

Reverse Engineering for Injection Parts

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The aim of this paper is to present a proper methodology for obtaining active mould parts. The originality of the paper consists in the fact that building these active objects starts from some distinctive marks (machine parts) for which there's no technical documentation. Using reverse engineering procedures (scanning and reconstruction) for polymeric material machine parts and rapid prototyping procedures by material sampling, we will finally obtain both the wanted distinctive mark and its active elements.

Keywords: reverse engineering, rapid prototyping, polymeric material, mould

Reverse engineering and rapid prototyping techniques overview

Plastics are essential for current modern life. The steady growth rates in the consumption of plastics over the past few years are evidence of the fact that plastic products are now an indispensable part of our everyday life and are set to gain even greater importance in the future [1]. Technological progresses improving the quality of our lives by telecommunication, computers, transport, health, hygiene, recreation, education, sport, banking system, clothes, food, water and energy- just to mention few of them- are possible because of the unique electric, thermal and isolation properties of thermoplastic and thermo rigid materials.

A very important domain of the projected moulded part is projecting the cavity. It directly influences the whole moulding process, being one of the most important phases.

About the active mould parts and the shape cavity, there were published many articles which present the injection mould parameters into the mould cavity [2-9], the actual tendencies in the construction and the control of the injection machines [10], rapid prototyping of the active mould parts [11] and for a specific part [12, 13], the dimensional variances and tolerances of the injection plastic parts and the precision injection moulding [14-17] according to the shape cavity. In this paper we refer to the manufacturing of the active mould parts for plastic parts without technical documentation (drawings). For this purpose, the reverse engineering (RE) and rapid prototyping (RP) techniques will be used. Next, it will be presented a short overview about RE and RP techniques, followed by a RE technical application for a plastic part.

Reverse Engineering is defined by the Military Handbook MIL-HDBK-115 (ME) as "...the process of duplicating an item functionally and dimensionally by physically examining and measuring existing parts to develop the technical data (physical and material characteristics) required for competitive procurement" [18].

Usually, most reverse engineering processes can be used without actually manufacturing a real prototype. One solution is using a 3 axis milling machine to palpate the surface of the part to be copied. Digital data obtained can be processed by CAD/CAM software [19]. Figure 1 shows RE principle.

Faster and low cost manufacturing of a model or a new product was and still is a dream of any engineer. Starting in the 90's, this dream has become true and still becomes true with every day that goes by, because of the arising

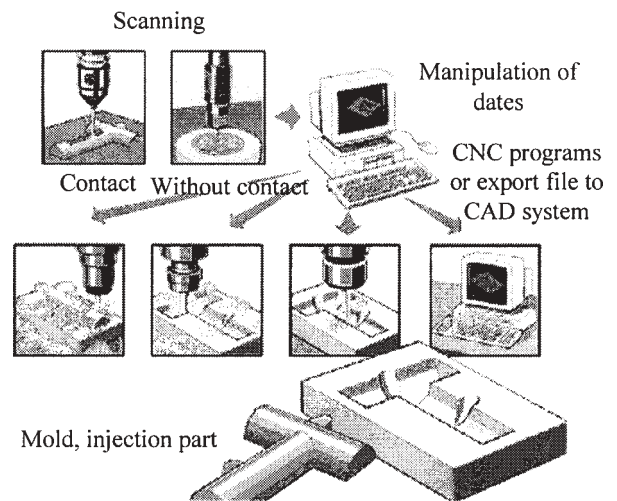


Fig. 1. Reverse engineering principle [20]

and practical implementation of rapid prototyping industrial technologies (*Rapid Prototyping - RP*), which are fundamentally different from well known and used technologies until now. Rapid prototyping is associated with a range of relatively new technological procedures which allow a fast manufacturing for physical object, functional prototypes, distinctive marks, sub-assemblies and all the tools involved in product development process. We will define rapid prototyping process the same way Lennings did: "The process which automatically creates a physical prototype using a 3D CAD model, in a very short period of time" [21]:

