INTEGRATED TECHNOLOGIES FOR CAD/CAM/CAE ANALYSIS OF A CYLINDER PISTON ROD

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Abstract: *The aspects presented in this paper focuses on the design engineering phases of the product development process. The evolution of many software packages enables easier and faster designing and development of the mechanical systems in the automotive industries. This paper presents some applications of computer aided engineering on specific part of earthmoving machine (loader with side discharge bucket).*

Keywords: *CAD, CAE, CAM, technologies, piston rod*

1. Introduction

Over the past few decades, the manufacturing has evolved to a sophisticated set of information technology based processes, named advanced manufacturing [Sadiq, 2020], [Khan, 2009]. Thus, development and application of methods to solve problems in engineering manufacturing systems are based on the previous analyses using computer-aided design or computer aided manufacturing (very often used worldwide in many industries).

As above mentioned, one of the manufacturing systems represents the integration of computers and computer-based tools to support different activities from various fields in industry. The literature provides many descriptions of computer aided engineering applications that have used to reduce the product development time [Naga, 2013], [Rix, 2016], [Donghui, 2014]. A shorter design cycle allows companies to respond more quickly to competitive challenges, incorporate new technologies into their products, and charge higher prices for unique performances [Gilmanova,2020],[Chen, 2010].

2. Problem statement

In this paper, the author verifies and validates the design analysis concept using of the available methods of design (CAD/CAE/CAM technologies) as modern tools that allow to efficiently conducting the time-consuming and costly stages in the process of creating a new product [Vasiljević, 2018].

Will be described the results of computer aided engineering application using integrated technologies for virtual analysis for one element as part an industrial project (a heavy machine: wheel loader). The example given is not a typical one, but refers to a bucket loader with side discharge (Fig. 1), often used for the direct placement of the construction materials.

Figure 1. *Work principle of loader with side discharge bucket.*

Firstly, wheel loader with side discharging in SolidWorks software was performed. As can be seen, a hydraulic cylinder is mounted between the loader bucket and its support bracket on the arm to help unload the side of the bucket (Fig. 2).

Figure 2: *Virtual modeling of side bucket loader [Miron, 2018], [Debeleac, 2019b].*

Figure 3 shows schematically the forces acting on the lateral discharge of the bucket.

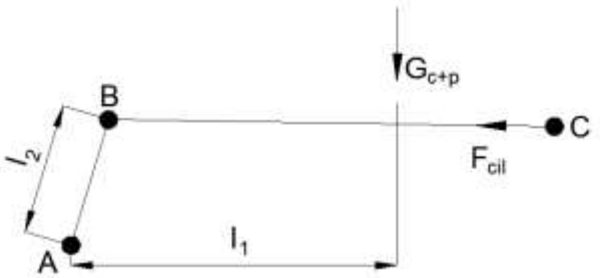


Figure 4. Forces acting on the bucket during discharging phase

Using the equation of moment equilibrium around the point A is possible to solve the reaction force from hydraulic cylinder (F_{cil}):

$$\sum M_A = 0 \tag{1}$$

$$F_{cil} l_2 = G_{c+p} l_1. \tag{2}$$

$$G_{c+p} = G_c + G_p. \tag{3}$$

where: l_1, l_2 – distances (l_1 = 285 mm; l_2 = 1100 mm); G_c – bucket weight (G_c = 1400 daN); G_p – load weight (G_p = 3300 daN). Results: G_{c+p} = 4700 daN.

Replacing into Eq. (2), is obtained the cylinder force: F_{cil} = 18140 daN.

The diameter of the piston is then calculated taking into account the value of the pressure in the hydraulic circuit (p = 240 bar).

3 CAD/CAE/CAM modelling of piston rod of the hydraulic cylinder for side bucket discharging

3.1 CAD modelling

CAD systems are computer tools that support the design and design engineering processes. A lot of different computer applications can be employed (e.g. Ansys, Catia, SolidWorks, Solid Edge etc.) for geometric representation of the design part of a cylinder ensemble (for exemple) [ThankGod, 2017], [Baroiu, 2017].

