# Caster, Camber and King Pin Inclination Measurement With The Help Of Chaapa Yantra

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## Abstract

Chaapa Yantra is one of the instrument that was used for the astronomical measurements in ancient India. This paper is to make use of this chaapa yantra to measure caster, camber and king pin inclination of a car.
Caster and king pin inclination are the inclinations provided to the king pin. King pin is located inside and attached to the axle of a car. Since king pin is not directly accessible, its angle cannot be measured directly. To measure these angles, the steering tires mounted on the vehicle are turned 30 degree left and 30 degree right about the vertical axis and its tilt is measured. With the help of this tilt caster and king pin inclination are calculated. Camber angle can be measured directly. This instrument is simple, reliable and a cheap substitute for the computerized type of very costly equipment.

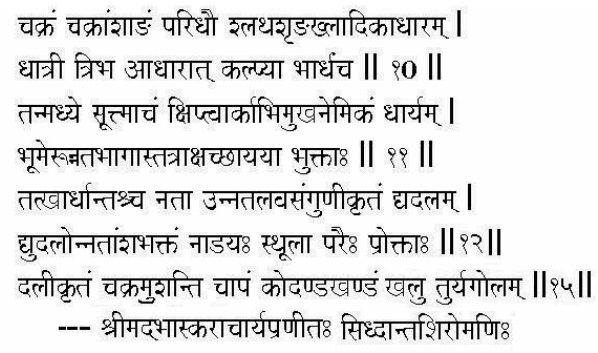
**Keywords:** Chaapa Yantra, Automotive application. Cheap, Reliable.

## 1 Introduction

Chaapa Yantra is one of the astronomical instruments used in ancient India for astronomical measurements. This paper is an attempt to use this instrument to measure front end geometry of a motor vehicle.
Section 2 describes the Chaapa Yantra, Section 3 gives a review of existing instruments, section 4 includes the modifications done for the chaapa yantra to use it for the measurement of front end geometry of car, section 5 includes the calibration of the proposed gauge, section 6 deals with experimental set up to test the gauge and finally section 7 concludes the paper.

## 2 Chaapa Yantra

This is one of the astronomical instruments used to measure the angle [1]. Angle of planets and stars was measured with this instrument. Description of this instrument is available in the script of Shidantashiromani of Bhaskaracharya [2]. Script is shown in the fig (1) and the instrument is shown in the fig (2).



चक्रं चक्रांशाङं परिधौ श्लथशृङखलादिकाधारम् ।
धात्री त्रिभ आधारात् कल्प्या भार्धच ॥ १० ॥
तन्मध्ये सूत्माचं क्षिप्त्वार्काभिमुखनेमिकं धार्यम् ।
भूमेरून्नतभागास्तत्राक्षच्छायया भुक्ताः ॥ ११ ॥
तत्खार्धान्तश्च नता उन्नतलवसंगुणीकृतं द्यदलम् ।
द्युदलोन्नतांशभक्तं नाडयः स्थूला परैः प्रोक्ताः ॥१२॥
दलीकृतं चक्रमुशन्ति चापं कोदण्डखण्डं खलु तुर्यगोलम् ॥१५॥
--- श्रीमद्भास्कराचार्यप्रणीतः सिध्दान्तशिरोमणिः

Figure. 1 Script of Shidhantshiromani (1145 AD) describing chaapa yantra.

Figure 2 Chaapa Yantra of Bhaskaracharya (1145 AD).

As per the script it has a protractor, a stick and a heavy chain. Chain remains vertical when suspended similar to a plumb bob. In some cases a plumb bob was also used instead of a chain. A stick attached to the protractor was used to focus the instrument at the target, which may be the top of a tree, or a star and then the angle was measured with the help of the protractor with respect to the chain. Basically it was used to measure the vertical angle.
Similar versions of this instrument have been also mentioned by Astronomer Lalla (700 AD) as a Dhanu yantra [3] fig (3). It also consists of a protractor and a plumb bob. It was also used for the measurement of angle.

