Research Note

Introduction and Development of the Screw in Seventeenth-Century China: Theoretical Explanations and Practical Applications

by Ferdinand Verbiest

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Abstract: This research note gives a short account of the introduction of the screw into China. It focuses on the transmission of the technological knowledge and practical application of screws by the Jesuits of the China mission in the seventeenth century. The main source used is Terrenz (Johann Schreck) and Wang Zheng’s Yuanxi qiqi tushuo (Record of the Best Illustrations and Descriptions of Extraordinary Devices of the Far West), which in chapter two contains a description in twenty-one sections of the screw as the sixth of the six single machines. This source is significant as Ferdinand Verbiest, who focussed on the practical applications of the screw, copied some parts of the text in his Lingtai yixiang zhi (Treatise on Astronomical Instruments at the Imperial Observatory; 1674) and some of the illustrations in his Yixiang tu (Illustrations of Astronomical Instruments). The research note starts with an analysis of Verbiest’s text on the use of
screws, which is linked to illustration 87 (Fig.4) in the *Yixiang tu*. Other applications of mechanical techniques can be seen in his illustrations 62, 66 (see Fig. 2, 2a, 2b), 67 (Fig. 3) and 88 (Fig. 5), but without any explanations. They were presumably introduced by Verbiest as additional reference material for those interested in the practical use of screws. This is followed by an analysis of Verbiest’s explanations of the use and particular functions of screws as provided in the specific texts dedicated to each of his six new instruments. Finally, the origin of the *Yixiang tu* prints will be elucidated and the original pictures from the Western sources reproduced.

The continuously winding screw–thread and the cylindrical worm are the most outstanding examples of mechanical systems apparently unknown to the Chinese until the seventeenth century. Before the Ming dynasty (1368-1644) no clear records of inventions and applications of the screw appear in Chinese records. The first picture of a screw in Chinese literature is found in the encyclopaedia *Sancai tuhui* 三才圖會 (Pictorial Compendium of Three Powers) (1609) compiled by Wang Qi 王圻. We find it in the section Qi yong 器用 (utensils), where it is shown being used for the cap of a gun. However, Yan Hong-Sen 頭鴻森 in his “Reconstruction Designs of Lost Ancient Chinese Machinery” also mentions (in addition to the *Sancai tuhui*) chapter 15 of the *Baopuzi neipian* 抱朴子內篇 (Master Embracing Simplicity, Inner Chapters; fourth century AD) that seems to describe a flying device named fei che 飛車 (flying machine) that used the principle of the screw. He also refers to a reconstruction of such a mechanism in Liu Xianzhou’s 劉仙洲 book (1962) about the history of Chinese mechanical engineering.

According to Yan Hong-Sen, a clear description of the invention and application of the screw appears in the books *Wubei zhi* 武備志 (Treatise on Armament Technology) (1621), and *Wuli xiaoshi* 物理小識 (Brief Knowledge of Things) (1664) written by Fang Yizhi 方以知 (1611-1671). But these seventeenth-century works were undoubtedly influenced by the introduction of Western technology after 1600.

Although heliocoidal forms were known in traditional China, the principle of the screw as a simple machine was not represented among her

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1 Needham (1965), pp. 119ff.
2 *Siku quanshu zhenben* 第十集, vol. 132, chap. 8, Qi yong lei 器用類, f. 44r (Qi zhong fa 起重法, a short description of the use).
technology, and the continuous screw and worm were absent till the seventeenth century, when the screw and the Archimedian water-raising screw were mentioned and illustrated in two Chinese works of the Jesuits: Sabatino De Ursis and Xu Guangqi’s Taixi shuifa 泰西水法 (Hydraulic Methods of the Great West), and Johann Schreck (Terrenz) and Wang Zheng’s Yuanxi qiqi tushuo 遠西奇器圖說 (Record of the Best Illustrations and Descriptions of Extraordinary Devices of the Far West). Koetsier and Blauwendraat have suggested that the absence of Greek mathematics in China could be the reason for this, “as the reconstruction of the invention starts with the problem in pure Greek mathematics of the quadrature of the circle, which led to the study of different kinds of spirals, among them the cylindrical helix.”

