



TECHNICAL UNIVERSITY OF CLUJ-NAPOCA

ACTA TECHNICA NAPOCENSIS

Series: Applied Mathematics, Mechanics, and Engineering
Vol. 61, Issue IV, November, 2018

AUTOMATING THE FEEDING OF A FUSE BOX FOR THE AUTO INDUSTRY

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Abstract: *The general objective of the presented paper was to design and make an automated system for the feeding of a fuse box with automotive fuses, in order to decrease the number of the damaged fuses and to reduce the process time. To achieve this goal, we have focused on designing a simpler, cost-effective, easy-to-use and easily achievable mechanism with the purpose to be facile to implement within the industrial company. In order to design and model the concept, we used SolidWorks software and for the calculations for the motors and the ball-screw, the MathCad software was used. We took the concept from a type of Cartesian robot that is best suited to the requirements. Six Sigma methodology was used in the development stage of the product and finite element analyzes were performed to verify the structure of the automated system and to observe the strength of the used parts and the degree of their deformation.*

Key words: *Cartesian robot structure, CAD, Six Sigma, high productivity.*

1. INTRODUCTION

A robot is a mobile mechatronic system - especially one programmable by a computer - designed to automate human interaction with the environment in which it evolves. The name "robot" was first used by Czech writer Karel Čapek in the 1920 play R.U.R. ("Rossum's Universal Robots") to denote a fictional humanoid and comes from a Czech word, *robota*, meaning "forced labor" [1,2].



Fig. 1: Unimate robot pouring coffee 1967 [5]

Into the driving force of development, electronics evolved as well with the occurrence of the first electronic autonomous robots created by William Grey Walter in Bristol, England in 1948, as well as Computer Numerical Control (CNC) machine tools in the late 1940s by Frank L. Stulen and John T. Parsons [3].

The first digital, programmable and commercial robot was constructed in 1954 by George Devol and it was named the Unimate. In 1961 it was sold to General Motors and it was used to lift pieces of hot metal from die casting machines [4,5].

Brief presentation of the subject

In this paper is presented the solution of a problem related to the feeding of a fuse box with automotive fuses for a car, within an industrial enterprise. At present, the population of the boxes with fuses is done by human operators as shown in Figure 2.

Presently, human operators in an 8-hour work period install over 12,000 fuses, this leads inevitably to wrong insertion. These errors are only discovered in the next process step, and

thus the operation needs to be restored from beginning.



Fig. 2: The current state of fuse mounting within the enterprise

The fuse population process starts by scanning a barcode containing all the wires that come on that wiring harness; after scanning, the monitor shows in which cavity the fuses should be inserted and which type of fuse should be inserted.

The operator takes the fuses from the place where they are stored, inserts them into the box and with a special device presses all the fuses to be arranged at the same height.

After all fuses have been inserted, the end of the process is checked on the monitor and the wiring goes into the next process.

2. DEVELOPMENT OF THE CONCEPT

2.1 Objectives

The overall objective of this work was to design an automated system capable of

inserting fuses into a fuse box housing. Three types of fuses and a type of relay were required. In the paper, we only treat two types of fuses because the relay and one of the fuses are being inserted in a previous process.

The developed robot had to be quite simple because it is composed of standard metal sheet profiles that are fixed to the support legs and to the linear axis by screws. By making and implementing this robot, the industrial enterprise will benefit from greater productivity due to the decrease of the fuses population time, elimination of errors caused by the human operator implicit lower manufacturing costs.

2.2 Development based on Six Sigma methodology

From up to date literature, we can summarize that current trends in product and

process development are heavily relying upon simulations and computer based solutions, as the complexity and required precision that are to be achieved in the design stage have grown at maximum rates [6, 7].

We used DMAIC Six Sigma methodology for the design of the concept, in order to eliminate all the existing errors from the manufacturing processes. Starting from the specific requirements of the manufacturing process, all elements were analyzed down to part level using a cascade of 3 QFDs. The first for requirements and CTQs, the second correlating CTQs with functions and the latter for functions and parts.

