THE NEW ACTUATION MECHANISM OF THE SCREW JACK - ROTATING NUT

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Abstract*: This work presents research conducted to increase the level of safety and durability of the actuation mechanism of the screw jack - rotating nut. The study promotes the principle of competitive design by reducing the number of components in a mechanism without compromising the safety, maneuverability, and reliability of the product. The main focus of this study is a metal ball and two plungers housed in a metal box, which replace the functional role of other elements found in similar mechanisms. The calculations, determinations, and verifications in this work were performed using both classical analytical methods and modern calculation methods using the SolidWorks-Simulation program, applied to the components of the box, plungers, and metal ball. Both calculation methods yielded the same results, which fall within the permissible values of the required strength and safety limits.*

Keywords*: ball, plunger, computational, competitive design, compression, shear, contact mechanics, Hertzian elastic contact, deformable solid, tensor, SolidWorks-Simulation.*

1 INTRODUCTION

The design activity is complex and involves a combination of interdisciplinary knowledge. Any rotating part is in equilibrium under the action of active moments, namely those generated by reactive forces and frictional forces. In this regard, *Newton's third law* plays an important role in the design and calculation of mechanical transmissions.

Previous designs of mechanical jacks are characterized only by ratchet-type actuation mechanisms, either horizontal or vertical, which include components subject to premature wear, thus affecting their operational performance.

This paper presents a new variant of the ball actuation mechanism, which innovates by replacing the old ratchet mechanisms used in jacks with simpler elements that are manufactured with less labor and more cost-effective means.

In my approach, I started from a simple idea based on the Brinell Hardness model, which determines the hardness of a component subjected to a hardening process through heat treatment. The goal of this study is to increase the efficiency of this mechanism and reduce manufacturing costs without compromising performance and, consequently, operational safety.

The novelty of this project lies in the design of a housing box and the replacement of the classic ratchet with a 14mm diameter ball, along with two plungers that can withstand the forces developed within the system.

The mechanism in the new version can be adapted to all types of screw-jack systems with a rotating nut, and its manufacturing can be done in various sizes, ensuring a high degree of maneuverability without any operational failures.

The primary factor in designing the external shape of this mechanism is its functional role, which we have taken into account to fully integrate it into this structure. We aimed for a simple and sleek aesthetic design, incorporating modern trends of the current era, while also capturing the complexity of the phenomena occurring within the component

2 PRESENTATION OF THE HOUSING (SIMPLIFIED)

The device consists of a disc equipped with equally spaced holes along a predetermined diameter and with a fixing-drive location adapted to the geometry of the connection with the rotating nut of the respective screw jack. Additionally, it includes a housing containing two plungers and a metal ball, which, together with the presented disc, enable the actuation of the mechanical jack.(Fig. 1)

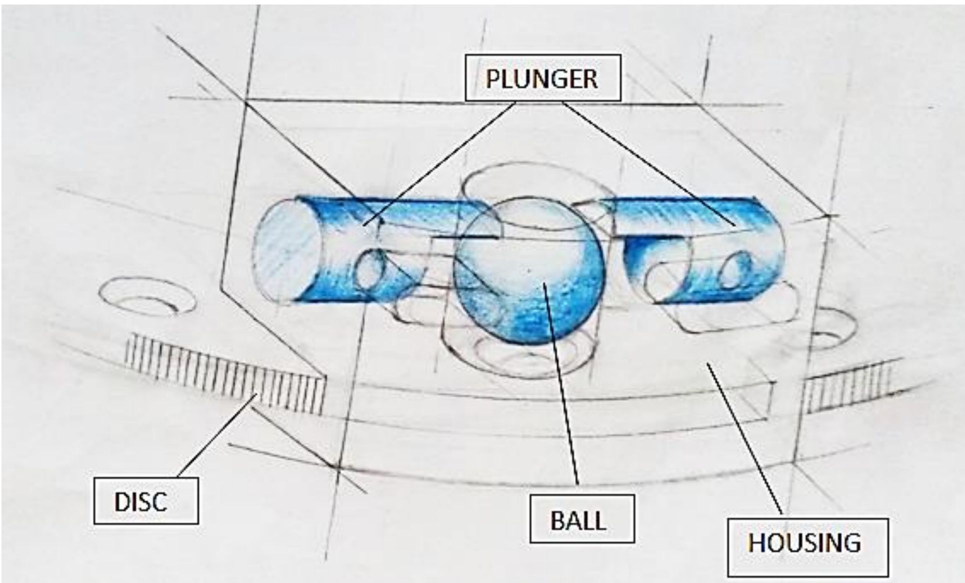

Fig.1 - Assembly drawing of the box

This paper will present the actuation of a mechanical jack by introducing a solid geometric element - a sphere, based on the model of the Brinell Hardness Tester for determining the hardness of a component. The metal ball in the Brinell model supports a force of 1471 N, while in this case, the ball supports a force of 350 N. We take advantage of this opportunity to integrate it efficiently into the current project.