In the Renaissance, the five simple machines (the lever, the pulley, the wheel, the wedge and the screw) were based on the description of Hero of Alexandria (c. 10-70 AD). He gave the first technical description of the development of the screw-thread in his book Mechanica, which has been preserved in fragmentary form in the “Mathematical Collections” of Pappus (c. 290-c. 350 AD). The method is to wind a sheet of soft metal in the form of a right-angled triangle around the cylinder, so that one arm of the right angle is parallel to the axis. The hypotenuse would then trace a spiral on the surface of the cylinder. The explanation of the screw by Guidobaldo del Monte (1545-1607), found in his Mechanicorum liber of 1577, was reconstructed based on the hints of Hero (Pappus). The relation between the screw and the right-angled triangle was also the starting point for Galileo Galilei (1564-1642) when explaining the nature of the screw. Galileo’s original text “Delle macchine” (1592-1593) was included in his book Le Mechaniche (1598-1599). The latter was also included and first published in French by Marin Mersenne (1588-1648) in his Les mécaniques de
Galilée (1634), where the screw is described in chapter IX (“De la Viz”). Evangelista Torricelli (1608-1647) also treats the screw in “De dimensione cochleae”, an appendix to the last tract in his Opera geometrica (1644).12

1. Transmission of Technological Knowledge of the Screw by the Jesuits

The first theoretical analysis of the origin and nature of the screw in China was given by the Jesuit Johann Schreck (Terrenz; Deng Yuhan 登玉函) in cooperation with Wang Zheng 王徵 in the Yuanxi qiqi tushuo 遠西奇器圖說 (Record of the Best Illustrations and Descriptions of Extraordinary Devices; 1628). Ferdinand Verbiest copied some of this work and its illustrations into his Lingtai yixiang zhi 靈臺儀象志 (Treatise on Astronomical Instruments at the Imperial Observatory; 1674), chapter 2, f. 47.

In their treatises, Terrenz and Verbiest follow for the most part the didactic explanations of Galileo Galilei and Guidobaldo del Monte. For the explanation of the theory of the screw they use the theory of the inclined plane as given by Simon Stevin (1548-1620)13 in De Beghinselen der Weegkundt and by Galileo in Le Mechaniche.

In chapter two of the work of Terrenz and Wang, they describe and illustrate the six simple machines or instruments (qi zhi zong lei 器之總類) in 92 sections.15 These six are:

1. balance (tianping 天平; section 9-15);
2. steelyard (dengzi 等子; section 16-33);
3. lever (ganggan 槓杆; section 34-48);
4. pulley (hua che 滑車; section 49-55);
5. windlass or capstan (yuanlun 圓輪; section 56-71);
6. screw (teng xian 藤線; section 72-92).16

We will have a look now at the contents of the twenty-one sections (72-92) on the screw.

First of all we have to note that, with regard to terminology, Terrenz and Wang do not use the same characters as Verbiest to describe a screw. Terrenz and Wang, who aimed to transmit theoretical knowledge in their treatise, use luosizhuan 螺絲轉 (luo 螺 refers to the spiral conch; si 絲, silk or...
thread, refers to a continuous fibre; and zhuan 轉 to revolving). Verbiest, who transmits practical knowledge, uses luoxuanzhuan 螺旋轉 (xuan 旋 means “revolving”, “circling” or “spinning”), which refers to the function and application of the screws (setscrews), emphasizing the revolving aspect through the two last characters.

Returning to the sections:

Section 72: refers to the spiral form (helix of winding line) of the screw that has a resemblance to the creeping tendrils of vines. This can also be seen in the character teng 藤 (a general name for climbing plants) used for denoting the screw.

Section 73: describes the components of the screw: the cylinder (yuanti 圓體), its axis (yuanti zhi zhou 圓體之軸), and the winding line [helix] (tengxian 螺線).

Section 74 (Fig. 1c): mentions three kinds of screw shape—cylindrical screw (zhuluo 柱螺), spherical screw (qiuluo 球螺), and conical screw (jianluo 尖螺). “The cylindrical screw is used for lifting weights. The spherical screw is what an astronomer certainly needs to use. The conical screw is an instrument to deeply penetrate into solid materials.” The drawings of these three kinds of screw are copied by Verbiest in print 62 of Yixiang tu (Fig. 1).