Using this environment, a double-acting cylinder with the following design dimensions shall be considered for the lateral handling of the bucket: D = 100 mm; d = 70 mm; stroke = 590 mm.

A three-dimensional model of the hydraulic cylinder with all component elements was generated based on the designed data (Fig. 3 and Fig. 4).

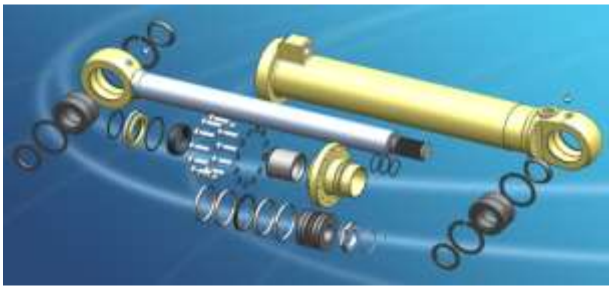


Figure 3. *Expanded parts of the hydraulic cylinder.*

Figure 4. *Virtual modelling of the hydraulic cylinder ensemble.*

3.2 CAE modelling

The connecting rod of cylinder represents a component element which is subjected to alternating direct compressive and tensile forces. Since the compressive forces are much higher than the tensile forces, therefore the cross-section of the connecting rod is designed as a strut and the Rankine's formula was used. Analysis of stresses and strains acting on the cylinder rod during the process of unloading the bucket will give us information about ensemble resistance at requirements of equipment performances [Țălu, 2010], [Lateș, 2008], [Ravishankar, 1981], [Singiresu, 2005].

In this context, the geometry of the assembly consisting of rod and eyelet, spherical joint and bolt developed with SolidWorks software will be available for the next stage of analysis. Furthermore, the above mentioned ensemble was imported in Femap environment owned by Siemens PLM for a finite element analysis. In the finite element method, an integrated model of the studied phenomenon is used as a starting point. It is applied separately to a series of small regions of a contained structure obtained by the discretization process using finite elements.

The commands used in Femap software to perform the analysis are as follows:

- *file-import-geometry* for importing geometry created in other design environment;
- *model-material* for introducing the mechanical properties of the material;
- *model-property* for introducing the type of property, usually solid;
- *mesh-mesh control-size on solid* for choosing the size and type of discretization;
- *mesh-geometry-solids* for the actual discretization according to the property;
- *model-load-...* for choosing the type of force / forces acting on the solid;
- *model-constraint-...* for choosing the type of constrains;
- *file-analyze* as command for simulation of analysis with finite elements.

As far as that goes the material used for manufacturing of the piston rod, this must meet the following conditions: resistance to crack; high stiffness as piston executes the imposed moves; wear resistance; light weight; low cost; available; minimum environmental impact.

The material adopted to simulated the side loader bucket behavior is E295 Steel (EN 10025 - 2: 2004), which has the mechanical properties given in Table 1.

Table 1: Mechanical properties of material E 295

Property name	Value
Density	7,85 kg/dm^3
Tensile strength	470…610 MPa
Minimum yield strength	245 MPa
Poisson coefficient	0,3

The reaction force acting on the piston rod is equal to the force required to perform the lateral discharge of the bucket. Taking into account the payload in the bucket, but also the geometry of the drive mechanism, it resulted that F_c = 181.400 N. The tension force was distributed to the end of piston rod.

The values of deformation and maximum stress are centralized in the table 2, and represented in the figures 7 and 8 [Debeleac, 2019b].

