3D Modeling of the Ball Bearing for the Front Axle Knuckle

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Abstract

In this work, the questions of ball bearings operation and their constructive features are considered. A 3D model of a detail is created as a ball bearing for for The Front Axle Knuckle. With Solid CAD, a finite-element analysis of the developed detail type is implemented. In the SolidWorks Simulation module, a ball bearing deformation analysis was carried out as a result of the 2000 N impact force. Based on the constructed model and the results of the analysis it was found that the support meets the requirements of strength in its application.

Keywords — *Modeling, construction, ball support, analysis, deformation*

I. INTRODUCTION

Among the multitude of vehicle suspension assemblies, a ball bearing is the most important bearing unit. It is the link between the wheel and the suspension, allowing the wheel to rotate to change the direction of travel, so the entire load from the suspension to the wheels is transmitted through the ball bearings. In this connection, the reliability of the ball bearings in the front suspension of cars determines the entire car reliability [1-4].

The ball bearings designs are continuously being improved, this is confirmed by the large number of patents, which is associated with the appearance of new materials, lubrication and technological making methods and strengthening fingers [4].

The general tendency of the ball supports development goes along the way of changing the material and the design of the inserts: from metal "crackers" to cermets, then to polymer "crackers" and a Teflon "shirt" in a plastic holder [5-7].

Technical progress led to the changes appearance in the initial arrangement of ball supports, although they were not of a fundamental nature [1, 6].

The stamped halves of the hull, connected by spot welding, were replaced by molded and demountable supports – with a threaded lid, maintenance-free and serviced – with grease nipples. These improvements were justified and became useful [2, 3].

All designs of ball bearings require reliable protection of friction pairs from environmental influences (water, dirt).

One of the most important elements of the modern cars suspension that determine the safety of their operation is a ball bearing, so the 3D modeling of the "ball bearing" detail for front axle swivel fist is an urgent task.

II. MATERIALS AND METHODS

A. Related work

Requirements for the car design are numerous, diverse and concern the issues of performance, economy, safety, reliability, comfort, car information. The requirements may vary significantly depending on who nominates them.

The quality of the car is determined by the combination of its properties, which determine the ability to meet specified requirements under certain operating conditions.

Therefore, a lot of attention has been paid to the basic properties modeling, components of cars and the evaluation of their design, as this is a complex multifunctional design.

Research on the form design of mini car in perceptual consumption times are described in [8]. The innovation method proposed by this research can rapidly obtain user's needs, shorten the overall operation steps and improve the development efficiency. Meanwhile, the method can be effectively used in other industrial product designs.

Rigid body dynamic simulation of steering mechanism is presented by authors in [9]. Project work present rigid multi body dynamic analysis approach in design. The application of this methodology simplify design process and give correct result. For the case study here work of design done on Ackerman steering mechanism for tipper. In this first according to Ackerman conditions basic geometry is design and then optimize it for static loading, modal analysis and then for dynamic forces generated on steering linkages while turning using Rigid Dynamics tool in Ansys. The results obtained from rigid body dynamic analysis are used for testing individual components and if necessary, corrective actions are taken in design in order to sustain that load. Results shows rigid dynamics approach for design reduces time for optimization, simulation and provide the chance to take most corrective action.

Process design for a companywide geometrical integration of manufacturing issues in the early development phases based on the example of automotive suspension is examined in [10].

Investigation and optimization of front suspension and steering geometrical compatibility is described in [11]. In this paper, a design of experiments (DOE) study is used, to gain an insight as well as to improve the quality of life in the environment, such as bump steer, percent Ackermann error and lock to lock rotation angle of the steering wheel.

The design of the tribological tester of the ball joint is given in [12]. This paper focuses on the design of a test rig that allows parametric research on these ball joints in order to increase the performance.

B. Features and specifications of the detail

The main function of the ball bearing: to ensure, during the vertical movement of the wheel, its fixed position in the horizontal plane. The ball finger can rotate in the body, while swinging at small angles. That is, in the plane of its fastening the ball support provides both rotational and linear (limited) movement of the finger [5].