In the case of DMAIC related to Lean Six Sigma, the phases are:

- Define: design or project goals that meet the demands of the customer through voice of the customer (VOC), analysis (external requirements) and business needs (internal requirements);
- Measure: identify and measure factors that are Critical To Quality (CTQs), customer needs, potential risks;
- Analyze: the purpose of this step is to identify, validate and select root cause for elimination;
- Improve: the objective of this step is to identify, test and implement a solution to the problem, in part or in whole.
- Control / maintenance: once the corrective action has been implemented, the final effort is focused on maintaining the competitive level achieved.

The first step in developing the concept for the fuse box feeding is the hierarchy of customer needs and their transformation into technical characteristics.

Following the discussions with the company's representatives and an AHP analysis, the most important customer requirements are:

- low cost of use;
- to contain standardized parts and a simpler design;
- good operating precision;
- reduced dimensions;
- high working speed;
- the ability to handle different types of fuses;
- safety in exploitation;

- user-friendly interface;
- easy maintenance.

Also, the gripper for handling the fuses had to be chosen in such a way that it could handle fuses of different sizes and have a correct grip without the fuses suffering deformation or detachment during transport. In order to do that, the gripper needs to have malleable material in the contact area.

2.3 Product designing

The resulted concept is a Cartesian robot that has four degrees of freedom: a translation on the X-axis, a translation on the Y-axis and a translation plus rotation on Z-axis.

The fuse box for which the robot was designed has dimensions ranging from 260×150 mm to 300×200 mm. A mockup is presented in Figure 3. The used fuses have different dimensions and a negligible weight of up to 2g.

For modeling and designing the Cartesian robot, the SolidWorks software package was used. The mechanism is based on four supporting legs of 40×40 mm square pipe with a thickness of 2 [mm]. At the ends of each supporting leg two pieces of 80×80 mm metal sheet with 5 mm thickness are welded and the legs are fixed to the floor with sixteen M5×120 screws.

Over the supporting legs is fixed a support part in which the fuse box is placed. The support piece is made of 5 mm sheet under which a 30×5 mm plate for resistance is welded.

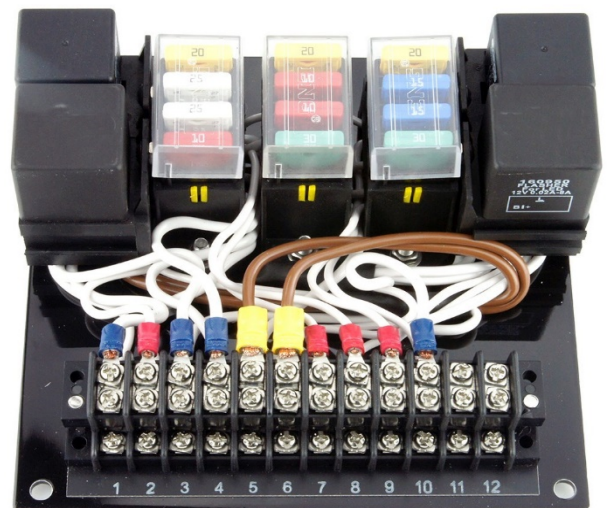


Fig. 3: The car fuse box [8]

On the fuse box support are fixed the entrances on the conveyor belts on which the fuses are arranged automatically, presented in Figure 5.

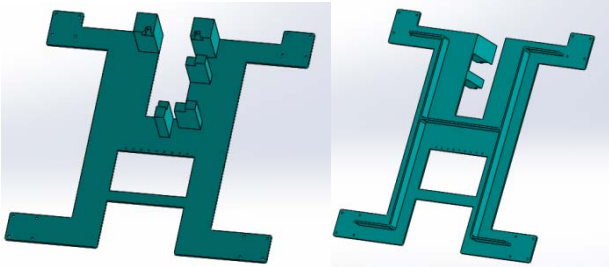


Fig. 4: The support holder for the fuse box

The connection between the support and the linear axes with mounted motors is made by four parts similar to the supporting legs, only shorter, fixed also with screws.

