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Methodology for Correlating Experimental and Finite Element Analysis of a Gear Shift Lever

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Abstract : *The widespread use of finite element models to evaluate the dynamics of the system for structural evaluation has directed to the appreciation of necessity for better procedures to correlate replicas with experimental consequences. This study progresses and relates a procedure to correlate an experimental stress analysis with a FEA of the gear shift lever. A procedure of analysis prior to the test is used to guide the implementation of the tests used in the correlation procedure. Here method advances the effectiveness of the test procedure, ensuring the test item is not under nor too instrumentation done. The test study model that results from the previous test the simulation offers a method to relate the test and the model both throughout the experimental method and during the course of updating the model. The validity of correlation procedure is established over its application.*
Keywords - *Gear Shift Lever, Strain Gage, Creo Parametric Model, Ansys, FEA, Virtual validation*

I. Introduction

The Purpose of this project is to develop a procedure to compare an experimental test procedure with a FEA of Gear shift lever. This procedure will define a process to perform FEA that replicates the results of practical stress test on gear shift lever. The requirement for this comparison between both experimental stress analyses and FEA is important to the authentication of Mathematical model. FEA that possesses the similar strain readings of an actual mechanical model can be contemplate a consistent model and is regularly called a FEA model.

A mathematical model of machine system can be of huge utility in prototype building and modify the design processes. A FEA is effective tool to state diverse problems of structural found in both the design and field test of the machine. For case, many structural problems are due to geometric irregularities; geometric irregularities can cause amplification of regular working forces, consequentially in an improper structural forces. In such instances, a structural alteration should be suggested intended at reducing the strain values that is causing the not expected stress values. With authenticated Mathematical model, substitute modifications can be appropriate and cost-effectively assessed using the computer. The “what if?” method should be have been done many times prior to the hardware changes are employed and lastly tested. A model piston and cylinder were manufactured and set of three calibration were processed out to identify important areas of the piston and cylinder, numerous dimensional quantities of both the piston and cylinder are collected to actual gap profile were processed. The efficient area of the piston and cylinder unit was attained experimentally and dimensionally as well. The validation are done by utilizing Finite element analysis by getting elastic distortion constants. It is almost 3% variance is observed between experimental and finite element analysis method [1]. It is been explained the procedure of evolving mathematical and parametric finite element analysis models for design analytical synthesis of hat stiffened compound panels these design procedures are unnecessarily continual by design engineer and effort been taken to consistent to shorten the design procedure[2].

Speed shift lever is one of the component in manual gearbox equipment’s of vehicle been taken for investigation purpose. The speed shift is component of transmission in which is having speed changing handle further permits the connection after the operator to change gears and it allows it for picking the gear ratio which operator would like to ride and to switch inside or outside.

II. Problem Formulation and Objective

Correlation is procedure of measuring the degree of resemblance and difference between the FEA and experimental stress analysis methods, with better incidence of FEA models previous the primary prototype build, it is now experimentally to use prior test analysis procedures to direct the implementation of experimental tests applied in correlation procedure, This progresses the effectiveness of the test procedure, confirming the test object is not under instrumented or otherwise not over instrumented, Test and finite element analysis model that is the outcome from the prior test analysis delivers a method to relate the test and analytical model through the experimental method and through the model updating procedure. The usage of prior test finite element analysis approaches for preparing the test and assisting the correlation can meaningfully diminish the time needed for model verification. This paper aims at framing criteria for measuring the relationship between test data and finite element results.

III. Finite Element Analysis of Gear Shift Lever

1. CAD Model: The structure taken for investigation study comprises of tube which has outer and inner both, box type structure supporting the tube of outer periphery and tube of inner periphery as well, appropriate fasteners are utilized to fasten the box structure plate along with part of gearbox enclosure and shift knob at top end side of lever outer tube to make comfort for grabbing operator using hand so that he can effortlessly operate. Speed shift lever knob known generally gear lever knob, gear change lever knob else speed shift knob. Classically speed shift gear lever head (knob) comprises a figure of speed changing pattern of the available gear ratio range of gearbox system; that is stances to which speed shift lever should be operated whenever choosing the required ratio of gear. These CAD models are prepared using creo, it is the CAD modelling packages. Figure shown below is the creo parametric CAD model of the speed shift lever.