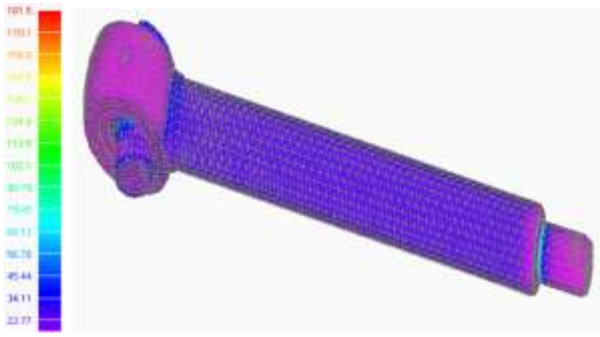


Figure 7. *Von Mises Stress (nodal value), N/mm^2*

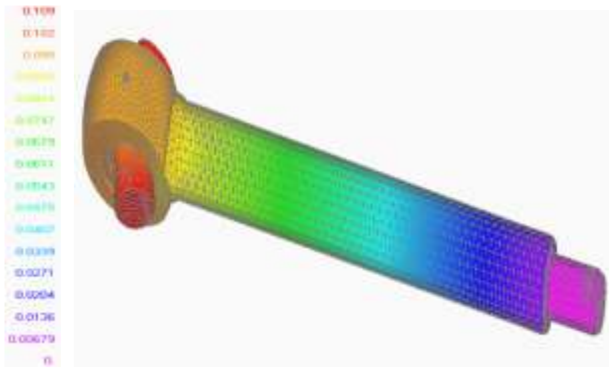


Figure 8. *Displacement magnitude, mm*

The obtained results of the finite element analysis are centralized in Table 2.

Table 2: The deformations and stress values

	Equivalent stress [N/mm^2]	Total deformation [mm]
Min	22,77	0
Max	181,5	0,109

In this way, it was verified the good response of piston rod subjected virtual loads similar to real working situations. Thus, the low values of stress and nodal deformation of the analyzed part are noted. Good agreement between predicted and simulated results was obtained establishing the finite element method as an accurate analysis tool.

3.3 CAM modelling

NX CAM software redefines manufacturing productivity through a complete range of NC programming capabilities optimized for machinery parts. These capabilities contain a lot of technological operations as: face milling, pocketing, profiling, boundary cutting, hole making, turning, mill-turning, wire EDM, graphical-driven programming.

Virtual manufacturing has unlimited potential in production design and manufacturing process applications. The requirements for a virtual manufacturing system are: function consistency, structure similarity and flexibility, system integration, intelligence.

The typical process for programming machine tools in NX 11 manufacturing is to perform the following steps:

- creating the manufacturing septum: this step involves creating a manufacturing set and adding other data about the manufacturing process. The manufacturing assembly includes the 3D model of the piece, but may also contain fasteners, machine tools, etc.;
- creating or modifying parent groups: minimizes the process of selecting objects from technological operations when they are used repeatedly and establishes the concept of inheritance of characteristics, so that parameters can be transmitted to the component objects. Most operations allow this step to be omitted, but for others it is mandatory. It may also be useful to define these groups for operations that use the same selections of information;
- creating operations: these can be inherited, but other parameters must be specified in the operation window. These parameters define how the tool path is created;
- generation and verification of the tool trajectory: after the appropriate setting of the parameters in the previous step, the operation is "generated" (the created tool trajectory). Trajectory checking minimizes errors;
- post-processing of the tool trajectory: in this stage the machine code (G-code) is generated depending on the particularity of the machine tool-controller combination;
- creation of technical documentation: generates information that can be used by those in the production service (material lists, tools, comments etc.).

