CONCEPTUAL DESIGN OF FOLDABLE ALL-WHEEL DRIVE OFF-ROAD MOTORCYCLE

S. Saravana Prabhu[1] and Dr. R. Gandhinathan [2]

[1]*Department of Production Engineering, PSG College of Technology, Coimbatore, India*

[2]*Professor, Department of Production Engineering, PSG College of Technology, Coimbatore, India*

ABSTRACT

All Terrain Vehicles (ATV) and dirt bikes have wide range of applications apart from motorsports due to their ability to operate easily in rough terrains. But portability of these vehicles is difficult due to their size, which limits their applications. However foldable light weight motorcycles with off road capabilities were found to overcome this limitation. Thus, the work mainly focuses on designing an innovative foldable light weight motorcycle with all-wheel drive system, so that it can be used for off road transportation. Also Portability limitation of existing vehicles can be eliminated. Initial design requirements for design of foldable all-wheel drive off-road motorcycle are found. Based on that data, four concepts are generated and concept selection has been carried out using Pugh chart and weighted matrix method.

Keywords: *Foldable motorcycle, All-wheel drive, Anthropometric Dimension, Concept Generation, pugh chart, Weighted Matrix.*

INTRODUCTION

In recent years, foldable motorcycles have become very popular due to their practicality in cities.But foldable motorcycles with off road capability are less or not available in market currently. Vehicles available for this purpose are dirt bikes and ATVs. Even though these kinds of vehicle are ideal for off road utility, they have certain limitations. Because of their size and range limitations, Separate trucks or modified cars or trailers will be required for transportation of this vehicle. Foldable off-road motorcycle will completely eliminate these kinds of problem because it will easily fit even into the smallest car's trunk. Some other drawback of existing off road bikes and ATVs is that separate storage space is required for them. Thus foldable motorcycle with off road capabilities can be used in small-scale forestry, plantation estates, construction sites, military, search and rescue, surveying, agriculture, etc because of their portability and light weight.

Analysis of role and at which specific points proceeding of feasibility study are to be done in product development were documented[1]. Applicability of benchmarked linearized dynamics equations to a variation of modern bicycle designs investigated and compared with experimentation results [2].Anthropometric survey of 140 UK motorcyclists was undertaken and six body dimensions relevant to the design of the riding package of a motorcycle were considered. The work imply that considerable care was needed when considering the design of any components whose functiondependent on the relative location of parts of the rider [3].Ergonomic design of Nigerian motorcycle was done in which the ideal angles for body posture

was found out and redesigning of motorcycle was carried out to reduce the risk of musculoskeletal disorders of the lower back and other related pains around the body [4].

Starting from an existing advanced motorcycle dynamics model, which allows simulation of reasonably general motions and stability, modal and response computations for any trim condition, improvements are described. A new model was used for steady turning, stability, design parameter sensitivity and response to road forcing calculations. The results suggest that frame flexibility remains an important design and analysis area [5].Strain gauges were used to measure dynamic loads on a foldable bicycle while it is being ridden on public roads and real-life data was gathered for various riding situations. The results were shown for some riding situations and their impact on the design of foldable bicycles[6].Based on literature survey, methodology for new product design and development was derived and Initial design requirements for motorcycle design were found.

METHODOLOGY

The design begins with defining the basic design parameters of motorcycle, and then concepts are created and modelled using CAD software. The best concept is identified using concept selection methods. Embodiment design involving material selection for different component and detailed design of motorcycle has to be done using CAD/CAE software.

INITIAL DESIGN REQUIREMENTS

Before entering into the design stage, data of some geometric parameters shown in fig 1has to be known. The geometric parameters that are usually used to describe motorcycles are wheelbase, caster angle, front and rear wheel radius, fork offset and trail. These parameters are measured in a vertical position and the steering angle of the handle bars set to zero[7].