Regarding the linear axis design and the choice of guides used, were taken into account several factors such as maximum load, acceleration, speed, travel, etc. as well as factors that depend on the operating environment, like temperature, dust level, vibration, etc.

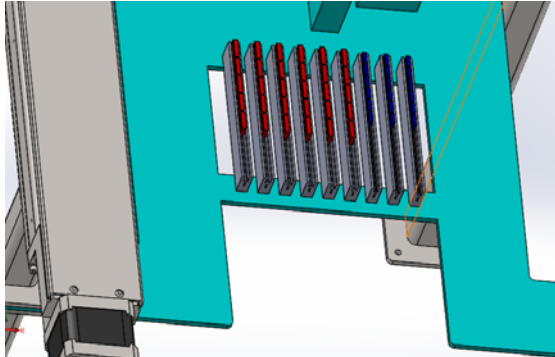


Fig. 5: Fuse storage

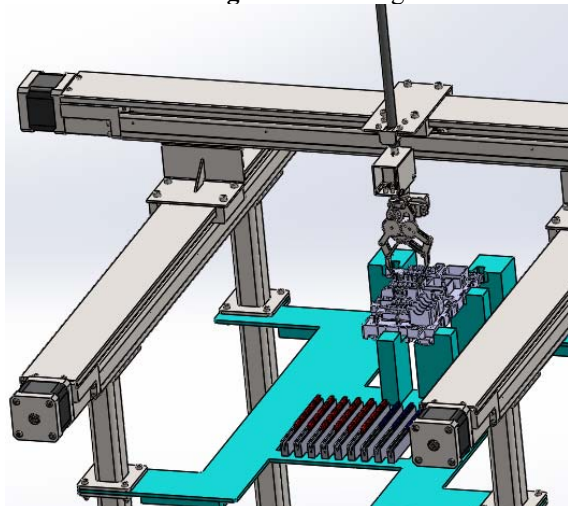


Fig. 6: Z axis with attached pneumatic cylinder

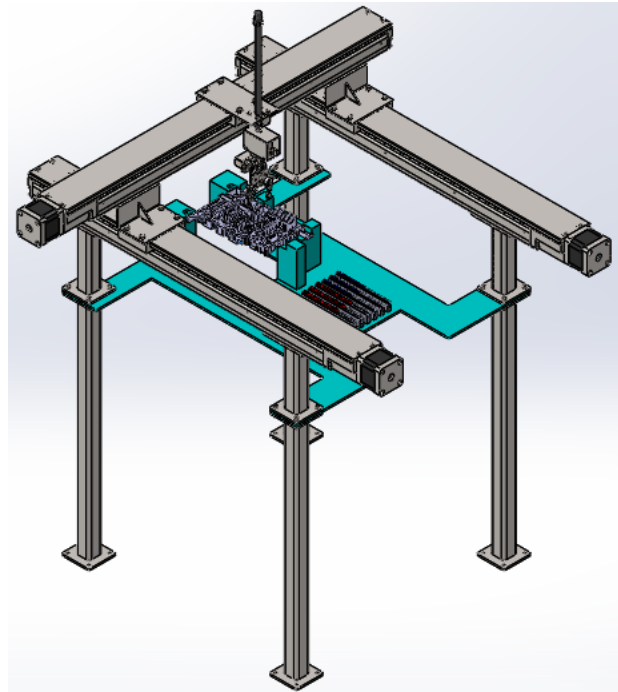


Fig. 7: The final 3TR Cartesian robot structure

Following these criteria, the CKK-110-NN-1 type of linear axis system with mounted motor from Bosch Rexroth was chosen. The linear axis has ball rail system guideway and a maximum travel of 840 mm, max. acceleration of 50 m/s^2 and max. perm. torque of 13 Nm [9].

We used two synchronized motored linear systems on X axis for better stability of the mechanism and one for the Y axes; the one from Y axes is attached to the ones from X axes through two Z-shaped flanges (Figure 6).

The command and control system is based on an Arduino ATmega 2560 controller (drivers for motors supplied by Bosch-Rexroth). The gripping force sensors were acquired sparsely. The design of the end effector is particular to the parts are to be manipulated.

