COMPUTATIONAL ANALYSIS OF A KNUCKLE JOINTAND IMPLEMENTATION OF THE GENERALIZED REGRESSION NEURAL NETWORK

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ABSTRACT

A Knuckle joint can be used to connect two rods that are under tensile force. This joint permits an angular misalignment between the rods and can support compressive load when it is controlled. The joints are used to make different kinds of connection i.e. tie rods, tension links in bridge structure. In this case, one of the rods has eyes at the rod's ends and the one end is forked with eyes at both legs. Pin (knuckle pin) is put through the rod's end and fork eye and held by a collar as well as split pin. Normally, empirical relationships can be found to determine the various sizes of the joint, and they are secure from a design perspective. The purpose of this paper is to determine the stresses within Knuckle joint using the analytical method. Further studies in this direction is possible by using different ways of contact, as well as the capability to handle loads. This research focuses on the type of meshing that is the best for components. The knuckle joint model is created using CATIA V6 R20. Later the model is loaded into the ANSYS 15.0 and is then implemented in both meshes, which are hexagonal and tetra mesh. A lot of industrial systems utilize knuckle joints, which ismade up of two components which are cast iron and steel. We are proposing modifications of the materials Steel, AL 6061-T6 and Teflon. The structural analysis was conducted for the Knuckle Joint at loads of 100N, 105N and 110N as well as 115N. The most effective combination of parameters such as Von Misses stress and equivalent shear stresses, shear stress, deformation, as well as weight loss for the knuckle joint was determined using ANSYS software. Teflon offers more factors of security, it is lighter and stiffness, as well as reduce stress, and is more rigid than other materials. Based on the findings, the machine learning method i.e. the neural network program that studies deformation, shear stress and von-Miss stresses, widely called Generalized Regression Neural Network (GRNN) was developed. The process involves defining specific variables for input (Different Materials and Loads) as well as output parameters which have been pre-defined and are readily available (Shear Stress, Von-Mises stresses and deformation)

Keywords: GRNN, Knuckle Joint, Von-Mises Stresses, Machine Learning, Shear Stress

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INTRODUCTION

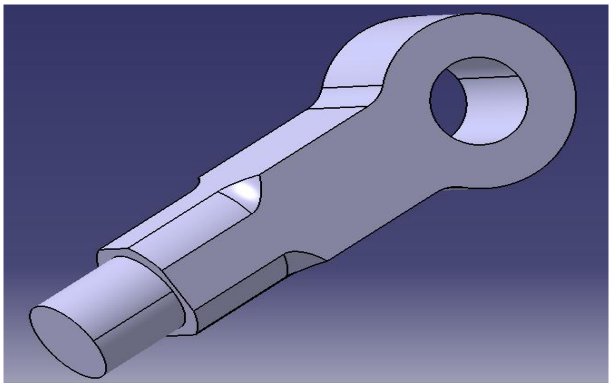
A knuckle joint can be described as a mechanical connection designed to join two rods that are under the pressure of a tension load. This is in situations where a need of a minimal quantity in flexibility or angular force is required. There is always an axial as well as a linear line motion of the load.

Parts of a Knuckle Joint:

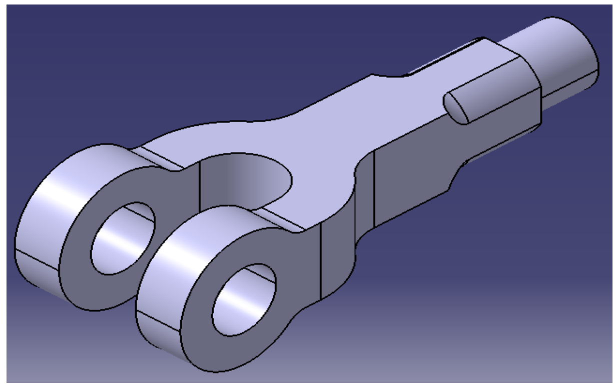
A typical knuckle joint has the following parts:

1. Fork end
2. Eye end
3. Knuckle pin
4. Collar
5. Taper pin

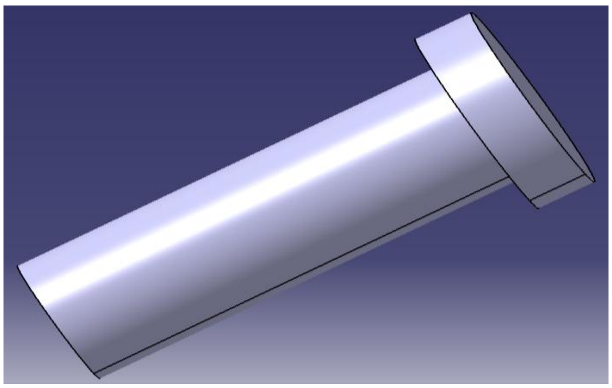
The steering knuckle in your car is an assembly which lets the steering arm rotate forward on both wheels. The forces that are exerted by the joint are cyclic in nature, as the steering arm rotates in order to steer the vehicle the left or right and back to the center again. The steering knuckles are available in a variety of sizes and shapes. The designs of their knuckles vary to accommodate every kind of application and suspension styles. But they can be separated into two main varieties. The first is equipped with a hub, while the other has a spindle. In this research, the steering knuckle was utilized as a element for research. The reduction in weight or mass is a major issue in automobile manufacturing. Weight reduction will have a huge benefit to fuel efficiency and efforts to cut emissions, and, consequently, help save the environment. The weight can be reduced by various technological advancements like advancements in materials analysis and design manufacturing processes, optimization methods, etc. Steering Knuckle is exposed to varying load times throughout its lifespan, leading to failure due to fatigue. So, the design of it is a crucial aspect of the development process. Automobile makers are constantly developing new vehicles that are more luxuriousefficient, comfort, and security. They often reduce the weights of vehicles, which leads to lower energy consumption. A decrease in the weight of suspension parts also enhances the handling of the vehicle. Sangamesh B. Herakal et.al. [1] In their research paper, they looked at the stresses in the Knuckle joint by using an analytical technique. Further study in this area can be done by using different ways of the pin as well as the capacity to handle loads. The current research focuses on what type of meshing is best for the components. Sanjay Yadav et.al. [2]. Their research papers performed static analysis of the steering knuckle part. The development of Steering Knuckle components is carried out by using Computer Aided Engineering (CAE). Mahesh P. Sharma et.al. [3] In their research they conducted static analysis of the steering knuckle. We've developed an knuckle that can accommodate dual caliper mountings that increase brake efficiency and decrease the stopping distance of a car. The CAD model of the knuckle was developed in CREO2.0. Static analysis was performed using the ANSYS WORKBENCH by limiting the knuckle and applying brake torque loads on the caliper mount and longitudinal reaction caused by traction, and vertical reaction due to weight of the vehicle and the steering reaction. AMEYA BHUSARI et.al. [4] in their study paper, they have redesigned the steering knuckle to decrease the weight of a single-seat All Terrain Vehicle (ATV) and still maintain a safe aspect to enhance the quality of performance for the automobile. Two steps have been implemented for this. The first step is to model the knuckle in accordance with the structural requirements and design limitations set by suspension and steering assemblies and determining the load that are imposed upon the knuckle. The next process is stress analysis with finite element software, and then design adjustments to reduce weight without compromising the strength of the structure. Purushottam Dumbre et.al. [5] in their study paper, they reduced the weight of the vehicle by adding additional luxurious and security features. The increased weight of the vehicle impacts the efficiency of fuel as well as the overall efficiency of the car. Thus, the reduction in weight for the car is a crucial necessity of the automotive industry of today. Atul Yadav, et.al. [6] The goal of their study is to reduce the weight of the existing steering knuckle piece of a car model local to you with the help of Creo 2.0 and performing shape optimization by using Hyper works as a pre and post processor as well as Nastran to solve the problem in order to satisfy the strength requirements with the least weight. Nilesha Patil et.al. [7] In their study, they evaluated and calculated the strains in Knuckle joint using the analytical method. Knuckle joints are utilized to join two rods under the tensile load. The joints are used to connect various types of components e.g. tie rods, tension links in bridge structure. S V Dusane et.al. [8] In this study, they examine the steering and suspension system that allows the front wheels to turn , and allow for the suspension arms to move motion. The lightweight and high strength components are frequently required for racing car applications. B.Babu et.al. [9] in this study, they investigate the potential for performance in the development and manufacture of the steering knuckle. This is possible through a thorough load analysis. Thus, this research was conducted using two steps. Gondi Prabhu Charan Teja et.al. [10] in this study, they developed a steering knuckle that is optimized for weight reduction as an objective feature with the necessary strength and stiffness. In the automotive suspension the steering knuckle is that component that contains the wheel hub, also known as a spindle. It is connected to the suspension parts. It's also known as a steering knuckle, spindle upright, or hub as well. P. Ganesh et.al [11] measured the stresses in the Knuckle joint by applying an analytical method. Further research in this direction is possible using different angles of the pin as well as the ability to bear loads. Dinesh Shinde et al. [12] within their paper of research discuss the tractor trailer that is that is used in the field of agriculture to transport heavy items. To connect the trailer to the tractor in a flexing manner, using a knuckle joint that consists of forks as well as pins. One fork is connected to the tractor rigidly while a different fork is joined to the trailer with pin. When the tractor is moving and trailer, the force exerted upon the joint will be tensile while when deceleration occurs, it becomes compressive. Ravindra S. Dharpure et.al. [13] He has investigated the issue of failure of the knuckle pin the railway coupling because of shearing. Based on the function of the knuckle pin , the pin is suited for the retention of the knuckle . No loading requirements are set over it. However, due to the manufactureability of the knuckle the possibility of failure of the knuckle is determined, and thus the potential solution is described within this dissertation. J. Bala Bhaskar Rao et.al [14] proposed that heat transfer rates can be altered in a variety of methods. The idea was to study the heat exchangers by introducing the elliptic double-shaped leaf strips inside the heat exchanger with a double-pipe, and the speed of heat transfer and pressure drop are planned for various angles of inclination . Based on these results, a neural network software was developed to evaluate the thermal performance. It is called"generalized neural network (GRNN). Nishant Vibhav Saxena et.al. [15] In their research paper they developed a modified system. This has resulted in has led to a reduction in accidents and also safety is improved. Numerous systems employed in industries utilize knuckle joints which are made up of two components that are cast iron and stainless steel. This is a modification of one materials, which is changing the cast iron material into a composite material. The system we propose has many benefits over the other methods, such that it makes the system more user-friendly and ensuring maximum security and environmental protection. The system's analysis is a proof of all the features that were mentioned earlier. J. Bala Bhaskar Rao et.al [16] developed the numerical method to alter materials such as Steel, AL 6061-T6 and Teflonand then finding the parameters of the highest principal stress and maximum shear stress. The structural analysis was performed using the Knuckle Joint with loads ranging from 100N to 185N. The most effective combination of parameters, such as deformation, shear stresses and principal stresses of the joint was calculated.



