# THE USE OF REVERSE ENGINEERING FOR THE ELIMINATION OF STRESS CONCENTRATORS IN AUTOMOTIVE PARTS - CASE STUDY

**Tamașag Ioan[1,*], Beniuga Marius-Constantin[1*]**

[1] *Department of Mechanical Engineering, Stefan cel Mare University of Suceava, Romania*
*13 University Street, 720229,*
*e.mail: marius.beniuga@usv.ro, ioan.tamasag@usm.ro,*

**Abstract:** *The stabilizer link, also known as the anti-roll bar link or anti-roll bar link, is an important component of a vehicle's suspension. It plays a major role in keeping the vehicle stable during cornering and reducing unwanted vehicle movement. The main function of the anti-roll bar is to reduce body roll during cornering, i.e. when the vehicle turns, the weight is transferred from one wheel to the other on the same axle and this can lead to body roll. The stabiliser linkage provides an inertial link between the two suspension axles and prevents lateral roll. Stopping the roll phenomenon contributes to better vehicle handling and to maintaining optimal contact of the wheels with the road surface. This paper presents studies on a stabilizer bar linkage made of a polymer often used in the automotive industry, namely acrylonitrile butadiene styrene (ABS). This research will show by finite element method the limit values supported in tension for each end with ball joints and identify the areas where concentrated loads are found. The study also uses the application of reverse engineering by scanning a stabilizer bar linkage in the vehicle suspension subassembly.*

**Keywords:** *stabilization, bead, loads, polymer.*

## 1. Introduction

Research over time has led to the development of new polymers with high mechanical properties and characteristics, which has led to the trend of replacing metal parts with plastic parts [1]. This trend has been observed in several industries, including the automotive industry, where the main reason for using plastic parts is weight reduction [2].

However, in most cases, component parts have geometrical details that lead to stress concentrators [3], which require increased attention in part design, even more so for plastic parts. One method of part verification is finite element analysis of the CAD (Computer Aided Design) model of the desired part.In some cases, when the part is no longer being manufactured, or when it is desired to improve the CAD model, various reverse engineering methods can be used [4].

A classification of the possible applications of reverse engineering is presented by Kender [5], where the author also presents the possibility of using finite element analysis of various components. Among the most widely used reverse engineering methods in manufacturing or automotive is the 3D scanning method, also applied in a wide variety of studies [5, 6, 7].

This paper presents a case study of the application of reverse engineering by scanning of a part used in the automotive field, more specifically a stabilizer bar linkage in a suspension subassembly.

The stabilizer bar (the one in the front suspension subassembly, figure 1 but also in the rear), is often connected to shock absorbers or other suspension components to ensure an efficient connection between the wheel assembly and the body.

This allows the oscillatory movements of one wheel at one end of the axle to be transmitted to the other wheel on the same axle, influencing the stability of the vehicle.

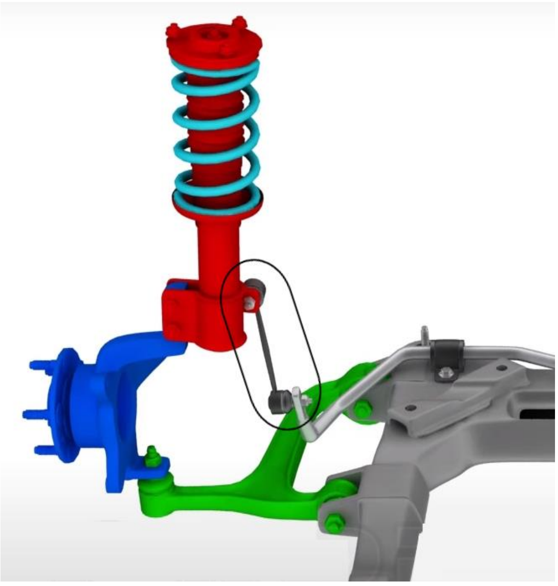


**Figure 1:** *Positioning the anti-roll bar in the suspension sub-assembly (front axle).*

Stabilizer rods, as part of the suspension system (8), may wear over time and require periodic replacement, even more so due to improper design, with stress concentrators. A worn or defective stabiliser rod can lead to poor handling and reduced stability during cornering.

