Review of Some Recent Innovations for Structural Performance Improvement of Cotter joint

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Abstract- **In this review paper, we have studied various recent research articles of different authors for finding out the parameters, variables and factors which affects the structural performance of cotter joint which used to support various rotating and stationary shafts. Cotter joint is frequently used in providing base for shafts which are continuously rotating and have a large length. It suffers various forces and stresses in the condition of loading. Minimizing these stresses is of very much importance and we find out the variables and factors such as material of construction, optimization methods, stress concentration, geometrical dimensions and mechanical construction, finite element analysis meshing methods, weight reduction and life cycle. These are the parameters which can be optimized for getting better results of structural performance enhancement.**

INTRODUCTION

A cotter is a flat wedge shaped piece of rectangular cross-section and its width is tapered (Either on one side or both sides) from one end to another for an easy adjustment. The taper varies from 1 in 48 to 1 in 24 and it may be increased up to 1 in 8, if a locking device is provided. The locking device may be a taper pin or a set screw used on the lower end of the cotter. The cotter is usually made of mild steel or wrought iron. [1]

A cotter joint is a temporary fastening and is used to connect rigidly two co-axial rods or bars which are subjected to axial tensile or compressive forces. It is usually used in connecting a piston rod to the cross-head of a reciprocating steam engine, A piston rod and its extension as a tail or pump rod, Strap end of connecting rod etc.

Cotter Joint has mainly three components – spigot, socket and cotter as shown in Figure 1.2. Spigot is formed on one of the rods and socket is formed on the other. The socket and the spigot are provided with a narrow rectangular slot. The cotter is tightly fitted in this slot. Spigot fits inside the socket and the cotter is passed through both the socket and the spigot. A cotter is a wedge shaped piece made of a steel plate. It has uniform thickness and the width dimension is given a slight taper. [2]

FACTORS AFFECTING PERFORMANCE OF COTTER JOINT

After studying various research articles of different authors we have found out these parameters and factors which can be further optimized for improving the structural strength of cotter joint.

1. Material of Construction

Studied and calculated the stresses in Cotter joint using analytical method. In this study, modeling and analysis of a cotter joint was performed by using Finite Element Method. The commercial finite element package ANSYS version 17 was used for the solution of the problem. The modeling of the cotter joint was done using 3D software. Here CATIA V5 has been used for modeling. The simulation part was carried out using the Analysis software, ANSYS. With the Boundary constrains and the tensile load applied, the cotter joint is analyzed and the values are tabulated. They used structural steel as the new material instead of white cast iron and grey cast iron. They found this replacement effective in terms of von mises stresses [1]. Studied in this project for stresses calculation on the cotter joint and to improve the performance of cotter joint to a certain extent with CATIA V5 and FEM. After study of cotter joint used in supporting shaft and analysis on cotter joint they concluded that material plays a very important role in stress reduction acting on cotter joint especially on shaft and braces. They changed material like grey cast iron (ASTM grade 20 (EN-JL 1020), ASTM grade 35 (EN-JL1040), ASTM grade 60 (EN-JL 1070)), Stainless steel and Titanium alloy and found that deviations in Equivalent stress (von mises), shear stress and total deformation occurs at same load and diameter in which it has maximum stresses. They concluded that increase in cotter joint shaft diameter can lead to protect bending of joint [2]. Studied for cotter joint made of stainless steel, gray cast iron magnesium, aluminum, stainless steel, structural steel and gray cast iron. They analyzed for stress and deformation under different loading conditions. The CAD model of cotter joint was made in CATIA V5 R20 and analyzed in ANSYS 15. It was observed that stresses developed for cotter joint made of magnesium were least and the cotter joint made of aluminum can sustain maximum tensile load without failure [3]. analyzed the E Glass and S2 Glass epoxy composite. Structural and Fatigue analysis were done using Cosmos. By observing the structural analysis results, the stress and displacement values were less than their respective strength values. They concluded that using composite materials is safe for serial cotter joint shaftned joints. Damage factor was very less for both materials and life was about 106 cycles [4]. Studied on design and analysis of a cotter joint which is used in supporting shafts. Cotter joint was design for 50KN axial load by theoretical calculation. Final dimensions from theoretical calculation, model of Cotter joint was made in CATIA V5 and model was taken to ANSYS and simulated with various material and check for best material which suit for given design load. it was concluded that Teflon was best for design and it was close to stress got for stainless steel and cast iron. [5]. Studied and changed the existing material made of GCD45 to Al6082M and recommended the lightweight design of the cotter joint. Six shape design variables were selected for the optimization of the cotter joint and the criteria relevant to stiffness and durability were considered as the design requirements during the optimization process. The meta model-based optimization method that uses the kriging interpolation method as the optimization technique was applied. The result shows that all constraints for stiffness and durability are satisfied using A16082M, while reducing the weight of the cotter joint by 20% compared to that of the existing GCD450.[6]

