Methods of Design of Ergonomics Parts

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Abstract— The article deals with modern procedures for ergonomic design of holder part for working tool. Reverse engineering method is described into details. This method is used to shorten design times and the subsequent preparation of serial production. Design procedures are using modern scan methods and data are completely processed by software NX 7.5.

Keywords— Ergonomic design, reverse engineering, 3D scanning, PUR foam material, rapid prototyping, hand tools

I. INTRODUCTION

Modern company that produces parts in high level of quality need to focus on more aspects of manufacturing process. The main aspects are in conjunction among other things with production parameters and quality control issues. But there are more issues connected to working comfort of workers in work environment. The company SIEMENS witch producing electric motors were looking for ergonomic solution of some types of their hand tools to improve ergonomics, hygienic and working environment for their employees. [1].

Several years ago, these project were solved in cooperation with designers, foundry and highly skilled machinery workers. All these departments were involved into process of ergonomic design. The main problem was missing interoperability and very long production times. Production companies are looking for fast and flexible solutions nowadays, therefore implementation of modern methods of design and manufacturing is expected.

The main issue in ergonomic design is to produce high quality A-class surfaces in 3D model for smooth and high performance programming of modern CNC machines. These surfaces should be prepared by several ways. First way is to build 3D model from sketch. Second one is to prepare these surfaces by using of 3D scanning device to keep all proportions exactly how they was designed. And directly this modern method is described in this article.

II. EXPERIMENTAL PARTS

2.1 Problem Formulation

The Default tool was made of polymer resin reinforced with fibers. Shape of this tool was roughly determined by methods of manufacturing. These holder parts were made by milling on conventional milling machines. [2]

Fig. 1 Default tool shape

This manufacturing process defined shape which was easy to manufacture but not comfortable for workers. Short holding area caused enormous stress loading of muscle groups in the area of hand and wrist. Also the weight for this tool is too high. The default shape of working tool describes fig.1. [3,5]

2.1.1 Requirements for new tool

As was determined in previous paragraph, the tool holding area is not sufficient for long-term work. After several sessions

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in company SIEMENS were defined requirements for new holding area of tool. Main requirements are listed below in table 1. Requirements are sorted from the most important to less important ones.

Table 1 Requirements for new shape of the tool

The most important requirement	Minor requirements
Reduction of muscle stress	Easy production
Increase of working comfort	Steel insert part may not be changed

2.2 Problem Solution

After evaluation of all the requirements first model was needed. As was mentioned before it was decided to use latest methods of reverse engineering such as 3D non-contact scanning and rapid prototyping modern tools.

Fig. 2 First model (Real view)

2.2.1 First Clay Model

Modeling clay was used for easy shaping of first model. This solution helped to make ergonomic shape based on anatomic basis. By the exploration of working process, the decision for new idea was made. The force applied on wrist and hand was distributed by almost whole handgrip area to decrease pressure peaks in hand. First idea included wrist support area to hold the wrist in ideal position and protection. This area was declined in further development due to working place issues. Basic shape is on the Fig. 2 and 3.

Only right handed design solution was accepted for further production due to whole workplace layout. But modern 3D modeling techniques with interoperability in design can produce left handed solution in very short time. Every change implemented in right hand design can be automatically applied on left-hand solution as well.

Fig. 3 First model (side view)

2.2.2 Scanning and modeling 3D model

First step of production was to scan the model by the optic scanning machine Atos. Data contained STL model and were used as modeling support. STL healing and repair operations were made in GOM Inspect v 7 specialized software.

2.2.2.1 Optical 3D scanning principles

The ATOS Triple Scan uses a specially developed measuring and projection technology from GOM.

Using this brand new technology the ATOS Triple Scan produces a high accuracy and improved measurement of shiny surface, complete data on complex components with deep pockets or fine edges such as turbine blades, reducing the number of individual scans and resulting in a simple handling.

ATOS uses high resolution measuring cameras and specially developed optics for precise measurement.

The accuracy, measurement resolution and measuring area are completely adaptable to the application requirements. This allows for the highest resolution for highly detailed, small parts with measuring volumes down to 38mm, or for extremely fast digitizing of large objects with measuring volumes up to 2m. This flexibility allows measurement of a large part spectrum with the same sensor head, and when used in combination with TRITOP, the ATOS System is capable of scanning parts of over 30m with a high local resolution.