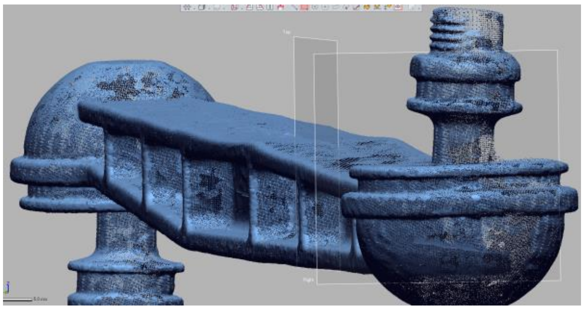
For the present case, reverse engineering methodology was applied by scanning a plastic stabilizer rod, followed by finite element analysis to detect areas with stress concentrators and redesigning the rod to eliminate them.

## 2. Reverse engineering application methodology

### *2.1. Scanning of the part*

The first step was to scan the part for which the 3D model was to be obtained. The scanning was performed using a Nikon MCAx type polyarticulated arm (figure 2.a). The scanning results in a point cloud in the form shown in figure 2.b, where it is made for the rod to which the reverse engineering process was applied.


a.



b.

**Figure 2:** *Scanning of the part.*

After obtaining the point cloud and processing it to remove impurities, proceed to the triangulation of the MESH part (figure 3).

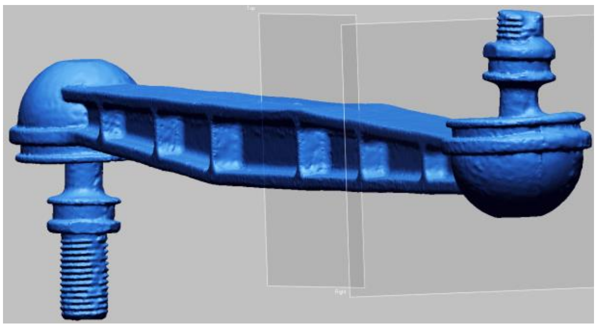


**Figure 3:** *MESH format.*

### *2.2. CAD modelling*

Dedicated reverse engineering software can be used to obtain the CAD model. In this case, Geomagic Design X was used. To reproduce the CAD part relative to the scanned file, a series of steps are followed:

1. *Determining the regions of the part*

This step involves establishing approximate primitive geometries at the surfaces of the scanned part (figure 4).

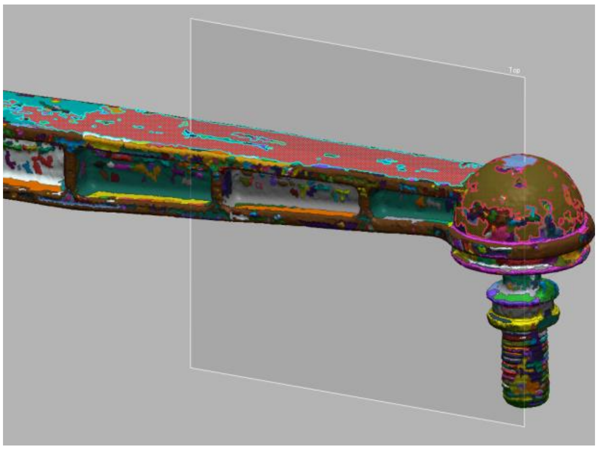


**Figure 4:** *Determination of the regions.*

2. *Alignment of the piece in Cartesian system*

After determining the primitive geometries, align the piece according to the desired orientation as shown in figure 5.

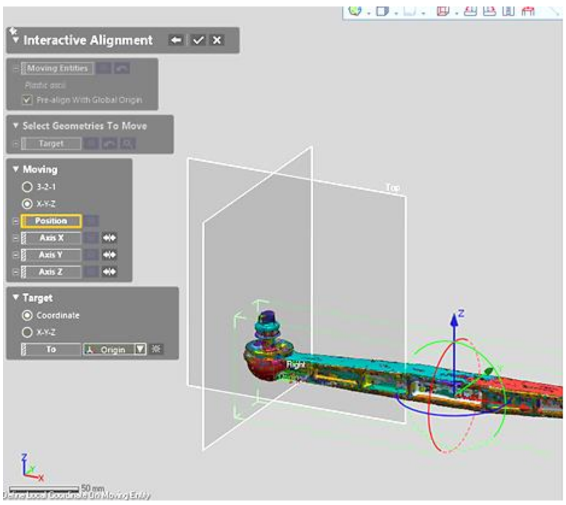



**Figure 5:** *Alignment of the track.*

## 3. 3D modelling

After aligning the scanned model, the part can be modelled by several methods offered by the software. In this case, the scanned part has no organic surfaces, so a standard modelling method is applied by going through the following steps:

### *3.2. Creating a plane parallel to the base plane*

Since in most cases the scan itself is difficult to apply in areas with sharp edges and therefore in the contact area of the workpiece with its supporting platform, a plane is created parallel to the base plane at a predetermined distance and sectioning the workpiece (figure 6).