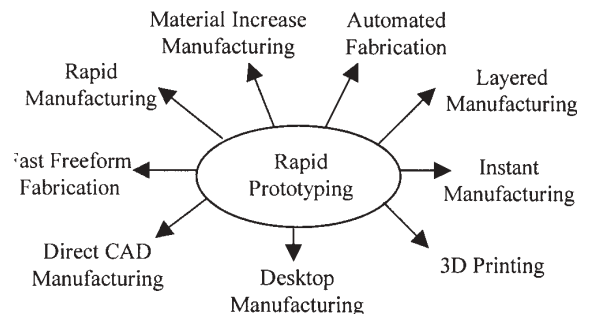


Fig. 2. Terminology associated for rapid prototyping [22]

The equipment used

The equipment used for this application, presented in the figure 3, is:

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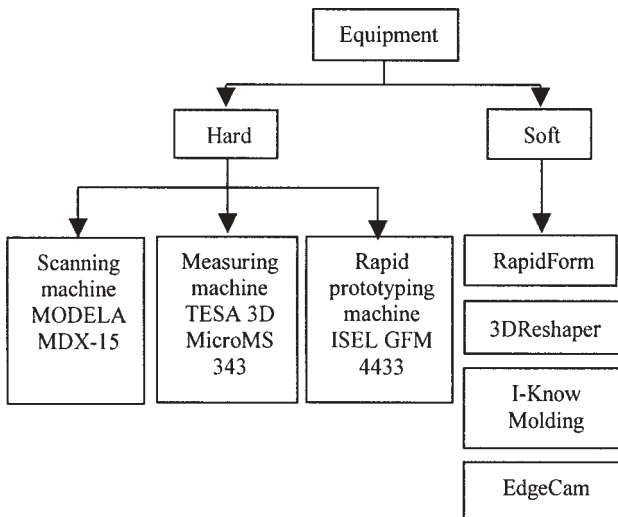


Fig. 3. Equipment used

MODELA MDX-15 scanning machine:

- working area (X,Y,Z in mm): 150 . 100 . 60;
- XY table size (X,Y in mm): 170 . 110;
- max. table load weight: 0.5 Kg;
- sensor: Roland Active Piezo Sensor;
- scanning speed: 15mm/s;
- scanning pitch: 0.05 la 5.00 mm for X and Y and 0.025 mm for Z;
- exportable file formats: STL, DXF, VRML;
- type of axis-motors: Stepper.

TESA 3D Micro MS 343 coordinate measuring machine:

- measuring volume (X, Y, Z in mm): 300 . 400 . 300;
- volumetric length measurement uncertainty: $E = 4 + L/400$ [μm]
- Renishaw PH1 manually operated probe head;
- Renishaw TP2 touch trigger probe with 5 probing directions ($\pm X, \pm Y, +Z$);
- stylus ruby ball with 2 mm ruby ball diameter, 14 mm steel stylus length.

-the evaluation software: Quindos® V3.3

ISEL GFM 4433 rapid prototyping machine:

- 3 or 4 CNC axis (X,Y,Z, R)
- working area (X,Y,Z, in mm): 330 . 430 . 160;

RapidForm:

Rapidform XOR/Redesign is the first software solution that allows users to go from 3D scan data to a fully parametric CAD model. Rapidform XOR addresses the limitations of existing 3D scan data processing software by complementing its mesh modelling and NURBS surfacing capabilities with newly developed CAD modelling capabilities, providing users with the tools to go from 3D scan data to a parametric CAD model.

3DReshaper:

3DReshaper Application is a 3D point clouds processing software for users who need to handle rapidly point clouds files to obtain high quality 3D meshes at affordable price.

The generated models can be used directly for rapid prototyping, tool path generation, animation, simulation, finite element analysis, control and inspection.

I-know Moulding:

I-Know Moulding offers Instant Mould Previews for each stage of product development.

I-Know Moulding features:

- import any 3D model as STL;
- mould creation in one single click;
- identify possible tooling problems;
- customise the mould geometry;
- export results in 3D or 2D.

EdgeCam:

EdgeCAM is a complete CAM software solution for production machining and mould & die applications. State-of-the-art visualization tools are provided by EdgeCAM Simulator, with the ability to accurately model the machine tool and simulate all movement within the manufacturing process [20].

