to replicate shape of nature object with precision 0.2 mm:

1) 3-dimensional scanning and making an injection mould using CNC machining or 3-dimensional printer;

2) Casting an imprint directly in a silicone mould.

The advantage of the first method is that a scan of a 3dimensional object can be adjusted, the disadvantages are that the ray of the scanner is unable to reach hidden areas (cavities, gaps) of the object, the technology used in 3dimensional printers gives a grainy structure to a surface (average grain size 0.2mm) and processes of machining a casting mould and 3-dimensional printing are relatively expensive.

The study examines the second method that currently is cheaper**.** Let us have a look what it encompasses. A casting mould is made using two-part liquid silicone which initially is mixed using slowly rotating mixer until a homogeneous consistency is achieved. Next it is placed in a vacuum chamber (pressure approximately 10 hPa) and kept for 30 minutes. As a result silicone is freed from humidity and air it contains. In a container with a size at least 5 cm bigger than the size of the natural specimen (a fish with length 22 cm and mass 300 g was used in the experiment; see Figure 1) approximately 5 cm thick layer of silicone is poured, the natural specimen is placed in it, straightened and more silicone is then poured on top of it until the specimen is fully covered. The specimen is left motionless for 24 hours for silicone to harden. If density of the specimen differs from density of liquid silicone, surfacing or sinking of the specimen is possible. If the specimen has surfaced, after silicone has hardened, another at least 3 cm thick layer of liquid silicone is added. In the case of sinking, the specimen enclosed in hardened silicone is to be taken out of the container, turned over with bottom side up, returned to the container, covered

Fig. 1. The fish in silicone

with 3 cm thick layer of liquid silicone and left for another 24 hours to harden.

The next stage is to remove the natural specimen from hardened silicone. It is done by cutting the silicone mould in the middle with a scalpel leaving surface of the cut as serrated as possible. If necessary additional cuts into silicone are made in order to take out remains of the specimen. Due to malodor this stage has to be done outside wearing protective mask. After removing organic matter, the silicone form has to be rinsed under strong running water and dried.

III. Making the model

Holes are drilled into the silicone casting mould: the one hole with diameter 10mm in the top part of the mould, e.g. in the area of the fish's mouth as shown in Figure 2, to allow liquid elastomer to flow into it; the other holes with diameter 3 mm in the middle and bottom parts, e.g. in the area of fish's back, belly, at the end of a tail and fins as shown in Figure 2, to allow air to escape during casting process.

In order for the model to generate movement it is necessary to place actuator leads (e.g. wires, rods, plates etc) in the casting mould with one end of leads melted into elastomer and the other attached to a servomotor, electromagnet or any other mechanism generating movement. Next both parts of the casting mould have to be carefully aligned and put back together.

Fig. 2. The silicone casting mould

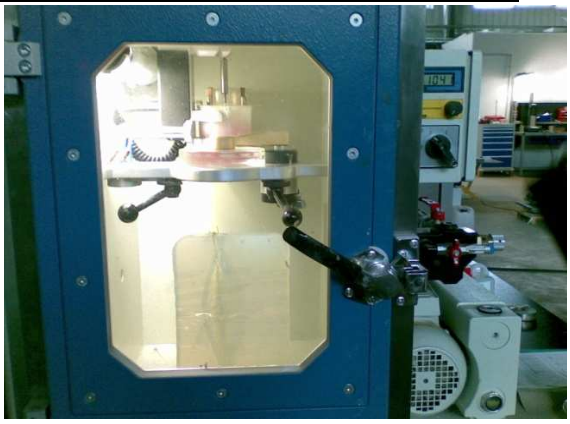

Fig. 3. Plastic vacuum moulding machine

Sides of the casting mould can be strengthened with organic glass plates of corresponding size on one or both sides and tied together with adhesive tape or screws. The holes for airflow must not be covered. The model for this study is made using the plastic vacuum moulding machine (see Figure 3) and Altropol 2-component liquid elastomer: base Neukadur ProtoFlex 150-05N (2K-PUR-Vakuum-Griessystem) is mixed with hardener PTG8 in ratio given by manufacturer and small amount (3 – 5%) of liquid dye is added.