Fig1: Creo parametric model.

2. Meshing : Finite element analysis is done using Ansys Workbench 14.5.7. Every part of the system assembly is modeled with three dimensional solid elements. Meshing is done in Workbench itself. Shift lever is modeled using quad element as this is the part more interest. All the experimental gauges were placed on this part and all F.E. results will be extracted from the same. This assembly part is modeled with total 13068 no. of quad element. Box plate is modeled using quad as well as tria elements with total 4613 no. of elements. Nut and bolt are modeled using hex elements with 2980 no. of elements. Part of transmission housing is modeled using tetrahedrons as this is the part of less interest. This assembly part is modeled with 30614 no. of tetrahedron elements. Figure below shows the meshed model of gear shift lever assembly.

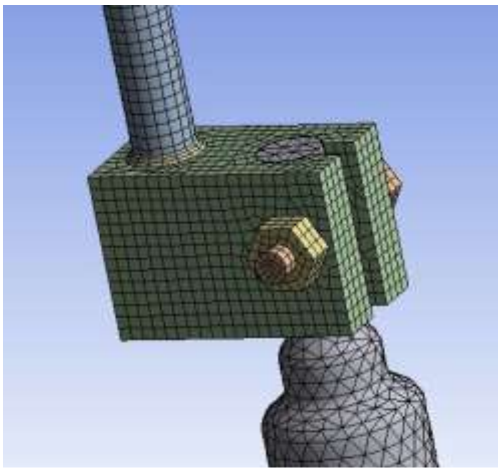


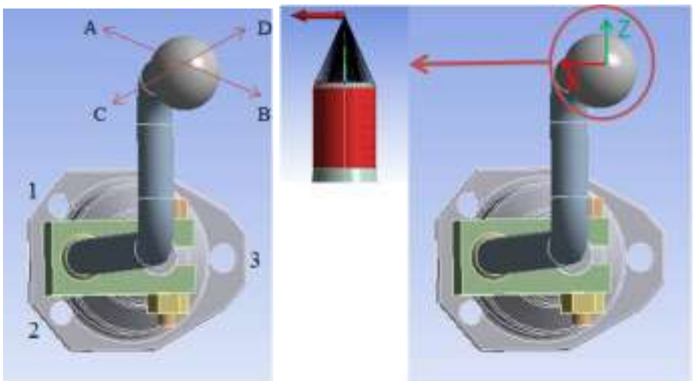
Fig2: Meshed model

3. Material Properties: All these parts, (gear shift lever, box plate, nut, bolt and transmission housing part) are of structural steel material. Shift knob is made up of ABS plastic material and Table1 shows the Structural steel properties of the gear shift lever.

Table no 1: Material Properties

Material	Structural steel
E-modulus [MPa]	2.06E+05
Density [kg/m³]	7850
Yield strength - min [MPa]	235
Ultimate strength [MPa]	360

