Annals of DAAAM for 2010 & Proceedings of the 21st International DAAAM Symposium, Volume 21, No. 1, ISSN 1726-9679
ISBN 978-3-901509-73-5, Editor B. Katalinic, Published by DAAAM International, Vienna, Austria, EU, 2010
*Make Harmony Between Technology and Nature, and Your Mind will Fly Free as a Bird*
*Annals of DAAAM International*

# COMBINED STUDY OF STRESS STATE IN TWO TYPES OF MANIPULATOR GRIPPERS

**RUSU - CASANDRA, A[urelia]; ILIESCU, N[icolae] & BACIU, F[lorin]**

***Abstract:*** *In order to increase the productivity and for ergonomic reasons, the manipulators and industrial robots are used for the automatic feeding of the machine tools with semi-products and final products to be processed. This paper presents a combined numerical and experimental study of the stresses in the grippers of two types of manipulators. The study was carried out using the three-dimensional finite element method and the photoelasticity technique. Agreement between calculated and measured results obtained for each model was good and maximum stress in each case was predicted with reasonable accuracy. The results of the study led to the correction of the geometry of the models and to an improvement of performance and safety in operation of new types of grippers.*
***Key words:*** *stress analysis, FEM, photoelasticity, industrial robots, manipulator*

## 1. INTRODUCTION

In the construction industry of rolling stock one of the key sectors is represented by the compartment for processing and assembling of axles, bogies and mechanical transmissions, its output influencing the execution of the final products. The production of average series with tendency to shift to large series of the components of these assemblies on one hand, and the large dimensions of the structures on the other hand require, both in terms of increased productivity and for ergonomic reasons, the use of manipulators or industrial robots for the automatic feeding with semi-products of the machine tools on which they are processed. This paper presents a study of the handling systems of the semi-products and products of the type axles and shafts processed on the technological lines.

The design and manufacture of the manipulators and portal robots used for the flexible systems of processing these parts are done depending on their dimensional type range. Thus, there are several categories of dimensional types, determined by the diameter of the part in the clamping area, by its length and weight respectively (Nicolescu, 2009; Monkman, 2007). For all dimensional types the manipulation of the parts is made with two rows of claws, placed at a fixed or adjustable distance, depending on the constructive type of the gripping module. The driving system of the manipulator arms is electromechanical or hydraulic or pneumatic.

Figure 1 shows one of the widely used versions of these gripping modules, i.e. the one with articulated lever mechanism and spatial cam gear. The paper contains a study of the gripping systems belonging to the category showed in Fig.1, that are specific for manipulating parts with masses larger than 80kg. The aim of the study is the constructive standardization of several correctly designed solutions, relatively similar for all gripping modules of the investigated manipulators, with minimum sizes and reliable operation. This was achieved by conducting a comparative study on two models of gripping systems (model type A and model type B), using two methods of analysis, a computational and an experimental method.

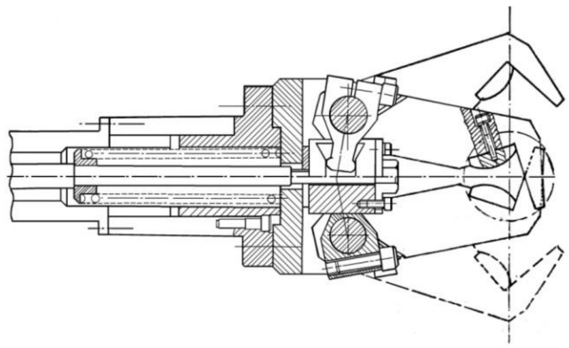

Fig. 1 Gripping module

The mathematical model of calculation obtained using the finite element method was validated by means of the photoelasticity technique (Iliescu, Atanasiu, 2006). Starting from the constructive suggestions given in the specialized catalogs of several well known companies, there were designed and realized two types of grabbing modules belonging to the analysed category, for which the next analysis was developed. The first type is for handling parts with diameters between 20 and 90mm and the second for parts with diameters between 60 and 120mm respectively.

## 2. NUMERICAL CALCULUS

A finite element analysis was performed using SOLIDWORKS software. The finite element meshes for the two investigated models of the gripping system were generated using 3D tetrahedric elements (Huebner et al., 2001). The models have the Poisson's ratio value applicable to photoelastic materials. Both the applied load and boundary conditions used for the finite element models were chosen to be similar to those of the photoelastic models. The contour plots of the principal stress $\sigma_1$ in the two models obtained with the finite element method are presented in Fig.2 and Fig.3.

## 3. PHOTOELASTIC INVESTIGATION

The two models representing cross sections through the cam and clamping arms were made of POLYCARBONATE plates with thickness of 6mm and 3mm respectively, at a scale 1:1. The cam was modeled from the thicker plate in which a groove was milled, thus on its lower edge the contact with the arms was achieved. In order to remove the compound stress of bending and traction of the arms due to the axial force produced by the hydraulic driving system, the groove of the cam of the second model (model type B) was milled inclined at an angle of $30^0$ with respect to the horizontal. Thus, the reaction forces that act on the groove are normal to the spherical surface that takes over the internal forces of the upper part of the arms.