In the hole on top of the casting mould a flexible plastic tube with diameter 10 mm was inserted. The other end of the tube was attached to the container where liquid elastomer will be poured (Figure 4). Base and dye are mixed using the mixer of the vacuum moulding machine; hardener is placed in the specially allocated container in the vacuum moulding machine. Vacuum in the working chamber of the moulding machine allows liquid components of elastomer to be freed from humidity and air trapped in it. Then hardener is added to the solution and mixed for one minute. The vacuum moulding machine is designed in a way that all manipulations with liquid elastomers are performed without need to open the door of the chamber. Prepared liquid elastomer is poured into the

Fig. 4. Preparation for casting elastomer into the mould

casting container which has plastic tube connected to the mould (see Figure 4); the container with elastomer is covered and atmospheric air is let in. Because of vacuum in the working chamber and consequently in the silicone mould, atmospheric air flowing into casting container pushes liquid elastomer through the plastic tube into the silicone casting mould until it is filled. Casting has to be done rather quickly because liquid elastomer starts to harden in about 5 minutes after the hardener is added. Transparency of the casting mould allows visual control of the casting process.

If it is planned to attach mechanisms to the model to generate movement, electronic components, electrical power supply, etc., it is necessary to leave empty void inside the model. It can be achieved as follows: fill about half of the silicone casting mould with liquid elastomer; stop casting process, take casting mould out of the vacuum chamber, for approximately 15 minutes keep turning silicone mould in different direction to spread evenly along the sides to form uniform thickness around and leaving void in the centre. It has to be taken into account that after turning is stopped, liquid elastomer that has not hardened yet will run to the bottom of the casting mould creating thicker layer of elastomer.

To finish casting process the silicone mould has to be left in a warm (20-30^{0}C) area for approximately 24 hours then the elastomer model can be taken out (see Figure 5).

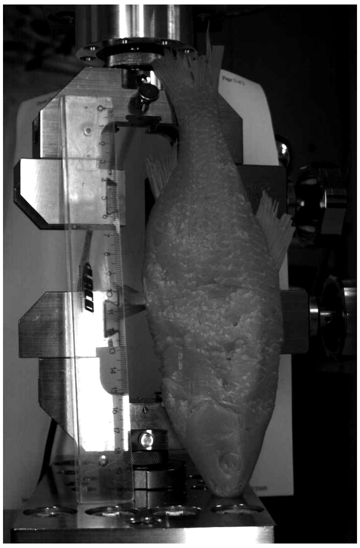

Fig. 5. The elastomer model of the fish

IV. THE MECHANICAL TESTS OF THE MODEL

The model produced can now be tested. In this study the model is submitted to one point bending test in horizontal and vertical directions and tension tests using universal testing machine Zwick/RoellZ-150 in small and medium deformations section (see Figures 6 - 8) with deformation velocity 100 mm/per minute.

The results of the mechanical tests are given in Figures 9, 10 and 11. In theses graphs horizontal axis shows deformation (mm), vertical axis – force (N). One point bending tests are performed with 5 different distances (55, 50, 45, 40, 35 mm)

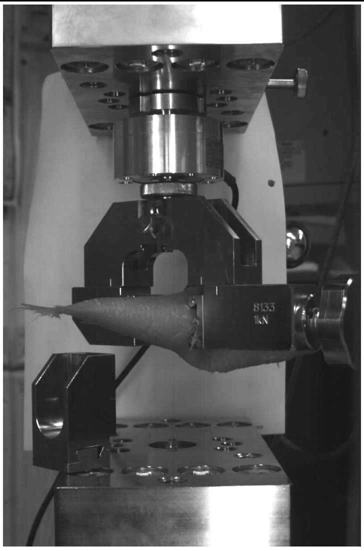

Fig. 6. One point bending test in horizontal direction

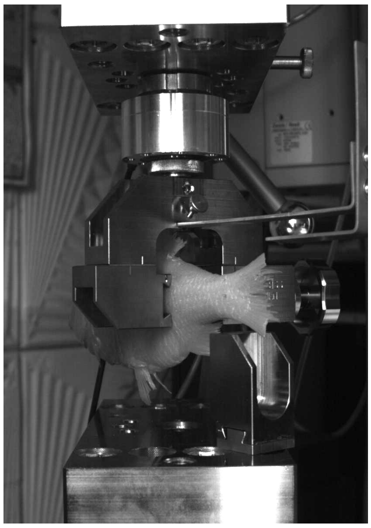

Fig. 7. One point bending test in vertical direction

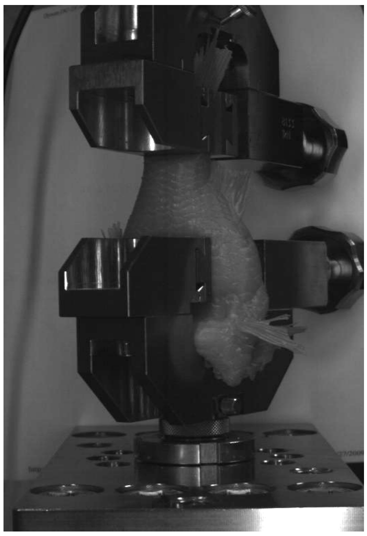

Fig. 8. Tension test

between clamping point and support point (see Figures 6, 7). Tension tests are performed with 5 different distances (55, 50, 45, 40, 35 mm) between grips of the tension machine (see Fig. 8).