The ball bearing consists of: a body with a spherical groove and a finger with a ball at one end and thread on the other. An anther, worn on the finger, prevents moisture and dirt from getting into the body filled with special grease [4].

All parts of the ball joint are made, as a rule, of steel.

The number of ball bearings installed in the suspension depends on its type. The single-lever design includes no more than two ball bearings and is most widely used.

To reduce the contacting working surfaces friction, spherical recess of the housing is covered with plastic or other polymeric material [6]. However, there are ball bearings, in the construction of which there is a polymeric coating between the body and the finger. This concerns, first of all, obsolete cars models. This model was equipped with collapsible ball bearings, in which the backlash was eliminated by a tightening of the cover [4].

There are two ways of securing the ball bearing.

In the first case, it is bolted to the lever.

In the second – it is pressed into it. When the ball-bolt is out of order, it can be replaced by a separate unit. To do this, simply buy and install it, bolted to the lever. Also in the second case – you will have to change the suspension lever with the already installed, pressed ball bearing. The cost of such repairs is much higher, because it includes the cost of the lever [4].

An example of the scheme for testing the lower ball joints is shown in Fig. 1 [7].

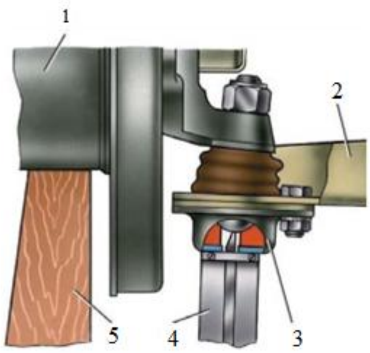

Fig. 1 Scheme Of Testing the Lower Ball Joints

In Fig. 1 element: 1 – the wheel hub; 2 – the bottom lever; 3 – the bottom spherical hinge; 4 – calipers; 5 – the shoe [7].

Pressed ball bearings, as a rule, are installed on Japanese cars. Asian auto parts manufacturers offer the customer ball bearings for such cars in the form of separate units. It is much cheaper, but their quality is much inferior to the original, and the lever will have to be altered in an "artisanal way", turning it into a detail, is not subject to warranty repair [4].

The ball bearings detail swivel fist of the front axle is made of 40X steel.

Cam support – the rotation body, which is used for hinged joints capable of transferring variable loads from the wheel to the car body at different angles [4].

The ball bearing (Fig. 2) is a unit connecting the hub of the controlled wheel and the suspension arm. Its task is to ensure the rotation of the hub while keeping the wheel in the horizontal plane while moving it vertically.

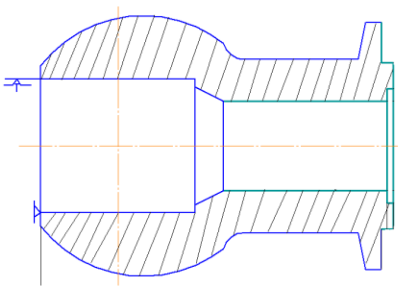

Fig. 2 Ball Bearing Detail

The detail has overall dimensions: length 355 mm, maximum flange diameter 235 mm.

The detail contains a through hole with a diameter of 78 mm, and two spherical surfaces: one external with ø235 mm, and an inner ø200 mm.

On the sphere there are two through-mutually symmetrical holes drilled at an angle of 9 degrees relative to the ø55 mm piece axis for the king pin.

On the left side, a milled slot with an 8 mm depth and a width of 125 mm for precise positioning behind the swivel fist. On the right side of this detail is a flange with ø212 mm and a 24 mm length. It contains 8 holes 23 mm in diameter for connection to the axle floor casing.

Detail weight is 23 kg.

Unspecified parts surfaces are machined to 14 accuracy and roughness grade Ra 12.5 [4].

Technical rationing is a system of scientifically substantiated and verified in practice the labor costs establishment for the particular work performance [13].