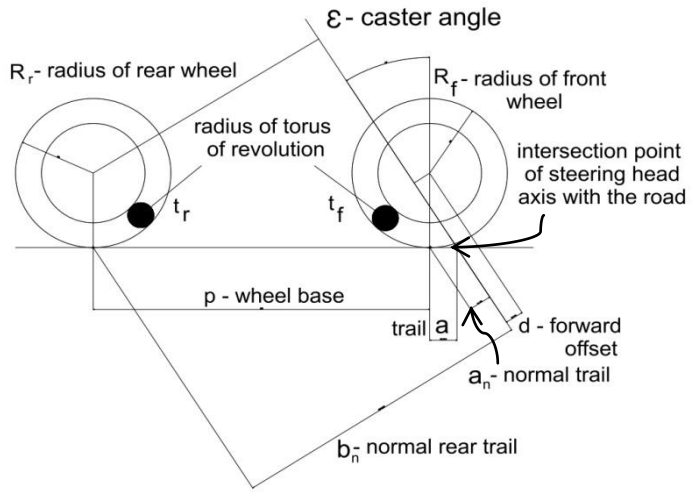

Fig 1. Geometry of motorcycle

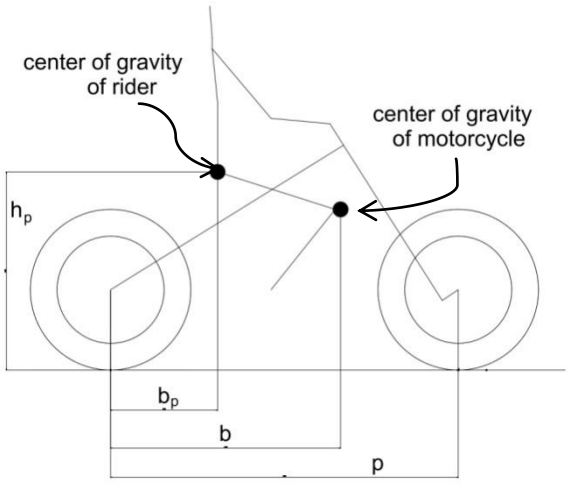

Fig 2. Center of gravity of the motorcycle and the rider.

For this purpose, dataare assumed arbitrarily based on information available from existing design andfunctional requirements, which are listed below,

- Maximum weight carrying capacity taken as 80 kg.
- Approximate weight of bike would be less than 30 kg.
- Since the motorcycle is meant for off road utility, the wheel base should be shorter for more stability and handling. So for initial design, the wheel base is ideally taken as 1000 mm.
- Radius of the front and rear wheel are taken as 6 inch, as portability and light weight are main agenda of design.
- The caster angle is taken as 20° to have high manoeuvrability.
- Fork offset is taken as zero.
- Since vehicle has to be used for off road purpose, minimum ground clearance of 200 mm is required.

The caster angle and trail are important as they not only define the geometric characteristics of the steering head but also the properties of manoeuvrability and directional stability of motorcycles depend on them. The value of the trail is most important for the stability of the motorcycle in rectilinear motion. From a geometric point of view, the classic steering mechanism has been described by three parameters which are caster angle, fork offset, and radius of the front wheel [7]. These parameters make it possible to calculate the trail using the equation below,

$$a = (R_f * \tan \varepsilon) - (d / \cos \varepsilon) \quad (1)$$

By substituting the values in Eq 1, the trail value obtained is 54.5 mm. Also the trail is considered to be positive i.e. front wheels contact point with the road plane is behind the point of the axis intersection of the steering head with the road itself, to have stabilizing effect during forward movement.

Centre of gravity of the motorcycle and the rider shown in fig 2 above, from the rear wheel for assumed wheel base and gross weight of the bike along with rider can be found out using formula,

$$N_{sr} \cdot (b) = N_{sf} \cdot (p-b) \quad (2)$$

Since values like weight of the rider and wheel base length are known, it is substituted in Eq2 to find b and height of center of gravity ($h_{p)}$ neglected initially. From the calculation, the value of b is found to be 400 mm. Here Centre of gravity acts vertically and majority of the gross weight is contributed by human body as the weight of the motorcycle is planned to be less than 30 kg, hence the center of gravity of rider have been taken as point of centre of gravity of the motorcycle i.e. b = b_p. Also this distance can be taken as seat position from rear wheel.

Anthropometric Dimension. As the motorbike must be designed for Indian population, based on specifications [3,4], the basic dimensions like seat height, handle bar height and foot rest position are determined using Anthropometric dimensions available for Indian population[8]. For this, 50th percentile of combined male and female anthropometric dimensions are taken, which are listed below in the Table 1 and 2.

Table 1. Anthropometric dimensions of Indian population

Parameter	Dimension[mm]
Crotch	760
Acromion	541
Knee	509
Buttock to poplitel length while sitting	451
Acromion to olecranom	309
Olecranom to stylion length	239
Hand grip	50
Waist	253
Elbow to elbow while sitting	494