2. Optimization Methods

Studied and calculated the stresses in Cotter joint and optimized the model of Cotter joint for its weight reduction. Modeling of the cotter joint was done using 3D software. Here CATIA V5 had been used for modeling. The simulation part was carried out using the Analysis software, ANSYS. With the Boundary constrains and the twisting moment applied, the cotter joint was analyzed. Then using Topology optimization material was removed. Again, analysis was done on an optimized model for stresses and deformation and optimized values. The maximum stress and deformation values were in the acceptable limits[7]. Have done static analysis of cotter joint. They designed a cotter joint which accommodates dual caliper mountings for increasing braking efficiency & reducing a stopcotter joint shaftg distance of a vehicle. CAD modal of cotter joint was prepared in CREO2.0. Static analysis was done in ANSYS WORKBENCH by constraining the cotter joint, applying loads of braking torque on caliper mounting, longitudinal reaction due to traction, vertical reaction due to vehicle weight and steering reaction. They have also done shape optimization of same cotter joint and saved material resource. Shape optimization of cotter joint was done using ANSYS WORKBENCH making objective function as reducing weight. Shape optimization method used in this study reduced the mass of cotter joint by 19.35%. Also factory of safety is between 3 to 4. Maximum stress and displacement were within control. They concluded that the overall weight of the cotter joint can be reduced to achieve savings in costs and materials [8]. Studied and calculated the stresses and deformation in Cotter joint of a vehicle and optimized the model of same Cotter joint. They used CATIA V5 for modeling. They aimed to use FEA and Taguchi method to improve the quality of manufactured goods and engineering development of design for studying variation. Taguchi recommends the use of the S/N ratio to measure the quality characteristics deviating from the desired values analysis. Regardless of the category of the quality characteristic, a greater S/N ratio corresponds to better quality characteristics. It was predicted that Taguchi method is a good method for optimization of various machining parameters as it reduces the number of experiments. Stress, strain and deformation were within acceptable limits [9].

Studied the problem of the failure of the cotter joint in any mechanism for general due to crushing, tearing and shearing. The aim of the present paper was to study calculate the stresses in Cotter joint using analytical method. The study focused on the optimization of design parameters kept in mind for the cotter joint. The Neural Network Tool, a nontraditional global optimization technique had been used as the solution methodology for its inherent advantages. Optimal results so obtained were compared with remodeled cotter joint cotter joint shaft with stress minimizing effect considered as a key factor. After remodeling of the cotter joint using the predicted optimized parameters obtained by neural network the model was used to generate the value of stress which was compared with the neural network result in order to prove that optimized model is better as compared to the previously selected four models. [10]