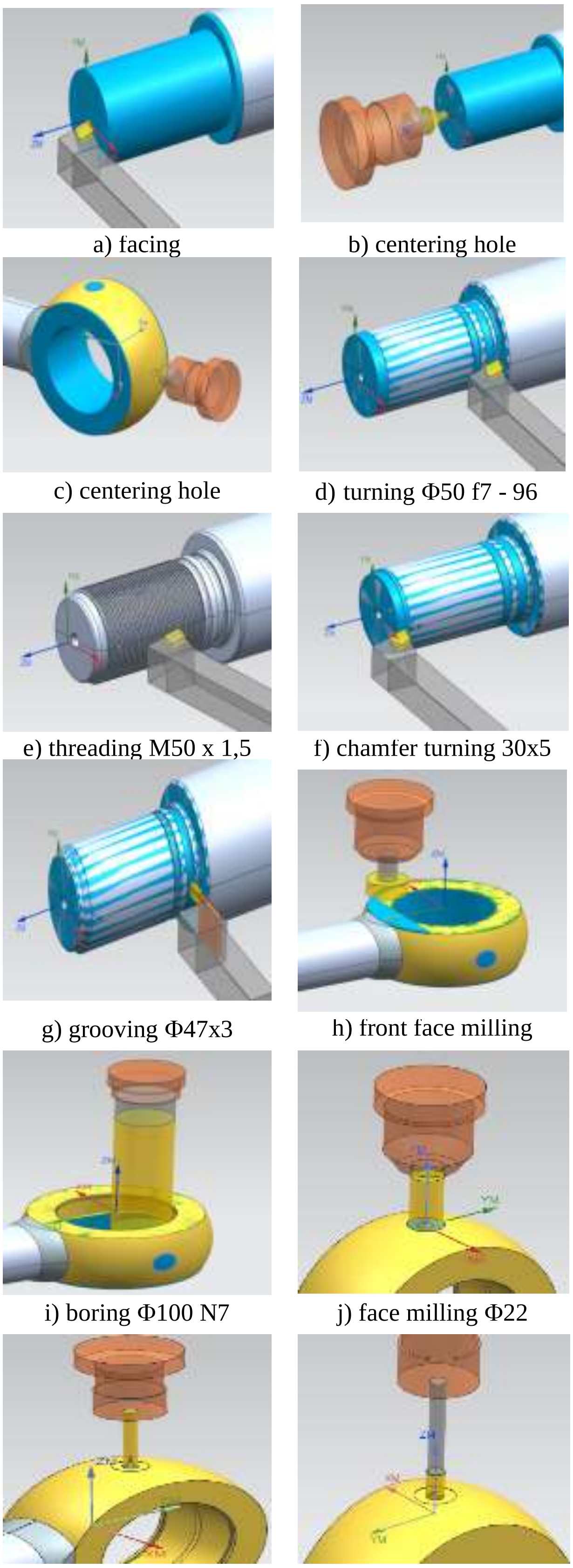
NX can also cooperate with other design programs, it can open and save files created in other CAD systems, as well as neutral transfer files (iges, step, dxf / dwg etc). Also, the links to these files may remain associative, if the imported files are modified in the native software, NX will notice this and update its own imported files.

As example for computer integrated manufacturing systems-machine tool, will be presented the steps for virtual manufacturing of the piston rod of hydraulic cylinder, using NX 11 Manufacturing.

The main steps taken in the virtual manufacturing of the piston rod are listed below:

- creating operation and tool paths;
- creating Parent Group objects that are supply information to the operations;
- utilizing options and parameters that are common to various operation types;
- creating all operations needed to finished the objects.

Order of technological operations is presented in Figure 9.



a) facing
b) centering hole
c) centering hole
d) turning Φ50 f7 - 96
e) threading M50 x 1,5
f) chamfer turning 30x5
g) grooving Φ47x3
h) front face milling
i) boring Φ100 N7
j) face milling Φ22
k) hole Φ8,5
l) threading M10x1x10

Figure 9. *Piston rod performed with Siemens NX 11 Manufacturing [Debeleac, 2019a].*

4 Conclusions

Computer-aided technologies offer high-performance modeling, drafting and assembly design. With help of some computer integrated technologies, in this paper, a part of construction machine was performed using methods and techniques provided by engineering software such NX environment.

Using the NX software offers three main advantages:

- advanced solutions for design concepts, 3D modeling and documentation. It should be noted that CAM functions address the programming of numerically controlled machine tools (CNC) based on the 3D model generated in the CAD module;
- multidisciplinary simulation for structural, kinematics, dynamics, thermal, fluid flow, physics and optimization applications;
- complete manufacturing solutions for machine tools, processing and quality inspection.

Undoubtedly, the computer systems have made rapid progress, and certainly the applications for which they will be used will multiply. The evolution of new versions will bring better quality, excellent skills and increased work procedure friendliness with these.

Additionally, engineering CAD/CAM/CAE began to has available in educational environment and as training tools for virtual simulations of various scenario, similarity with cases meted in the real applications. Thus, virtual laboratories represent an innovation in the use of information technology for the purpose of education.

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