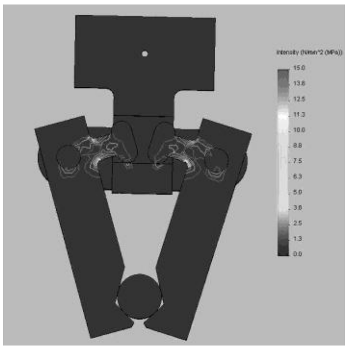

Fig. 2 Principal stress $\sigma_1$ for model type A

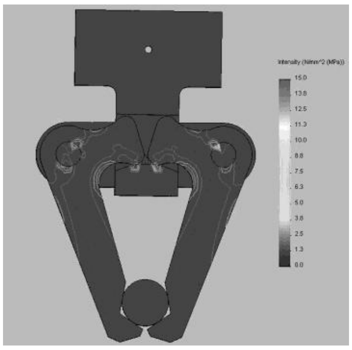

Fig. 3 Principal stress $\sigma_1$ for model type B

Each model was loaded with a force P=220N through a system of levers and weights and examined in the polarized light from a circular polariscope. The pure bending method was applied to calibrate the material, using a strip made of the same material as the models. The stress photoelastic constant for the model was determined to be $f_\sigma$ = 2.62 MPa/fringe.

Figure 4 and Fig.5 show the isochromatic patterns photographed for the two models. The curves of the principal stresses $\sigma_1$ on the boundary of the gripper models are plotted in Fig.6 and Fig.7 using the above fringe patterns.

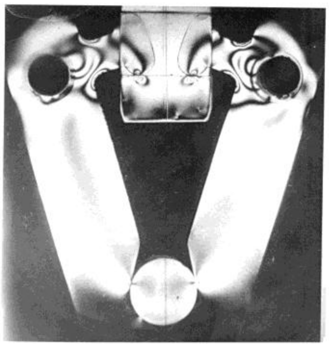

Fig. 4 Isochromatic patterns for model type A

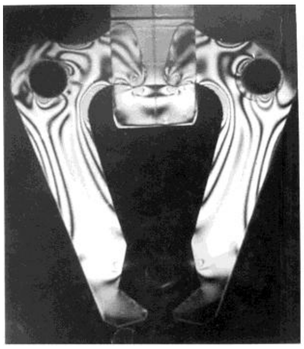

Fig. 5 Isochromatic patterns for model type B

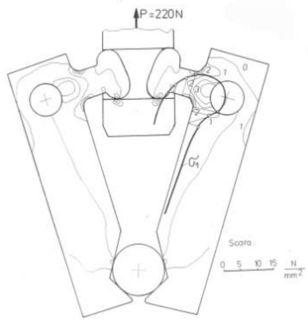


Fig. 6 Principal stress $\sigma_1$ for model type A

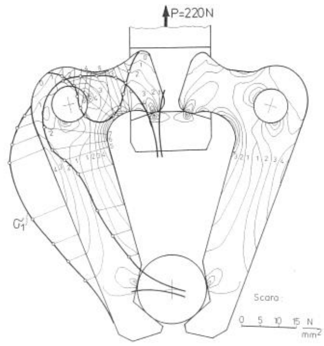


Fig. 7 Principal stress $\sigma_1$ for model type B

## 4.CONCLUSIONS

Comparing the results obtained for the state of stress in two designed models of gripping arms, using the finite element method (Fig.2 and Fig.3) and the photoelasticity technique (Fig.6 and Fig.7) the main conclusions are:

a) The maximum stress area in model type A is in the upper part of the arms, in the area with concentrators (Rusu-Casandra, 2008).

b) Due to the changes in the arms geometry by eliminating the unloaded portions, it can be remarked for model type B a much higher degree of use of the material, a reduction of the consumption of the material and an opportunity of overloading.

c) The agreement between the calculated and the measured results is good, very small differences may be seen.

d) Considering the simplifications made in the design of the two models, the experimental measurements represent a qualitative analysis which provides useful information about the general stress state of the investigated structures, for a future optimization of the structural shape of the manipulator gripping arms.

e) As further research, a quantity analysis of the mechanical behavior of the gripping modules can be performed associating to the photoelastic investigation a laser interferometer or using the strain gauge technique.

## 5. REFERENCES


Huebner, K.; Dewhirst, D.; Smith, D.& Byrom, T. (2001). *The Finite Element Method for Engineers*, Wiley-Interscience, ISBN 978-0471370789, Canada

Iliescu, N.; Atanasiu, C. (2006). *Metode tensometrice in inginerie (Stress Analysis Techniques in Engineering)*, Editura AGIR, ISBN 973-720-078-0, Bucuresti

Monkman, G. (2007). *Robot Grippers*, Wiley-VCH, ISBN 978-3527406197, USA

Nicolescu, A. (2005). *Roboti industriali (Industrial Robots)*, EDP Publishing House, Bucharest, Romania

Rusu-Casandra, A. (2008). *Elasticity in Engineering*, Editura AGIR, ISBN 978-973-720-188-1, Bucuresti