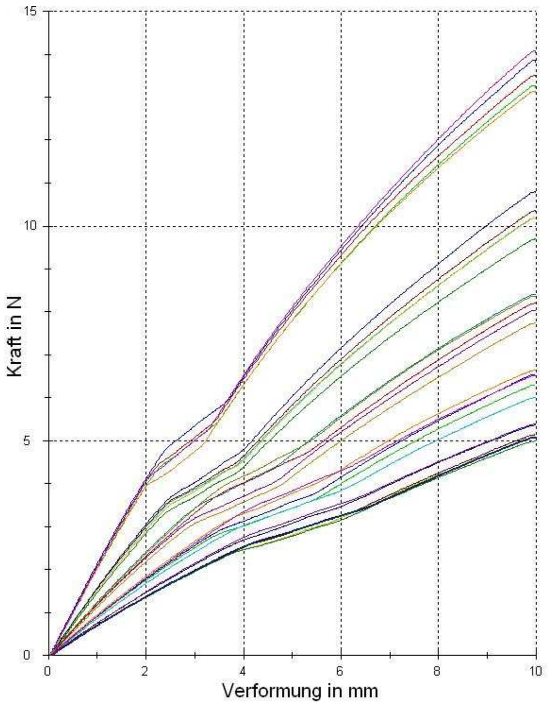

Fig. 9. Results of the one point bending test horizontally

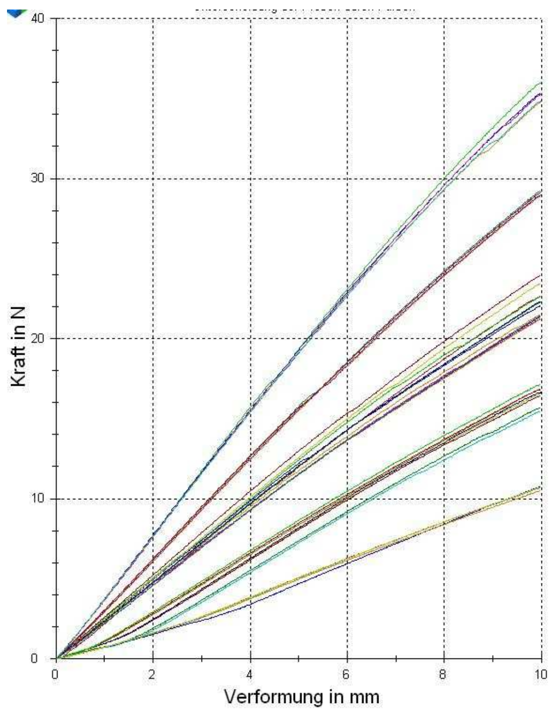

Fig. 10. Results of the one point bending test vertically

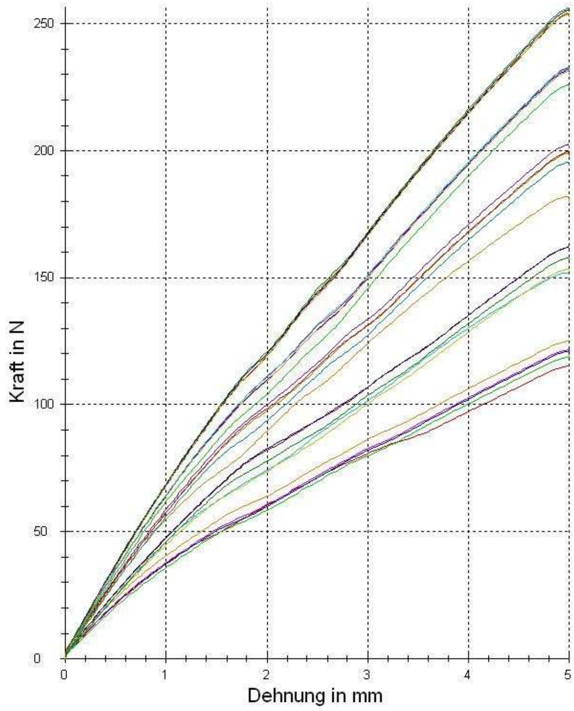

Fig. 11. Results of the tension test

V. Conclusions

This study develops a new method that allows replicating shapes of the living objects and producing their models from plastics and elastomers that is based on existing technology of casting plastic parts in silicone.