Reverse engineering applications for polymeric parts

The framework for these applications is shown in figure 4:

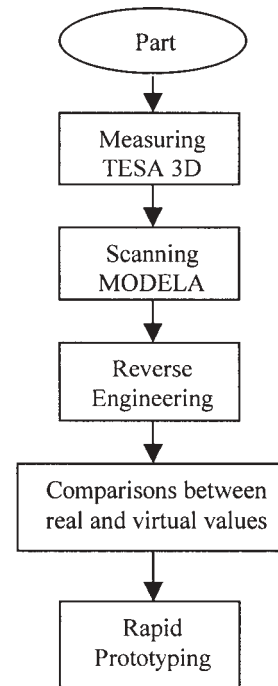


Fig. 4. The application principle

The parts, for which mould insertions were to be made, are presented in the figure below:



Fig. 5. The scanning parts

Step 1:

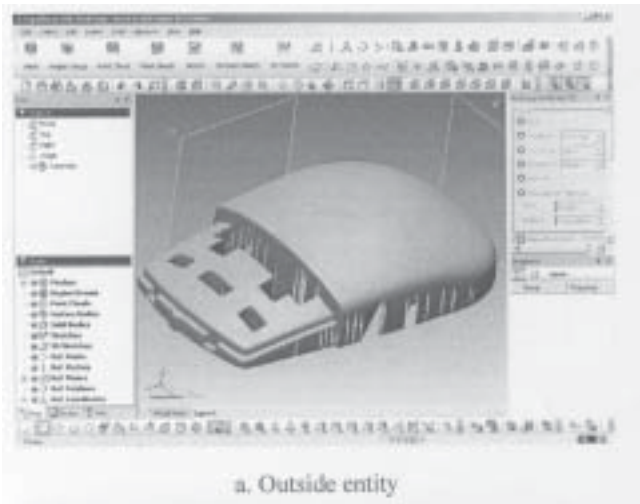
The part to be manufactured after scanning is a mouse digitizer. Both, inside and outside are scanned, a junction of the two resulted entities being made afterwards. As a result of scanning, two files will be obtained saved in STL form.

These will be further analyzed resulting two entities (the internal and external part of the digitizer) as it is shown in figure 6.

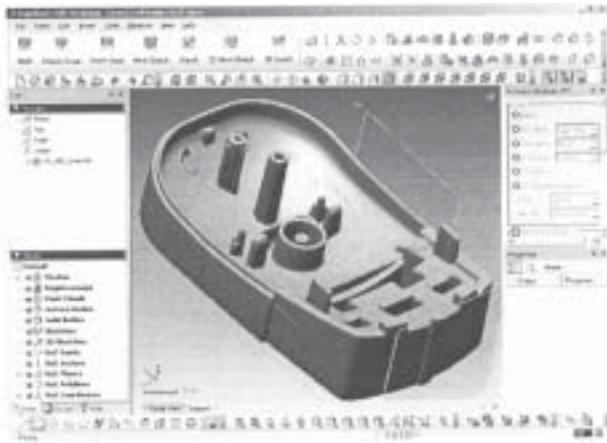
The geometric model will be manufactured using RapidForm software by overlapping and alignment up the two entities (translation and rotation) on all 6 axes (the red area (fig. 7) indicates if the two entities are too much imbedded, thus rotating or translating one of them being necessary).

Once alignment the entities by using Booleans operations (cross section) geometrical model of scanned part is obtained (fig. 8).

Using software properties a cleaning of the model will be made (removing the trace of the extractors, the



a. Outside entity



b. Inside entity

Fig. 6. The entities obtained after scanning



Fig. 7. Alignment of both entities



Fig. 8. AThe geometric model of the scanning part

identification number for the part, the faults made during injection or extracting the part form the plug (fig. 9).

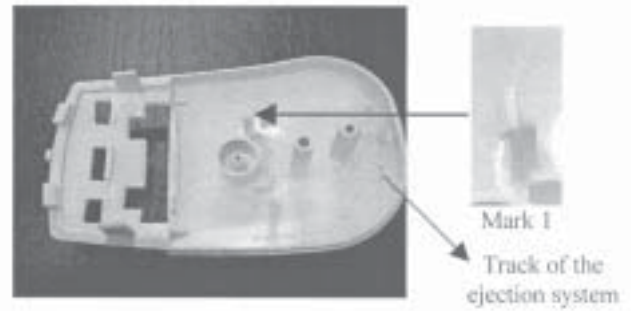


Fig. 9. The mark which can be scanned

As it is shown in figure 9, mark 1 could not be scanned because it was impossible for the scanning needle to penetrate that area. Two solutions can be used in such a situation:

- we destroy the part by breaking mark 1, we scan it and intersect it with internal entity;
- if the mark is simple (like it is shown in fig. 10), we reshape it using a conventional CAD software (SolidWorks, Catia, ProE, etc).