3 OPERATING MODE

To begin with, it is necessary to present the preparatory positions of the ball, plungers, and housing in order to initiate the assembly process and facilitate the subsequent rotational movement of the nut, which further contributes to the translational motion required for the functioning of the screw jack. This process involves several steps in order to achieve the functional act of the jack :

Step 1. We secure the winding crank to the right plunger, positioning the housing (Fig. 2a) with the left plunger being passive in Step 1. We continue the clockwise pulling motion with an angular value of one radian. Then, we reverse the direction of motion counterclockwise by the same angle (Fig. 2b). The ball is released, passing successively through multiple holes, and we achieve the position shown in Fig. 2a. We repeat this cycle until reaching the required height for lifting the load.

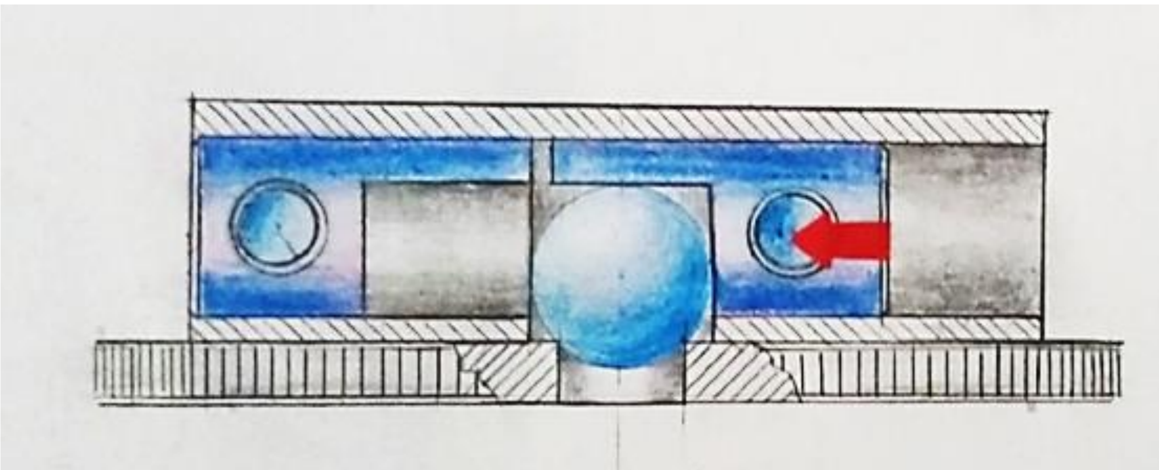

Fig. 2a The winding crank to the right plunger, positioning the housing

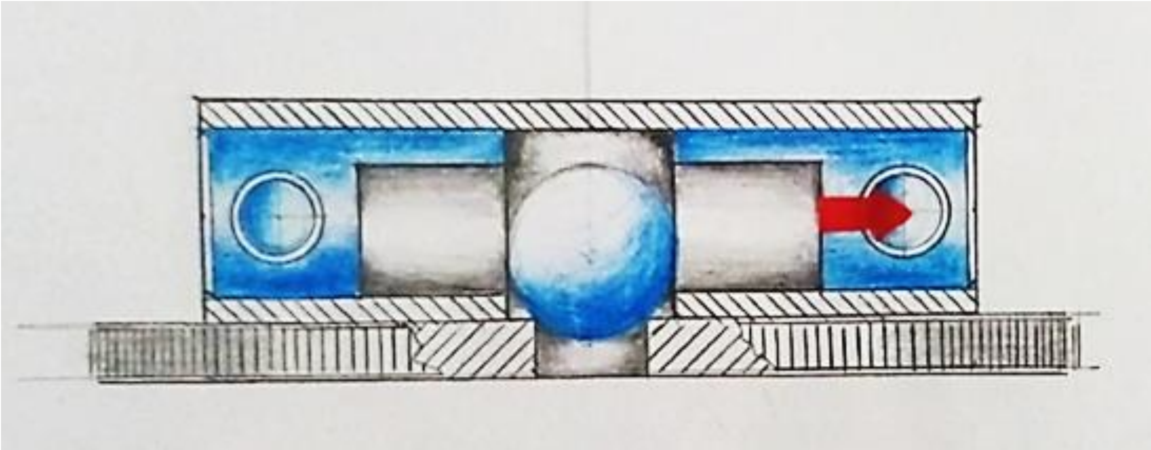

Fig. 2b The reversed direction of motion counterclockwise by the same angle

Step 2. We secure the winding crank to the left plunger, positioning the housing as shown in Fig. 3a, with the right plunger being passive in Step 2. We continue the counterclockwise pushing motion with an angular value of one radian. Then, we reverse the direction of motion clockwise by the same angle Fig.3b. The ball is released, passing through multiple holes, and we achieve the position shown in Fig. 3a again. We repeat this cycle until reaching the required lowering height of the load. We have limited the angle of rotation to one radian to ensure that the operator does not place their hand underneath the load. This safety measure helps to prevent any potential accidents or injuries during the operation.