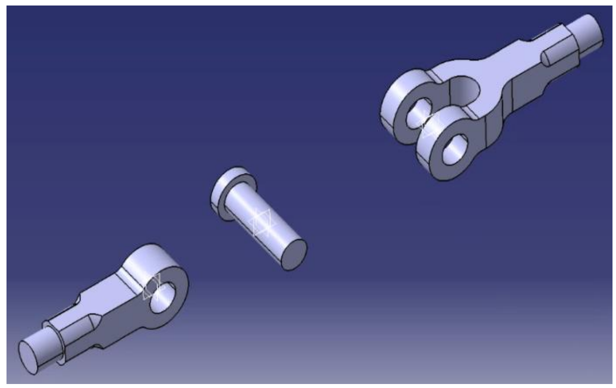
Virtual model of Knuckle eye with hexagonal end



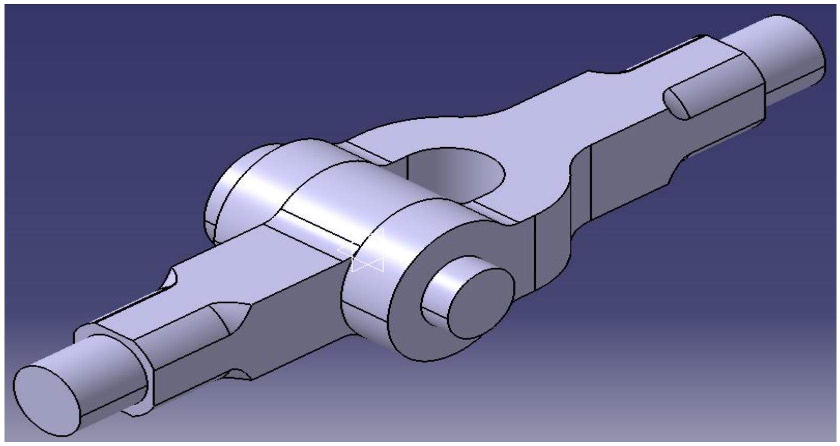
Virtual model of Double eye with hexagonal end



Virtual model of Knuckle joint pin



Virtual model of alignment of Knuckle joint

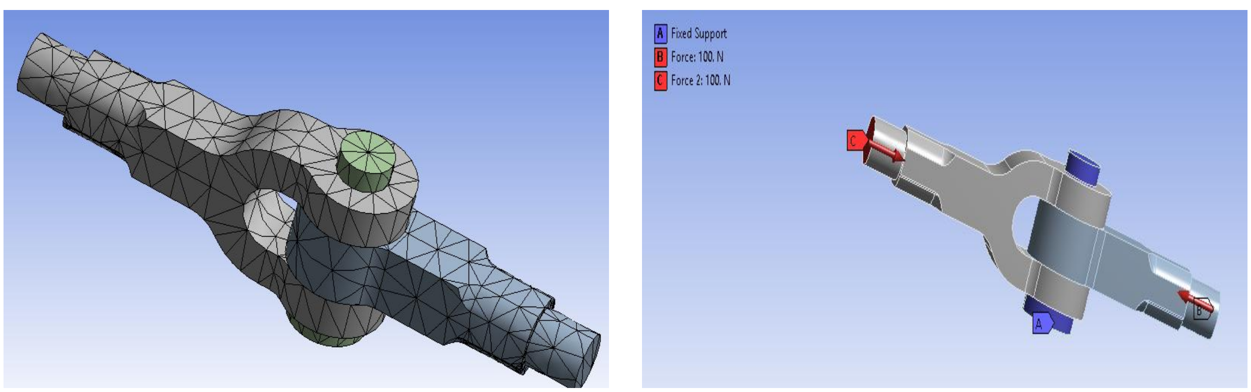


Virtual model of Assembled Knuckle joint

RESULTS AND DISCUSSIONS

The principal goal of this study is to perform an analysis of the structure of the knuckle joint made of different materials under different loads, and to determine the performance of the joint under various forces. In this study, various factors were calculated using the appropriate loads to specific portions of the joint.

