

Identification of changes in the microstructure of damaged elements spherical joint

Mr. Sc. Mujanović Enes¹, Dr. Sc. Denijal Sprečić²

^{1,2} University of Tuzla, Faculty of Mechanical Engineering, Univerzitetska Str. 4, 75000 Tuzla, Bosnia and Herzegovina

Abstract: Spherical joint are a special kind of mechanisms which serve to transmit the torque and the force between the individual aggregates, respectively, in which case their shafts, connected with this gear, are under certain constant angle or under a variable (changing) angle during the operation. These gear are widely used in automobile industry. The main characteristic of these gears in that during the torque transmission relative moving (displacing) in allowed, which can be under an angle or translatory and that, except for purely mechanical losses, there are no other losses such as may be the torque increase or decrease. During the operation damages occur on the parts (elements) of hinged gear. For this reason the analysis of the microstructure is essential to establish the causes and to decrease the damages on the observed parts.

Keywords: Mechanism, spherical joint, universal joint, microstructure, machine vision.

I. INTRODUCTION

The main parts of the universal joint are shaft and the hinged coupling. The Universal joints can have one or more hinged couplings. The wide application and diversity of functional requirements conditioned the creation of a high number of types of hinged couplings (spherical joints) of different constructions (designs), the construction of a hinged coupling influencing the construction of universal joint. The hinged couplings are basically divided into asynchronous and synchronous hinged couplings. The asynchronous hinged couplings make possible the periodic variability of the angle velocity of the driven shaft, while the synchronous couplings ensure a constant angle velocity of the outlet (driven) shaft, under the variable (changing) and relatively big operating angles between the shafts.

II. THE ELEMENTS OF THE TRANSMISSION OF THE UNIVERSAL JOINT

The basic characteristic of the asynchronous gears is the periodic variability of the angle velocity of the driven shaft, the variability being greater, the greater the angle between the intersecting shafts is.

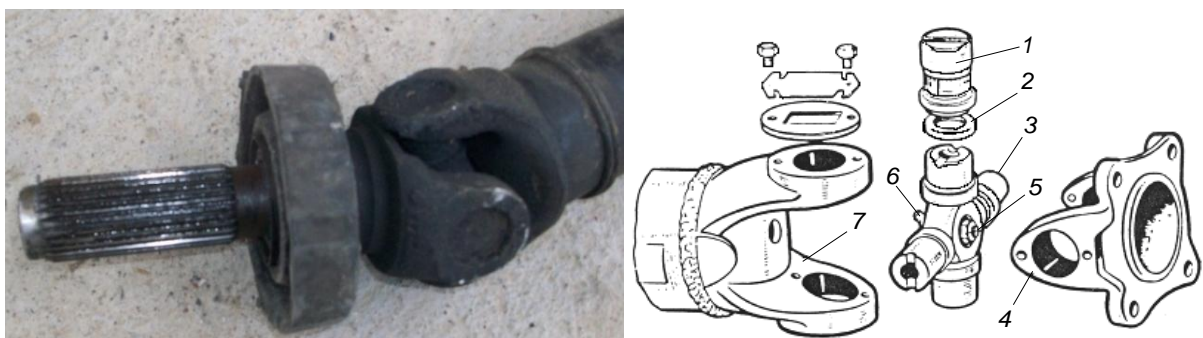


Figure 1: Universal joint with constituent elements

From the group of asynchronous hinged couplings we performed laboratory analyses of the parts of the universal joint. The universal joint is constructed in the form of two separate forks firmly connected to both parts of the shaft. The legs of the forks are turned under the angle of 90° one towards the other and they are hinged interconnected by means of the cross. On the pins we set needle bearings which consist of a cover, safety fuses, sleeve, needles and pickings which retain lubricant within the bearing. Those parts of the universal joints which are subjected to the most intense strains are between the other cross axes and the sleeves of the needle bearing. The asynchronous universal joint of the hinged type is illustrated in the Fig. 1, and consists of: 1-bearing needle, 2-ring, 3-cross joint, 4-fork complete with a flange, 5,6-grease-gun and valve and 7-fork complete with the shaft. Owing to unequal angle velocities of the driving and the driven shafts additional strains of the above mentioned transmission parts (elements) occur, consequently, it is for this reason necessary to carry out experimental laboratory analyses and to determine the deformations of the above mentioned parts of the

universal joint. Particularly interesting are the changes in the microstructure of the above mentioned parts which occur during the testings of the above mentioned universal joints in operation.