The scanning process is shown on the figure 4.

Fig. 4 Scanning process of model by using ATOS 3D optical scanning device with optional positioning device

2.2.2.2 Preparation of raw 3D STL data

After finishing 3D scanning procedure, raw 3D data was obtained. These data are processed in GOM inspect v7 SR2. GOM Inspect Professional is a process-safe, parametric, traceable evaluation software for dimensional analysis of 3D point clouds from white light scanners, laser scanners, CTs and other sources.

GOM Inspect Professional automatically converts point cloud data into 3D mesh data and offers extensive post-processing functionalities. Inspection is performed by comparing scanned data to nominal CAD and analyzing false-color plots, 2D sections or multiple inspection points.

GOM Inspect Professional offers deep and comprehensive traceability, from result back to element creation, to increase overall process safety. The exact creation parameters, measurement and point selection of any element are known and can be traced back to origin and checked.

Whole shape is simplified and all surfaces are processed through smoothing functions to optimize first pass of STL raw data. Optimized and not optimized STL structure is shown on the figure 6.

Basic surface tolerance is set to 0.04mm to provide simple but valid basic 3D shape of tool holder. New STL data was exported and processed into NX7.5 CAD software. Imported data are represented on the figure 5.

Random surface roughness and unevenness are caused by type of hand processing and cannot be eliminated by GOM inspect software functionality. Therefore advanced modeling techniques are used for A-class surface modeling output.