The structural analysis was performed using the Knuckle Joint at loads of 100N, 105N and 110N and 115N using three different kinds of metals Stainless Steel, AL 6061-T6 and Teflon and the effects of strain and stress on the joint's knuckle at different loads were studied.



Fine meshed model, boundary conditions and loading conditions of Knuckle joint

STAINLESS STEEL:

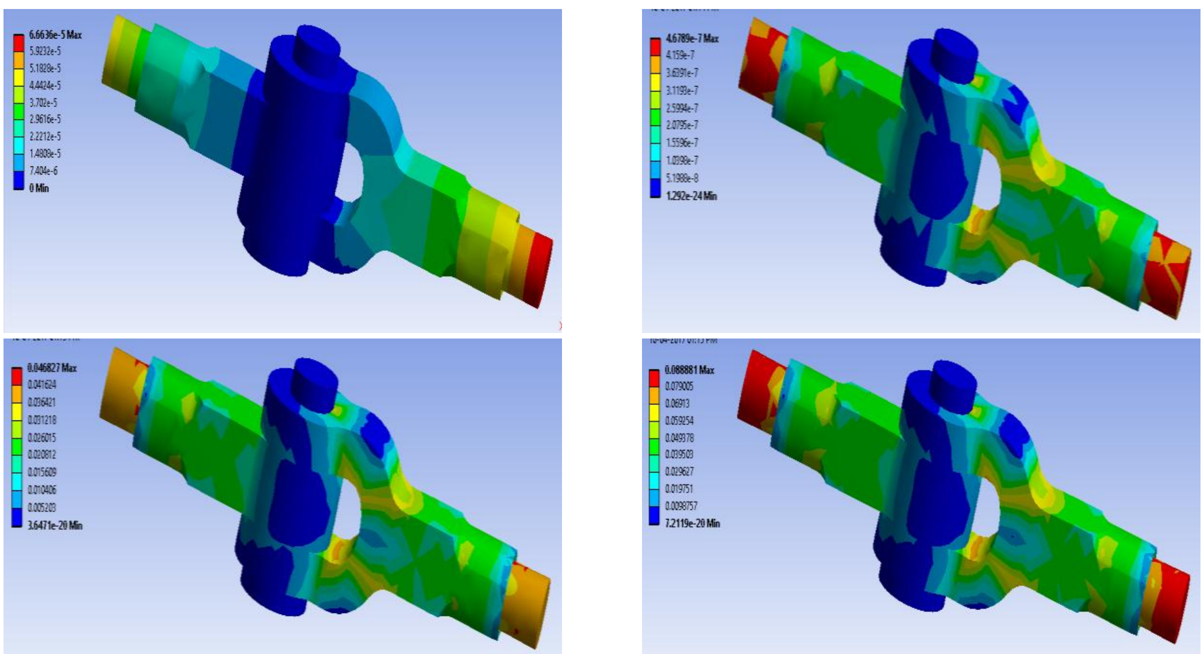
In this instance, the material is stainless steel. The tension applied to the joint of the knuckle is around 100N. The structural analysis is performed to determine the amount of deformation within the knuckle joint. The results are clearly as shown in the image. The analysis above was carried out on every part of the joint knuckle and these results support the similar

In this study, the material as well as the geometries used and the load are the same as in the previous analysis, however in this study we computed equivalent elastic strain in the structural analysis because we are aware that the material selected for this analysis is yield-strengthy and thus elastic strain is calculated . The outcomes of elastic strain are illustrated in the image below.

