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# Design and Development of Handle Bar Switch Assembly (RH) for High Torque Loading Condition

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**ABSTRACT**

**This paper describes design and development of handle bar switch assembly (RH) for high torque loading condition. The steel pipe constituting a member of handle bar of two wheeler on which handle bar switch-RH unit assembled with upper and lower thermo-plastic casing and secured in place with the help of cross pin i.e. locating pin. Upper and lower case are in turn secured on handle bar by using the two mounting screws. The throttle pipe incorporated in switch assembly which rotates in CW and CCW direction when rider accelerate or decelerates with the help of throttle grip. Throttle pipe rotation in CCW direction is constrained for specific angular movement by stopper incorporated in lower case. When rider intends to rotate throttle pipe after its zero throttle position or while doing manual assembly of throttle grip on throttle pipe, it may lead to application of unsafe torque on upper and lower case of switch assembly. The torque load act on casing, when throttle pipes rotates in CCW direction and its effect is taken into consideration. In this paper, how the lower case of handle bar switch assembly is met to failure near accelerator end of handle is explained. Study over cross pin disengagement from handle bar, due to breakage of lower case boss on the application of up to 110 kgf-cm torque load on switch assembly in assembled position with handle bar is done. The FEA outcomes are also well allied by the experimental results in which failure site and pattern is closely matched. Detail analysis is done to identifying the source of this failure and addressing the same with modified or improved design. The modified switch assembly is manufactured and validated to withstand at 225 kgf-cm of torque load for eliminating the incidence of failure to avoid accidents.**

***Keywords***- **a Handle Bar Switch Assembly, Lower Case Design, Cross Pin, Throttle Pipe, Torque Load, FEA, Torque Test.**

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## I. INTRODUCTION

The two wheeler and the four-wheeler industry are normally faced with challenges related to safety. The compliance of vehicle in this regard is of utmost importance while the same could be approved by the concerned regulatory authorities for being used on the public roads. Besides, all other parts and components that support and/or form an integral part of the assembly of the sub-system could be required to comply with the norms.

The other areas attracting compliance are the warranty claims received from the customer during usage over the field or the report filed by the concerned field engineer observing the field test for the vehicle. The breakage and damage to the component is highlighted during the time the vehicle is put to actual use. The scope of this paper falls in area where the design of the component or the sub-assembly needs to be analysed for the sake of failure during use.

Casing of handle bar switch assembly is a part mounted on handle bar. This casing consists of different switches, knobs, buttons etc. This part is near to accelerator on right hand side. Throttle pipe is rotate in passage provided in housing. It accelerates and decelerates by rotation in clockwise and anticlockwise direction. The pictorial view is as shown in Fig.1. The steel pipe constituting a member of the handle bar of the two-wheeler is assembled with the thermo-plastic casing and secured in place with a cross pin and the two halves of the cases are in turn secured with two screws. This assembly is subjected to torque load when the rider holds the grip of the accelerator and rotates in clockwise and antilock wise direction. Throttle pipe rotation in CCW is constrained for specific angular movement by stopper incorporated in lower case.