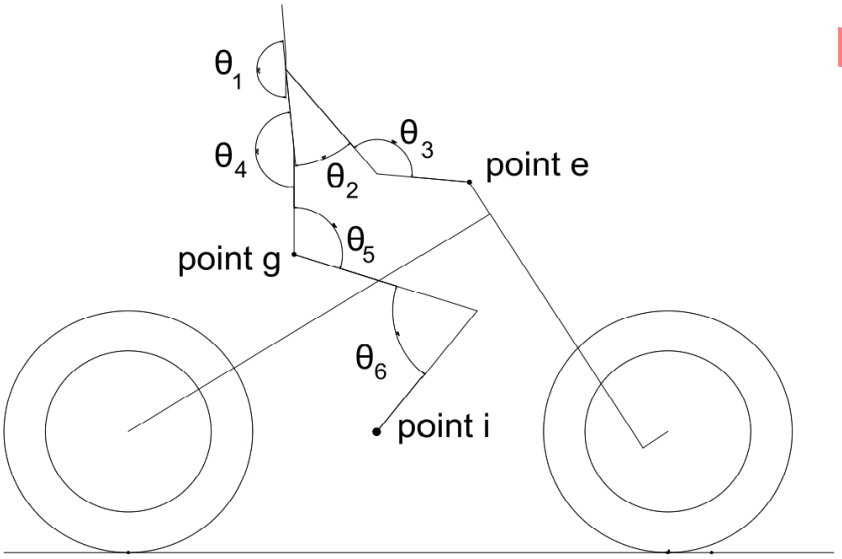

Fig 3: Posture of rider along with angle between their joints

Table 2. Angle between joints of Rider

Characteristic Angles	Proposed value [x°]
θ_1 – angle between neck and trunk	160°
Point e.θ_2 – upper arm position from trunk	41°
θ_3 – angle between upper arm and fore arm	144°
Point g. $\theta_4$ng – angle between trunk and lumbar	171°
θ_5–angle between lumber and thigh	102°
Point i. θ_6 – angle between thigh and leg	81°

By inferring the value obtained from calculation, anthropometric dimensions of Indian population given in table 1 and posture of rider from table 2 and figure 3, the following dimensions of the motorcycle are obtained which is listed in table 3. It has to be noted that (L-b) i.e. 600 mm has been taken as the horizontal distance between seat and handle bar.

Table 3: Basic dimensions of motorcycle

Parameter	Dimension[mm]
Height of seating position from ground (h)	700
Height of handle bar position from ground	850
Distance of foot rest from rear wheel	120
Distance from acromion to hand grip	500
Length of handle bar	500
Width of seat	150

CONCEPT GENERATED

Four different concepts have been developed based on geometric characteristics of the motorcycle assumed. The visual details of these concepts are presented below from fig 4 to 7. All the four concepts are created using Pro-E Wildfire 5.0.

Concept 1. Folding mechanism is provided near the handlebar. The motorcycle's handlebar is folded about the axis of folding joint.

Concept 2. Motorcycle's front half is rotated 180° about the axis of seat position to fold. Gear mechanism is provided to guide the rotation.

Concept 3. Two universal joints are provided at the middle of the spine type frame which is used to fold motorcycle as well as to transmit power to the front wheel.

Concept 4. Linked frame with pin type joints are used for folding the motorcycle. In this concept some pins has to be removed to make the motorcycle foldable.

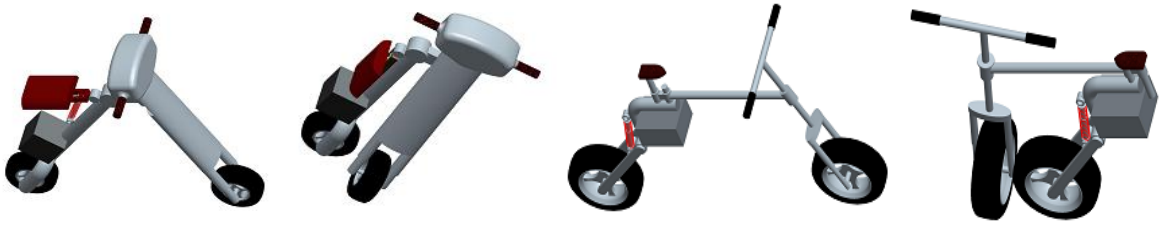

Fig 4. Concept 1Fig 5. Concept 2

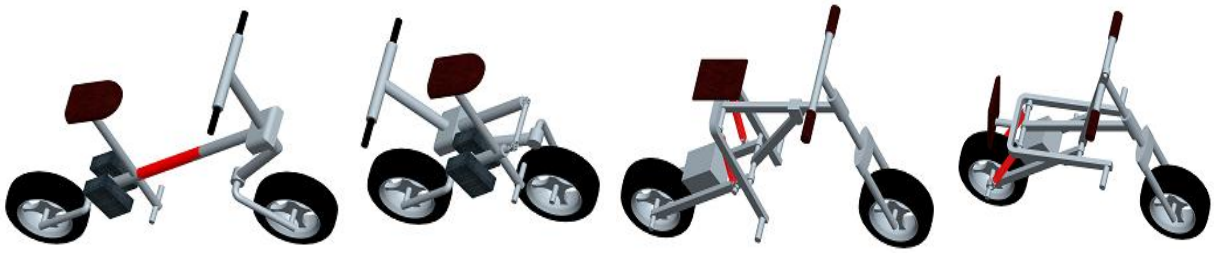

Fig 6. Concept 3 Fig 7. Concept 4

CONCEPT SELECTION

There are many methods available for selection of a concept, like Pugh chart, weighted matrix method, etc. Here Pugh chart and weighted matrix method are used for concept selection [9].According to this charts in Table 4 and 5, concept – 3 is found to be more suitable for this work.

