3D MODEL BASED BOAT HULL DESIGN AND MANUFACTURING

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1. ABSTRACT

Design and fabrication of double curved sheet metal parts means a time operation. 3D model based design may be the entering data of the Incremental Sheet Forming (ISF) process by an industrial robot. Such a 3D model of a sailing boat was developed by the author and used for the ISF when manufacturing the boat's hull. A complete remote controlled sailing boat model was built this way, proving that the ISF method can be used for production of very complex surfaces.

2. INTRODUCTION

ISF method was developed on the basis of early researches by Leszak [6] by the researchers of the Computer and Automation Research Institute (CARI) of the Hungarian Academy of Sciences in the past few years [3], [5]. ISF design and manufacturing of sheet materials is a rather successful, easy to modify technology to produce rapid prototypes and one-of-a-kind products, as no expensive dies are needed for the sheet forming. The method was tested on metallic and plastic sheets of simple geometry. After a series of successful experiments a need for manufacturing of more complex shapes was manifested. Such a complex shape is a boat hull, for example. The international MicroMagic sailing model boat class has strict geometry requirements [1], [2] related to competitors' boats. On the basis of these geometry data a 3D model of the boat was developed with SolidWorks and it was used by a FANUC industrial robot in aiming to form the hull shape by means of the ISF technology. Some 2D parts were cut by traditional cutting methods. The boat structure and the additional parts (mast, keel, sails, rudder, etc) were mounted by an undergraduate student of Dennis Gabor College [5].

3. 3D MODEL WITH SOLIDWORKS

On the basis of the downloaded geometry a solid model of the boat hull was developed with SolidWorks. This solid model was safeguarded (and made in two copies) for the future parts such as lower hull and upper hull expected to be fixed on one on another by glue. Both the upper and lower hull was prepared by "Shell" operation from the whole solid with expected wall thickness of 0.5 mm. Two copies of the original solid model were used by the same way to prepare the upper and lower shell. A special attention was paid to the fact that the minimum radius of the available forming tool was 5 mm. Note that the applied minimum curvature radius has an important effect on the manufacturing time and quality. The internal nervures of the hull were cut from the copy of the original solid model as well.

The 3D model can be used directly for planning and testing the FANUC robot programming without any additional drawings. However an A0 size drawing was made from the model, in aiming to explain the mounting of the boat.

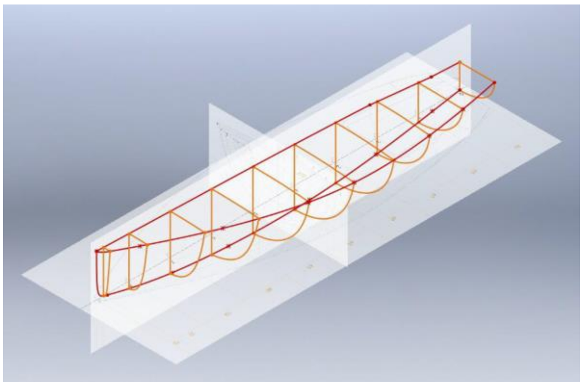

Figure 1.
3D skeleton of the boat hull

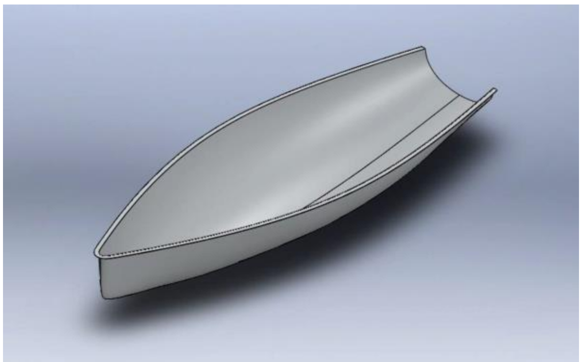

Figure 2.
3D model of the boat hull after shelling operation

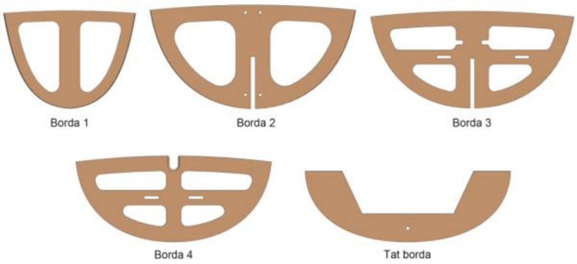

Figure 3.
2D cuts of nervures

4. INCREMENTAL SHEET FORMING WITH INDUSTRIAL ROBOT

The FANUC programming was prepared and tested in the Virtual Collaboration Arena VIRCA [3] developed by CARI researchers. The complete remote control of the manufacturing process still needs further development, so the majority of operations were made on site.