III. LABORATORY ANALYSES OF THE MICROSTRUCTURE OF THE PARTS OF UNIVERSAL JOINT

The analyses of the microstructure were carried out on the optical microscope. The microstructures appeared after the corrosion of the sample in the reagent 1% HNO₃ in ethyl alcohol, and the observation was carried out at the magnification X 625. The analysis was carried out on the necks of the cross axle and on the sleeves of the needle bearings. The picture of the microstructure of the cross-section of the neck is given in the Fig. 2 and from the analysis of the photographic picture it is possible to see martensite + residual austenite which is not desirable in the cemented layer because of its lower hardness. This indicates that the thermal treatment was not performed well. Most probably the sample was heated to a higher temperature during its tempering than it is allowable for this quality of treated steel which resulted in the increase of the austenite grain so that a certain quantity of austenite was retained between the martensite needles during the cooling.

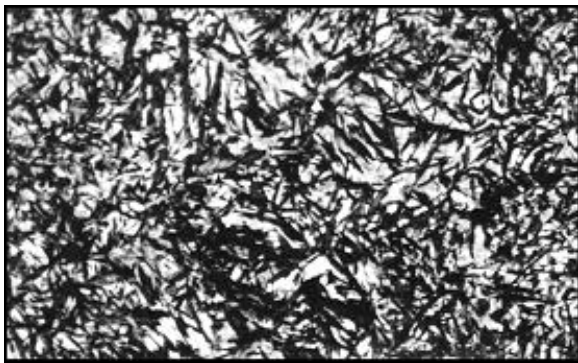


Figure 2: Neck sample; cross section; cemented layer, martensite + residual austenite

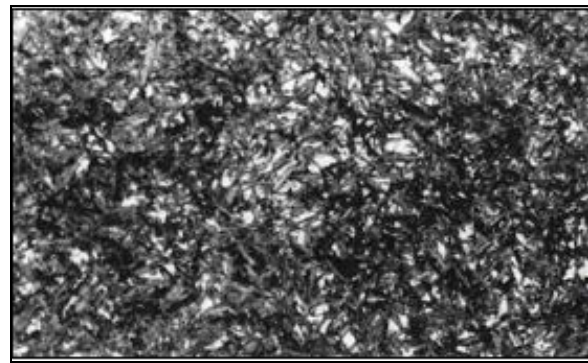


Figure 3: Neck sample; longitudinal section; cemented, layer; martensite + residual austenite

The picture of the microstructure of the longitudinal section of the sleeve is given in the Fig. 3, and from the analysis of the photographic picture it can be seen that in the microstructure of the sleeve the cementite is present on the grain border in the cemented layer in addition to martensite and the residual austenite. This phenomenon in the structure occurs at higher temperatures of cementing by means of carbonizing. These temperatures are not appropriate for the quality of the given steel in which case higher carbon content on the surface is achieved. This results in the separation of cementite on the borders of grains. In parallel to the appearance of cementite the grain increases too, which, in turn, increases the brittleness of the cemented layer.

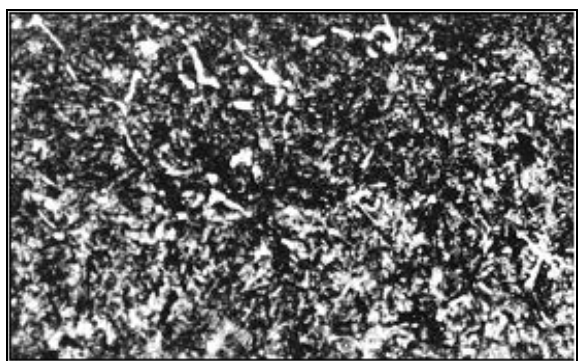


Figure 4: Sleeve sample; cemented layer on the outer edge; martensite + residual austenite + cementite

