INTEGRATING A LASER FOR LASER ENGRAVING OPERATION AND FINITE ELEMENT ANALYSIS

TURTUREA Petre-Gabriel, SĂTEANU Claudiu-Constantin, MOROȘAN Teodor,
GIGOI Ștefan-Alexandru and MINODA Shogo-Victor
Faculty: IER, Major: Robotics, Year: III, e-mail: turtureagabriel@gmail.com

Scientific leader: Assoc. Prof. Ph.D. Eng. **Liviu-Marian UNGUREANU**

ABSTRACT: This paper has the objective to present the integration of the FB03 laser in an engraving operation on an articulated six axis robot KR 6 R 700-2 in association with finite element analysis. For this type of process, the CAE model designed in Autodesk Fusion 360 helps us to understand better the impact of the laser on poplar plaques. Phenomenon data like heat flux, thermal gradient and the temperature are collected to improve the path, which the TCP is tracking, and to streamline the process of 3D engraving for future operations.

KEYWORDS: laser, engraving, finite element analysis, articulated robot.

1. Introduction

The engraving operation using laser is a process that vaporizes materials into fumes to engrave permanent, deep marks. This technology is typically used on a cartesian structure. The opportunity to exploit the freedom of movement of the six-axis robot allows us to expand its range of applicability. The laser used for this operation is FB03 [1], 4th class, with 10 mm minimum focal distance. For engraving in poplar wood, FB03 works without any unexpected difficulties.

Our six-axis robot used for this engraving application is a KR 6 R 700-2 [2], [3], [4]. It is the best option to improve from the first version of structure, with a high precision, about ±0.02mm, and 726 mm of workspace.

2. Overview

Initially, the laser used for this operation was installed on a cartesian structure, however this structure proved to be unsteady, and the level of vibrations was unsuitable for the purposes of engraving. Therefore, we changed the operation from the first structure to a six-axis robot, a KR 6 R700-2.

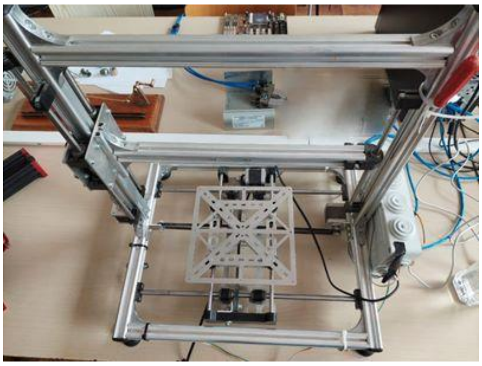

Fig. 1. Cartesian structure

Another problem we have encountered was the radiation emitted by the light which was over safe levels. To solve this issue, we used filters to prevent the light from leaking outside the workspace.

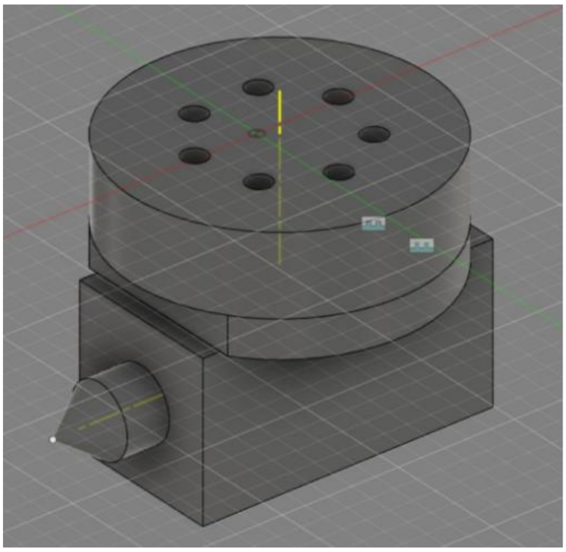

Fig. 2. Adapter flange and the laser with a model focal distance CAD

For the laser to be mounted on the robot, we designed in Autodesk Fusion 360 [5] an adaptor flange (fig. 2). Furthermore, we added the laser with a representation of the focal distance for a better TCP precision in simulations (fig. 3). With the imported CAD model (fig. 2) in KUKA sim 4.0 software, we modified the TCP to the focal point and simulated the path desired.