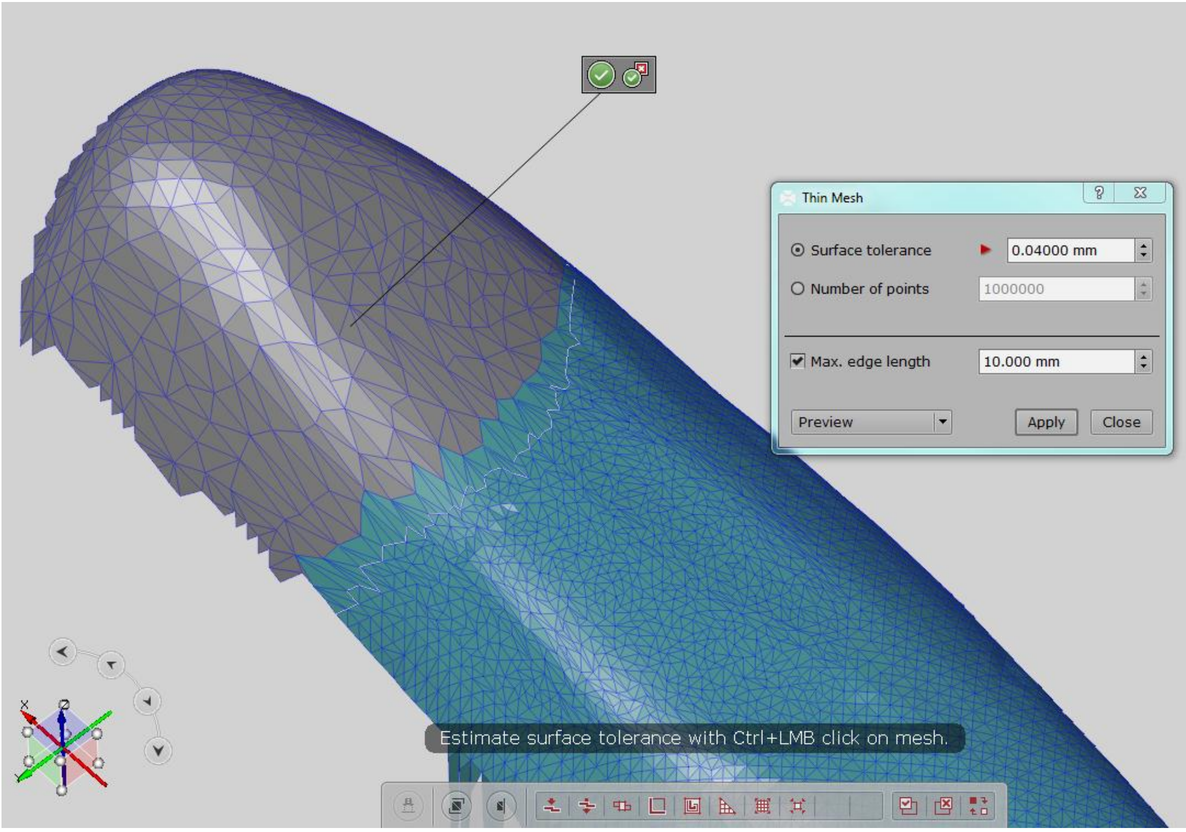

Fig. 6 Left side simplified and optimized / Right side raw STL data

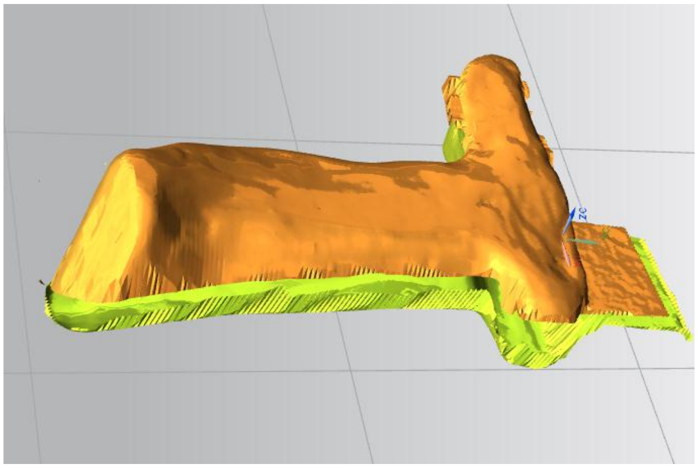

Fig. 5 STL data imported into NX7.5

2.2.2.3 CAD modeling

After the scanning of model, NX 7.5 software were used for 3D modeling to make exact, error free 3D model which allows us to produce manufacturing tools in short time. Final 3D model can be seen on the Fig. 7. Mostly used modules of NX 7.5 software was Freeform and shape modeling and NX Shape Studio.