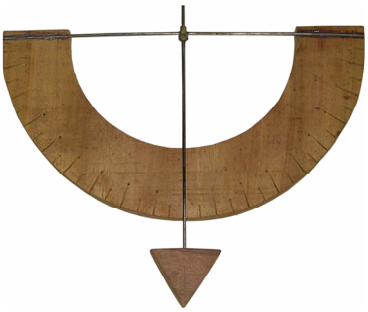


Figure 3 Dhanu Yantra of Lalla.

Units used for the measurement of angle in ancient India were also same as those being used today i.e. seconds, minutes and degrees. Other units of angle were also used by ancient Indian astronomers. These units of angle [4] are described in the script of Suryasidhanta (1000 BC) as mentioned below in the fig (4).

विकलानां कलाषष्टया: तत् षष्टया भाग उच्यते
तत्रिंशतां भवेद्राशि: भगणो द्वादशैव ते ॥
--- सुर्यसिद्धांत

Figure 4. Script of Suryasidhanta (1000 BC) describing the units of the angle.

The above script can be translated as 'sixty vikala is one kala, sixty units (kala) is one bhaga, it is said this way that, thirty units (bhaga) makes one rashi, twelve rashi makes one bhagana'.
It means that vikala, kala, bhaga, rashi, bhagana are the units of the angle. In the modern notation vikala, kala and bhaga are second, minute and degree respectively. Thirty degrees makes one rashi and twelve rashi makes one bhagana. One bhagana is three hundred and sixty degrees.

## 3 Existing Methods to measure wheel alignment

There are some equipments commercially available in the market used to measure wheel alignment. One of them is spirit level type and the other is electronic resistance type of angle measuring gauge. But the procedure adopted for the measurement of caster, camber and king pin inclination is same in all cases [5]. Usual procedure to calculate these angles is as mentioned below.
Initially a gauge is attached to the wheel rim in its respective position. If we want to measure caster angle 'θ', then the wheel is rotated 30° left and the angle on the gauge is measured (say $\beta_1$). The next step is to rotate the wheel 30° right and the angle on the gauge is measured again (say $\beta_2$). The required angle $\beta$ is calculated as $\beta = \beta_2 - \beta_1$. Based on this angle $\beta$, the actual caster angle 'θ' is calculated with an appropriate scale factor. Sometimes angular scale is calibrated with the required scale factor. King pin inclination is also measured in a similar manner. The camber angle can be measured directly.

The angle measured above ($\beta$) is the tilting effect caused on the wheel. With the help of this tilt, caster angle and king pin inclination are calculated. The spirit level type of angle gauge mentioned above is manual type of gauge. Where as the electronic resistance type is a computerized type of gauge. This computerized gauge is easy to use for a layman but very costly, and not very reliable.

## 4 Essential modifications for original instrument.

To use Chaapa Yantra (a proposed gauge) for measurement of front wheel geometry, it needs following modifications:
The gauge has to be mounted on the wheel rim with the help of fixture at suitable location.
To measure caster angle, there should be a provision to mount the gauge on the fixture such that it is mounted perpendicular to the plane of the wheel. Secondly it should be possible to mount it parallel to the plane of the wheel to measure king pin inclination.
It should have three separately calibrated angular scales to measure camber, caster and king pin inclination. If the regular angular graduations are used, then the required caster or king pin inclination has to be calculated with a suitable scale factor.
Only a sector of the gauge is sufficient instead of the full semicircle. The proposed gauge with these modifications is shown in the fig. (5).
Wheel is placed on the turn table to rotate it 30° left and 30° right. Fig (6).

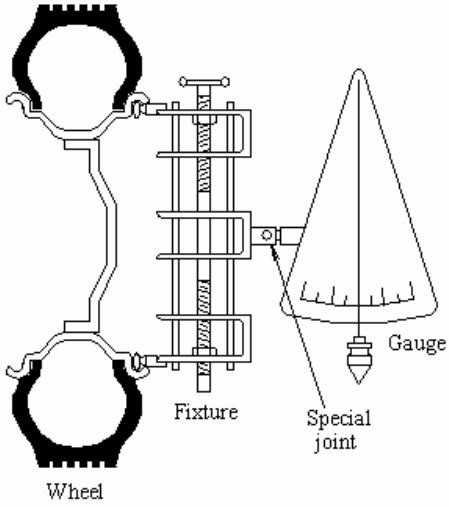



Figure 5. Proposed gauge with essential modifications.