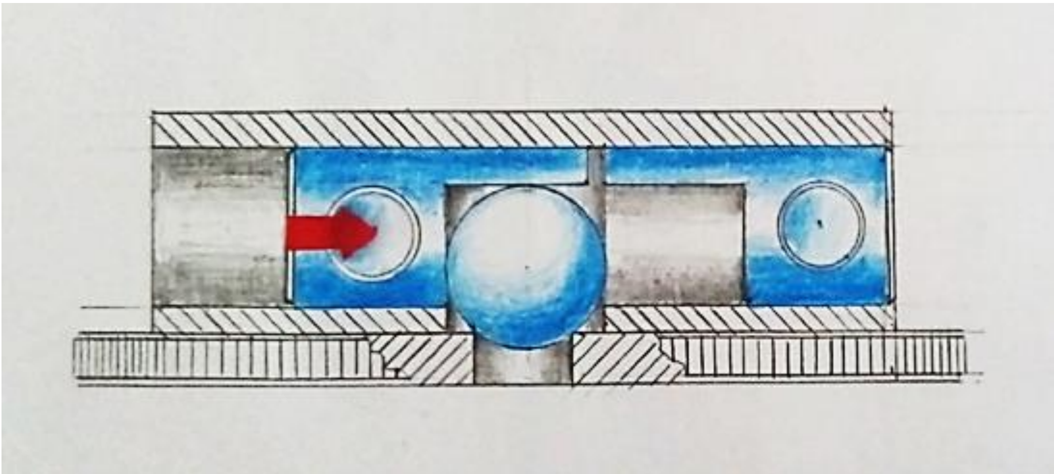

Fig. 3a The winding crank to the left plunger

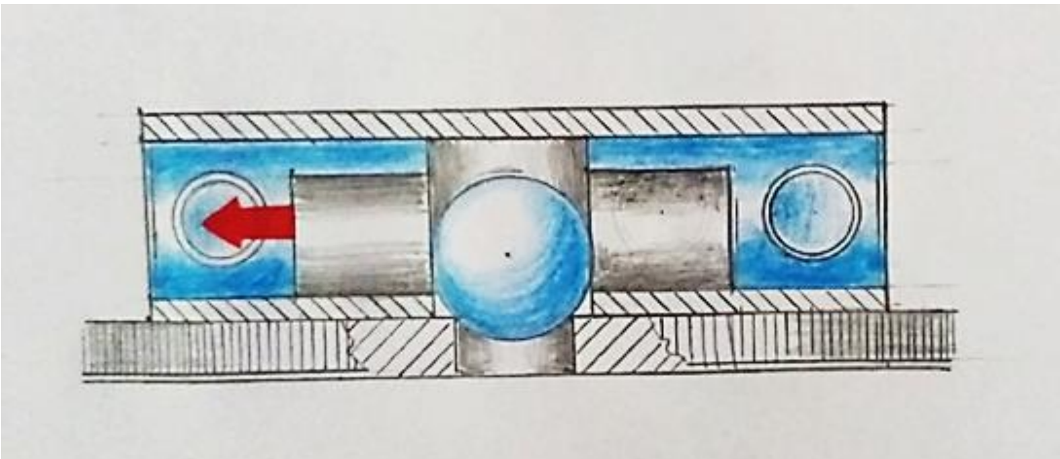

Fig. 3b The reversed direction of motion counterclockwise by the same angle

3.1 The path of the ball during operation

The path of the ball in the second part of Step 1 is presented in Fig. 4 . The same situation applies to Step 2, but the direction of ball movement is reversed. To highlight the path of the ball in the vertical plane, as this is primarily considered in the construction of the ball's allocated space, we will apply the