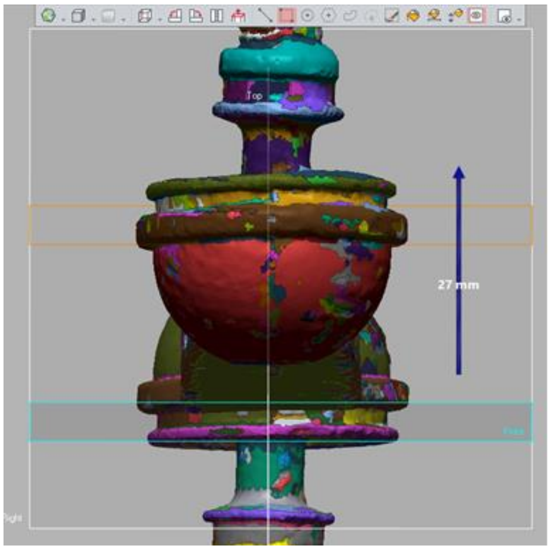



**Figure 6:** *Creating a plane in the body of the piece.*

### *3.2. Creation of MESH based outline*

In the previously positioned plane, a new sketch is created in which the contour of the part in that plane is automatically detected. Based on this layout, the new desired contour is generated and superimposed on the part contour (figure 7).

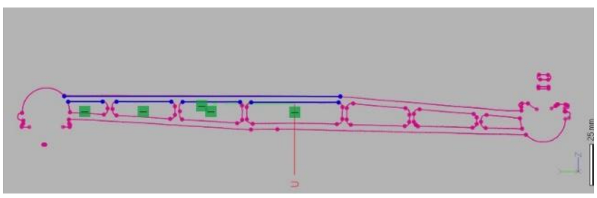


**Figure 7:** *Creating a new draft.*

### *3.3. Create the CAD part*

After creating the sketch select the desired modelling option (Extrude, Revolve etc). The previous steps are repeated as many times as necessary to create the shapes of the 3D part. Finally, the CAD design is designed with sufficiently high accuracy. Thus, in this case, the modelled rod has a satisfactory accuracy, with design errors within ±0.1mm (figure 8).

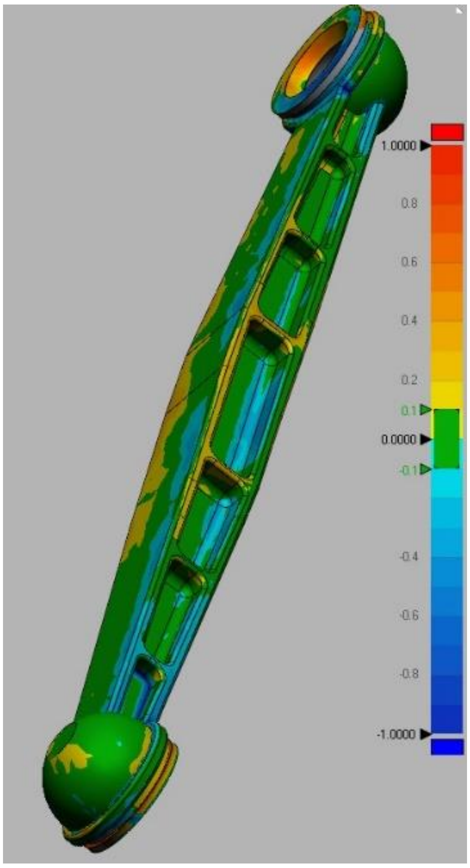



**Figure 8:** *Accuracy check.*

### *3.4. Finite element analysis*

After creating the 3D model, the CAD file was imported into the software provided by Autodesk INVENTOR using the NASTRAN extension. In this way it was possible to perform finite element analysis to determine the stress concentrators (figure 9) for tensile testing of the anti-wall rod subassembly. For the analysis, the material of the part was taken into account as a polymer often used in the automotive industry, namely acrylonitrile butadiene styrene (ABS), with the technical specifications in Table 1.

*Table 1. ABS technical specifications.*

| Mechanical properties | | | |
|---|---|---|---|
| Tensile strength, MPa | Tensile elongation, % | Density, g/cm3 | Vicat Softening Temperature, °C |
| 42.168 | 30 | 1.04 | 94 |
| Chemical composition | | | |
| Acrylonitrile-butadiene-styrene copolymer | | | |
| Aluminium powder | 0.1 – 0.25 % | | |

## 4. Results

### *4.1. Original linkage*

The results of the finite element analysis revealed that the part analysed shows a stress concentration in the joint area between the ball foot and the outer body of the ball joint (figure 10), with a value of 197.6 MPa.