Technical rationing in modern conditions allows: to organize correctly the work of all categories of enterprise employees; to provide data, on the basis of which it is possible to plan, prepare and organize the work of numerous enterprise departments; reasonably estimate the labor costs of repairing the product [13].

Therefore, in addition to modeling the detail geometric shape in the future, it is also necessary to determine the technical standardization.

One of the main characteristics of the production type is the consolidation operations coefficient $K_{c.o}$, which is calculated by the formula [13]:

$$K_{c.o} = \frac{O}{P}, \quad (1)$$

where O – number of different operations, P – number of jobs that perform various operations.

The use of CNC machines is one of the main ways to automate the machining of metals by cutting, it gives a great economic effect and allows to release a large amount of universal equipment, as well as to improve the products quality under the machinist labor conditions [14].

The greatest economic effect from the introduction of CNC machines is achieved when processing details of a complex profile, when the work is associated with constantly changing cutting parameters (speed, direction of feed) [14].

The time norm for performing operations on CNC machines when working on the same machine consists of [12]:

$$H_{c.o} = \frac{T_u + T_{pft}}{n}, \quad (2)$$

where T_{pft} – preparatory-final time norms, T_u – unit time norms, n – number of details in a batch.

The norms of unit time can be determined by the formula [13]:

$$T_u = (T_{ca} + T_{au} \cdot K_{cf}) \cdot \left(\frac{1 + a_{tec} + a_{org} + a_{ned}}{100} \right), \quad (3)$$

where T_{ca} – cycle time of automatic machine work according to the program, T_{au} – auxiliary time, K_{cf} – correction factor for the duration of manual auxiliary work depending on the parts of the details, 0,76; a_{tec}, a_{org}, a_{ned} – time for technical and organizational maintenance of the workplace, for rest and personal needs for one-time maintenance,% of the operational time.

The cycle time of the machine's automatic work according to the program can be determined from [13]:

$$T_{ca} = T_{ma} \cdot T_{cas}, \quad (4)$$

where T_{ma} – main (technological) time for processing one part, T_{cas} – computer-assisted (to bring the detail or tool to the size, change the tool, change the value of the feed direction, the time of technological pauses (stops), 2.0 min).

The main (technological) time for processing one part [13]:

$$T_{ma} = \sum \frac{L_i}{S_{mf}}, \quad (5)$$

where L_i – length of the path traveled by the tool or detail in the feeding direction when processing the i[th] technological section (taking into account the cutting and overtaking), mm, S_{mf} – minute feed on the given technological site, mm / min.

The auxiliary time specifications for the installation and removal of the details differ depending on the type of device and do not depend on the type of machine.

The standard time for the installation and removal of the detail provides for the following works [4]:

- take and install the detail;
- measure and fix;
- turn the machine on and off;
- unfasten, remove the detail and put in a container;
- clean tools from chips;
- wipe the base surfaces.

$$T_{pft} = T_{pft1} + T_{pft2} + T_{tpr}, \quad (6)$$

where T_{pft1} – time for organizational preparatory, mines; T_{pft2} – time norm for setting up the machine devices and tools, T_{tpr} – time norm for trial processing, mines.

III. RESULTS

A. 3D Modeling of the "ball bearing" detail for the front axle knuckle

Using the SolidWorks program capabilities, the basic elements of the ball bearing were created.

Let's consider in more detail the process of creating a support.

First you need to select the type of document in which the 3D model will be created.

The support is one solid piece, so choose the type "3D representation of one component".

To determine the dimensions and shape of the bearing, the drawings developed earlier in the Compass program were used.

To create a new three-dimensional model, select the "Model" item in the model creation window, specify a name and specify the folder to save.

The first step in creating a model is to create a sketch. To do this, select the "Sketch" tab on the control panel. In the sketch creation window, you must specify the sketch parameters: select the plane or face on which the sketch will be created.