principle of reversing the motion. We will keep the housing fixed and determine the successive positions of the holes in the disc corresponding to the ball's path. This path is equivalent to the height of the ball's spherical cap resulting from the design, plus an additional 0.2 mm to ensure smooth movement and avoid ball jamming. Fig. 5

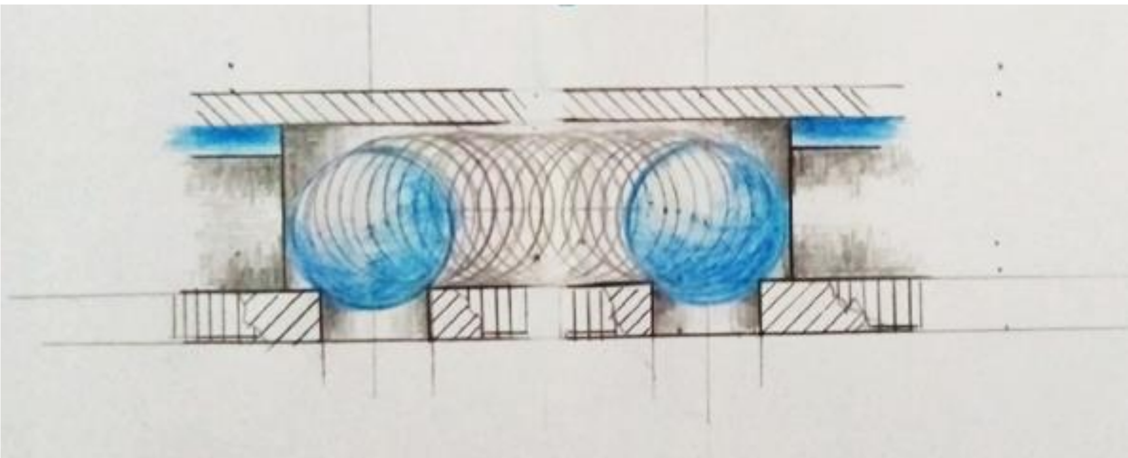

Fig. 4 The path of the ball in the second part of Step 1

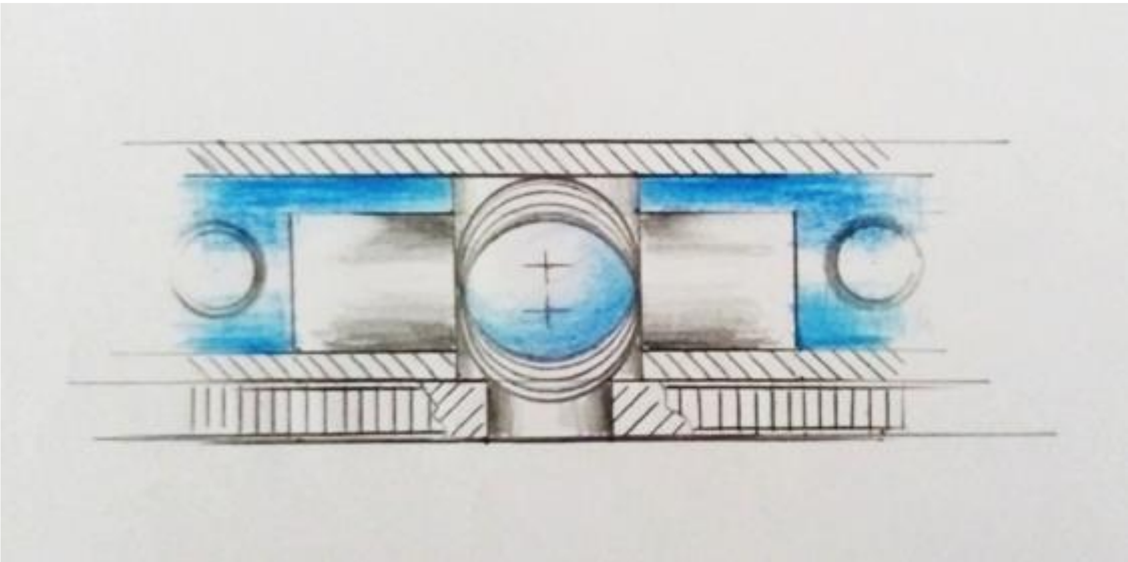

Fig. 5 The same situation applies to Step 2, but the direction of ball movement is reversed