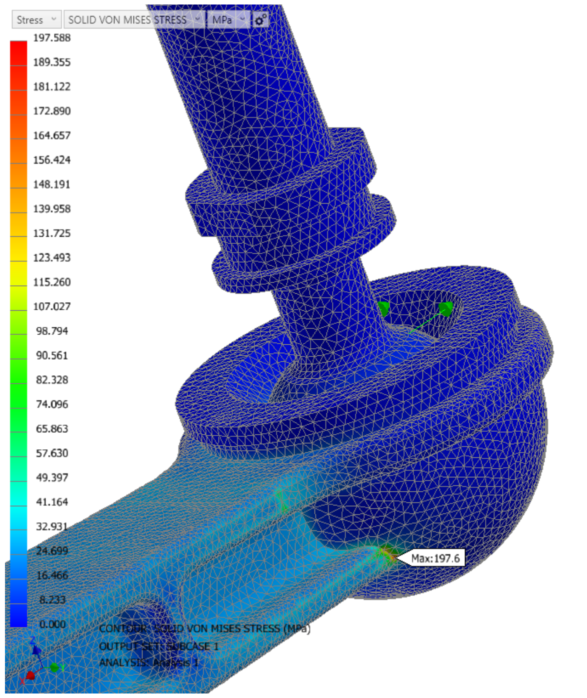
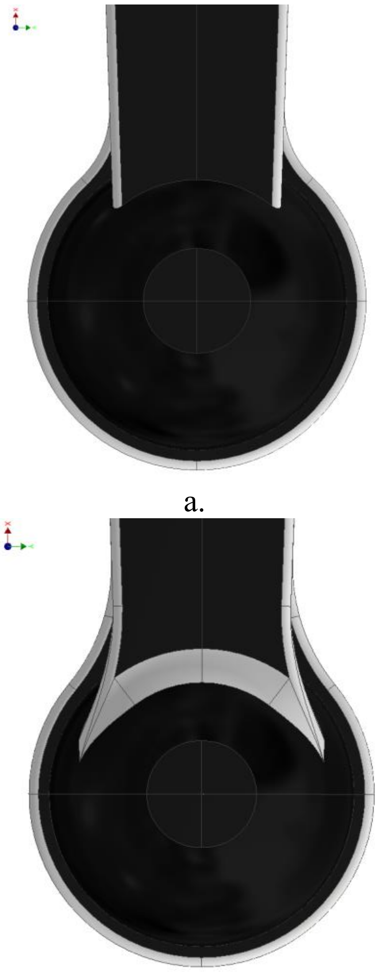



**Figure 10:** *FEM analysis of the original part.*

### *4.2. Remodeling of the track*

After determining the areas with stress concentrators, an attempt was made to eliminate them in order to reduce stresses by redesigning the body of the rod. Thus, in the Autodesk INVENTOR program, a 10mm radius was created in the area of the stress concentrators. Figure 11.a shows the original shape of the connecting rod and figure 11.b shows the redesigned shape.



a.

b.

**Figure 11:** *Redesign of the part to eliminate stress concentrators.*

### *4.3. Finite element analysis of the redesigned part*

After redesign, using the same procedure as for the original part, finite element analysis was performed (figure 12).

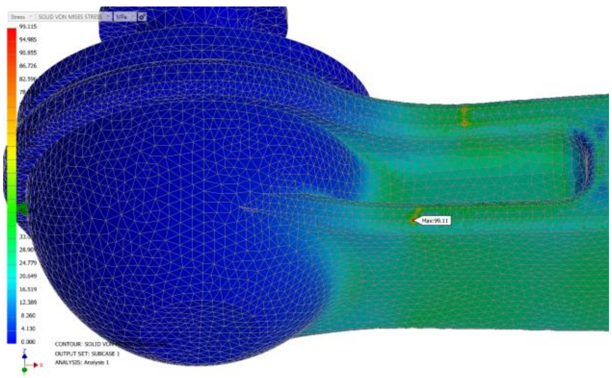


**Figure 12:** *FEM analysis of the redesigned part bottom view.*

According to the new analysis, it was found that the stress concentrator area was eliminated, obtaining a maximum stress of 99.1 MPa at the beginning of the connection radius.