The method offers way to replicate and investigate energy efficient movement mechanisms from animal world and transfer them to technology.

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Andris Martinovs, Andris Igavens, Edgars Kovals, Jānis Vība, Viljams Megills. Metode dzīvās dabas objektu modeļu izgatavošanai no elastomēriem
Darbā, balstoties uz eksistējošo tehnoloģiju - plastmasas detaļu liešanu silikonā - ,ir izstrādāta jauna metode, kas ļauj kopēt dzīvās dabas objektus un izgatavot to modeļus no plastmasām un elastomēriem. Metode paver iespēju kopēt, pētīt un ieviest tehnikā energoefektīvus dzīvnieku kustības mehānismus.
Metodes būtība: traukā 5 cm biezā slānī ielej šķidru silikonu, kas iepriekš 30 min. izturēts vakuumā 10 hPa spiedienā, ievieto dzīvās dabas objektu un uzlej tam virsū silikona kārtu. Pēc silikona sacietēšanas (24 stundas), iegūto liešanas formu pārgriež uz pusēm, no tās izņem dzīvās dabas objekta atliekas, formu izmazgā ar ūdens strūklu un izžāvē. Formā izurbj caurumus - augšpusē 10 mm diametrā elastomēra ievadīšanai, vidus un lejas daļā 3 mm diametrā gaisa izplūdei. Formā ievieto aktuatora pievadus; tās abas daļas rūpīgi saliek kopā un sastiprina. Modeļa izgatavošanai tiek izmantots šķidrs divkomponenšu elastomērs, piemēram, firmas Altropol šķīdinātājs Neukadur ProtoFlex 150-05N un cietinātājs PTG8. Formu ievieto plastmasu liešanas vakuuma kamerā un piepilda ar šķidro elastomēru. Ja nepieciešams iegūt modeli ar tukšu vidu, formu piepilda ar elastomēru līdz pusei, izņem ārā no kameras un groza visos virzienos (15 minūtes), lai šķidrais elastomērs, izplūstot pa formu, pieliptu pie sienām un sacietētu, vidū atstājot tukšumu, kurā pēc tam var ievietot aktuātoru, elektronikas komponentes un barošanas avotu.
Darbā ir veiktas iegūtā zivs modeļa mehāniskās pārbaudes (liece un stiepe).

Андрис Мартынов, Андрис Игавенс, Эдгарс Ковалс, Янис Виба, Вилиам Мегилл. Метод изготовления моделей объектов живой природы из эластомеров
Основываясь на существующую технологию литья пластмассовых деталей в силиконе, разработан новый метод, позволяющий копировать объекты живой природы и изготавливать их модели из пластмасс и эластомеров. Метод позволяет копировать, исследовать и внедрять в технику энергоэффективные механизмы движения животных.
Сущность метода: в сосуд наливают жидкий силикон (толщина слоя 5 см), который выдержан 30 мин. в вакууме (давление 10 hPa), помещают объект живой природы и заливают сверху слоем силикона. После затвердения силикона (24 часа) полученную литьевую форму разрезают пополам, изымают останки объекта, вымывают форму струей воды и высушивают. В форме просверливают отверстия - в верхней части диаметром 10 мм для ввода эластомера, в средней и нижней части диаметром 3 мм для выхода воздуха. В форме размещают приводы актуатора; ее обе части аккуратно складывают вместе и закрепляют. Для изготовления модели используют жидкий двухкомпонентный эластомер, например, продукт фирмы Altropol, включающий растворитель Neukadur ProtoFlex 150-05N и затвердитель PTG8. Форму помещают в вакуумную камеру устройства литя пластмасс и наполняют жидким эластомером. Если необходимо изготовить модель с полостью внутри, форму заполняют эластомером до половины, вынимают из камеры, болтают 15 мин, чтобы эластомер, растекаясь по всей форме, прилип к стенкам и затвердел, внутри оставляя полость, в которую впоследствии помещают актуатор, компоненты электроники и источник питания.
В работе осуществляется механическое тестирование (изгиб, растяжение) изготовленной модели рыбы.