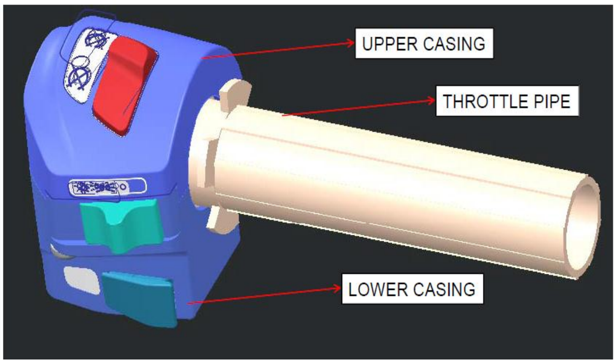


Fig. 1 Pictorial view of handle bar assembly

The inner surface of lower case boss is subjected to normal stress or direct stress due to perpendicular force acting on cross pin when the rider accelerates or decelerates throttle grip gradually and intend to rotate after zero throttle position or while doing manual assembly of throttle grip on throttle pipe when two wheeler at rest. The current handle bar switch assembly withstands 110 kgf-cm torque which is unsafe as customer recommended development of switch assembly for higher torque as per actual field data. For our case, the lower case of the handle bar is met with failure near the accelerator end of the handle. A study is being initiated by the sponsoring company for identifying the source of this failure and addressing the same with improved design feature for eliminating the incidence of failure. The material of the case is Nylon-6 (30% glass-filled). Fig. 2 shows actual failure in field.

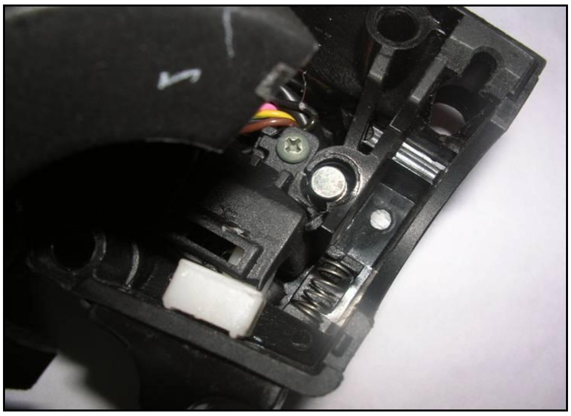

Fig. 2 Actual failure in field

The throttle pipe incorporated in switch assembly which rotates in CW and CCW direction when rider accelerate or decelerates with help of throttle grip. Throttle pipe rotation in CCW is constrained for specific angular movement by stopper incorporated in lower case. When rider intends to rotate throttle pipe after its zero throttle position, it may lead to application of unsafe torque on upper and lower case of switch assembly. The torque load act on casing when throttle pipe rotate CCW direction, is considered for analysis.

## II. STRESS FORMATION IN CROSS-PIN ASSEMBLY AREA

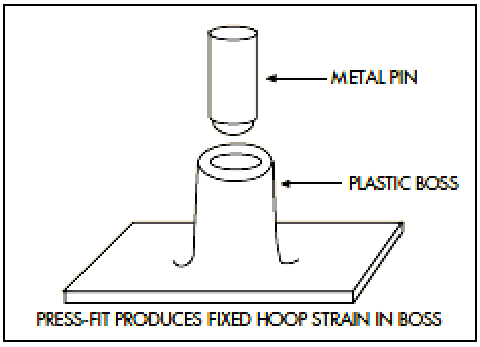


Fig. 3 Strain induced loads

Fig. 3 shows the constant strain induced in the inner surface of boss of lower case during the assembly operation, these considered as assembly stresses which are depends on modulus of elasticity of thermoplastic materials. Strain induced loads generally decrease in magnitude over time. Many assembly stresses and thermal stresses are a result of strain-induced loads. Hoop stress induced in boss due to press fitment of cross pin i.e. antirotation pin. Although the use of press-fit assemblies can be dangerous with thermoplastic parts, their low cost, assembly, speed, and convenience often result in their use. A common use is with a plastic hub or boss accepting either a plastic or metal shaft or pin. The press-fit operation tends to expand the hub, creating a tensile or hoop stress. If the interference is too great, a very high strain and stress develops. The plastic part either:

1. Fails immediately by developing a crack parallel to the axis of the hub relieving the stress, a typical hoop stress failure, or
2. Survives assembly but fails prematurely when the part is in use for a variety of reasons related to the high induced stress levels, or
3. Undergoes stress relaxation sufficient to reduce the stress to a lower level that can be maintained.