The fixture helps to mount the gauge on the wheel rim. A special joint helps to mount the gauge in the required position so as to measure caster angle or king pin inclination.

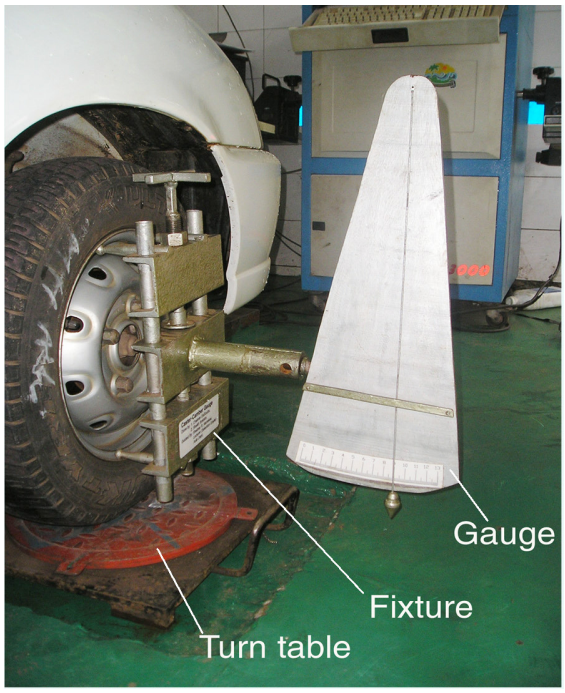



Figure 6. Fabricated gauge mounted on the wheel.

## 5 Calibration of angular scale.

The camber angle can be measured directly but the caster and the king pin inclination cannot be measured directly. We need to calibrate the scale for this reason.

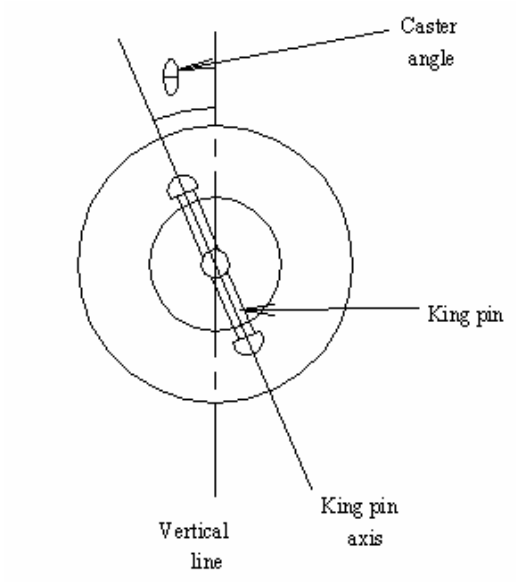



Figure 7. Caster angle is the inclination of king pin.

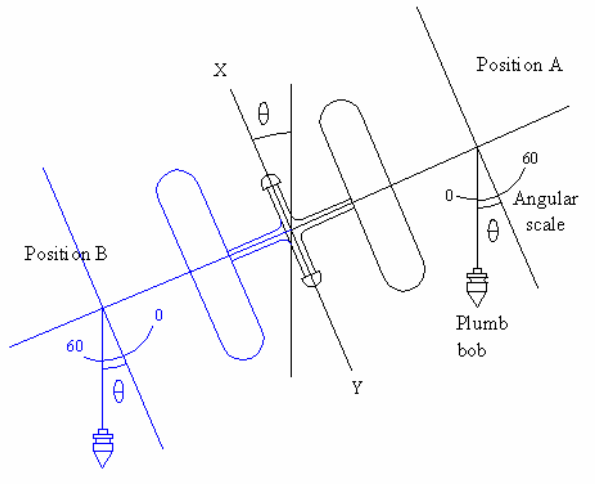



Figure 8. Variation in angle when wheel is rotated by 180°.

