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Mathematical operations in *Sadratnamālā*: An analysis with modern interpretation

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Indroduction

Śaṅkara Varman popularly known as Kaṭattanāṭṭu Śaṅkara Varman a 19th century astronomer as well as mathematician from North Malabar in Kerala. Śaṅkara Varman was born in the Kaṭattanāṭṭu Royal family in Karyadu near Nadapuram in Kozhikode. He was born as a younger prince in the third line of the principality of Kaṭattanāṭṭu. To the local people, the author was known as Appu Tampurān or Onciyil Appu Tampurān. It is said that his formal education was commenced only late, but he was a precious child, once introduced to learning, soon he blossomed out into an astute astronomer, astrologer, and poet.[1]

Sadratnamālā is the masterpiece of Śaṅkara Varman. It contains six chapters named as *prakaraṇa-s* viz. *parikarmāṣṭaka prakaraṇa, paribhāṣā prakaraṇa, pancānga prakaraṇa, Jyācāpādi prakaraṇa, pancabodha prakaraṇa, gaṇita pariṣkarma prakaraṇa.* The first chapter *parikarmāṣṭaka prakaraṇa* deals with names of numerals; defines the eight operations of addition, subtraction, multiplication, division, squaring, extracting square root, cubing, and extracting cube root. All of us know that, establishment of modern educational system in India vanishes the traditional method calculations and finding results Śaṅkara Varman is a person who knows the traditional as well as Modern mathematics. However, he used the traditional method in *Sadratnamālā*

Mostly astronomical as well as mathematical texts roughly mentioned the calculation or sometimes directly going into the calculation so the new researchers are very confused with the calculation methods with in the text. Here in *Sadratnamālā*, the author starts the text with the eight primary operation methods. So that a new one can understand the methods directly from the text itself. K.V Sarma's critical edition and English translation of Dr. S. Madhavan make the text very simple and make it as user friendly. In this paper, an analysis of traditional method of Mathematical Operations in *Sadratnamālā* with modern interpretation is included.

The *parikarmāṣṭaka prakaraṇa* begins with the four introductory verses. Then after 2 verses deals with the names of the decimal numerals as follows-

एकं दशं शतं चाथ सहस्रमयुतं क्रमात्।
नियुतं प्रयुतं कोटिरर्बुदं वृन्दमप्यथ॥1.5||
खर्वो निखर्वश महापद्मः शङ्कुश्च वारिधिः।
अन्त्यं मध्यं परार्धं च संख्या दशागुणोत्तरा॥1.6||[2]

They are one, ten, hundred, thousand, ten thousand, lakh, ten lakh, crore, ten crores, hundred crores, thousand hundred crores, ten thousand hundred crores, one lakh hundred crore, ten hundred crore, one crore hundred crores, ten crores hundred crores, thousand core hundred crores, and ten thousand crores hundred crores respectively.

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[1] Sarma K.V, *Sadratnamālā of Śaṅkara Varman*, Indian National Science Academy, New Delhi, 2001, p.1.,

[2] ibid. p.16.

10^{0}	एकं	1
10^{1}	दशं	10
10^{2}	शतं	100
10^{3}	सहस्र	1000
10^{4}	अयुतं	10000
10^{5}	नियुतं	100000
10^{6}	प्रयुतं	1000000
10^{7}	कोटि	10000000
10^{8}	अर्बुदं	100000000
10^{9}	वृन्दम	1000000000
10^{10}	खर्वो	10000000000
10^{11}	निखर्वश	100000000000
10^{12}	महापद्म	1000000000000
10^{13}	शङ्कु:	10000000000000
10^{14}	वारिधि:	100000000000000
10^{15}	अन्त्यं	1000000000000000
10^{16}	मध्यं	10000000000000000
10^{17}	परार्धं	100000000000000000

The next verse deals with the names of eight logistics or arithmetical calculation methods are

संख्यानं युतिवियूती गुणनं हरणं च वर्गमूळे च|
घनघनमूळे चैतत् साध्यतमं गणितमाहुराचार्या: ||1.7||[3]

Yuti or *Saṅkalitam* (addition), *Viyuti* or *Vyavakalitam* (subtraction), *Guṇanam* (multiplication), *Haraṇam* (division), *Vargaparikarmam* (finding squares), *Vargamūlam* (extracting square roots), *Ghanaparikarmam* (cubes), and *Ghanamūlam* (extracting cube roots) of a numbers constitute mathematical operation as stated by teachers.
From 8th verse to 19 verses he explains how to find the above arithmetical calculations in a general method.