3.2. The mechanical stresses developed within the housing

The stresses developed within the housing of this mechanism are a consequence of the reciprocal action of the components in contact, each with its well-defined role, participating in the functioning of the system through forces, moments, and reactions. In a statically loaded structural element, the internal stress tensor can be decomposed into six components known as stress components. In our study, we encounter multiple forces that result in a composite stress. Therefore, within this actuation mechanism, we encounter a combination of composite stresses. At two points, we have compressive stresses: the contact between the plunger and the ball, and the ball and the upper wall of the housing. Additionally, at the contact point between the ball and the hole in the disc, there is a shearing stress acting on the ball.

In my study, I sought to evaluate the shape and size of the contact area while respecting the boundary conditions introduced by Hertz in a chosen approach that laid the foundation for the research field known as ** Contact Mechanics **. To define the contact surfaces, Hertz generalized the problem by representing them analytically using quadratic functions, with a sphere being a particular case. In the study of these stresses, I applied methods to estimate the variation of sectional stress values by successively applying Navier's formula, isolating the bodies, developing and solving the equilibrium equations, and considering the Hertzian elastic contact in detail. I also exemplified the logarithmic calculations for treating problems in Strength of Materials regarding compressive and shearing stresses due to crushing. Due to space limitations, I presented the results of the strength stresses only through advanced testing and estimation methods using the Solid Works - Simulation software (F=400 N). After the design phase, I subjected the housing subassembly to the aforementioned program to quantify the mechanical stress values generated within the system. By knowing the distribution of stress tensor components, the distribution of Von Mises stresses for the contacting portions was determined. Upon interpreting the results of these virtual experiments, it was concluded that the new system can withstand the applied force without failure. Fig.6.