Section 75: explains why the screw is more suitable to use and nicer to work with. He refers to its use in juice presses and (water) gates, and that the spherical screw enables one to follow celestial phenomena. He mentions that these screws are described and illustrated in Western books.

Sections 76 to 84: elucidate the relation between the screw helix and the inclined plane. The theory of the inclined plane is given by Simon Stevin in De beghinselen der Weeghconst and Galileo in “Della Meccaniche”.

Section 84: specifies the threading of the screw. “In this way we learn that the more dense the threading of the screw by its helical line, the more powerful it becomes” (tengxian yu mi, qi nengli yu da 螺線愈密其能力愈大).

Sections 85 to 92: deal with specific propositions and requirements of spiral implements (screw).

Section 85: explains that when two cylinders are different, but the height of the worm is the same, then the biggest uses less force.

Section 86: treats the problem that whatever is gained in force is lost in time.

Section 87: is about the three materials used to construct screw devices—steel, wood and copper. As for small screw devices, for the male (outside screw) (mu 牡) and female (inside screw) (pin 牝) you have to use copper, and to prevent rust never use copper and steel together.

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18 Galilei (1808), vol. II, pp. 155-190.
Section 88: describes how to make a helical implement (screw) when the diameter of the cylinder and the inclination of the winding line are given. Explanation is given using the method of the triangle.

Section 89 to 92: deal with mathematical solutions in the application of the screw, namely:

Section 89: how to find the angle of the worm (spiral) when we know the length and the height of the (spiral) helix.

Section 90: how to find the angle of the worm (spiral) when one has a helical implement (screw).

Section 91: how to find the force when one has a helical implement (screw) (see item 84).

Section 92: how to find the revolutions of the helical implement (screw) when one has a helical implement (screw).

2. Practical Applications of the Screw

Ferdinand Verbiest used the screw as a setscrew\(^\text{19}\) to elevate a weight or to bring a device into a certain position in order to adjust and to fix it. In the *Astronomia Europæa* Verbiest only mentions the word “cochlea”,\(^\text{20}\) a setscrew to raise, lower and balance the support of the ecliptic armillary in all directions.\(^\text{21}\)

In the Constantinople manuscript (1676)\(^\text{22}\) he describes figura 80 (*Yixiang tu* 儀象圖, print 87; see below Fig. 4) as showing the differences between setscrews:

This figure corresponds to the chapter, in which I show the difference between two setscrews, one with a major cylinder, and one with a minor cylinder or a cylinder with a transversal diameter, although the height of the spires of the screw is the same.\(^\text{23}\)

He gives a short explanation for this in his *Yixiang zhi* (*YXZ*), chapter two, pp. 47a-47b: *Xinyi yong luoxuanzhuan yi bian qi* 新儀用螺旋轉以便起 (The new instruments use screws to facilitate lifting) with reference to print 87 (Fig. 4). This text Verbiest also reproduced, without the illustration, in his *Qiongli xue* 窮理學 (*Study of Fathoming Principles*) 1683 (chapter 8), chapter 3: *Xingxing zhi litui* 形性之理推, ff.11b-15b.\(^\text{24}\)

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\(^{19}\) The term ‘setscrew’ is used here in the broad meaning of any screw used for adjusting the setting of a machine in any way.


\(^{21}\) Golvers (1993), pp. 95 and 397.

\(^{22}\) Golvers & Nicolaidis (2009), pp. 233 and 296n293.


\(^{24}\) Dudink & Standaert (1999), p. 27.
Print 87 (Fig. 4) is copied from chapter three of Buonaiuto Lorini’s *Delle fortificationi* (1609), as ‘Della lieva con la vite’ (Fig. 4a). Although he does not refer in his texts to print 88 (Fig. 5), it is also reproduced from *Delle fortificationi*, viz. chapter five: ‘Strumento overo Argagnocon la vite, e ruote per alzare un peso’ (Fig. 5a). The Constantinople manuscript (figura 81) describes this print as ‘to lift up heavy weights.’

It is interesting that Simon Stevin in the second part of the supplement to the *Art of Weighing* ‘On the pulley weight’ (Bijvoughs der weeghconst, vant catrolwicht) mentions *Delle Fortificationi di Buonaiuto Lorini*. The growing interest in machines in the Renaissance and support from kings and princes stimulated this kind of publication.