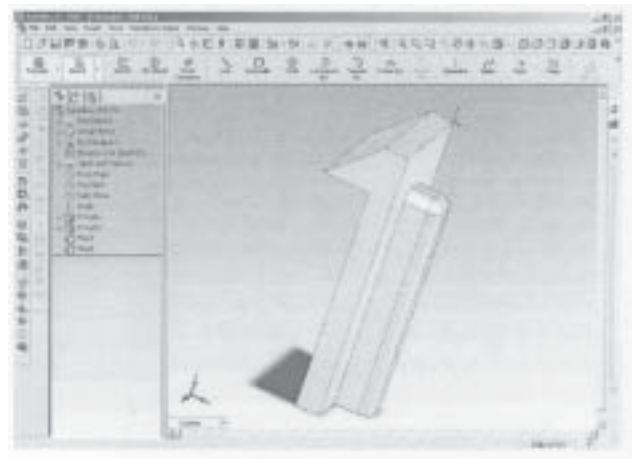


Fig. 10. The mark 1 reshaped

Finally, using RapidForm software, the part will be like the one shown in figure 11.

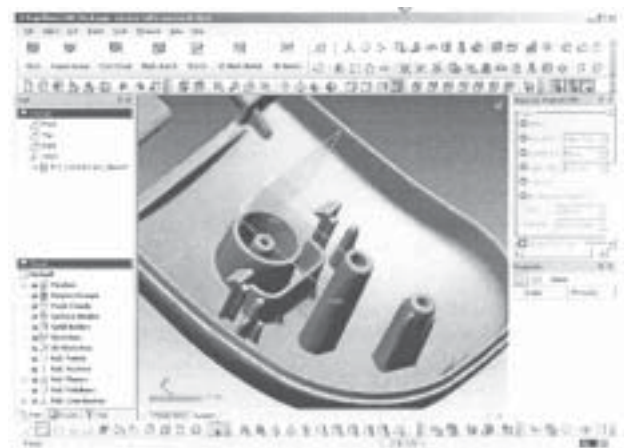


Fig. 11. The final geometric model

Step 2:

Next step consist in comparing geometrical model virtually obtained dimensions with the ones of physical model. Measures have been made with coordinate measuring machine TESA 3D MicroMS (fig.12). The procedure consists in setting up the part on the measuring table without damaging it and measuring some geometric



Fig. 12. Dimensional control of the part

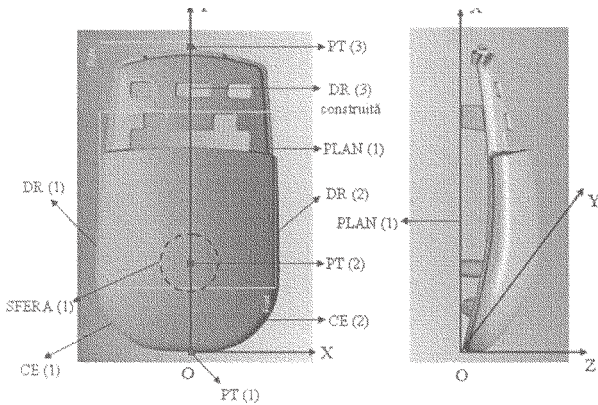


Fig. 13. The geometrical elements used for dimensional control

elements needed for alignment the part and determining its reference system (fig. 13).

The distances below represent part's dimensions for x, y, z axes.

- DIST (1) = PT (1) - PT (3);
- DIST (2) = CE (1) - CE (2);
- DIST (3) = max [CE (1) - CE (2)];
- DIST (4) = PLAN (1) - PT (2);
- DIST (5) = PT (3) - max CE (1);
- DIST (6) = PT (3) - max CE (2);
- DIST (7) = PLAN (1) - SFERA (1).

Table 1 shows the measured data. The bolded numbers are the actual values for the three axes (X, Y, Z). Figure 14 shows measures made for virtual model obtained after scanning. As it can be observed, the differences between physical model values and virtual model values are maximum 0.3 mm (table 2).