(1) *Yuti* (Addition) and (2) *Viu£ti* (Subtraction)

यथास्थानं व्युत्क्रमेण क्रमेण यदि वाङ्क्यो: |
मेलनं युतिमत्राहुर्वियुतिं च वियोजनम् ||1.8||[4]

Finding the sum of two quantities by adding the numbers in them either direct order or in reverse order is called addition. Similarly finding the difference between the two numbers is known as subtraction.

16 + (method of Addition)	18 - (method of Subtraction)
18	16
34	02

(3) *Guṇana* (Multiplication)

गुण्यान्त्योपात्यादीन् सर्वान् गुणयेद् गुणेन पृथगङ्कान् |
गुण्यान् गुणखण्डसमान् खण्डैस्तैर्वाथ तद्युतिर्गुणनम् ||1.9||[5]

Multiply separately the last the last but one etc. digits of the multiplicand by the multiplier. The sum of these in accordance with the place value in the multiplicand is the product.

If we multiply two digits 52×25

52× (Multiplier)
25 (Multiplicand)
250+
104
1290

(4) *Haraṇa* (Division)

यद्घ्नो हरो हार्यसमस्तत्फलं हरणे भवेत् |
हार्याद् धृति: स्वानधिकहारेण तथोत्क्रमात् ||1.10|[6]

The first half of the stanza defines division and the second half gives the procedure. In division the quotient is that which, on multiplication by the deviser becomes equal to the dividend. Division by a divisor which is less than the dividend is carried out in the reverse order.
$36 \div 4 = 9$ (Here 9 is the quotient, 36 is dividend and 4 is divisor. By dividing 36 by 4 gives 9. By multiplying 9 and 4 gives 36.

(5) *Vargaparikarma* (Squaring)

तुल्योभयहतिर्वर्गएकत:क्रमश:पदै:|| का वा धेनुस्तटे शुभ्रा तुङ्गो धावेद् वृशो यदि ||1.11||[7]

The product of to equal numbers is the square of that number.
$6^2 = 36$; $6 + 6 + 6 + 6 + 6 + 6 = 36$ Or $6 \times 6 = 36$
After defining the square of a number, the next stanza gives the squares of a single digit number from one to nine. The numbers are denoted using the *Kaṭapayādi* system of notation. They are का-one, वा-four, धेनु-nine, तटे-sixteen, शुभ्रा-twenty-five, तुङ्गो -thirty-six, धावेद्-forty-nine, वृशो -sixty-four, यदि-eighty-one in order from one to nine.

स्ताप्योन्त्यवर्ग: शेषोपि द्विघ्नान्त्यघ्नो निजोपरि |
उपान्त्यादिम् अथोत्सार्य भूयोप्येवं क्रिया क्रिति: ||1.12||[8]

Having placed the square of the last digit in the line of the square, the remaining part, multiplied by twice the last digit, is added on the right of the square already placed. This procedure is repeated with the remaining digits of the number. This is the method.
Ārybhaṭa explains Vargasvarūpa or square as वर्गस्समचतुरश्र: फलन्च सद्रृशद्वयस्य संवर्ग: ||2.3||[9]. Multiplication of a number with its same number is known as squaring.

(6) *Vargamūla* (Square root)

शुद्धवर्गस्यमूळेन द्विघेनावर्गतो हतम् |

[3] Idem.
[4] Idem.
[5] Idem.
[6] ibid, p.17
[7] Idem.
[8] Idem.
[9] Sarma Satyadev, *Āryabhaṭīya*, Chaukhamba Surabharathi Prakasan, Varanasi, 2013, p.47.

तदादिमूलं तद्वर्ग: शोध्यो वर्गात् पुनस्तथा ||1.14||[10]

Having deducted the maximum possible square from the last square place divide the non –square place by twice the square root of the maximum square earlier deducted. Deduct the square of the quotient from the next square place. Repeat this to get the square root.
According to *Āryabhaṭīya*, Vargamūla or square root as

भागं हरेदवर्गान्नित्यं द्विगुणेन वर्गमूलेन |
वर्गाद्वर्गे शुद्धे लब्दं स्थानान्तरे मूलं ||2.4||[11]