3. Stress Concentration

Studied the Cotter joint which is a major component of supporting rods between each other. It experiences maximum shear and tensile stresses due to heavy weight. The FEA Analysis of Cotter joint was done and various shear and tensile stresses results were plotted. The Analytical solution of cotter joint was found out using standard calculations. The force applied cotter joint was 50 KN .The diameter of shaft was proposed to be around 30 mm. FEA software results were correct as per theoretical calculations. it was also concluded that certain high stresses were generated near cotter joints and this result were helpful for further reducing the stresses, increasing life and reliability of machine part.[11]. Studied stresses on loading shafts during acceleration (tensile) and during deceleration (compressive). Forces acting over the shaft were calculated by considering Newton's Second Law of motion. Shaft was considered separately for the analysis and finite element analysis is done on it. They concluded that Numerical value of tangential force and von mises stresses acting on the cotter joint were maximum in case of deceleration [12]. Conducted static structural analysis on a universal coupling using advanced computer aided engineering software and study the various stresses and strains developed in the joint. Results concluded that the shaft experiences the maximum shear stresses and strains as referenced earlier. Also stated that region where the shaft makes contact experiences generally higher compressive stress and bending stresses. Also analyzed that stress concentration in the shaft due to the presence of notch that leads to frequent wearing out of the shaft which causes the shaft to wobble unnecessarily which reduces the mechanical efficiency of the transmission system. This leads to failure of the transmission system [13].

4. Geometrical dimensions and mechanical construction

Have done modeling and analysis of cotter joint under a certain conditions. Modeling and analysis of a cotter joint was performed by using 3D software CATIA & Finite Element Analysis (FEA) respectively. The commercial finite element package ANSYS version 15 was used for the solution of problem. They concluded that 30C8 material having maximum permissible stress are 400MPa and Maximum stresses developed in cotter joint are 201MPa. So design is safe. They also concluded that shaft of 25 mm diameter can sustain load of 50 KN without a failure [14].analyzed cotter joint stresses during its operation. Force acting on the shaft were calculated by the theoretical study and analytical method. Subjected to high stresses in shaft were studied by using CATIA V5 and finite element method. According to their theoretical study, calculation and F.E.A results were similar on 50 mm diameter at 60 KN. They concluded that when stress on shaft increases, bending increases but when we increase the shaft diameter it will wear maximum stress on that force [15]. Reviewed the problem of the failure of the cotter joint cotter joint shaft in a railway coupling due to shearing as per the defined conditions and analysis the present steel material can be substituted with a proper elastic material. The presently for the problem of shear failure of the cotter joint shaft alternatively plastic cotter joint cotter joint shaft that will accept bending fatigue, thereby reducing cotter joint shaft failure can be used. The cotter joint shaft made of a plastic material having a flexibility that will allow it to bend and return to its original shape and to also be self- lubricating. Further, the cotter joint shaft eliminates rust and corrosion and produces a low coefficient of friction between the cotter joint shaft and the coupler body and cotter joint, thus enhancing opening and closing of the cotter joint by reducing rotational resistance, thereby promoting safety. It has been known that steel cotter joint shafts, either at the time of installation or after service, can cause a “lazy cotter joint”, i.e., a cotter joint that will not open all the way on decoupling [16]. Studied for calculating the stresses in Cotter joint using analytical method. Material of the cotter joint is considered as mild steel grade 30C8, ANSYS software was run and the stress contour, displacement contour, strain energy contour were obtained. It was proposed that instead of mild steel cotter joint shaft we can also use high strength high modulus steel cotter joint shaft that can further enhance the capacity to withstand higher loads. The shape of the cotter joint can be changed for improved properties. Further study in this direction can made by using various directions of the cotter joint shaft and the capacity to withstand load [17].

5. Finite element analysis meshing method

Studied to calculate the stresses in Cotter joint using analytical method. They concentrated on which type of meshing is preferable for components. cotter joint was modeled by making use of CATIA, later on that model was imported in HYPERMESH and carried out both mesh those were hexahedral and tetra mesh. The model was solved by using Abacus software. They concluded that shaft takes higher stress and braces takes less stress under loading condition. They showed that hex mesh is better than the tetra mesh. They also concluded that further study in this direction can made by using various directions of the cotter joint shaft and the capacity to withstand load [18]