Consider a king pin axis X-Y. Fig. (8). Let θ be the inclination of the king pin with the vertical line. This angle is the caster angle. Let us attach a plumb bob and the angle measuring scale on the line of the axis of the wheel as shown in the figure. Now rotate the wheel by 90° right hand side, of the king pin axis, ( i.e. position A) then the angle measured with the gauge is θ°. Similarly if the wheel is moved by 90° left hand side of the king pin axis ( i.e. position B), then the angle measured with the gauge is also θ°. The total angle moved by the wheel is 180° and the angle recorded by the gauge will be 2θ°.
If the wheel axis is moved for 90° then the angle recorded by the gauge will be θ°. Automobile wheels have the provision to move them only by 60° maximum. When the wheels are moved by 60° then the angle recorded by the gauge will be 0.667 θ°.
If β is the angle recorded by the gauge,
θ is the caster angle
and wheels are moved by 60° either side then we have:

$$\text{Caster angle} = \theta = \frac{\beta}{0.667}$$

The same relationship is valid for the measurement of king pin inclination but it is essential that the plane of the gauge should be parallel to the plane of the wheel. It is assumed that king pin inclination does not have any effect on the measurement of caster angle and vice versa.

## 6 Experimental setup to test the gauge.

Experimental setup to measure caster angle with the help of the proposed gauge, should have provision to set it for different caster angles with respect to the vertical. It should have provision to mount the proposed gauge, and to move the gauge by 30° left and 30° right with respect to vertical axis. It should have a provision to level the platform so as to set the gauge exactly vertical initially. The set up is shown in the fig 9.
It is essential that the wheel should be moved more than 60° wherever possible to measure the caster angle more

accurately. But most of the vehicles have a provision to move the wheels only by 60°.

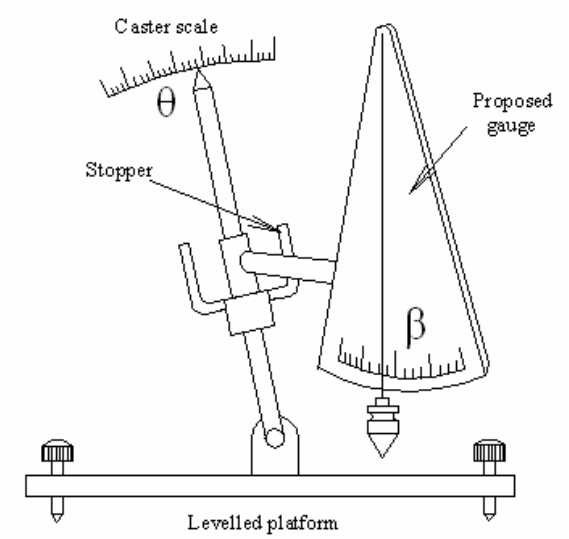



Figure 9. Experimental setup to test the proposed gauge.

Table 1: Some caster angle measured with the help of proposed gauge.

| *Sr. No* | *Caster Angle θ (Set)* | $\beta_1$ *(left)* | $\beta_2$ *(right)* | $\beta = \beta_2 - \beta_1$ | *Caster Angle θ Calcul.* |
|---|---|---|---|---|---|
| 1 | 2 | 5.8 | 7.2 | 1.4 | 2.09 |
| 2 | 4 | 5.1 | 7.7 | 2.6 | 3.89 |
| 3 | 6 | 4.5 | 8.6 | 4.0 | 6.00 |
| 4 | 8 | 3.8 | 9.1 | 5.3 | 7.94 |
| 5 | 10 | 3.2 | 9.8 | 6.7 | 9.89 |
| 6 | 12 | 2.5 | 10.6 | 8.0 | 12.00 |
| 7 | 14 | 1.8 | 11.1 | 9.3 | 13.94 |
| 8 | 16 | 1.1 | 11.7 | 10.6 | 15.90 |
| 9 | 18 | 0.5 | 12.5 | 12.0 | 18.00 |

The caster angle measured with the help of the proposed gauge and actual angle are approximately equal. With this we can conclude that this gauge can be used for the measurement of front end geometry of a car.

# 7 Conclusion

Astronomical Instrument 'chaapa yantra' can be used for the measurement of caster, camber and king pin inclination of front wheel of a car. The original astronomical instrument is modified to use it for the above application. The caster angle measured with the help of the proposed gauge and the actual angle set with a protractor are almost same. Hence it can be concluded that this gauge can be used to measure front end geometry of the car.
Since the proposed gauge is simple it can be a cheap and reliable substitute over the existing equipment.

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