On the linear Y axis we have a flange fixed in 4 screws to which a pneumatic cylinder is attached which translates on the Z axis for picking up and inserting fuses, shown in figure 6. The cylinder is a C85KE12-200 ISO Cylinder, Double Acting, Single Rod, Non-Rotating type, with a bore size of 12 mm and a standard stroke of 200 mm. A unique rod packing design prevents the entry of dust and the C85 series is suitable for use in extremely dusty environments.

In figure 7 is represented the final mechanism with motors and cylinder that performs the needed translations and rotation movements. The end-effector is an electric gripper especially designed to handle car fuses. It is powered by two electric servomotors, one for closing and opening the claws and the other for a complete 360° rotation for the fuse setting.

Finite element analyzes was performed to check the structure of the automated system and to observe the strength of the used parts and the degree of their deformation. A value of 10 mm deflection was considered acceptable. The model showed a 52.11 mm deflection. Thus, it was reinforced with one rib of 5 mm thickness.

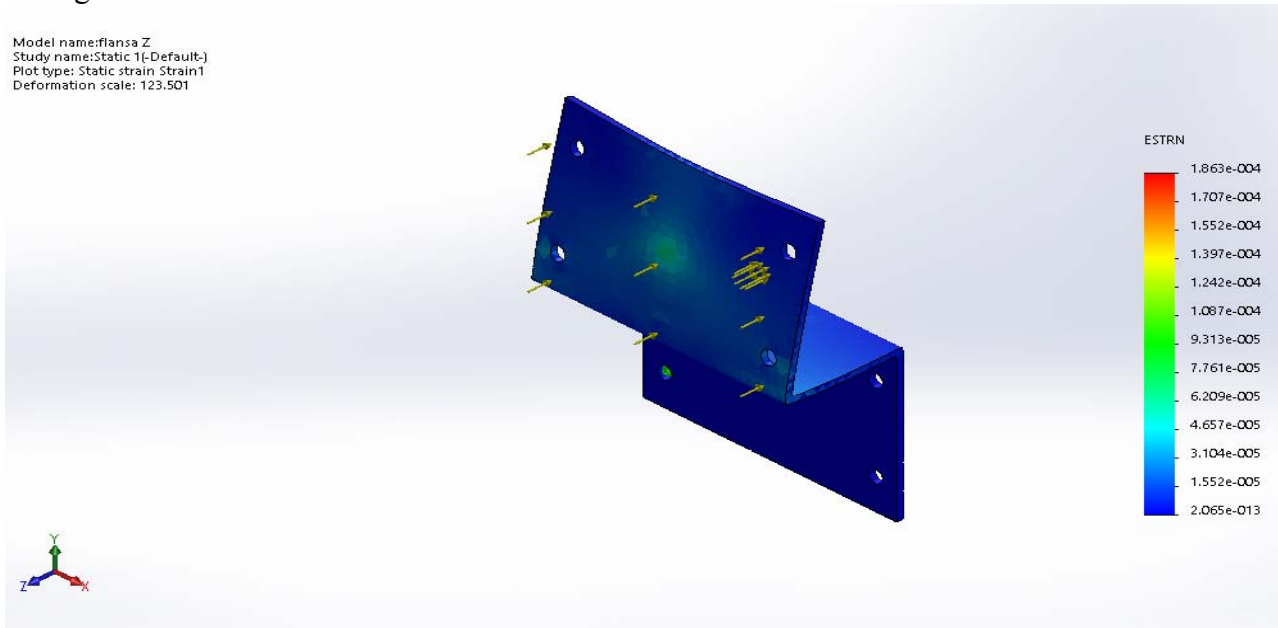


Fig. 8: FEA of flange linking the X and Y axes

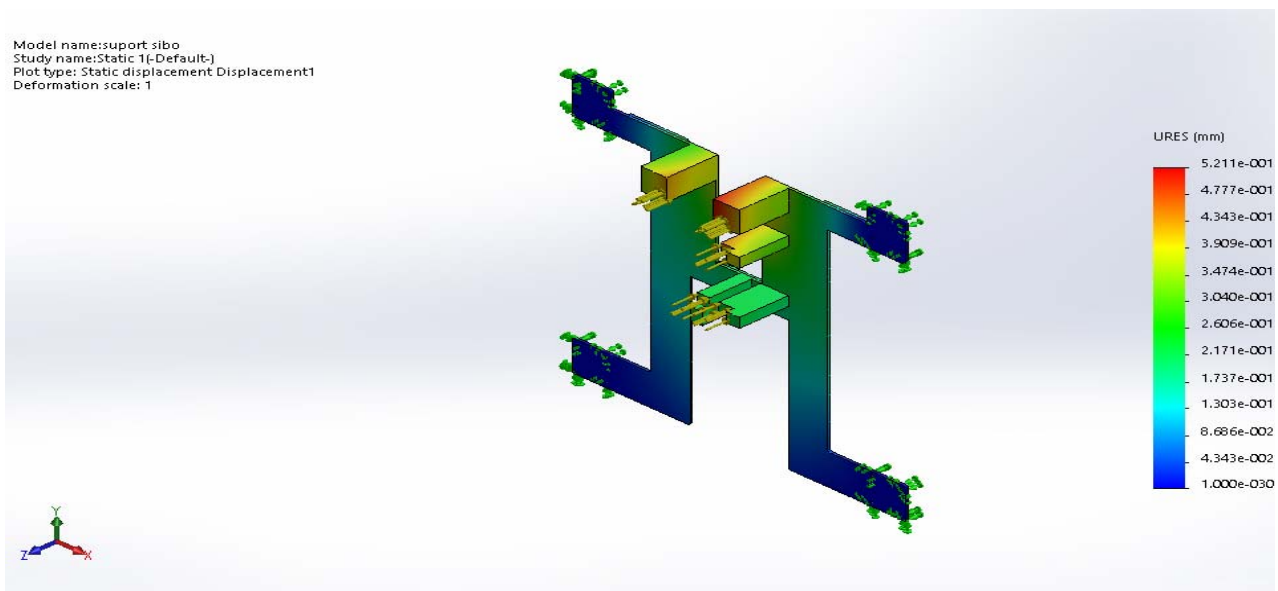


Fig. 9: Support board

3. CONCLUSIONS

This paper deals with the improving of the efficiency for a process of feeding a fuse box with auto fuses within an industrial enterprise,

by replacing the human operator with a 3TR Cartesian robot type.

Starting from the customer's needs and using six sigma methodology, an automated system of high precision has been developed, able to