Method of evaluating these press-fits is to assume that the shaft will not deform when pressed into the hub. This is reasonably accurate when a metal shaft is used in a plastic hub. The hoop strain developed in the hub is given by $\varepsilon = i/di$. The hoop stress can then be obtained by multiplying by the appropriate modulus. For high strains, the Secant modulus gives the initial stress. However, for longer term stresses, the apparent or creep modulus should be used. The main point is that the maximum strain or stress must be below the value that produces creep rupture in the material. It must be noted that a weld line is usually present in the hub, which can significantly affect the creep rupture strength of most plastic materials. An additional frequent complication with press-fits is that a round hub or boss is often difficult to mold. There is a tendency for the hub to be slightly elliptical in cross-section, increasing the stresses on the part. In view of the preceding, all press-fits must be given end-use testing under actual operating conditions to assure product reliability. Fig. 4 shows the condition of uniform internal pressure formation while press-fitment of metal pin in plastic boss or hub. The equation mentioned in fig. 4 is for the maximum hoop stress which occurs at the surface of the inside wall of the boss or hub.

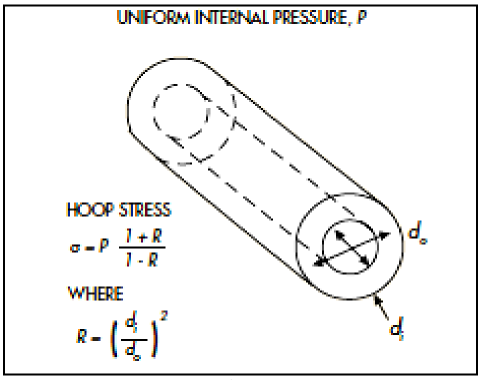

Fig. 4 Hoop stress formation in boss area

Geometry factor considered for press fit situations is given by,

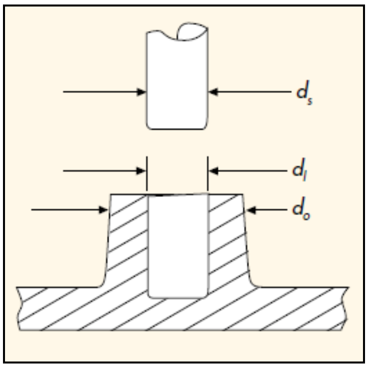

Fig. 5 Press fit situations

$$r = \frac{1 + (ds/do)^2}{1 - (ds/do)^2}$$

$E_p$ = Modulus of Elasticity of Plastic Hub or Boss
$\nu_p$ = Poisson's ratio of Plastic
$\sigma_a$ = Allowable design Stress For Plastic
$i = d_s - d_i$ = Diametral Interference
$i_a$ = Allowable Interference

Hoop stress given i is,

$$\sigma = \frac{i}{ds} . Ep . \frac{r}{r + \nu p}$$

The allowable interference is,

$$ia = \frac{\sigma a}{Ep} . ds . \frac{r + \nu p}{r}$$

The shear stress induced in boss area of lower case due to application of torque load on casing of Handle bar switch assembly because of rotation of throttle pipe after zero throttle position would be evaluated by,

$$\sigma = \frac{Shear\ load}{area\ resisting\ shear} = \frac{Q}{A}$$

The shear stress acts on the inner surface area of boss of lower case which become as failure stress.

## III. METHODOLOGY

Methodology will be followed to complete dissertation work which describes in this paper includes modeling of lower case, upper case and cover case will be carried out by using CAD software. Static analysis has to carry out on the handle bar switch assembly in assembled condition on handle bar using numerical (FEA) means by considering different forces acting on the lower case, upper case and cover case during the application of torque load. It also includes steps for execution as below:

1. Identify the inputs – Spec. for test conditions.
2. Check existing physical sub-assembly on field.
3. Explore the existing 3D model for components.
4. Evaluate the part design for fit and function.
5. Review the existing assembly for the given application.
6. Perform analysis using suitable CAE software.
7. Study the results of analysis.
8. Generate a revised layout for the components.
9. Review the modified design of lower casing.
10. Finalize the specifications.
11. Conduct trials for experimentation.
12. Document the results for validation.