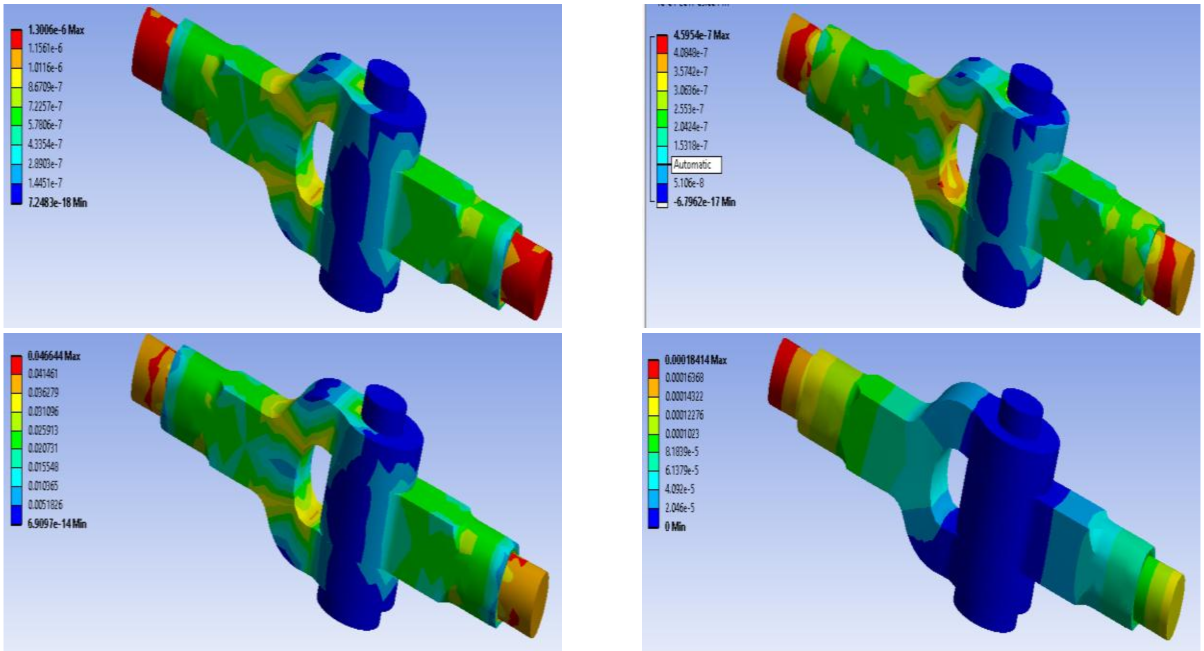
In this analysis, the materials, geometries, and the load are similar to those in the previous analysis. However, in this study we computed maximum principle stress using structural analysis. Upon conducting the structural analysis, we obtained an average principle stress of 0.0301MPa and a minimum stress of -0.0188 MPa, which are clearly illustrated in the image.

This analysis is also the material, the geometries and load are identical to those in the previous analysis however in this study we computed the maximum shear strain in the context of structural analysis. following the structural analysis. We found the maximum shear stress to be around 0.0468 MPa, and a minimal of 0.0252MPa and these are clearly displayed in the image.

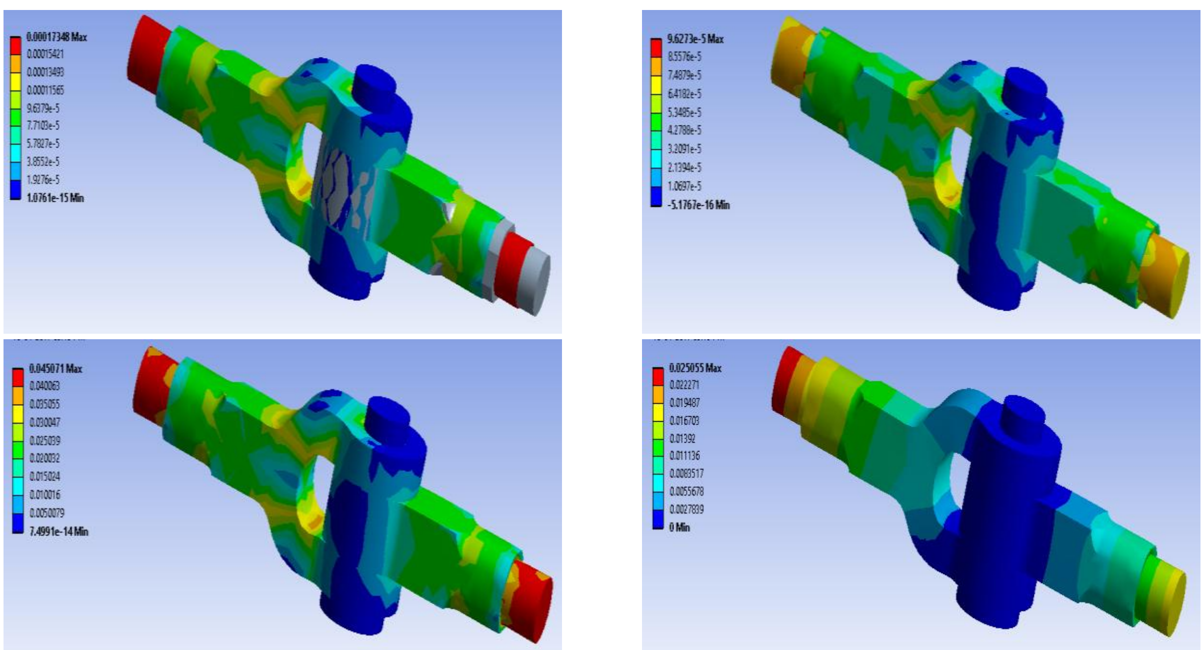
In this analysis, the material as well as the geometries used and the load are the same as those of the previous analysis, however, in this case we computed the equivalent Von-Mises strain in the structural analysis. following the structural analysis we obtained a maximum shear stress of around 0.0888 MPa and a low of 0.009 MPa. These values are clearly displayed in the figure below. The maximum load can be measured at fixed supports.