6. Weight reduction and life cycle

Have done finite element analysis of the universal joint to find the stress and displacement. For modeling of the component PRO-E software was used. Pre-processing work like meshing and analysis work was carried out in HYPERWORKS software. The geometry was modified using topology and free size optimization which enabled to reduce stress level marginally well below the yield limit. They got a percent mass reduction of about 7%. The developed stresses for this model were within the acceptable limits which showed the safety of model [19]. Focused on optimization of cotter joint targeting reducing weight as objective function with required strength, frequency and stiffness. They used optimization which refers to different cases in the shape optimization and also the topology optimization. The modeling of this project was done in CREO Parametric 2.0 and the analysis is carried out in ANSYS 15.0. The optimization of results was achieved i.e. less stress value and also less weight. The model was analyzed with Cast Iron, Aluminum alloy and S- Glass Epoxy composite. There was a significant amount of weight reduction when they used S-Glass Epoxy material [20]. proposed the modification of one of the material that changed cast iron by a composite polymer material. The proposed system had many advantages over other system such as making the device, simpler and having maximum safety and is eco friendly. Composite polymers are characterized by a high flexibility material. They used ANSYS 13 used for analysis of cotter joint with modified material and varying loads. They concluded that parts made out of composite materials are economical to produce, and facilitate overall systems cost reductions by eliminating secondary operations for parts, such as machining, as well as facilitating reduction in part count when compared with metal parts [21]. Analyzed advanced materials focusing on a mechanical joint, i.e. the Cotter joint. They suggested a modification over the conventionally used material, such as Aluminum alloy that is widely used for manufacturing the Cotter joints. They used CATIA V5R18 for modeling the 3D geometry of Cotter joint and ANSYS (Workbench 16.2) was used for finite element analysis of the same with the conventional and composites materials respectively. The results approved that the use of composite material not only decreases the weight of the material but it also improves the life of the component as the composite material shows less deformation in comparison to the conventional one. Due to application of composite material there was a negligible change in stress value but directional deformation and weight of the system got reduced by 73.7 % and 22.02% respectively [22].

SUMMARY OF REVIEW

There review papers summarize that following factors and parameters can be used and analyzed to get the improved structural strength of cotter joint.

- material of construction

- optimization methods
- Stress concentration
- geometrical dimensions and mechanical construction
- Finite element analysis meshing methods,
- Weight reduction and life cycle. These are the parameters which can be optimized for getting better results of structural performance enhancement.

CONCLUSION

This review article concludes that is a very important consideration to reduce the stresses, unbalanced forces and deformation in a cotter joint so that the life cycle of the machine parts can be increased. The parameters mentioned above are very much of importance to be optimized to get the higher structural strength of cotter joint which are namely as material of construction, optimization methods, stress concentration, geometrical dimensions and mechanical construction, finite element analysis meshing methods, weight reduction and life cycle.

REFERENCES

[1] Ms. Nilesha Patil, Mrs. Sayli M.Sable and Mr. Kashinath Munde, "Static Structural Analysis of Cotter joint", International Journal of Advanced Technology in Engineering and Science, vol 4, issue 12, december 2016.

[2] Prof. Swati Datey, Amit A. Rangari, Adarsh A. Dongre, Kunal A. Paraskar & Sanket V. Lidbe, "Analysis of Cotter joint used in Mahindra 575 DL", IJARIIE-ISSN(O)-2395-4396, Vol-3 Issue-2 2017.

[3] Nipun Kumar, Dr. Gian Bhushan and Dr. Pankaj Chandna, "Analysis of Cotter joint of Various Materials using CAE Tools", International Journal of Engineering Technology, Management and Applied Sciences, Volume 5, Issue 1, January 2017.

[4] Kodali. Vikas and Kandula. Deepthi, "Analysis of Cotter joint shafted Joints in Composite Materials", International Journal of Computational Engineering Research, Vol, 04, Issue, 10, October– 2014.

[5] Shaik.John Bhasha and Hari Sankar Vanka, "Modeling and Analysis of Cotter joint", International Journal & Magazine of Engineering, Technology, Management and Research, Volume No: 2 (2015), Issue No: 11 (November).

[6] Geun-Yeon Kim, Seung-Ho Han and Kwon-Hee Lee, "Structural Optimization of a Cotter joint with Consideration of Stiffness and Durability Requirements", The Scientific World Journal, 2014.

[7] Ms. Nilesha U. Patil, Mrs. Rupali S. Sewane and Mr. Kashinath H. Munde, "Optimization of Cotter joint by using FEA", International Conference on Ideas, Impact and Innovation in Mechanical Engineering), Volume: 5 Issue: 6, 2017.