Note that the difference is given both by the scanning machine precision (Modela) and the worker's ability to overlap the two entities.

Step 3:

During step 3 the mould cavity is obtained. We use I-know Molding software. The advantage of this software is that it uses IGES and STL files only. Note that CAD software (Catia, ProE, SolidWorks) cannot manufacture active parts of the mould starting with a STL file. A conversion of STL file in an IGES file results in its enlargement by hundreds of Mb, its CAM processing thus being impossible. This is the reason for which I-know Molding is vital. Generating active parts of the mould is almost momentary (fig. 15).

Step 4:

Because the application was made for a mouse digitizer, and the reverse engineering process is used for obtaining a model or for manufacturing the tool used for that model

Table 1
MEASURING RESULTS

DATE: 26 - Sept - 07	TIME: 12:52	PART: MOUSE			
TEXT	EV.	ACT.	U. TOL.	L. TOL.	ACT-NOM
DIST (1)	DX	1.8460	0.05	-0.05	1.8460
	DY	107.9875	0.05	-0.05	107.9875
	DXY	108.0033	0.05	-0.05	108.0033
DIST (2)	DX	16.2122	0.05	-0.05	16.2122
	DY	0.1456	0.05	-0.05	0.1456
	DXY	16.2128	0.05	-0.05	16.2128
DIST (3)	DX	65.6573	0.05	-0.05	65.6573
	DY	0.5859	0.05	-0.05	0.5859
	DXY	65.6600	0.05	-0.05	65.6600
DIST (4)	DZ	-28.4179	0.05	-0.05	28.4179
DIST (5)	DX	-10.4191	0.05	-0.05	10.4191
	DY	-107.2719	0.05	-0.05	107.2719
	DXY	107.7767	0.05	-0.05	107.7767
DIST (6)	DX	10.6168	0.05	-0.05	10.6168
	DY	-107.3415	0.05	-0.05	107.3415
	DXY	107.8653	0.05	-0.05	107.8653
DIST (7)	DZ	28.4314	0.05	-0.05	28.4314

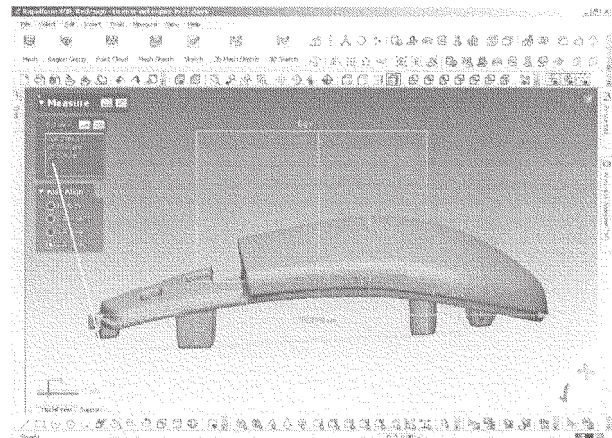


Fig. 14. The dimensions of the virtual model

Table 2
COMPARISONS BETWEEN REAL AND VIRTUAL MODEL

Axis	Physical model value [mm]	Virtual model value [mm]
X	107.9875	108.2766
Y	65.6573	65.7346
Z	28.4314	28.674

(the mould), we aim to present prototyping manufacturing by remove material from this digitizer.

The software used is EdgeCam. Being a "shell" part, we have to clamp it during processing. For this we shall built some bridges for the virtual model, processing the part being made inside of a frame. Generating tool's trajectory is presented in figure 16.

After processing with rapid prototyping machine ISEL the part presented in figure 17 is obtained.