Deformation, maximum shear stress, Von misses Stress and strain in Knuckle joint for stainless steel at different load conditions



Deformation, maximum shear stress, Von misses Stress and strain in Knuckle joint for AL6016-T6 at different load conditions



Deformation, maximum shear stress, Von misses Stress and strain in Knuckle joint for Teflon at different load conditions

3. GRNN Implementation

The principal function of a probabilistic neural system is that it can generate the unknown purpose of the data with the aid of some existing samples of training. To determine a relation between the parameters studied, GRNN can be used in the research. Initially, 65 experimental datasets are analysed to test the newly developed GRNN tool. The remaining seven experimental datasets are used to evaluate the tool. The model is proposed to estimate output values in relation to input values using the formula (6).

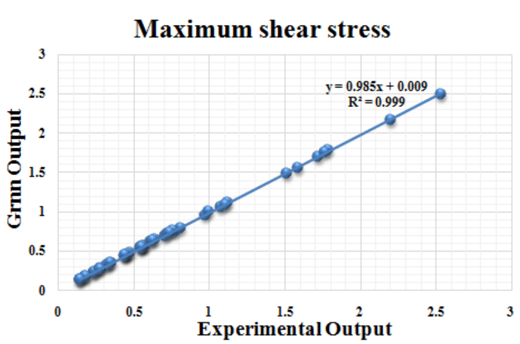
$$\hat{Y}(X) = \frac{\sum_{i=1}^{n} Y^i \exp\left(-\frac{D_i^2}{2\sigma^2}\right)}{\sum_{i=1}^{n} \exp\left(-\frac{D_i^2}{2\sigma^2}\right)} \qquad (6)$$

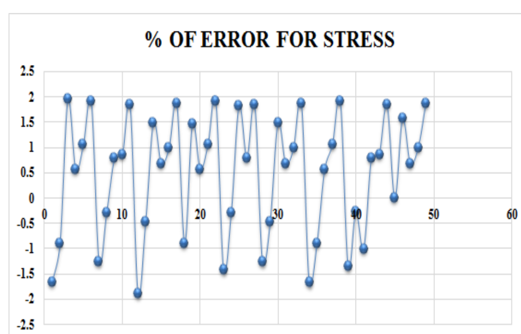
Here (X_i, Y_i) is the i^{th} data set point; $D^2i = (X- Xi)^T (X- Xi)$, and σ = smoothing parameter.

The study has included 72 different types of experimental datasets are studied and the outputs are analysed. The detailed experimental datasets are shown in Table.1

Table.1 Input and output constraints for implementation investigation

Symbolic representation	Input name	Input weight
X1	STAINLESS STEEL	10
	AL6061-T6	20
	TEFFLON	30
X2	LOADS	100N, 105N, 110N and 115N
Outputs		
Symbolic representation	Output name	Output weight
Y1	Deformation	As per experimentation
Y2	maximum shear stress	As per experimentation
Y3	Von misses Stress	As per experimentation