## IV.FEA-EXISTING DESIGN OF HANDLE BAR SWITCH ASSEMBLY

**A** Due to rotation of throttle pipe in CCW direction after zero throttle position, the torque load applied on casing. Cross pin i.e. Antirotation pin which engaged in handle bar restrict rotation of switch assembly which produces direct/normal stresses and direct shear stress in boss in which cross pin is assembled. At mentioned torque the boss is damaged and whole switch assembly rotate on handle bar due to disengagement of cross pin from handle bar. The mounting detail of handle bar switch assembly on handle bar is shown in sectional view as per Fig. 6.

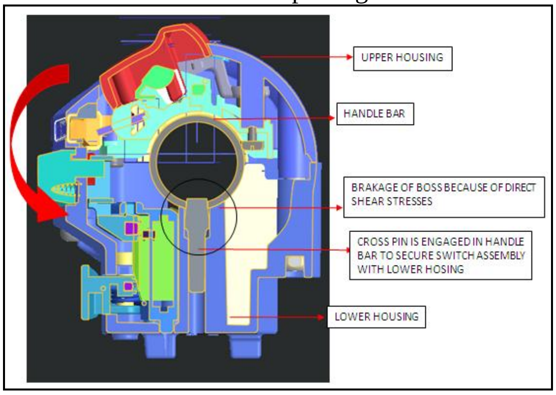


Fig. 6 Sectional view of handle bar switch assembly

FEA analysis is done by taken into consideration the existing test validation method and mechanical properties of thermoplastic material. Displacement plot as below

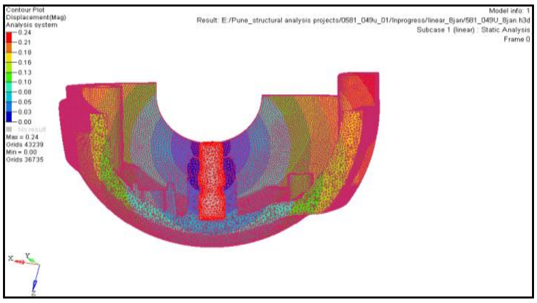

Fig. 7 Displacement plot of lower case

Stress induced in pin fitment area due to application of torque load shown as below.

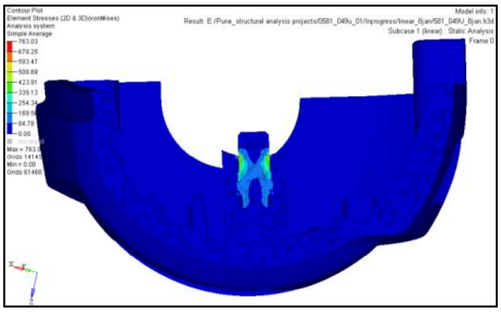

Fig. 8 Stress Plot of Lower Case with Cross Pin

As per FEA analysis, high stress region is top area of boss and crack may go from top to bottom as highlighted with arrow.

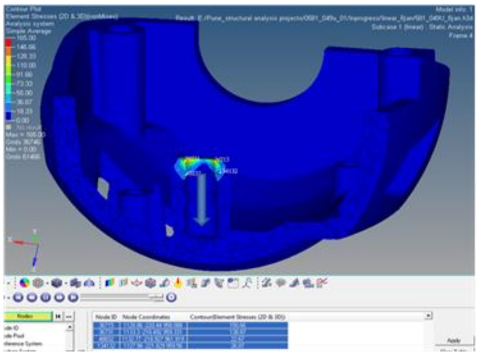

Fig. 9 Stress plot of lower case

FEA result shows lower case may sustain 90 Kgf-c.m torque load.

## IV. REVIEW OF MODIFIED DESIGN OF HANDLE BAR SWITCH ASSEMBLY

Fig. 10 shows overall structure of modified design in 3D model which is created in Creo Parametric 2.0.