reduce the number of damaged fuses, increase productivity due to the decrease of the fuses feeding time and eliminate errors caused by the human operator.

Finite element analyzes were performed in order to observe the strength of the used parts of the assembly and the degree of their deformation.

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SISTEM AUTOMATIZAT PENTRU POPULARE CU SIGURANȚE AUTO

Rezumat: Obiectivul principal al acestei lucrări a fost de a proiecta și de a realiza un sistem automatizat pentru popularea unei cutii de siguranțe cu siguranțe auto din cadrul unei întreprinderi industriale. Datorită faptului că actualmente acest proces de populare cu siguranțe este efectuat de către un muncitor, se dorește ca prin intermediul acestui sistem să se realizeze o scădere a numărului de siguranțe deteriorate, o reducere semnificativă a timpului de asamblare a acestora și reducerea erorilor cauzate de factorul uman. Pentru a atinge acest scop, studiul a fost axat pe proiectarea unui mecanism cât mai simplu, ieftin, ușor de utilizat și de realizat, pentru a putea fi ușor de implementat în cadrul companiei industriale. Pentru modelarea conceptului s-a utilizat software-ul SolidWorks 2016 iar pentru calculele întreprinse a fost folosit software-ul MathCad. Conceptul folosit este unul de tip robot cartezian care se potrivește cel mai bine cerințelor. Metoda Six Sigma a fost utilizată în etapa de dezvoltare a produsului și s-a efectuat analiza cu element finit pentru a verifica structura elementelor sistemului automatizat și pentru a observa rezistența pieselor utilizate, respectiv gradul de deformare a acestora.

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