[8] Mahesh P. Sharma, Denish S. Mevawala, Harsh Joshi and Devendra A. Patel, " Static Analysis of Cotter joint and Its Shape Optimization", IOSR Journal of Mechanical and Civil Engineering, PP 34-38, 2014.

[9] Ms.Nilesha U. Patil, Prof.P.L.Deotale, Prof. S.P.Chaphalkar, A.M.Kamble & Ms.K.M.Dalvi5, " Application Of Taguchi Method For Optimization Of Cotter joint" International Journal of Recent Trends in Engineering & Research (IJRTER) ,Volume 03, Issue 11; November - 2017 .

[10] Pankaj Dulani and S. A. K. Jilani, "Diameter and Spiral Thickness Optimization of Cotter joint Using Neural Network", International Journal of Science and Research, Volume 5 Issue 2, February 2016.

[11] Miss. Yogini .V. Deore ,Prof. J.R.Mahajan K, Mr. Vinay Patil & Mr. Balasaheb Ugale, " A Static Structural Analysis Of Cotter joint Used For Sugarcane Mill", International Journal Of Advanced Research In Engineering & Management (Ijarem) ,Pp. 10-22, Vol. 03, Issue 04, 2017.

[12] Dinesh Shinde And Kanak Kalita, "FE Analysis Of Cotter joint Cotter joint shaft Used in supporting shafts", ARPN Journal Of Engineering And Applied Sciences, Vol. 10, No. 5, March 2015.

[13] Abhishek Mandal & Utkarsh Sharma, "Static Structural Analysis of Universal Joint to Study the Various Stresses and Strains Developed in Power Transmission Systems", International

Journal of Engineering Research & Technology, Vol. 5 Issue 03, March-2016.

[14] Suraj Yadav, Sanket Benade, Sushil Angchekar, Vaibhav Dhokle and Prof. Rakesh Kolhapure, "Design And Analysis Of Cotter joint By Using FEA",Technical Research Organization India,Volume-4, Issue-6, 2017.

[15] Shankar Majhi & Shaheen Beg Mughal, "Modeling and analysis of cotter joint used in tractor", International Research Journal of Engineering and Technology, Volume: 04 Issue: 07, July -2017.

[16] Ravindra S. Dharpure and Prof D. M. Mate, "Study and Analysis of Cotter joint shaft of Cotter joint in Train power transmission", Journal of Emerging Technologies and Innovative Research, Volume 1 Issue 3.

[17] Sourav Das, Vishvendra Bartaria & Prashant Pandey, "Analysis of Cotter joint of 30C8 Steel For power transmission Application", International Journal Of Engineering Research & Technology, Vol. 3 Issue 1, January – 2014.

[18] Sangamesh B. Herakal, Ranganath Avadhani, Dr.S.Chakradhar Goud, "Structural Static Analysis Of Cotter joint", International Journal Of Engineering Research And General Science, Volume 4, Issue 2, March-April, 2016.

[19] Dhananjay S Kolekar, 2abhay M. Kalje, 3swapnil S Kulkarni, "Design, Development and Structural Analysis of cotter joint", International Journal Of Advanced Engineering Research And Studies, Vol 4, issue 4, July-September, 2015/09-12.

[20] Pilla. Anitha and V. Hari Shankar, "Design And Topology Optimization Of A Cotter joint Using FEA", International Journal of Scientific and Research Publications, Volume 6, Issue 11, November 2016.

[21] Nishant Vibhav Saxena And Dr. Rohit Rajvaidya, "Study & Analysis Of Cotter joint With The Replacement Of Material By Using Teflon", Int. Journal Of Engineering Research And Applications, Vol. 5, Issue 3, (Part -4) March 2015.

[22] Vivek Shaw, Tanuj Srivastava, Rohit Ghosh and Dr. Rabindra Nath Barman," Numerical Simulation Of Cotter joint Using Finite Element Method: A New Approach Based On Composite", International E-Journal For Technology And Research, Volume 1, Issue 5, May 2017.