The first paragraph of Verbiest’s text mentioned above on the use of screws corresponds to Galileo’s appreciation of the usefulness of the screw in *Le Mechaniche*:

> Among all the mechanical instruments devised by human wit for various conveniences, it seems to me that for ingenuity and utility the screw takes first place, as something cleverly adapted not only to move but also to fix and to press with great force, and it is constructed in such a manner as to occupy but a very small space and yet to accomplish effects that the other instruments could perform only if made into large machines.

Verbiest continues with the practical application of the screw in his instruments. He explains that:

> In order to turn (xuan 旋), untwist (kai 開) or fasten (jinsong 緊鬆) the head of the screw, we employ a handle (crank) (jiaobing 絞柄), and if the size of this handle is in a certain ratio to the radius of the screw (luoxuanzhuan zhi banjing 螺旋轉之半徑), the power saved (shengli 省力) has the same ratio.

This proportion is based on the principle of the lever. Guidobaldo gives the explanation of this principle and its system. He mentions two reasons why weights are easily moved by means of this small instrument:

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26 See Lorini (1592). Stevin was the Dutch tutor of Prince Maurits of Nassau (1567-1625) and notes that the Prince could understand thoroughly Lorini’s treatise about pulleys by studying his work *Art of Weighing*. See Dijkstra (1955), pp. 553 and 192.
28 *Lingtai yixiang zhi*, chap. 2, f. 47.
(1) “What makes the weight easy to move and what especially belongs to the nature of the screw is the worm; for, if there were around a given screw AB two unequal worms CDA and EFG, I say that the same weight is moved more easily on CDA than on EFG.” (Fig. 6)

(2) Weights are easily moved due to the (length of) the radius or handles by which the screw is turned: “If the power is known which must move the weight on the worm, we may arrange the handle in such a way that the given power on the handle has the same force as the power that moves the weight on the worm.”

Verbiest gives the following example: The new instruments, their bases included, all weigh from 4,000 to 5,000 jin. A screw with a diameter of 1 inch and a handle of 1 foot will make it possible for a child to set things going, even if it only harnesses a power of a few jin. Bearing in mind the method of combined proportions and employing the method of transmitted screws, the harnessed power of 1 jin will be able to lift a weight of some 10,000 jin.

Verbiest refers only to an increasing force, but omits the consideration that what one gains in capacity (or, the more force is multiplied by means of such a device), the more one loses in time and velocity. This rule was also omitted in his treatise on the toothed wheel. Galileo on the other hand explains it in his treatise on the screw.

Galileo explained the nature of the screw by means of a right-angled triangle, pulled forward under the heavy body that has to be lifted by slipping and pushing ahead. But for the construction of such a device that can be reduced to a smaller and more convenient form, he used the same triangle turned around a cylinder. The hypotenuse equals the screw thread and the upright side of the triangle the height of the cylinder. The multiplication of the force depends on the ratio of the entire thread to the entire height of the cylinder.

Verbiest mentions this theorem and refers to his print 87 (Fig. 4): “How the screw saves energy can be found in the ratio [bili 比例] between the hypotenuse and the vertical side of a right angled triangle (qi luoxuan suoqi shengli zhi gu, ze zai gouguxing zhi xian yu gu yiding zhi bili 其螺旋所以省力之故則在勾股形之弦與股一定之比例).” To understand the system of the screw, Verbiest refers to zhangxue 重学, the study of weights, which contains the basic principles of the balance, the lever and other lifting machines and their geometrical principles: “In the above-mentioned theory

31 1 jin = c. 596 g.
32 Lingtai yixiang zhi, chap. 2, f. 48.
33 I.e. statics. Some items are also to be found in his philosophical work Qiangli xue.
of weight, this is enunciated and this detailed explanation will be very clear.”

3. Applications of the Screw in the Newly Constructed Instruments

Most of Verbiest’s instruments correspond to those of Tycho Brahe (1546-1601), as described and represented in *Astronomiae instauratae mechanica* (1598). Some of Brahe’s instruments had already been mentioned and illustrated before in *Celiang quanyi* 測量全儀 (Complete Theory of Surveying) (1631) by Giacomo Rho and Johann Adam Schall von Bell. As in the prototypes constructed by Tycho Brahe, Verbiest used the screws to raise or to lower the instrument, to have it fixed in the right position, or to adjust it to its corresponding celestial circles.