Using the tools "Line", "Circle", "Rounding" and "Cut objects" on the plane we get the sketch shown in Fig. 3.

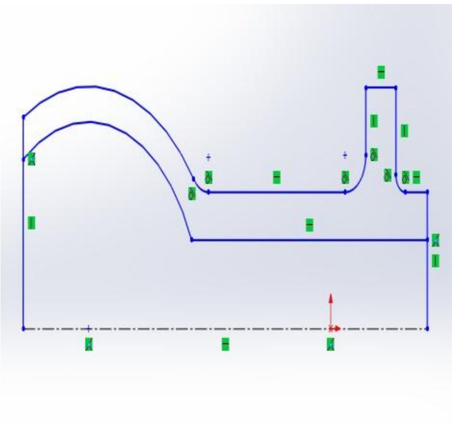

Fig. 3 Sketch for Obtaining 3D Model

Using the "Rotated lugs" tool on the "Elements" tab, we get the body of rotation (Fig. 4). To do this, you must specify the object to rotate, and the axis of rotation.

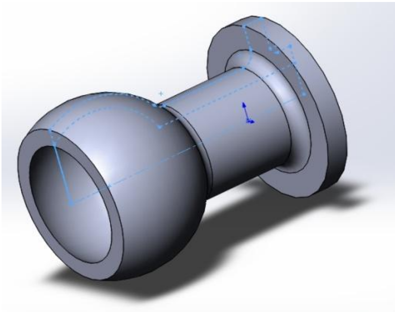

Fig. 4 Sketch For Obtaining the Body of Rotation

Using the "Cut" tool and selecting the right plane, we get the cut of the detail. Go to the sketch of the detail front and use the "Circle" tool to make an "elongated cut" to a small depth. In the cutout settings menu, select the direction and depth (Fig. 5).

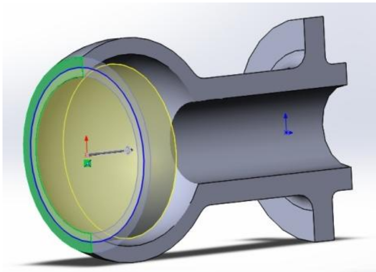

Fig. 5 Sketch for Obtaining a Cutout

During the work, the number of holes for the support – 8 was determined.

In order to create 8 holes symmetrically arranged in a circle, we use the "Circle array" command. To do this, create one hole with the help of the "outstretched" tool. For a circular array, choose the axis and the plane of the hole (Fig. 6).

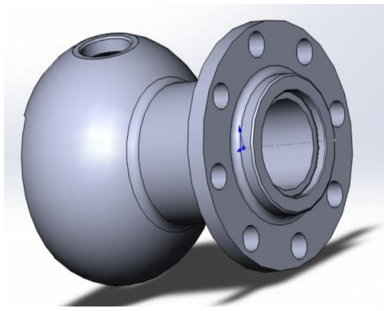

Fig. 6 Circular Array of Cutouts

B. Analysis of the ball bearing deformation

To analyze the ball part deformation, the SolidWorks Simulation module was chosen, which allows to optimize the design by minimizing / maximizing mass, volume, natural frequencies and critical force. The module allows to simulate structural deformation taking into account non-linearity, to simulate the effect of structural collapse and to perform fatigue calculation [15].

Using SolidWorks Simulation, you can optimize the design, and then avoid unnecessary costs for extra material. On the basis of the results obtained, it is possible to make the construction more durable, lightweight, elegant, and therefore more economical and more practical.

To begin with, you need to select the "New Study" item in the "Simulation" tab. After this, you need to specify the specific conditions under which the tests will be carried out – details material, fixing methods, forces and directions of their application, types of joints and mesh density.

Since the SolidWorks standard material library lacks information about the 40X steel material, it is therefore necessary to create new material.

Materials in the library cannot be edited directly, so you must first copy any of the materials, and then replace the characteristics with the necessary ones (Fig. 7).