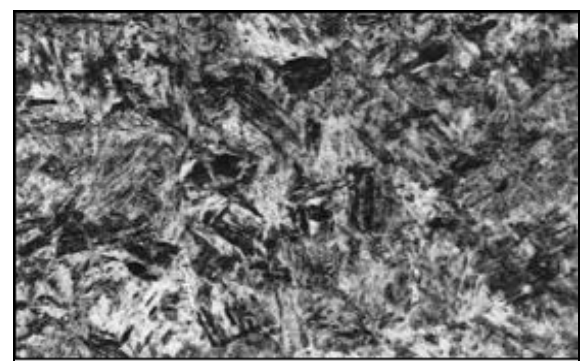


Figure 5: Sleeve sample; transit point between the cemented layer and the core

IV. THE POSSIBLE APPLICATION OF THE MACHINE VISION TECHNIQUES

For more quality identification of microstructure changes on parts of spherical joints, with the classical laboratory test we proposed the possible application of the machine vision to the microstructure analysis parts of the spherical joint. Improving basic inspection techniques may be accomplished by applying some new tools or devices that make inspection points easier to see.

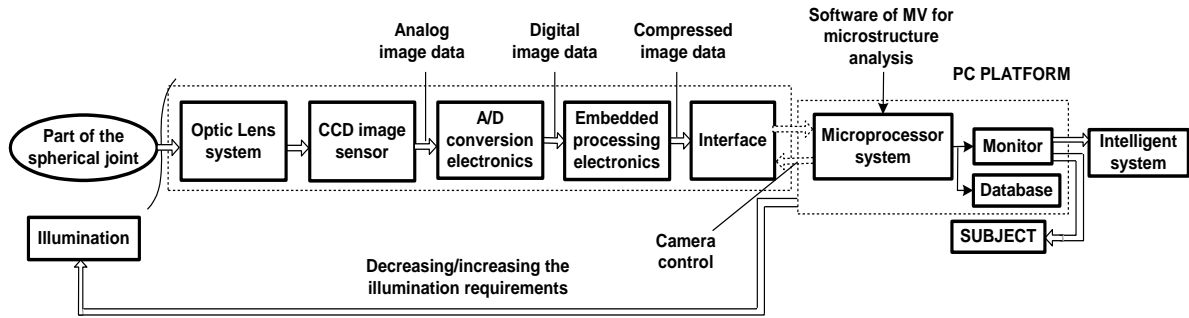


Figure 6: Generic schema of MVS for MA

Machine vision system will give us input information to intelligent system for microstructure analysis. The structure of the proposed machine vision system for microstructure analysis (MVS for MA) is shown in Fig. 6. In the cadre of the microstructure changes we marked the presence of: austenite, martensite, benite, ferrite and etc. For that the size, shape and colour are key characteristics for visual monitoring change of microstructure. It consists of next elements: microscope + CCD camera, PC platform – host processor system, software for microstructure condition monitoring- application software for end-user (developed GUI which user Neuro Inspector or IMAQ Vision functions as ActiveX control). Functional schema of proposed machine vision system is shown on Fig. 7. It consists from three functions: image capturing, image processing and features extraction. Fig. 8 shows flowchart of MA (Microstructure Analysis) software development. The basic idea is to develop a program which will be capable for automatic microstructure monitoring using image processing techniques.