(7) Ghanaparikarma (Cubing) –

ज्या ह्ऋत् सीरी भाति शरण्यस्तत्पुरि गूढाङ्ग श्रीकृष्ण: |
धीरोसावेकादिन्वन्तम् तुल्यत्र्यभ्यासो.त्र घन: स्यात् ||1.15||[12]

Here the first line indicates the names of cubes from one to nine in *Kaṭapayādi* system. They are ज्या-one, हत्-eight, सीरी-twenty-seven, भाति-sixty-four, शरण्य-one hundred and twenty-five, तत्पुरि-two hundred and sixteen, गूढाङ्ग-three hundred and forty-three, श्रीकृष्ण:-five hundred and twelve, धीरोसा-seven hundred and twenty-nine. The product of three equal numbers is the cube of that number.

घनेथ तन्मूळवर्गतदादित्रिवधे तत: |
आदिवर्गन्त्यत्रिवधे युतेष्वङ्केषथो घन: ||1.16||[13]

The cube of the last digit adds on the right the product of thrice he square of the last digit and the remaining digits. Then add the product of thrice the last digit and the square of the remaining part and then add on the cube of the remaining part.
Ārybhaṭa explains cubing as सद्रशत्रयसंवर्गो घनस्तथा द्वादशाग्रस्स्यात् ||2.3||[14] Multiplication of a number three times with the same number is known as cubing or Ghana Parikarma or cubing.

(8) Ghanam£lam (Cube root)

घनमूळस्य वर्गेण त्रिग्नेनाघनतोन्त्य: |
लब्धस्य वर्गस्त्र्यादिघ्न: शोध्यश्चाध्यात् घनात् घन: ||1.18||[15]
इष्टाप्तेष्टैक्यार्धमिष्टमविशिष्टकृते पदम् |
घनमूळम् द्विरप्तेष्टयोगार्धमविशेषितम् ||1.19||[16]

Having deducted the greatest possible cube from the last place and having kept the cube root of the number subtracted in the line of cube root, divide the second non-cube place by thrice the square of the cube root and subtract the square of the quotient multiplied by thrice the cube root from the first non-cube place. Then subtract the cube from the cube place.
Āryabhaṭīya gives the method to find out the cube root as

अघनाद्भजेद्द्वितीयात् त्रिगुणेन घनस्य मूलवर्गेण|
वर्गस्त्रिपूर्वगुणितश्शोध्य: प्रथमाद्घनश्च घनात्||2.4||[17]

Alternative Methods to find the square root and cube root.

इष्टाप्तेष्टैक्यार्धमिष्टमविशिष्टकृते पदम् |
घनमूळम् द्विरप्तेष्टयोगार्धमविशेषितम् ||1.19||[18]

Divide the number whose square to be found by any arbitrary number and find half of the sum of the arbitrary number and the quotient. Divide the number again by this new deviser. The same process is continued until the quotient becomes equal to the divisor.
In the case of cube root, the first quotient is divided again by the arbitrary number to get the second quotient. The half of the sum of the arbitrary number and the second quotient is found which the second divisor is. This is repeated until the divisor becomes equal to the second divisor.

Conclusion

Sadratnamālā deals with almost all the mathematical as well as astronomical things that are relevant in the period of first 19th century. It is a hand book which included all the Keralite Astronomical as well as mathematical theorems invented till his time. Almost all the important concepts related to the subjects are spoken in an easy manner using couple of verses. Sometimes this will not at all easy for the beginners. If someone know the basic concepts of astronomy and mathematics can follow the *Sadratnamālā¡*.
Without the commentary or the study of the *Sadratnamālā* common people cannot understand this text. The knowledge of both in mathematics as well as in Sanskrit person only means the concept given here. Detailed idea regarding his personal life and his contribution are not known. Through the works of Charles M. Whish, K.V Sarma, Dr. S. Madhavan are the text got more popularity. Through these texts one can understand the basic operations or the mathematical operations clearly. Unless it is difficult to understand.

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[10] *Sadratnamālā of Śaṅkara Varman*, p.17.
[11] *Āryabhaṭīya*, p.50.
[12] *Sadratnamālā of Śaṅkara Varman*, p.17.
[13] ibid, p.18.
[14] *Āryabhaṭīya*, p.49.
[15] *Sadratnamālā of Śaṅkara Varman*, p.18.
[16] ibid,p.18
[17] *Āryabhaṭīya*, p.56.
[18] *Sadratnamālā of Śaṅkara Varman*, p.18.