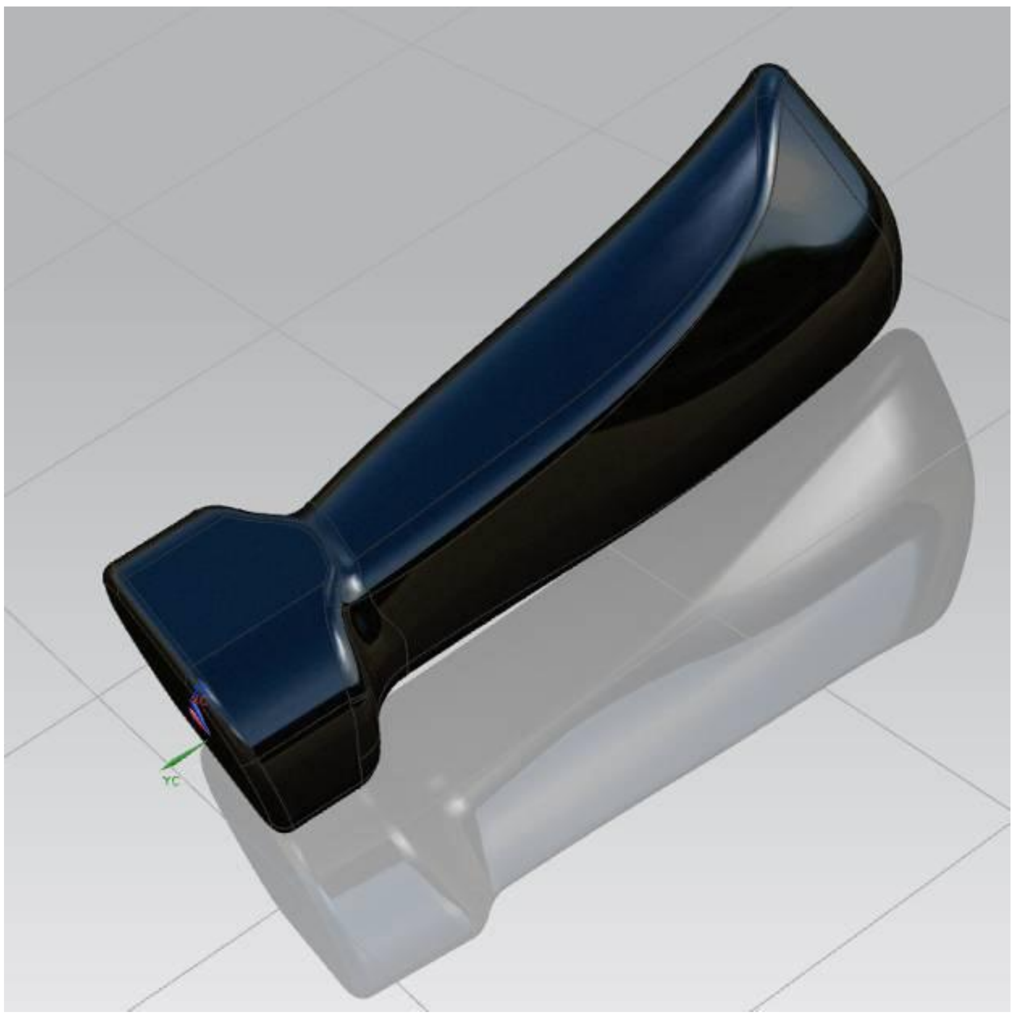

Fig. 7 Final 3D model

NX Shape Studio is a tailored styling and industrial design package that offers the freedom and accuracy designers need to explore shapes and what-if styling in the conceptual modeling phase. By seamlessly integrating curve- and surface-based modeling, NX Shape Studio puts cutting-edge CAD tools into the hands of industrial designers. At the same time, the easy-to-use toolbox fosters innovation. These flexible tools, from drag-and-drop templates to dynamic construction, enable fast, easy creation and evaluation of design alternatives while providing real-time visual feedback. And there's no worry about changes or iterations, as associativity takes care of downstream data integrity.

With Shape Studio, designers can use practically any approach or modeling technique. For example, the designer might begin modeling by using standard parametric design techniques that employ curve-driven geometry. Then, when creating contours and integrating ergonomics, the designer might use freeform techniques. Or the designer could begin modeling without precise definitions, adding geometric constraints later. Construction geometry and style details can be rapidly generated by the dynamic mapping of 3D curves onto freeform shapes. Or surfaces can be constructed using pre-set combinations of section and guide curves, with the designer monitoring impact as it occurs.

All model data transfers directly downstream. And the fully associative database ensures that any changes are automatically updated in related applications such as engineering design, assembly, drafting, simulation, and manufacturing.

First step before producing A-class surfaces which are needed for 3D model was to prepare sections of STL data and creation of the section curves through whole model. These section curves are smoothed by using Spline functions. All spline curves were processed and upgrade to high degree type. After updating these curves an analysis of curvature made final check before starting to create A-class surfaces.

After 3D shape modeling also final curvature and reflection shape analysis were performed and all problematic areas were repaired and rechecked.

Fig. 8 Rapid prototyping model

2.2.3 Rapid prototyping

Before mass production of tool, the final decision was expected. To support the decisions Rapid prototyping models were produced. All rapid prototyping tasks were ade on Dimension 1200es series. Dimension 1200es 3D Printers use ABS*plus* modeling material, a production-grade thermoplastic that is durable enough to perform virtually the same as production parts. Models are printed from the bottom up with