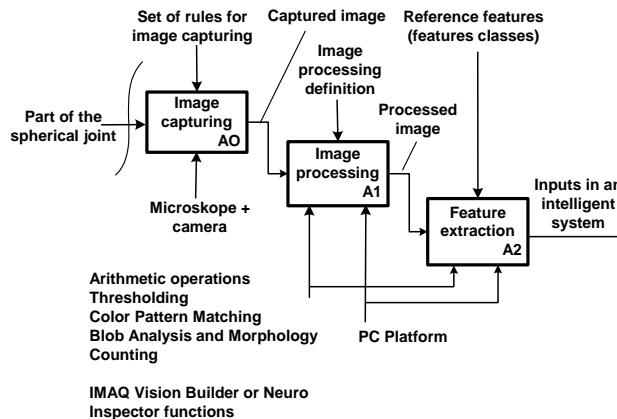


Figure 7: Functional schema of MV operations

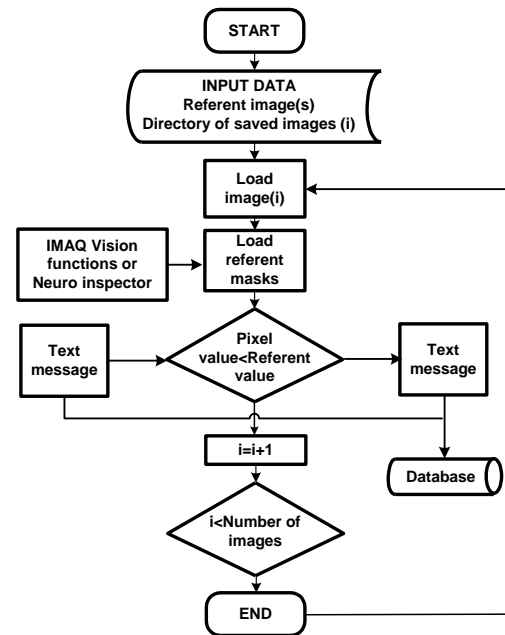


Figure 8: Flowchart of MA program

V. USING COMPUTER VISION TECHNIQUES TO THE ANALYSES OF THE MICROSTRUCTURE

The analyses of the microstructure were carried out on the optical microscope. The microstructures appeared after the corrosion of the sample in the reagent 1% HNO₃ in ethyl alcohol, and the observation was carried out at the magnification X 625. The analysis was carried out on the necks of the cross axle and on the sleeves of the needle bearings. The picture of the microstructure of the cross-section of the neck is given in the Fig. 9 and from the analysis of the photographic picture it is possible to see martensite + residual austenite which is not desirable in the cemented layer because of its lower hardness. This indicates that the thermal treatment was not performed well. Most probably the sample was heated to a higher temperature during its tempering than it is allowable for this quality of treated steel which resulted in the increase of the austenite grain so that a certain quantity of austenite was retained between the martensite needles during the cooling.

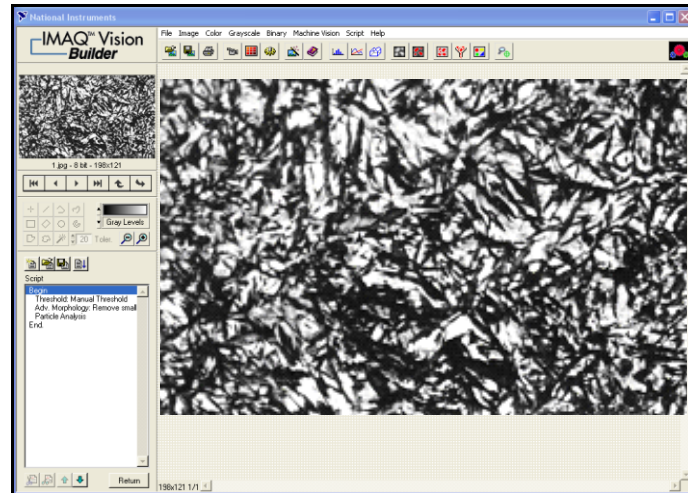


Figure 9: Image preparation

For example it's shown of the microstructure of the cross-section of the neck, which was for easiest analysis converted into JPEG format (8 bits grayscale) in IMAQ Vision Builder 6.1 software [6]. Other images, which are interesting for analyze of universal joint elements, are prepared and converted in the same image format Fig. 9. Image processing technique called BLOB (binary large objects) analysis is used for analyzing the structure of joint elements.