An industrial robot is a perfect tool to process incremental sheet forming (ISF) [5]. From the technological point of view ISF means a gradual plastic deformation of a metal (or polistyrol) sheet by the action of a spherical forming tool whose trajectory is numerically controlled. The interest in evolution of ISF is rather old; it started in 1967 with the patent of Leszak [6]. This idea and technology are still active today in the field of producing sheet metal and polystirol parts in small batch and one-of-a-kind production, rapid prototypes, in engineering and even in medical aid manufacturing and in architectural design. A specific forming tool (like a big ballpoint pen also biro) is mounted on the machine spindle or on a robot, and it is moved according to a well-defined tool path to form the sheet into the desired shape. The tool diameter and the tool path – generated by the operator – define the quality of the result of the procedure. In the actual case we used 0.5 mm alumina sheet as hull material and a 10 mm in dia forming tool. The proper selection of the manufacturing speed and the tool diameter are essential in respect of the quality of the result.

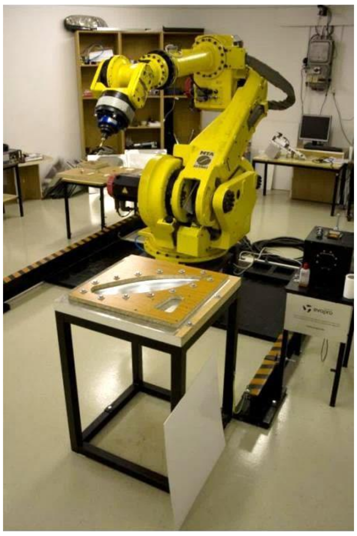

Figure 4.
Industrial robot with the boat hull shield

As it was mentioned already, the robot parameters (sizes, strength, etc.), the tool diameter, the tool speed and tool path on one hand and the sheet metal (quality, material, thickness and other physical properties) on the other hand define the ISF process. The appropriate data are partially defined by experience, partially by expert programs, and partially by traditional programming.

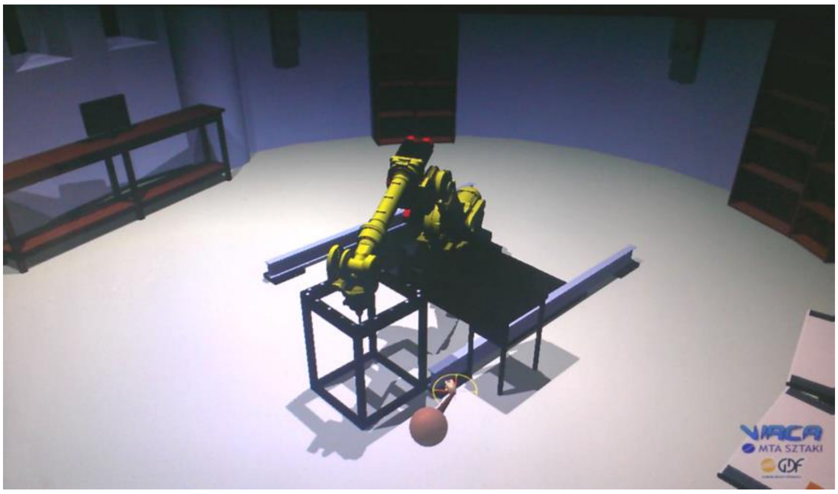

Figure 5.
ISF operation in the virtual space VIRCA

And the final word is given by the human, based on his/her cognitive as well tacit knowledge. He/she has to make decisions about the application of the communicating program systems to solve the given – seemingly simple tasks.

We faced a fatal destruction of the sheet, where the curvature radius on the model was too low. Instead of changing the parameters of manufacturing we fixed this problem with manual repair of the body. This problem could have been avoided by appropriate application of the cognitive information communication means and tools. There are several different technological parameters (as e.g. tool data, robot speeds, sheet thickness and material, etc.), which can be chosen by the designer and/or operator. And parameter selection based on experiences or assisted by prior experiments is often too difficult. There are local or distant data- and knowledge bases and earlier examples, which should be used to have the best technological performance supported by human cognitive information processing.

After mounting the boat body, an external surface skin was applied to the hull. The model equipped with all necessary sailing hardware and electronic control devices was tested in real sailing on a lake. Sailing tests showed positive results of the manufacturing and mounting procedures.

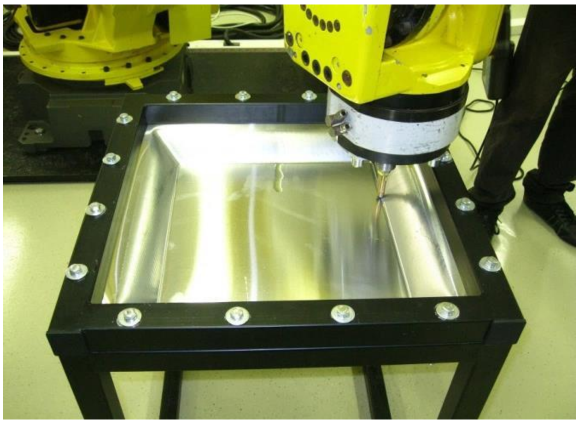

Figure 6.
ISF experiment with a FANUC robot

5. CONCLUSIONS

- The solid model of the thin hull can be developed by "Shelling" of an original solid.
- Using ISF very complex shapes with double curvature can be manufactured from thin sheet if appropriate tools and manufacturing speed are selected.
- A preliminary manufacturing test is suggested on a probe in aiming to avoid the fatal destruction of the sheet.

Figure 7.
The boat ready for sailing

6. ACKNOWLEDGEMENT

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7. REFERENCES

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