4.Loading and Boundary conditions: Speed shift lever is fastened to the gearbox enclosed housing, so every freedom of degrees at the bolt fastening location are secured, Fig.3(a) shows the boundary locations of 1, 2 and 3 of which all degrees of freedom are made rigid. Effort will be applied on to the shift lever knob by operator. Fig.3 (b) explains the boundary conditions and the type of element used to connect the operator hand and shift knob. As paper scope is limited, Ansys workbench software have been utilized for analyzing the static structural load case on speed shift lever, speed shift lever has to be solved for static, elastic and linear structural load cases. Under the loading situations linearity of the system is preserved by making huge deflection off in Ansys software. Only keeping speed shift lever in focus, operator makes the effort on speed shift knob through a horizontal direction. Referring to the Fig.3 (b) it will be in X and Z direction. The more important aspect here to understand is the direction of lever shifting effort. Applied effort might happen to be along X direction or else Z direction or there is also possibility of at an angle to both X, Z direction, one thing is very much sure is that, there is component of shift effort alongside Z and X direction. If incase the lever shifting effort is only alongside X direction, definitely effort component alongside direction Z is zero and same is the case for Sift lever effort alongside Z direction. If shifting effort is at an angle then shifting effort will be shared among both X and Z direction the part of load alongside X direction and part of load alongside Z direction. In case you rebuild the shifting effort alongside X, Z orientation, then get the resultant effort and direction as well.



(a) **(b)**

Fig.3: Loading & Boundary conditions

5. Analysis : After finite element analysis Minimum principal and maximum principal strains for 100N shift effort alongside direction X and 100N shift effort alongside direction Z which has been measured physically on gear shift lever using push/pull gauge, Fig.4 and Fig.5 shown below describes the maximum principal strain values drawn after the finite element analysis.

Fig.4: Max. Principal strain for load along X Direction

IV. Experimental Setup

Experimental results are needed in order to validate the analytical results, for similar system under similar working conditions. Actual strain histories will be recorded with the use of strain gages. These gages are pasted on the component on interested area from which strain to be recorded. Strain gage averages all the strain from the area on which it is mounted and output the strain value. Gauge area varies with the active gauge length of the strain gauge. Depending upon the regions from which strains to be recorded, gauge length will be selected. These are general purpose metallic bonded type strain gages. Constantan material completely captured in polyimide, with huge, copper covered tabs. Table 2 explains the Specification of strain gage used in physical experiment.

Table no 2: Strain Gauge Specification

Gauge factor- 2.15	Active gauge length- 1.5mm
Gauge width- 3mm	Resistance- 350 Ohm
Temp. Range- -750C to 175^{o}C	Strain capacity- 50000 microstrain

Strain gauge values has been noted for the number of Gear shift pattern on the speed shift lever. Speed shift lever might be exposed to different operations like changing gears, travelling on terrains and travelling on normal terrain. But Strain data was recorded only during gear shift operation and rest other operations are excluded to maintain static correlation. These strain gage values are recorded at only one locations. Fig 6 explains the strain gage location on speed shift lever. Gauge1 is along mounting hole axis.

Fig.6: Strain Gauge location

These gauges are connected to the data acquisition system which is connected to the PC via USB. Strain data will be extracted using eDaq software. User has freedom to manipulate some parametric data like sample rate, excitation voltage of Wheatstone bridge, bridge factor. Also one can set the maximum or minimum value of strain to be measured. Sample rate-500, Excitation voltage of Wheatstone bridge- 5Volt, Bridge factor-1 (For quarter Bridge) are the values of above parameter used while recording strain data.

V. Result and Discussion

Fig.7 shows the comparison of FEA vs experimental time history data of the strain gage mounted on the speed shift lever and strain values are for effort along X direction. Similarly Fig.8 shows the comparison of FEA vs experimental time history data of the strain gage mounted on the speed shift lever and strain values are for effort along Z direction.