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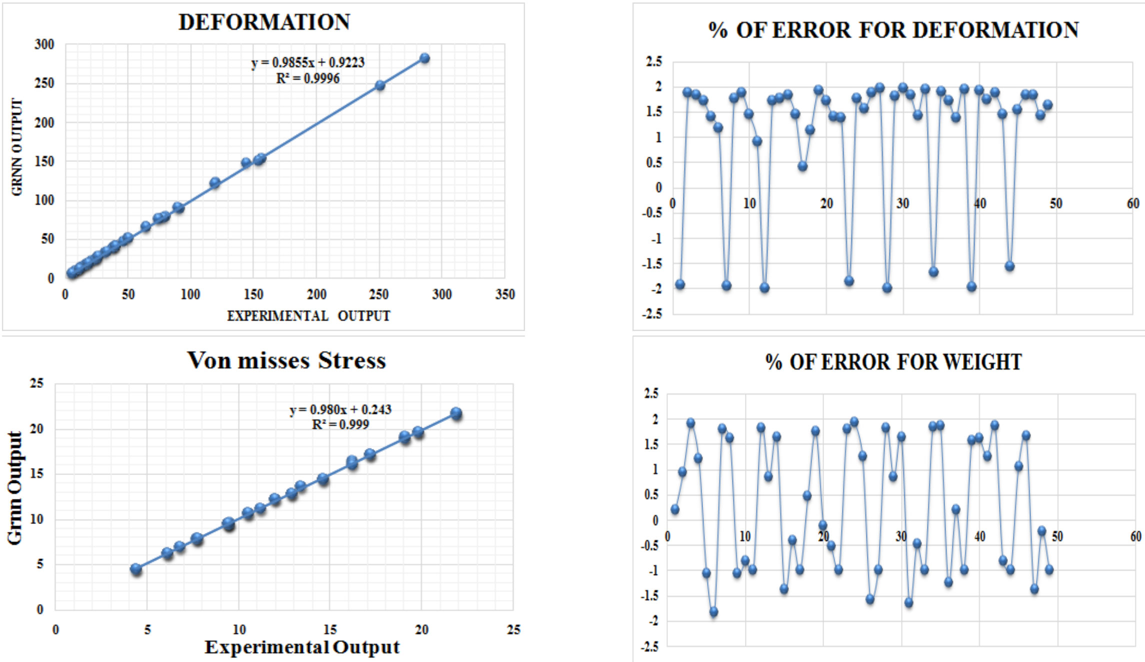
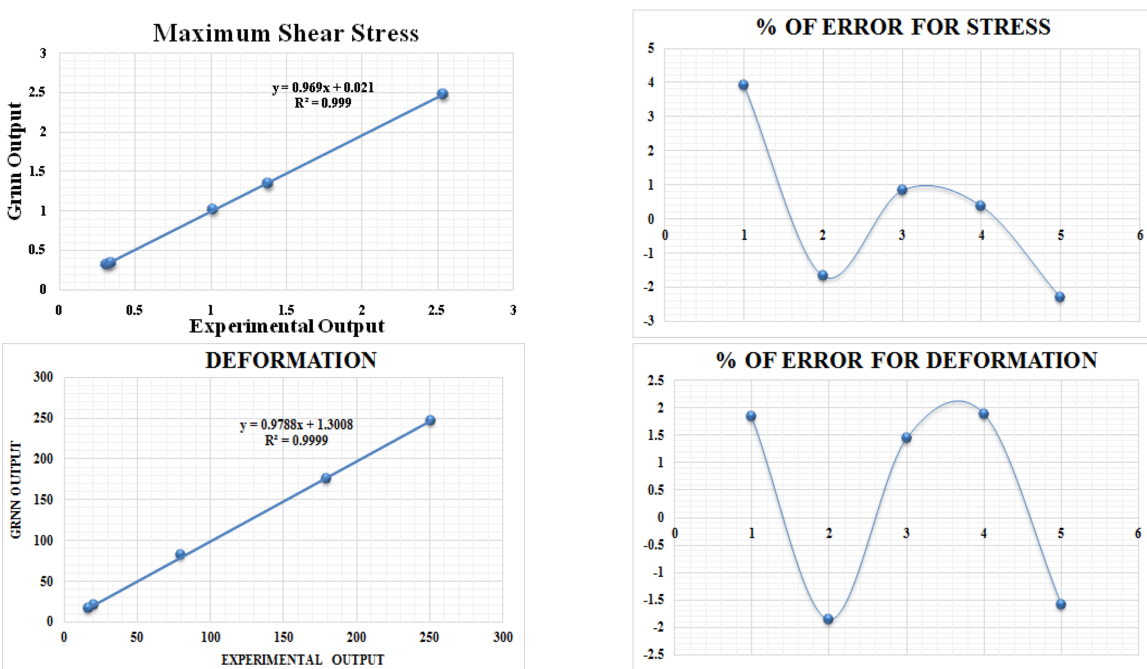
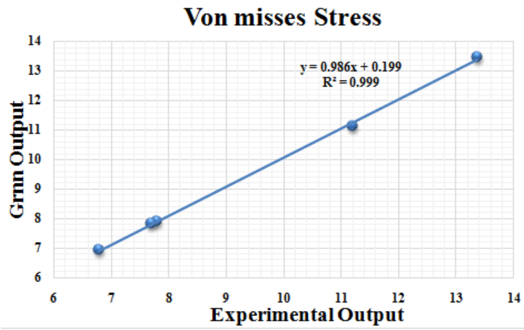
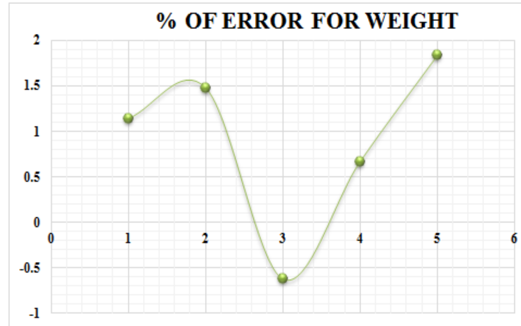


Variation of GRNN output values with respect to actual experimental results for trainee datasets and also percentage of error







Variation of GRNN output values with respect to actual experimental results for tested datasets and also percentage of error

Prior to processing the GRNN parameters, the scale factor and standard deviation that each input parameter has to be determined. Fig.4 illustrates the variations between GRNN output values compared to the output values of the experiments for the test and trainee datasets. The designed GRNN tool is much more accurate in estimating output values, with a +3-percentage error. The primary goal of the model proposed is to determine the shear Stresses and the Von-Mises stress for the specified values of input (Different types of materials and loads). The advantage of this work isthat, without performing the experiments , the results of the experiments are predicted for specified input values.

CONCLUSION

A Knuckle joint is used to join two rods with tensile loads. This joint permits an angular deviation of the rods and can also take compressive load if it is controlled. In general, empirical relations are used to identify the various dimensions of the joint, and they are secure from a design perspective. The purpose of this paper is to determine the strains in the Knuckle joint by using analytical techniques.