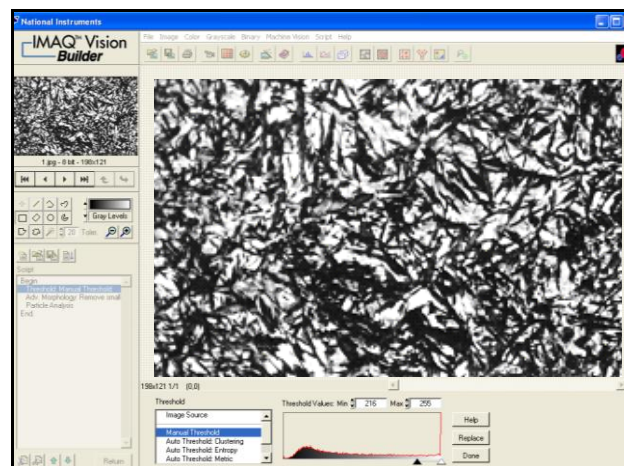


Figure 10: Tresholding

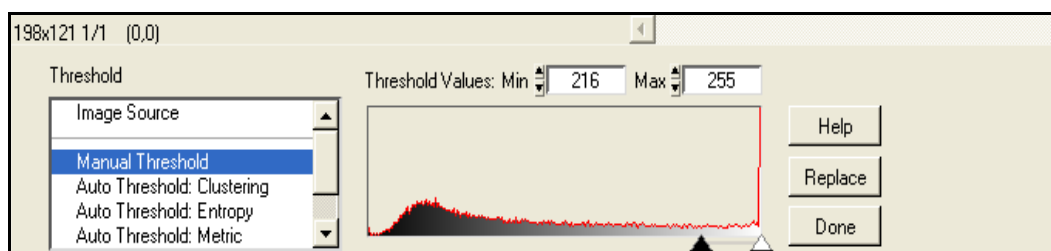


Figure 11: Tresholding values

Next steps have been performed: filtering the image to sharpen edges, separating particles from the background with tresholding Fig. 10, modifying blobs with morphological functions, analyzing the data.