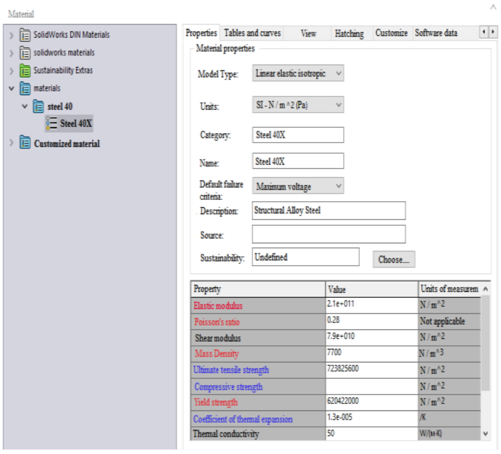

Fig. 7 Setting the Parameters of Steel 40X

After creating the material, set the force to 2000 N and the plane to which it will be applied.

After that, a grid was created for analysis using the finite element method. The density grid affects the calculation accuracy, but a high density grid can negatively affect performance, so the grid was created automatically to achieve the optimum size of the elements. A detail with all the given parameters is shown in Fig. 8.

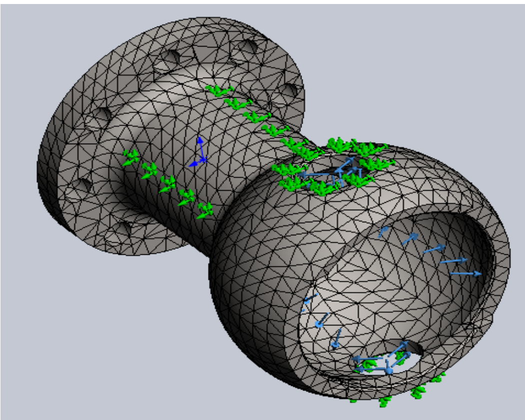

Fig. 8 Set Parameters for Calculation

After completing all the necessary steps listed, the operation "Launching this research" was selected.

As a result, in the SolidWorks Simulation module, the ball part deformation was analyzed as a result of the calculated force acting on them (Fig. 9).

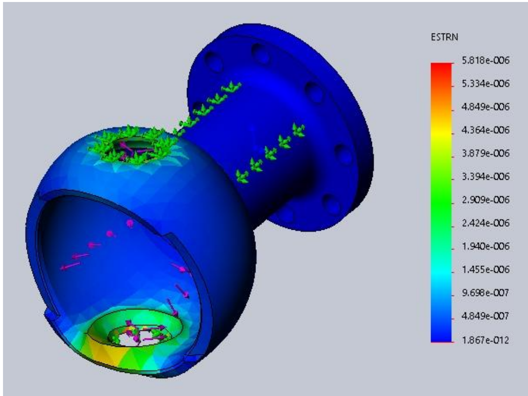

Fig. 9 Diagram of the Movement Distribution

In a real situation, this detail can tolerate other loads, but since it has a high wear resistance, additional calculations are not needed.

IV. CONCLUSIONS

The work was created on the analysis basis of the functional and design parameters features, a 3D model of a ball-bearing type of the swivel fist of the front axle was created.

Using CAD Solid Works, a finite element analysis of the developed detail type is carried out.

As a result, in the SolidWorks Simulation module, the ball bearing deformation was analyzed as a result of applying the calculated force of 2000 N. The material of the 40X steel construction was created, since such material did not exist in the standard SolidWorks database.

Based on the constructed model and based on the results of the analysis, it was established that the support meets the strength requirements in the field of its application.

The obtained model can be further used to optimize similar elements in engineering technology, which will significantly reduce the time for design work and improve the quality of such details.

ACKNOWLEDGMENT

The authors would like to acknowledge the keen support for this work of the Department of Computer Science, Prince Sattam Bin Abdulaziz University, Al-Kharj, Saudi Arabia and also the Department of Informatics, Kharkov National University of RadioElectronics, Kharkov, Ukraine [16-24].

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