In this thesis, we conducted structural analysis on the Knuckle Joint at loads of 100N, 105N and 110N and even 115N on three different types of metals Stainless Steel, AL 6061-T6 and Teflon and the effect of different combinations of parameters such as Von misses Stress and Equivalent shear stress, deformation Shear stress and strain on the knuckle joint under various loads were examined.Through the study the study, it was discovered that Teflon is more efficient than the other two materials. Teflon is superior in terms of security, reduces weight, improvesstiffness and reduces stress and is more rigid than other materials.

With the help of GRNN numerous results can be achieved using just the sources of information. By utilizing the results of trial and error, the possibility of establishing a nonlinear connection between the sources of data and the results was later evaluated. GRNN was utilized to establish the relationship between the data and the resulting parameters. The use of GRNN led to superior and faster results with errors that were less than 1. This paper could be used to study the connections between different types of loads , results, and data sources that will be the focus of a study to come. In the end the GRNN tool could be extremely useful in the search for different results from a variety of applications that are in development.

References

[1] Sangamesh B. Herakal, Ranganath Avadhani, Dr.S.Chakradhar Goud, "Structural Static

Analysis of Knuckle Joint", International Journal of Engineering Research and General Science Volume 4, Issue 2, March-April, 2016 ISSN 2091-2730.

[2] Sanjay Yadav, Ravi Kumar Mishra, Varish Ansari, Shyam Bihari Lal, "Design and analysis of steering knuckle component", International Journal of Engineering Research & Technology (IJERT)ISSN: 2278-0181.

[3] Mahesh P. Sharma, Denish S. Mevawala, Harsh Joshi, Devendra A. Patel, "Static analysis of steering knuckle and its shape optimization", IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE) e-ISSN: 2278-1684, p-ISSN: 2320-334X.

[4]Ameya Bhusari, Aditya Chavan, Sushrut, "FEA &Optimisation of Steering Knuckle of ATV", Proceedings of 54th IRF International Conference, 8th May, 2016, Pune, India, ISBN: 978-93-86083-10-4.

[5]Purushottam Dumbre, Prof A.K.Mishra, V.S.Aher, Swapnil S. Kulkarni, "Structural Analysis Of Steering Knuckle For Weight Reduction", International Journal of Advanced Engineering Research and Studies E-ISSN2249–8974.

[6] Atul Yadav, Scholar, "Optimization and fatigue analysis of steering knuckle", International Engineering Research Journal Page No 1041-1045.

[7] Nilesha Patil, Mrs. Sayli M.Sable, Mr. Kashinath Munde, "Static Structural Analysis Of Knuckle Joint",International journal of advanced technology in engineering and science, Volume No.4 ,Issue No.12 .

[8]S V Dusane, M K Dipke and M A Kumbhalkar, "Analysis of Steering Knuckle of All Terrain Vehicles (ATV) Using Finite Element Analysis" IOP Conf. Series: Materials Science and Engineering 149 (2016) 012133.

[9] B.Babu, M. Prabhu, P.Dharmaraj, R.Sampath, "Stress Analysis On Steering Knuckle Of The Automobile Steering System", IJRET: International Journal of Research in Engineering and Technology eISSN: 2319-1163 | pISSN: 2321-7308.

[10] Gondi PrabhuCharan Teja, K.V.P.P.Chandu, Ch. Rama Krishna, K. Yasoda Sreeram, "WEIGHT OPTIMIZATION OF STEERING KNUCKLE JOINT USING FEA", International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395 -0056

[11] P.Ganesh, J.Bala Bhaskara Rao, Structural and Static Analysis of Knucklejoint, International Journal & Magazine of Engineering, Technology,Management and Research, ISSN: 2348-4845 Vol-4 , Issue No-5, May 2017.[ESJI]

[12] Dinesh Shinde and Kanak Kalita, "FE Analysis of Knuckle Joint Pin Usedin Tractor Trailer", ARPN Journal of Engineering and Applied Sciences, VOL. 10, NO. 5, MARCH 2015 ISSN 1819-6608.

[13] Ravindra S. Dharpure,Prof D. M. Mate, " Study and Analysis of Pin of Knuckle Joint in Train", JETIR (ISSN-2349-5162) , Volume 1 Issue 3.

[14] J. Bala Bhaskara Rao, Implementation of A Neural Network Tool ForEvaluation Of Thermal Performance in a Heat Exchanger By Using DoubleElliptical Leaf Angle Strips With Same Orientation And Same Direction,International

Journal of Engineering and advanced technology,Volume-8,Issue-6, ISSN 2249-8958, August 2019.

[15] Nishant Vibhav Saxena and Dr. Rohit Rajvaidya, “Study & Analysis of Knuckle Joint with the Replacement of Material by Using Teflon”,Nishant Vibhav Saxena Int. Journal of Engineering Research and Applications ISSN : 2248-9622, Vol. 5, Issue 3, (Part -4) March 2015.

[16] J. Bala Bhaskara Rao, Evaluation of Knuckle Joint Performance with AlteredMaterials by Executing a Smart Prediction Tool, International Journal ofAdvanced Science and Technology Vol. 29, No. 5, (2020), pp. 6166 - 6173.