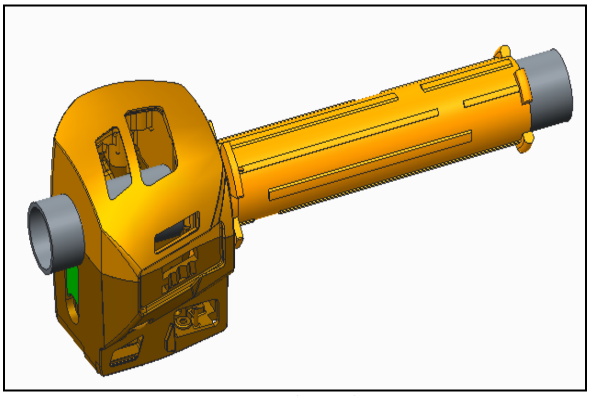

Fig. 10 Overall assembly of modified switch assembly

In modified design, the cross pin is not directly assembled in lower case boss to avoid Hoop stress development while assembly. Instead of this, cross pin is insert molded in cover case which forms one subassembly is fitted on T beam or rib integrated with lower case by sliding over two ribs as shown in Fig. 11.

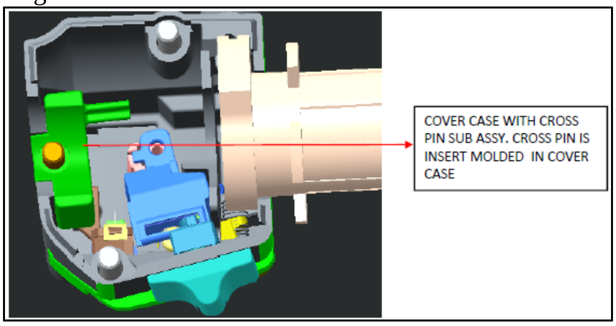


Fig. 11 Cover case sub-assembly with lower case

## V. FEA AND MOLD FLOW ANALYSIS OF MODIFIED DESIGN OF HANDLE BAR SWITCH ASSEMBLY

FEA analysis is done by taken into consideration the existing test validation method and mechanical properties of material by manufacturer. The main objective of FEA is to find the maximum torque load the handle bar switch assembly-RH can withstand and to calculate the peak stress and displacement magnitude of assembly by nonlinear static analysis.

 

- CAE Data considered as below:

1. CAD model of lower, upper and cover case in STEP format.
2. Static torque load nature: CCW on upper and lower thermo-plastic case model.
3. Constraints Nature: Fixed all DOF at steel handle bar.
4. Material Type: PA6 30%GF, Steel.
5. Material Property:

- PA6 30%GF

  1. Young's Modulus = 3.2-11.17 GPa => Considered average = 7.5 GPa = 7.5e3 MPa
  2. Poisson's Ratio = 0.35
  3. Density = 1.17-1.62 g/cc => Considered average = 1.35 g/cc = 1.35E-09 tonnes/mm^3