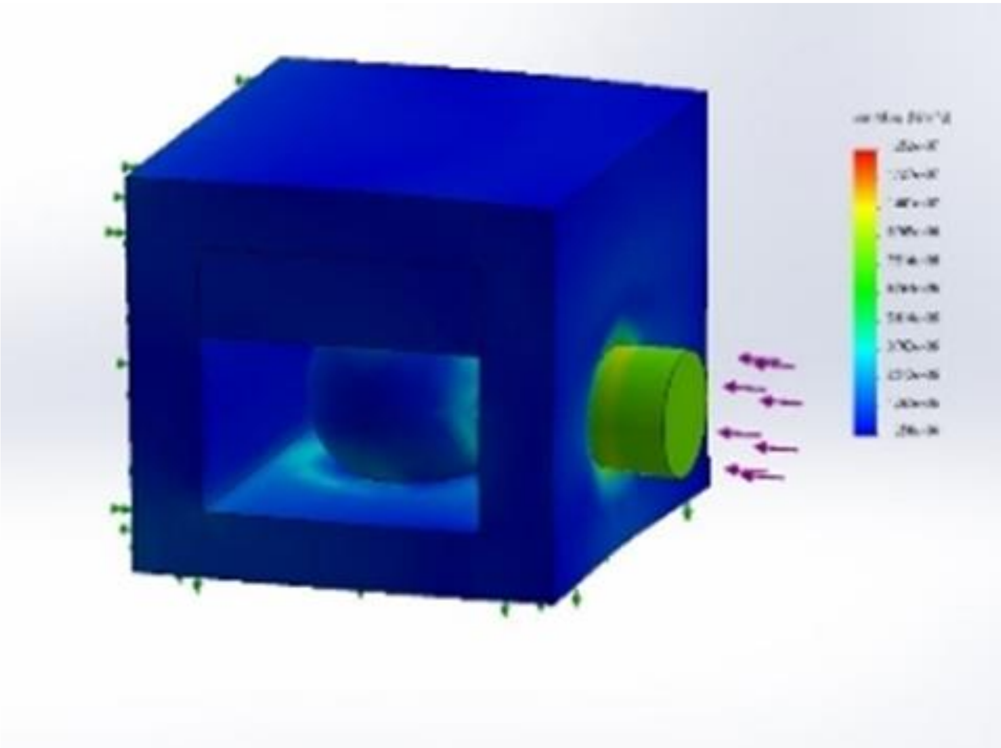

Fig.6 – Solid-Works simulation

4. RESULTS

Through competitive design, we managed to reduce the number of components in the presented actuation mechanism without compromising its intended functions and safety requirements. As a result, we have created an enhanced system that is competitive, highly maneuverable, simple, and safe. By incorporating the metal ball into this system, we have created the possibility of applying higher forces. We have eliminated the components found in previous designs that are prone to premature wear, which would otherwise compromise functionality and safety. With this project, we have achieved smooth and simple operation without the need for extensive instructions for the operator. Moreover, the materials used in the fabrication of this mechanism are common and do not require specific structural or compositional properties.

The new version of this mechanism can easily be adapted to any type of mechanical jack built on the screw-nut rotating principle. Its manufacturing can be done in various sizes without the need for specialized technology, machinery, or stringent dimensional precision requirements.

The central component, the highly stressed ball, undergoes heat treatment and does not fail until the mechanical jack is taken out of service, without any issues arising from its performance. The manufacturing process of the current mechanism is cost-effective. Changing the direction of ascent or descent is quick, efficient, and safe. The assembly process is simple and does not require special tools or devices. The current actuation mechanism is compact in size and lightweight compared to other similar designs.

The novelty of this actuation mechanism lies in its constructive form and its functioning principle, as well as the introduction of a solid geometric body, a *sphere*, which is included and subjected to compound solicitations that encompass compression and shear forces. Additionally, it withstands overloading conditions.

5. CONCLUSION

By incorporating the ball element into the design of this actuation mechanism, several issues encountered in previous versions are addressed. In addition to increasing safety, reliability, and maneuverability, the fear of uncertainty regarding overloading during operation is eliminated.

This central element, *the ball*, takes over all the possible malfunctions of elements in previous designs by replacing them with itself.

The process of arming and subsequent operation takes place at two points of contact, plus a minimal circular surface, compared to a single point of contact in previous designs.

The active components responsible for the safe operation, namely the two plungers, ball, and the disc with holes, are protected compared to similar components in other types of actuation mechanisms that are prone to disruption during arming due to the inadvertent entry of foreign objects into the ratchet's arming area.

This mechanism variant can serve as a model for further studies in this field, with the potential for expanding this idea towards new creative and innovative possibilities.

No negative results have been reported because this design underwent a comprehensive technical and constructive analysis, culminating in testing and evaluation using the *Solid Works - Simulation* program (F=400 N), which coincides with the force applied by the operator's arm and passed without issues.

I am confident that all the works of the past and present, aimed at bringing innovation, can be sources of inspiration and are always enduring. They serve as various reasons for further in-depth research and are never exhausted.

6. REFERENCES

Adams D. - O comparatie a metodelor de testare la forfecare. (2005)

Anghel A. - Rezistenta Materialelor (2001)

Bejan M. - Rezistenta Materialelor (2004)

Boazu D, Talmaciu N, - Teoria contactului partea I (2000)

Cretu S, - The Influence of the corelation Length on Pressure Distribution and Stress State in concentrated Ronght Contacth (2006)

Cretu S, Benghea M, - Analysis of Residual Stresses Impact on Fatigue Life of Rolling Bearing (2007)

Daniel Chaiteiger , - Rezistenta Materialelor (2012)

Ferdinand Pierre Beer, Elwood Russell Johnson, John T. Dewolf – Mechanics of Materials (1992)

Fung Y. C. - A Frist Course in Continuum Mechanics (1997)

Hortsuijker C, Welleman J. W. - Engineering Mechanics (2001)

Jean Perdijan - Materiaux sous surveillance (2021)

Johson KL, - Contact Mechanics Residual Stressand Shakedown in Rolling Contact(1985)

Kalker J.J, - The Dimensional Elastic Bodies in Contact (1990)

Kalker J.J, von Ronder , - A Minimum Principle for Functiolless Elastic Contact with Application to Non-Hertzian Half – space Contact Problems (1972)

Nagi an Kato, - Influence of a Hard Surface Layer on the Limit of Elastic Contact (1997)

Tudor A, - Contactul real al suprafetelor de contact (1990)

Wriggers P, - Computational Contact Mechanics (2002).