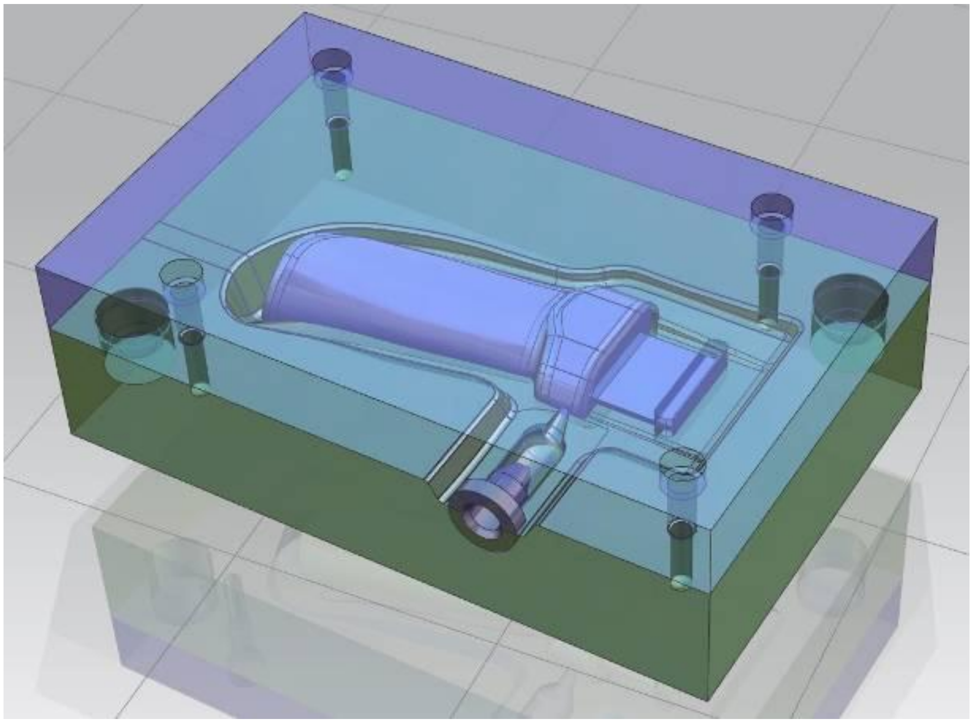

Fig. 9 Pre-production mold

precisely deposited layers of modeling and support material. There's no waiting for models to “cure” — they're ready for support removal right from the printer.

Models can be drilled, tapped, sanded and painted, making the 1200es ideal for producing functional prototypes, molds, patterns, even customized tools and fixtures.

The Dimension SST 1200es uses Soluble Support Technology which dissolves the supports in a water-based solution. This process is recommended for detailed or delicate models.

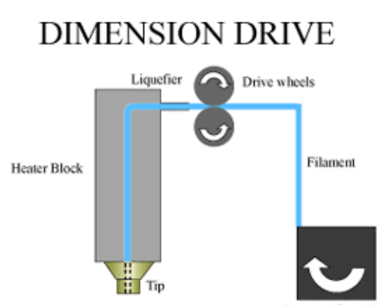

Fig.12 principle of FDM 3D printer

The Dimension BST 1200es employs Breakaway Support Technology in which the supports are simply snapped off to reveal the final model. Breakaway supports can be more convenient if there is no ready access to a sink or water supply. You can see principles of 3D printing on the figure 12.

This process helped us to not waste material and machining time. Two pairs of models was sent to Siemens factory for workers to evaluate the functionality and shape. Their comments were implemented to model.

Main issue of first model was small proportions in the middle section of model and this dimension had to be changed. Rapid prototyping models are on the Fig. 8.

2.2.4 Material requirements and first pre-production series

The material foam PUR (polyurethane) was selected for good properties and easy production. Main advantages of PUR material are anti-vibration effect, low weight, soft feel while holding in the hand. To review all properties pre-production mold which can provide all parameters required for low pressure PUR injection was manufactured. Pre-production Mold is on Fig. 9. [4, 6, 8]. After several testing sessions and softening modifications of PUR base material prototype tools was given to manufacturing process for long term testing session. After Siemens company confirmed these prototypes, all data was sent for mass production preparations. [11, 12, 14, 15]

2.4.5 Mass production PUR injection mold

For mass production of PUR tool holders Injection mold was need. Mold was designed from Aluminum 7075 T6 specific material for good material properties and good workability. Because of Siemens production batch requirements it was decided to manufacture mold with two cavities. Processing times was set to 3,5 minutes per cycle. Whole mold is on the Fig. 10. [5, 8, 7, 9]