- Steel

  1. Young's Modulus = 210000 MPa
  2. Poisson's Ratio = 0.3
  3. Density = 7.7799998E-009 tonnes/mm^3

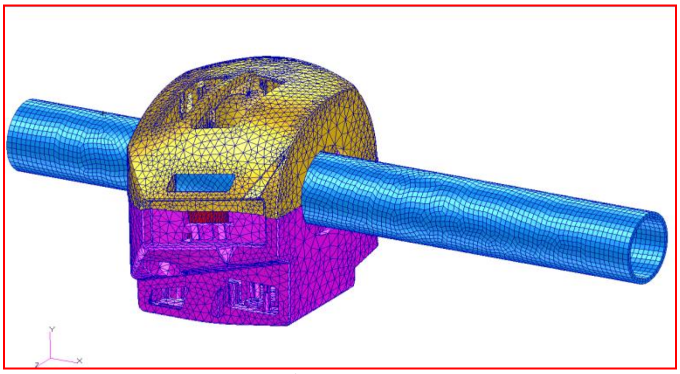

Fig. 12 FE mesh model of switch assembly with handle bar

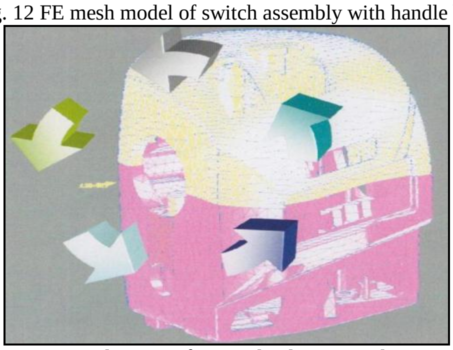

Fig. 13 Application of torque load in CCW direction

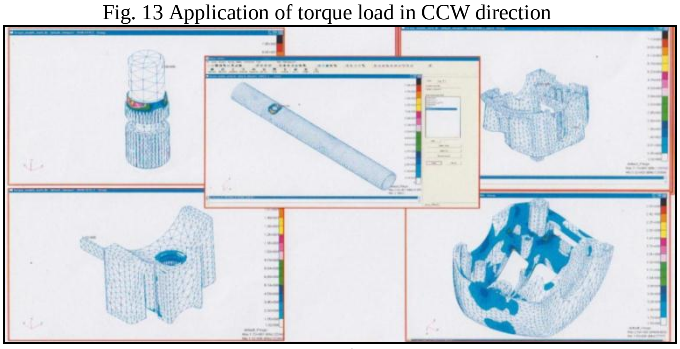

Fig. 14 FEA results for Torque load

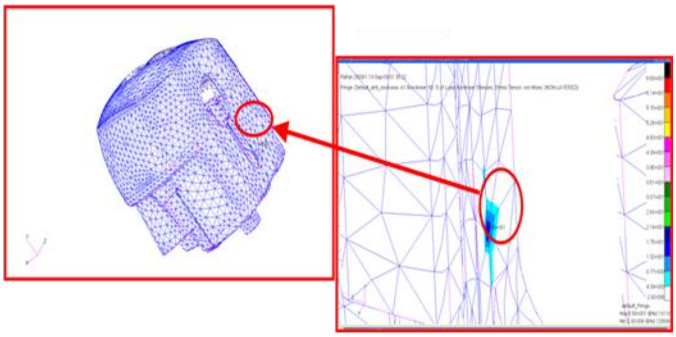

Fig. 15 High stress region in FEA evaluation

Mold flow analysis is done in Autodesk Simulation Mold flow to check parts structural strength, aesthetic value and manufacturing feasibility. It is easy to verify problems and fix them in early development stage. So, that we get the right components in trial 1.