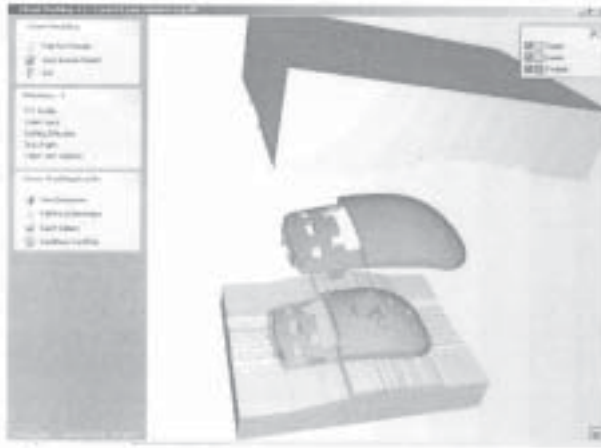


Fig. 15. Generations of the active parts of the mould

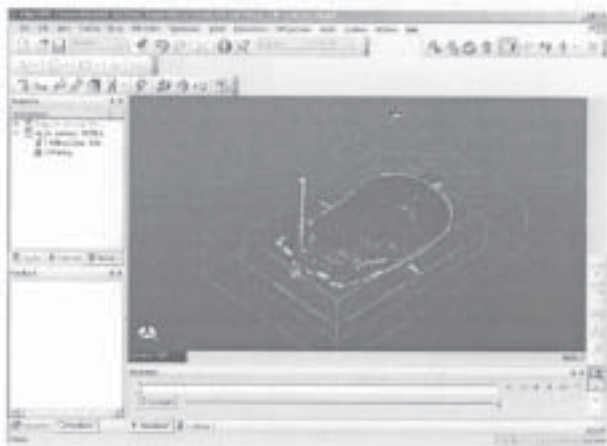
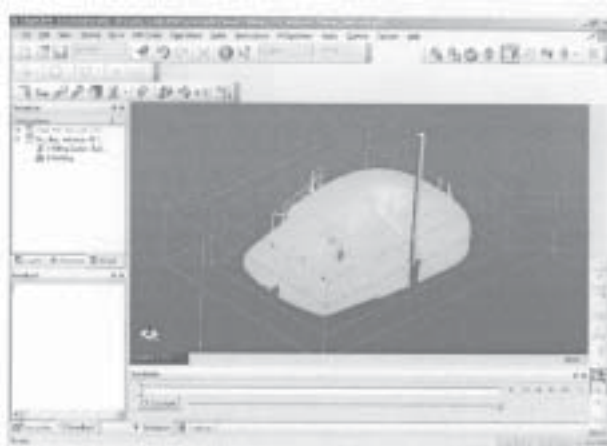


Fig. 16. Generations of the tool patch of part

Conclusions

The paper aimed to present a methodology for obtaining active parts of a mould starting with a physical model for which no previous documentation is available. The steps were succinctly presented starting with physical model scanning and finishing with its manufacturing.

Integrating reverse engineering process together with rapid prototyping processes and generating and processing software leads to manufacturing something impossible little time ago: a physical model (or its mould) for which no technical documentation is available.

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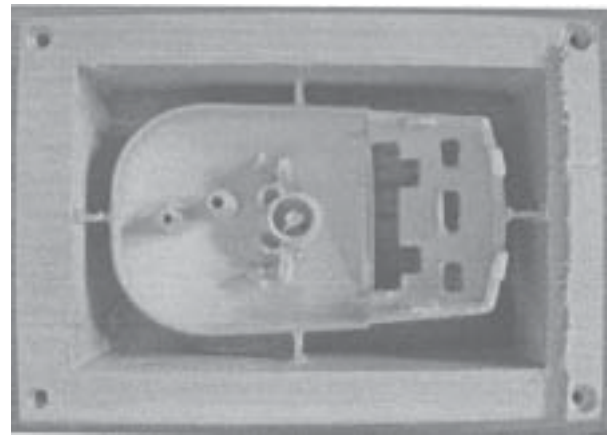
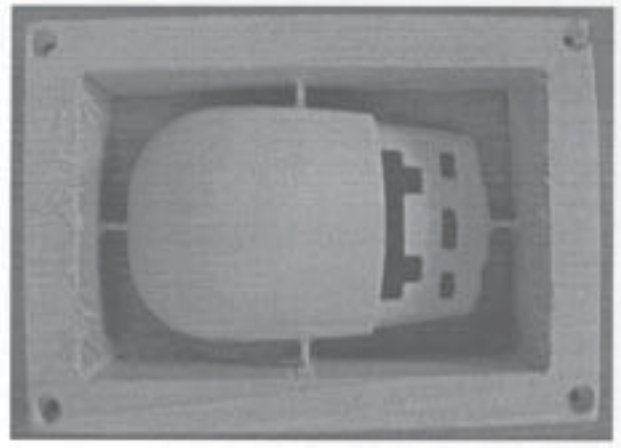


Fig. 17. Physical model obtained after prototyping

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Manuscript received: 21.04.2008