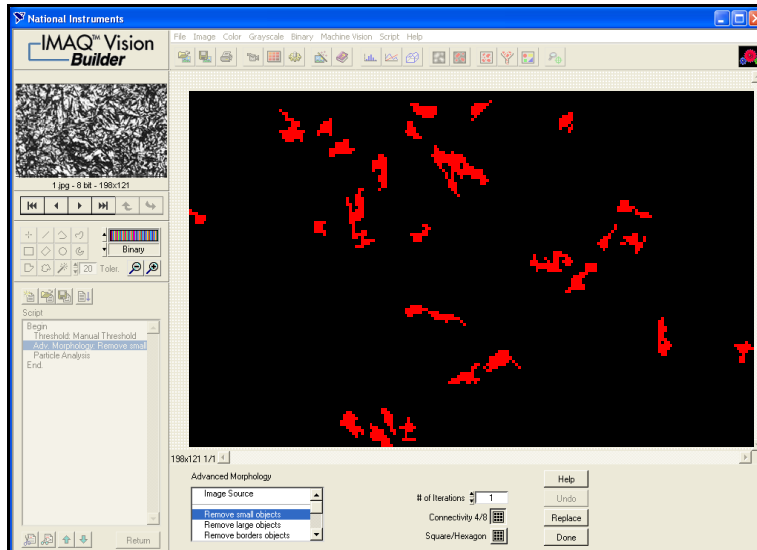


Figure 12: Advanced Morphology

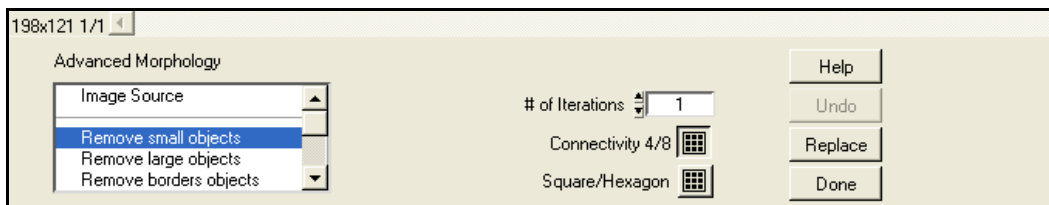


Figure 13: Remove small objects

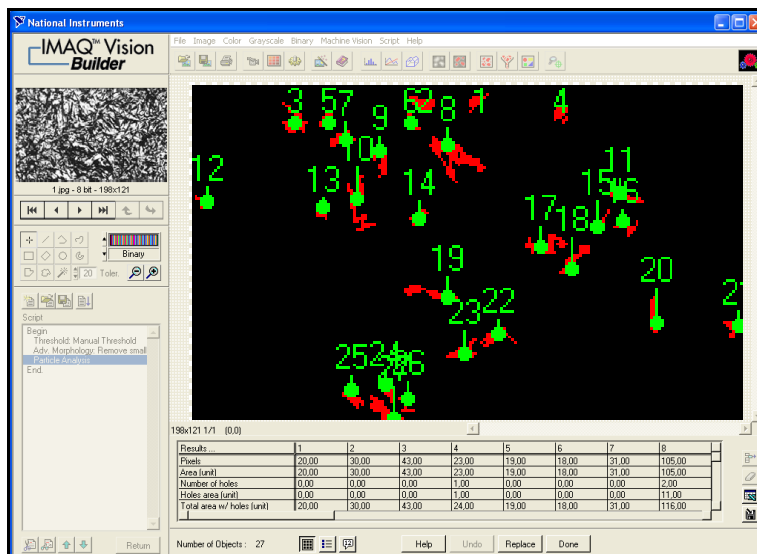


Figure 14: Particle analysis

Results ...	1	2	3	4	5	6	7	8
Pixels	20.00	30.00	43.00	23.00	19.00	18.00	31.00	105.00
Area (unit)	20.00	30.00	43.00	23.00	19.00	18.00	31.00	105.00
Number of holes	0.00	0.00	0.00	1.00	0.00	0.00	0.00	2.00
Holes area (unit)	0.00	0.00	0.00	1.00	0.00	0.00	0.00	11.00
Total area w/ holes (unit)	20.00	30.00	43.00	24.00	19.00	18.00	31.00	116.00

Figure 15: Measurement results

Morphological operations prepare blobs in the image for quantitative analysis such as finding the area, perimeter, or orientation. Advanced Morphology technique is used for removing small objects that touch the

border of the image Fig. 12. The measurement results are exported to Microsoft Excel for further analysis Fig. 15.

VI. CONCLUSIONS

Base upon the performed laboratory analyses on the microstructure of the parts (elements) of the universal joints all the samples of their damages can be classified into the damages resulting from poor maintenance, wear during the operation and from poor construction and fabrication technology. Due to poorly executed thermal - chemical treatments of the surfaces of the parts (elements) of the universal joints coarse-grained structures of lower hardness occur. This is illustrated by the picture of the microstructure of the cross section of the parts (elements) of the universal joints and measured hardness values on individual parts of these sections. This phenomenon is more pronounced on the elements in operation on which a sudden temperature increase occurs, and consequently, there are also the cases of noticeable plastic deformations in the form of increased width of impressions. Better quality cementation and greater depth of the cemented layer, as well as a better quality tempering and the yielding (releasing) period can influence the condition of the material on the surface and on the layer below the surface. In this way it is possible to achieve during the operation decreased damages on the parts (elements) of the universal joint as the integral part of the transmission mechanism. Beside of classical laboratory approach, this paper presents using of the computer vision techniques for the analysis microstructure of the parts of universal joint. Quality of information got it on this way gave sharpen picture about microstructure changes of observed elements which are caused by action of complex loads.

REFERENCES

- [1] Sprečić D.; Mujanović E.: Analysis of the Wear a Conical Gear Pairs, and the Possibility of Applying Machine Vision to Analyze the Microstructure, Intelligent technologies in logistics and mechatronics systems Itelms', Panevėžys, Lithuania, May 03-04, 2012, pp. 159-165.
- [2] Williams J.A.: Engineering Tribology, Oxford University Press, 2005.
- [3] Jain R.; Kasturi R.; Schunck G.B.: Machine Vision, McGraw-Hill, New York, 1995.
- [4] Janičijević N.; Janković D.; Todorović I.: Konstrukcija motornih vozila, Beograd, Faculty of mechanical Engineering, 1998.
- [5] Časnji F.; Klinar I.; Muzikravić V.: Savremene tendencije u automobilske tehnici – Mehaničke komponente i elektronski sistemi, Novi Sad, 2001.
- [6] Klinar I.: Oprema motora SUS, Novi Sad, Faculty of technical science, 1995.
- [7] Holmberg K.; Matthews A.: Coatings Tribology, Properties, Techniques and Applications in Surface Engineering, Amsterdam, 1994.