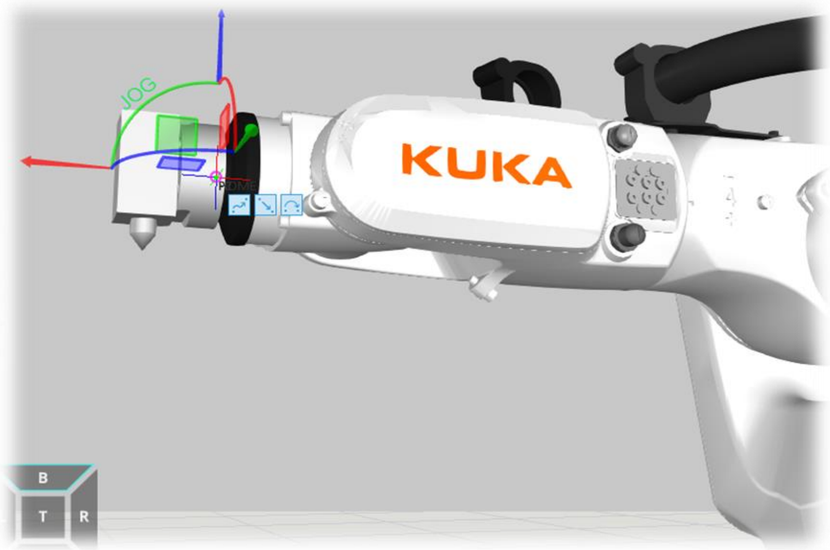

Fig. 3. Simulation of the articulated robot with the adapter flange

3. Finite element analysis

To better understand the process of engraving poplar wooden plaques and its effect, a finite element analysis [6] was required. For this, the software used was Autodesk Fusion 360 [7] which has CAE Module used for analysis. The studied phenomena for this application which interested us the most were the temperature (fig. 6), thermal gradient (fig. 5) and heat flux (fig. 4). These three would help us to better understand the reaction between the light amplified and the wooden plaque and thus signalling us if possible damage could be done. The results show that the parameters are within the optimal range and the operation will run without any problems.

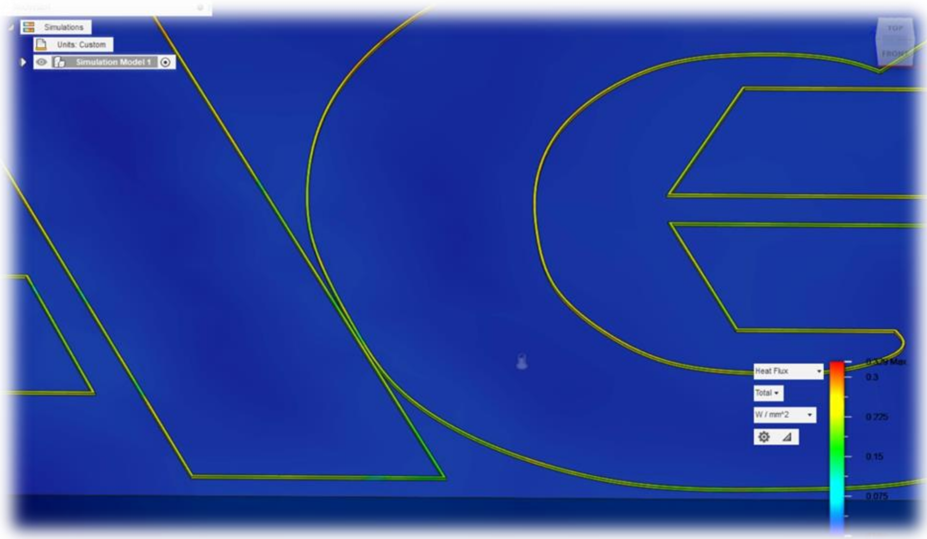

Fig. 4. Heat Flux

With a finite element analysis done, a possible optimization can be achieved by balancing heat distribution with the travel speed of the laser. The hottest parts of the trajectory must run faster to keep the same texture and to avoid hazards. In contrast, the coldest areas should run slower to avoid disruption of the contour and ruin the product.