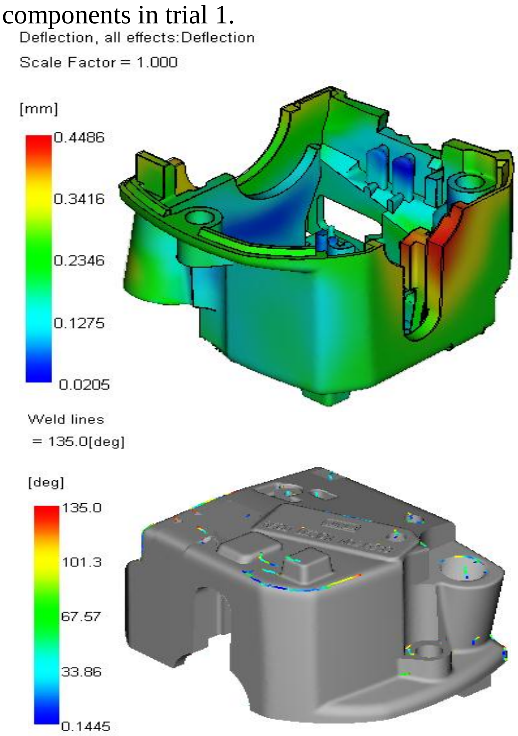


Fig. 16 Mold flow analysis of lower case

## VI. VALIDATION BETWEEN EXPERIMENTAL AND FEA RESULT

Experiments are conducted on the test rig at the company premises. The assembly is mounted on the handle bar rig and the frequency of the gradual loading for torque would be set based on the field data as well as the input received from the FEA analysis data (simulation). The result obtained by the CAE software is compared with the test performed at the sponsoring company premises. Torque test is conducted to confirm failure against exact torque loading, validated with FEA results. The mounted switch assembly is clamped by torque testing fixture and rotates by torque wrench. After application of 110 Kgf-c.m. torque load with the help of Torque wrench, lower casing of existing design break at the area where cross i.e. locating pin engaged in plastic boss area. In FEA evaluation of modified design, it is concluded that switch assembly withstand 268 Kgf-cm torque load. The torque test set-up is shown in Fig. 17 and Fig. 21.

Fig. 17 Torque test set up 1

Fig. 18 Switch assembly on handle bar test rig

Fig. 19 Torque test fixture

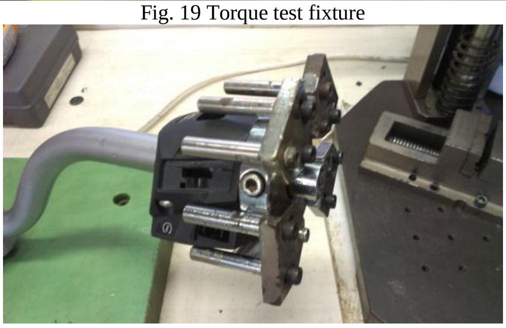

Fig. 20 Torque test fixture mounting on switch assembly

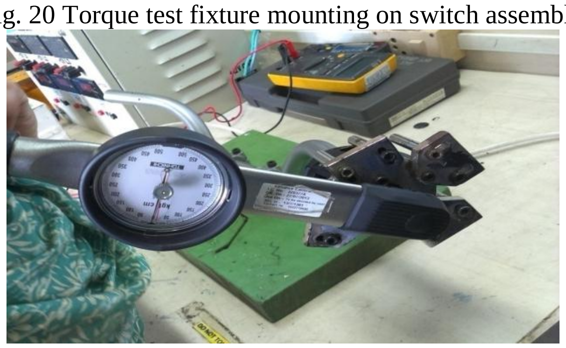

Fig. 21 Torque test set up 2

Where in torque test of modified design, crack initiated at 250 Kgf-cm torque load in high stress region which evaluated in FEA analysis is shown in Fig. 22.

Fig. 22 Crack at lower case in Torque test

## VII.DISCUSION

The objective of this paper is to determine failure region of existing design and value of torque load it can sustain. To modified failure design, its manufacturing and validation to sustain high torque load which recommended by customer or to withstand torque load which induced in field or service station.

## VIII.CONCLUSION

In this paper, failure analysis of handle bar switch assembly under high torque loading is concluded and discussed. The current design of handle bar switch assembly sustain torque load up to 110 kgf-c.m. After checking handle bar switch assembly and their respective parts for different load, it is concluded to change the material, change in cross pin assembly process i.e. to avoid press fitment of locating pin in lower case boss and change in design for handle bar switch assembly. Failure can be predicted before the modified component is to be produced through the use of software which relies on FEA principles by performing FEA validation. The prediction at the component design stage ensures that the chosen geometry is compatible with the conditions of use. For new design and material again analysis, experimentation and validation is done, to make sure that it can sustain under high torque loading i.e. 225 Kgf-cm torque. It is important to note that these promising results will reduce development time, no. of design stages, prototype making and cost of project.

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