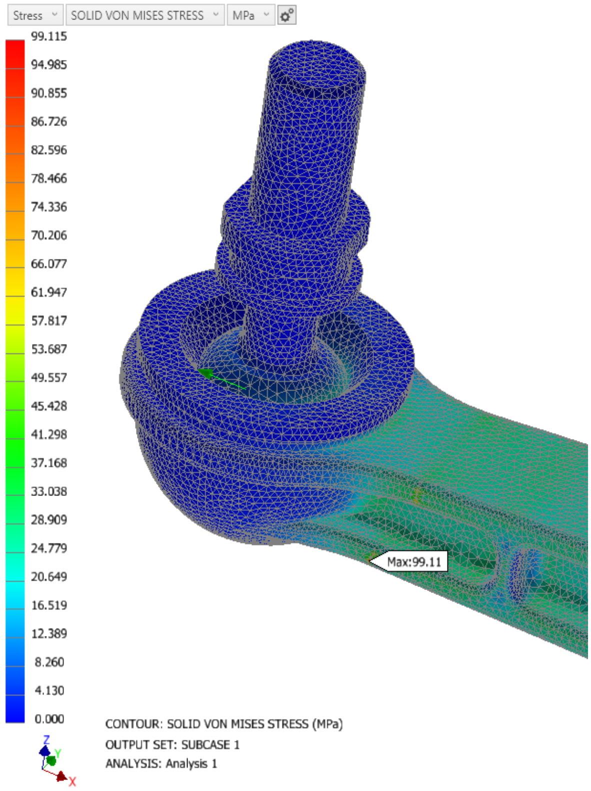



**Figure 12:** *FEM analysis of the redesigned part top view.*

## 5. Conclusions

Following the study carried out using the reverse engineering process followed by the use of the Von Mises finite element analysis method, a number of primary conclusions could be drawn:

- an increase in the strength of the stabilizing rod leg in the area of connection with the ball joint body at the ends by 49.85% is observed, thus a major decrease from 197.6 MPa to 99.1 MPa of the resulting stress concentrators, i.e. a difference of 98.5 MPa;

- a negligible increase in the mass of material in the component part, which will not affect the dynamics of the sub-assembly or the dynamics of the vehicle to be fitted with this reference mark.

**References**

1. [Candal, 2007] Candal M. A., Jiménez J. & Rojas H., *Methodology for the Study of the Stress Concentrators in Plastic Parts*, Polymer-Plastics Technology and Engineering, 46:10, pp. 991-999, 2007.
2. [Hariram, 2020] Hariram V., Godwin J. J., Subramaniam G.S., Sooryanarayanan S., Seralathan S., Premkumar T. M., *FEA based approach on replacing the metal cast wheel into thermoset plastic wheel*, V. Hariram et al. / Materials Today: Proceedings 33 pp. 3420–3425, 2020.
3. [Mengen Liu 2023] Mengen Liu, Antonio Carlos de Oliveira Miranda, Marcelo Avelar Antunes, Marco Antonio Meggiolaro, Jaime Tupiassú Pinho de Castro, *Plastic stress concentration effects in fatigue strength*, International Journal of Fatigue 168 107394, 2023.
4. [Vinesh 2008] Vinesh Raja and Kiran J. Fernandes, *Reverse Engineering, An Industrial Perspective*, ISBN-13: 9781846288555, Library of Congress Control Number: 2007934757, Springer Series in Advanced Manufacturing ISSN 1860-5168, 2008.
5. [Kender 2022] Kender Š., Brezinová J., *Reverse engineering in automotive design component*, year vii, issue 2, pp. 62-65, international scientific journal "industry 4.0" web issn 2534-997x print issn 2534-8582, 2022.
6. [Dúbravcík 2012] Dúbravcík a M., Kender Š., *Application of reverse engineering techniques in mechanics system services*, doi: 10.1016/j. proeng. 2012.09.491, Procedia Engineering 48, pp. 96 – 104, 2012.
7. [Haleem 2022] Abid Haleem, Mohd Javaid, Ravi Pratap Singh, Shanay Rab, Rajiv Suman, Lalit Kumar, Ibrahim Haleem Khan, *Exploring the potential of 3D scanning in Industry 4.0: An overview,* International Journal of Cognitive Computing in Engineering 3, pp. 161–171, 2022.
8. [Macarie 2023] Macarie T. N., *Automobile. Dinamica.,* Tiberiu Nicolae Macarie-Pitești. Editura Universităţii din Piteşti, ISBN 973-690-144-0, 2003.