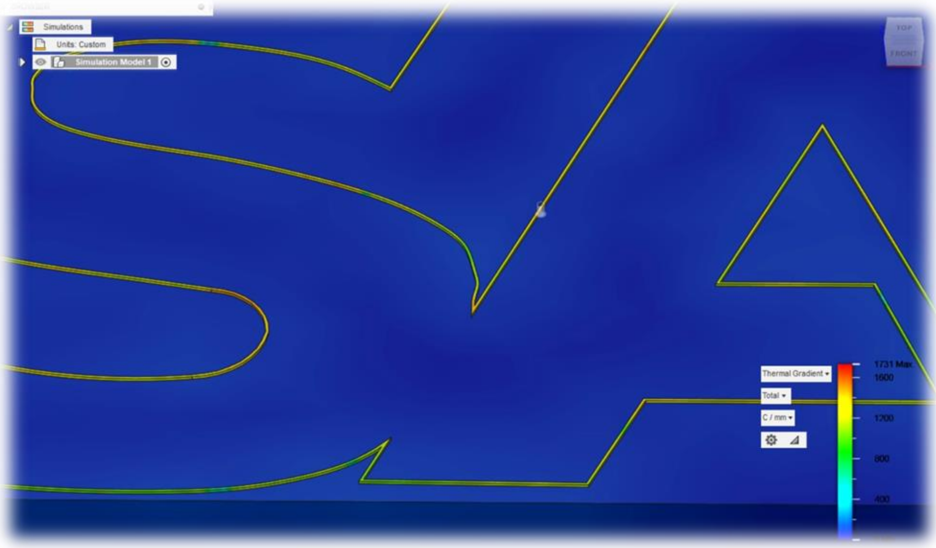

Fig. 5. Thermal Gradient

Different materials output higher or lower heat distribution, the height of the laser in relation to the surface of the etched surface affect the process, the shape of the contour can result in a deviation of the contact temperature, these are the factors that are considered while analysing, because we want the result to be done in the shortest amount of time without compromising the quality of the engraving.

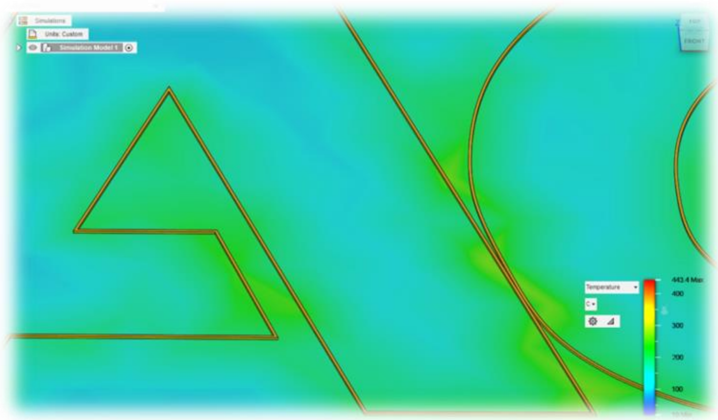

Fig. 6. Temperature

4. Conclusions and future work

Briefly, the operation of engraving with laser is by itself a very versatile application since it can be used on many materials from glass to coated metals or plastics. Adding the range of motion of an articulated robot arm, allows us to widen the possibilities of engraving on uneven surfaces, for example, a champagne glass or an engine block. We learned that the computer aided engineering assures us that the laser is used safely and efficiently, removing the need for trial-and-error tests that can take up time and resources. With this in mind, we could modify different parameters in such a way that the final product can be done multiple instances without lowering the quality or adding to the time needed.

For future endeavours, we will test the limits of this application with more irregular surfaces on different type of material and optimising the speed of which the laser is etching. Also, the size of the engraving will be tested to show the differences between smaller engravings like the serial number of an engine to larger engravings. Last but not the least, the laser will be used for other applications such as cutting, welding or even selective laser sintering.

5. Reference

[1]. GKTools (2019), *FB03 2500mW 445nm 12V Blue Laser Module datasheet*. Available at: https://www.aliexpress.com/i/32807063746.html (Accessed: 8 May 2023);
[2]. Mckinnon, P. (2012), *Robotics: Everything You Need to Know about Robotics from Beginner to Expert*, Editura Createspace Independent Publishing Platform, 240 pag., ISBN 9781523731510;
[3]. KUKA (2023), *Product Manual KR AGILUS-2*. Available at: https://xpert.kuka.com/service-express/portal/project1_p/document/kuka-project1_p-common_PB10511_en?context=%7B%7D (Accessed: 10 may 2023);
[4]. KUKA (2023), *Product and solution: KR6 R700-2*. Available at: https://my.kuka.com/s/product/kr-6-r7002/01t58000004l6iIAAQ?language=en_US (Accessed: 10 May 2023);
[5]. Autodesk University (2017), *Fusion 360: Simulating Reality with FEA.* Available at: https://www.autodesk.com/autodesk-university/class/Fusion-360-Simulating-Reality-FEA-2017 (Accessed: 6 May 2023);
[6]. Maksay, S.I. and Bistrian, D.A. (2008), *Introducerea in Metoda Elementelor Finite*, Editura CERMI, Iaşi, ISBN 978-973-667-324-5;
[7]. Autodesk University (2017), *Nonlinear Simulation in Autodesk Fusion 360*. Available at: https://www.autodesk.com/autodesk-university/class/Nonlinear-Simulation-Autodesk-Fusion-360-2017 (Accessed: 6 May 2023).