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Design and Development of Plastic Triple Tree/Yoke for Motorcycle

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Abstract—*This paper concerns with new design and replacement of automotive metal part with plastic part. In this project a new model of motorcycle triple tree made of plastic material has been designed and developed. The currently used triple tree of general purpose motorcycle is made of metal and its alloys having four or more assembling components. In this improved design introduced here, assembling components are integrated to achieve better mechanical reliability and performance of new model. A detailed design procedure is presented to optimize the torque and loads acting on this element. Motorcycle handling and stability have also been analysed during design of the model.The dimensions of model have been optimized to achieve maximum allowable stress. The forces and steering torque have been analysedand compared with metal part. Simulations and experimental tests are carried out in order to validate the performance of new model. The durability and performance of new designed model is parallel to the metal and alloys triple tree currently used in motorcycles. The present redesigned model of plastic triple tree is as reliable as metal triple tree.*

Keywords*: Steering torque, stress, consolidated part.*

1. INTRODUCTION

A triple tree/yoke attaches the fork tubes to the frame via steering head bearings, which allow the fork assembly to pivot from side to side, and therefore steer the motorcycle. Most bikes have upper and lower triple trees, providing two solid clamping point that keeps the fork tubes parallel, while also connecting the forks to the frame via the steering head bearings. With the tendency to employ fork tubes with single action damping, fork triple trees need to be reinforced more than when the forks shared both damping roles, because the rigidity of the triple trees are relied upon to distribute the forces within the forks without flex.

The 'Telever' fork has only an upper triple tree, which allows for greater overlap of the sliders over the stanchion tubes, which improves stiffness and helps to reduce flex.

The existing triple tree used in most motorcycle is made of metal and its alloy having four and more connecting components. The new designed model of plastic triple tree has integrated assembly components which have only one connecting component for attaching handlebar.

Since the automotive industry is on brink of a revolution and the plastics industry poised to play a major role. The ongoing development of advanced, high performance polymers has dramatically increased their uses [7]. Originally plastics were specified because they offered good mechanical properties combined with excellent appearance, including the possibility of self-colouring. The application of plastic components in the automotive industry has been increasing over the last decades. Nowadays, the plastics are used mainly to make automobile more energy efficient by reducing weight, together with providing durability, corrosion resistance, toughness, design flexibility, resiliency and high performance at low cost. The automotive industry uses engineered polymer composites and plastics in a wide range of applications, as the second most common class of automotive materials after ferrous metals and alloys. The clamp designed here will be cheaper, easy to be processed as compared to metal clamp.

Steering torque, steering force and impact load during bump are the primary constraints for the triple tree. For the variable speed of the motorcycle, steering torque changes. It is measured theoretically. This torque is necessary to be applied by the rider on the handlebar in order to maintain the desired path. The maximum steering torque at roll angle 30^0 and steering angle 30^0 is 112 N-m at motorcycle speed of 30 km/h. To have a motorcycle more maneuverability is needed that the rider feels the lowest possible force on the handlebar. So, if the torque is always same, we need to increase the distance between the axis of steering system and the point in where the rider apply force with his arms.

2. PROBLEMS DEFINITION

Fig. (1) shows a schematic representation of triple tree model. This design features two vertical clamps for mounting handlebar on the top of triple tree. This design is then attempts to redesign the integrated handlebar clamps triple tree. In an attempts to integrate these clamps, these are fixed with the base plate of the triple tree. This is shown in Fig. (2). In order to avoid the twisting of clamps and achieving maximum steering torque in front forks during application of force on handlebar, the two ribs of height 25 mm and thickness 3 mm are provided.These ribs also provide strength to the base plate when rider apply load on handlebar. This design is depicted in Fig. (3).The focus of preliminary design is to determine steering torque, load limit, stresses developed and other physical characteristics for an optimum triple tree design, which best maximize scores for competition. The complexity of the operating variable can be simplified by taking appropriate assumption. This help to develop a preliminary design. The very beginning of this project work, a model has been developed using appropriate assumption and mathematical approximation then conceptual design is feasibly represented using mathematical computer simulation software package in CATIA and Pro/E.

The remaining of this paper is concerned with the design and validation of this model. In section 3, different models to calculate steering torque, stress, dynamic loading etc. are presented. Section 4, outlines a design optimization based on presented model. Section 5, discuss about the results obtained from the mathematical and simulation analysis.