The selection criteria followed for selecting the concept are Compactness of the design when folded, how easily the motorcycle can be folded and assembled,suitability for off-road purpose.

Table 4. Pugh chart

	DATUM	Concept 1	Concept 2	Concept 3	Concept 4
Ease of assemble	0	+	+	_	_
Ease of disassemble	0	+	+	_	_
Lengthwise Compactness	0	_	_	+	0
Height wise Compactness	0	0	0	+	0
Aesthetic appeal	0	_	+	+	+
Suitable for off road	0	_	0	+	_
Total +		2	3	4	1
Total -		2	2	2	3
Overall total		0	1	2	-1
Rank		3	2	**1**	4

Table 5. Weighted matrix

Criteria	**Weight %**	**Concepts**				
		Existing Product	**Concept 1**	**Concept 2**	**Concept 3**	**Concept 4**
Ease of assemble	15	**1** 0.15	**2** 0.30	**1** 0.15	**2** 0.30	**1** 0.15
Ease of disassemble	15	**2** 0.30	**2** 0.30	**1** 0.15	**2** 0.30	**1** 0.15
Lengthwise Compactness	20	**2** 0.20	**1** 0.20	**3** 0.60	**1.5** 0.30	**1** 0.20
Height wise Compactness	20	**1** 0.20	**1** 0.20	**1** 0.20	**1.5** 0.30	**3** 0.60
Aesthetic appeal	05	**2** 0.10	**2** 0.10	**1** 0.05	**1** 0.05	**1** 0.05
Suitable for off road	25	**1** 0.25	**1** 0.25	**2** 0.50	**2** 0.50	**1** 0.25
Score	100	**1.20**	**1.35**	**1.65**	**1.75**	**1.40**
Rank		**5**	**4**	**2**	**1**	**3**

CONCLUSIONS

In this work, Initial design requirements like wheel base, rider and motorcycle weight, radius of wheels, caster angle, fork offset and ground clearance were assumed and parameters like trial and center of gravity of motorcycle from rear wheel while riding were calculated, for conceptual design of foldable all-wheel drive off-road motorcycle. Further seat positions, handle bar position, length of handle bar, foot rest location werefound by interpreting the initially assumed geometric parameters with Indian anthropometric dimensions. Then four concepts were generated based on these geometric parameters and concept selection was carried out using Pugh chart and weighted matrix method. In which concept 3 has been found to meet the majority of functional requirements like compactness when folded, suitability for off road utility and appeal. Followed by concept 2 which was easy to assemble and disassemble. Future scope of the work is to undertake detailed design and analysis to develop the chosenconcept into an engineering design.

REFERENCES

[1] Katharina Bause, Aline Radimersky, Marinette Iwanicki and Albert Albers, Feasibility Studies in the Product Development Process, 24th CIRP Design Conference 21,Elsevier Ltd (2014) 473 – 478

[2] David Stevens, The stability and handling Characteristics of bicycles, The University Of New South Wales, (2009)

[3] S. A. Robertson and A. Minter, A study of some anthropometric characteristics of motorcycle riders, Applied Ergonomics PII: S0003-6870(96)00007-5, Elsevier Ltd (1996)

[4] Akanbi GO and Imaekhai Lawrence,Ergonomic design of Nigerian motorcycle and its vibrational analysis, Research article Standard Scientific Research and Essays,Standard Research Journals,Vol2 (6): (2014) 251-259

[5] R. S. Sharp, S. Evangelou And D. J. N. Limebeer, Advances in the Modelling of Motorcycle Dynamics, Multibody System Dynamics,Kluwer Academic Publishers 12: (2004) 251–283

[6] Miha Pirnat, Zdenko Savšek and Miha Boltežar 2011, “Measuring Dynamic Loads on a Foldable City Bicycle”, Journal of Mechanical Engineering,Strojniški vestnik,57(2011)1, 21-26

Reference to a book:

[7] Vittore cossalter, Motorcycle Dynamics, second edition (2008)

[8] DebkumarChakrabarti, Indian Anthropometrc dimensions,National Institute of Design, Ahmedabad, India (1997)

[9] Kevin N. Otto, Product Design, Pearson Ltd (2012)