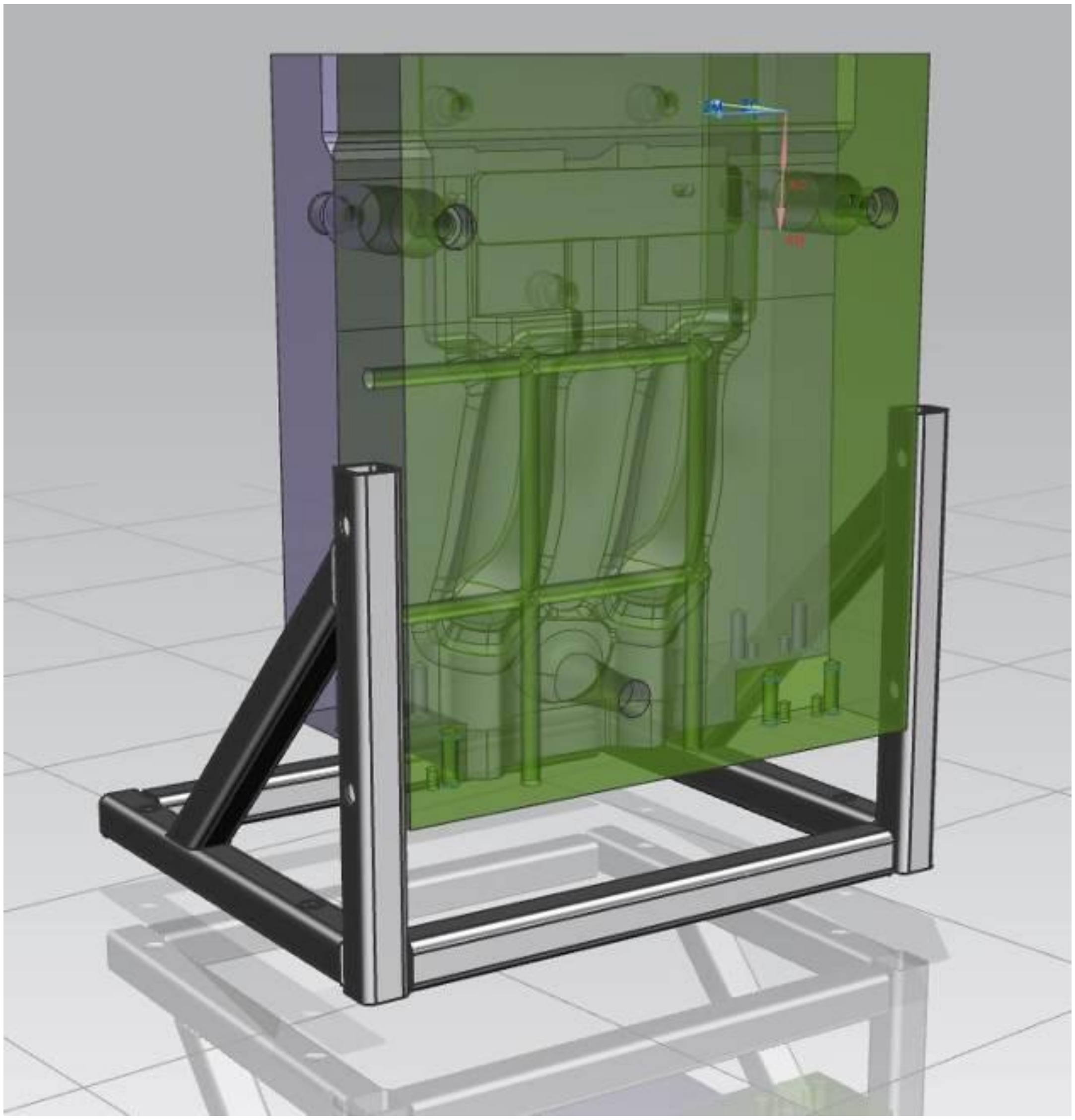

Fig. 10 Production mold tool

III. Conclusion

Methods of rapid prototyping were used to shorten the manufacturing time to minimum. These methods are applicable to the most of today's manufacturing processes. Rapid prototyping methods can save significant amount of resources

Fig. 11 Final result

mainly in field of pre-production and early design processes. In this article, the methods were applied to specific problem of ergonomic and functional design of hand tool. The result tool is on the fig. 11.

It was manufactured and sold about 700 tools to Siemens to date. Main benefits from new solution was observed on comfort of workers. Their muscles in wrist and hand area are not overloaded anymore. Also manufacturing process of new tool is shorter and don’t need any conventional milling operations which are not so productive as injection PUR molding.

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