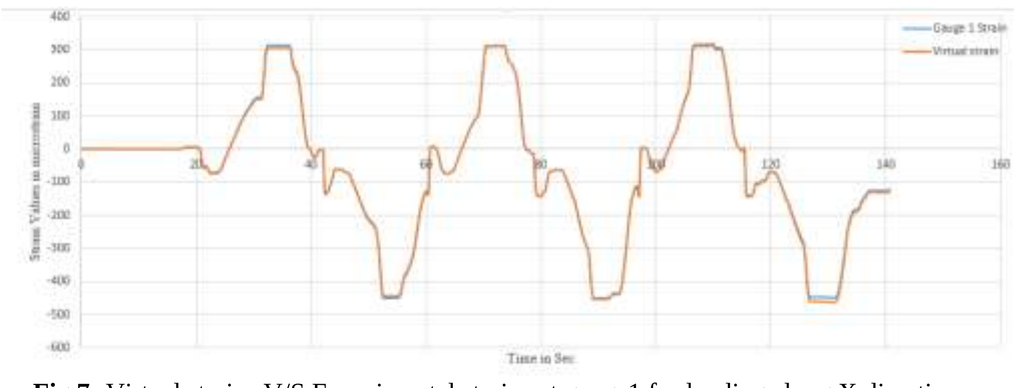


Fig.7: Virtual strains V/S Experimental strains at gauge1 for loading along X direction

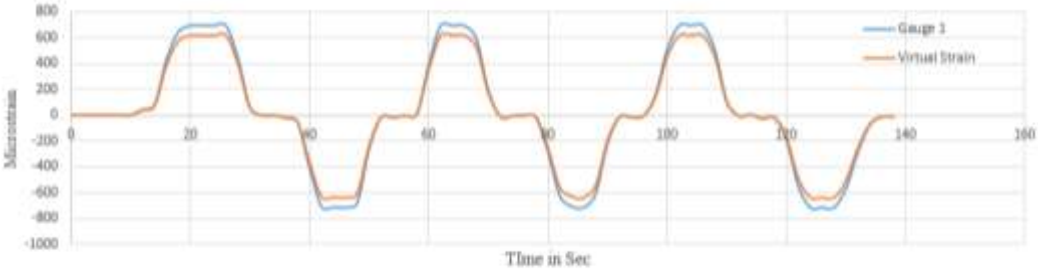


Fig.8: Virtual strains V/S Experimental strains at gauge1 for loading along Z direction

Table no 3: Percentage strain correlation between Experimental & Virtual strain

Loading	Strain Direction	Experimental strain	Virtual Strain	% Correlation
Along X direction	Tensile	313	317	98.74
	Compressive	-450	-461	97.61
Along Z direction	Tensile	693	720	96.25
	Compressive	-726	-750	96.8

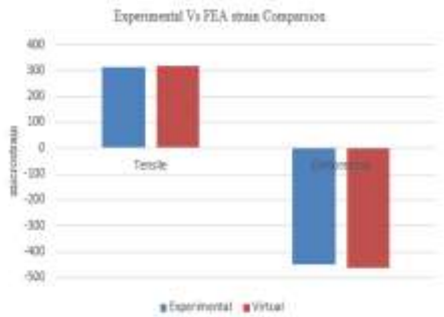


Fig4: Experimental & FEA strain Comparison during loading in X direction

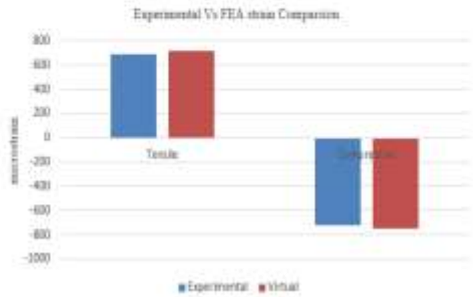


Fig5: Experimental & FEA strain Comparison during loading in Z direction

Table 3 shows the comparison of maximum principal strain values from both experimental test and finite elemental analysis. Fig.4 shows the graphical comparison representation of strains on gear shift lever for effort along X direction and Fig.5 shows the graphical comparison representation of strains on gear shift lever for effort along Z direction.

VI. Conclusion

Strain values collected from the experimental procedure are more close to realistic values compared to Finite element analysis, because of the reason Finite element analysis procedures are based on the assumptions from the free body diagram. But one can reduce the gap between experimental and finite element analysis by developing standard procedures for executing the finite element analysis, In the above gear shift lever example, it is been observed that experimental & FEA strain values are correlated very well and results are matching more than 96%, further this results gives the designer more confidence and future product development time can be reduced as product virtual validation proves to be reliable.

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