Fig. 1: Triple tree currently used

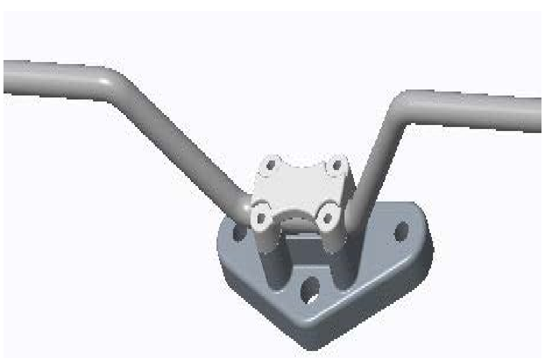

Fig. 2: New designed triple tree.

3. ANALYTICAL MODELS FOR TRIPLE TREE

A schematic representation of the triple tree assembly is shown in Fig. (2), so as to investigate its static and dynamic behaviour. Consider force *F*acting in handlebar at perpendicular distance *r* from the handlebar connector. In Fig. (4), a free body diagram of this acting force is illustrated. When free body was drawn in, two considerations were taken; (I) Fig. (5a): since the force in handlebar apply torque in connector which induced shear stress. The shear stress at two points A and B can be calculated from the equations (6) and (7) respectively. (II) Fig. (5b): a force F_v can act vertically which tends to bend the connector in the direction of applied force, from here bending stress can be calculated by using equation (8). The free body diagram of these two conditions are shown in Fig. (5). The free body diagram of baseplate and loads acting on it is shown in Fig. (6)

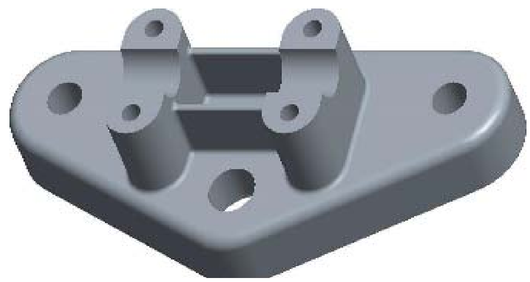

Fig. 3: (a).

Fig. 3: (b). Handlebar upper clamp.

3.1. Steering Torque

Steering torque is applied by the rider with respect to steering axis of motorcycle to maintain the desired path or turn the motorcycle. The steering torque varies with speed of motorcycle, dynamic load on front wheel, normal trail, caster angle etc. To have a motorcycle manoeuvrability, is needed that the rider should feel the lowest possible force on the handlebar[1]. So, if the torque is always same, we need to increase the distance beyween the axis of steering and the point where the rider applys force. This is shown in Fig. (4).

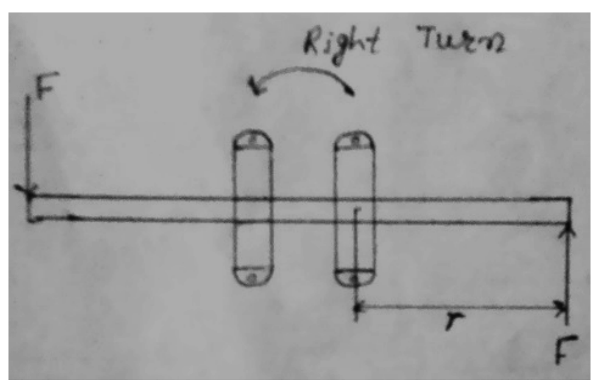

Fig. 4: Steering torque on handlebar.

Steering torque,

$$T = [F_{lf}\cos(W) - N_f\sin(W)]t_n \text{ ----------- ---- (1)}$$

where, T is steering torque, F_{lf} is lateral force induced/applied on front wheel, W is wheelbase, N_f is dynamic load on front wheel, t_n is mechanical/ normal trail.

Dynamic load on front wheel,

$$N_f = \frac{Mg}{W}(b_{cm} + \mu h_{cm}) \text{ ------------------- -------- (2)}$$

where, M is mass of motorcycle with rider, g is acceleration due to gravity, b_{cm} is distance of centre of mass from rear wheel centre, μ is coefficient of friction between tyre and road, h_{cm} is height of centre of mass from ground.

Normal trail,

$$t_n = \frac{R_f\cos(\delta)\sin(\phi)}{\sqrt{1-[\sin(\delta)\sin(\phi)]^2} - O_f} \text{ -------------- ----------- (3)}$$

where, R_f is radius of front wheel, δ is steering angle, ϕ is caster angle, O_f is fork offset.

3.2. Stress in Handlebar Connectors

Due to the steering torque applied by the rider, the handlebar connectors are subjected to twisting moment. Shear stress will be induced in these connector. Consider the connectors of rectangular cross section of length l and width b having semi-circular ends shown in Fig. (5a).

$$T = F.r \text{ -- ----- (4)}$$

where, F is the force applied by rider on handlebar, r is distance between point of application of force and handlebar connector.

From equation (4) steering force can be calculated.

Cross section area of connector,

$$A = (l-b)b + \frac{\pi}{4}b^2 \text{ --------------------- ----------- (5)}$$

Maximum shear stress at point A,

$$\tau_A = \frac{4.81\,T}{2Al} \text{ ------------------------------- ------------- (6)}$$

Maximum shear stress at point B,

$$\tau_B = \frac{4.81\,T}{2Ab} \text{ --- (7)}$$

When ridersometimes apply force vertically on handlebar, it will cause bending stress in connectors which is shown in Fig. (5b).

Bending stress,

$$\sigma_b = \frac{My}{I} \text{ ---- ----- (8)}$$

where, $\sigma_b$is bending stress, M is bending moment, y is force distance from neutral axis, I is moment of inertia about neutral axis.

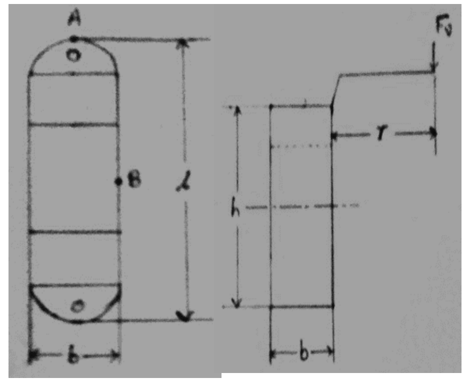

Fig. 5: (a).Fig. 5(b).
Fig. 5: Loads on handlebar connector

3.3. Design of Baseplate

When the motorcycle experience bumps on road during riding, there is an impact force induced, which is absorbed by the shock absorber. Due to this impact force, springs of shock absorber will be compressed. This compressed springs apply force on the triple trees via fork tubes. In order to find out this spring force, it needs to find out the deflection of spring or travel of forks and the load applied on the shock absorber which is roughly equal to front centre of mass of motorcycle. Considering front centre of mass 70 kg and travel of forks is 120 mm. This is shown in Fig. (6).

$$w = kx \text{ --------------------------- ------------------- (9)}$$

where, w is applied load, k is spring constant, x is deflection of spring.

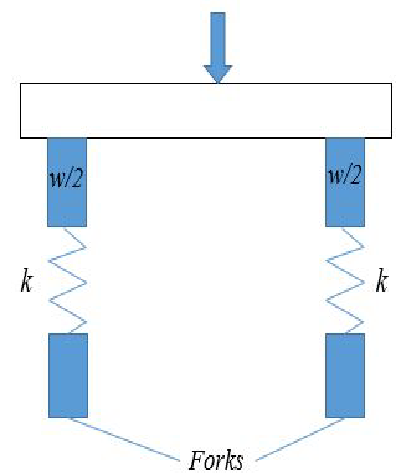

Fig. 6: Loads on baseplate

4. OPTIMUM DESIGN OF TRIPLE TREE

In this section, an optimum design is given for triple tree model. Maximum shear stress, bending stress, torque and impact load may be considered as the design criteria in the present problem. Variables to be optimized are thickness of baseplate, width of handlebar connector of triple tree. Based on the parameters and to simplify the fabrication first Nylon 6 is used for this model. The various design parameters are shown in table 1.

Table 1: Design parameters

Component	Symbol	Quantity	Unit
Handlebar connector	Length (l)	58	mm
	Width (b)	25	mm
	Height (h)	35	mm
	Shear stress at A (τA)	3.575	MPa
	Shear stress at B (τB)	9.431	MPa
	Torque (T)	112	N-m
Baseplate	Overall length	220	mm
	Overall Width	92.5	mm
	Offset (Of)	42.5	mm
Others	Wheelbase (W)	1255	mm
	Front wheel radius (Rf)	431.8	mm
	Caster angle (ϕ)	26.5	degree
	Steering angle (δ)	30	degree
	Spring deflection (x)	12	mm
	Front centre of mass (w)	70	kg

5. CONCLUSION

In this project, the triple clamp has been redesigned to provide better mechanical reliability and performance. This has been achieved by replacing the connecting components with integral connectors. The dimensions of the triple tree has optimized to provide maximum allowable stress. Different types of load acting on the triple clamp through handlebar and fork has analysed and stresses are calculated, the maximum shear stress in handlebar clamp is 9.5 MPa at a torque of 112 N-m.The forces and torque have been analysed and compared with metal part. The design is validated in a digital simulation and mathematical analysis. The durability and performance of new design is parallel to the metal and alloys triple clamps currently used in motorcycles. The present redesigned model of plastic triple tree is as reliable as metal triple tree.

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