As Verbiest was the first person to use setscrews (adjusting screws) in China he emphasized their correct placement. This was because the old instruments of Guo Shoujing 郭守敬 (1231-1316) at the Beijing observatory were fixed, and therefore could not be put in the correct position. Verbiest mentioned this in his introduction: “But if one has no way of placing them in position, then one cannot make good observations with their help, and so they are in fact useless.”

He emphasized the importance of his screws in every treatise he composed about the newly constructed instruments. The importance of using screws in instruments had already been mentioned by Jacques Besson (1540-1573), who depicted at the start of his book *Theatrum instrumentorum et machinarum* instruments that had been used as illustrations for geometrical and mechanical theories, on which the inventions included in the book were based. Johannes Hevelius (1611-1687) made further progress with screws on astronomical instruments. Such devices as the use of a threaded screw for fine adjustment of the alidade over the degree scale distinguish Hevelius’ instruments. The screw was attached to the ocular sight, and was not a tangent screw engaging with a toothed edge around the limbus, but a true adjusting screw fitting into a threaded screw hole. Verbiest, however, did not apply the refined use of screws by Hevelius.

In his treatise *Lingtai yixiang zhi* 靈臺儀象志 (Treatise of Astronomical Instruments at the Imperial Observatory) we can say that Verbiest refers to

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34 *Lingtai yixiang zhi*, chap. 2, f. 48.
36 *Celiang quanyi*, pp. 740-748.
37 *Lingtai yixiang zhi*, “序” (Preface), f. 10.
38 Besson (1578).
39 Hevelius (1673).
the screw as a technological requirement necessary for the improvements of mechanical devices like his new instruments. For him it was their practical application that was crucial.

We have no information in this period about in which (Palace?) workshop the screws for the instruments may have been made. We only know from a collection of memorials, the *Xichao dingan* (Settled Cases in Our August Dynasty), that Verbiest, as supervisor and under the control of the Ministry of Public works (gongbu 工部), demanded raw materials for the construction of the instruments and a salary for his craftsmen in August 23, 1669. In a letter of August 20, 1670, addressed to Jacques Le Faure, he mentions, “… the Gong bu has taken the responsibility to construct the instruments on the basis of his [i.e. Verbiest’s] prescribed prototype with the best brass …”

This means that Verbiest controlled the quality of the materials he used, and worked with skilled Chinese artisans. His appreciation of them is reinforced by his demand for a salary. These artisans who assisted in the construction of instrument should have, in due course, been able to copy Western instruments for themselves, but the court continued to retain Jesuit assistance for the construction of instruments.

Verbiest mentions the following application of screws for the six instruments:

*Ecliptic armillary instrument*

- Chap. 1, f. 7a: The ecliptic polar axis is fixed by two *luozhu* 螺柱 (screws). The axis can be untwistable if one does not want to use this.
- Chap. 1, f. 8a: Four *luozhu* 螺柱 (setscrews) are mounted at four equidistant points on the oblique base or support, to adjust the whole instrument.

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40 *Xichao chongzheng ji*; *Xichao dingan (wai san zhong)*, pp. 63-64, 工部請旨一疏 (估計新建觀象台費用), under the date KX 8/7/27 (August 23, 1669). This petition received imperial approval in KX 8/8/1 (August 26, 1669).


43 The list below shows that Verbiest uses *Luo xuan zhuan* 螺旋轉 and *luo zhu* 螺柱 interchangeably. Perhaps we should conclude that *luo xuan zhuan* refers to the strong setscrews that are mounted on the base or support to adjust the whole instrument, while *luo zhu* refers more to screws for fastening different parts of the instruments in order to put them in exact corresponding places. Both screws are important for accurate observations.
Equatorial armillary instrument
- Chap. 1, f. 12a: Four luožhu 螺柱 (setscrews) are placed at the four equi-
distant points.

Azimuth instrument
- Chap. 1, f. 13a: Luoxuanzhuan 螺旋轉 (setscrews) are mentioned for ad-
justing the level of the instrument. The four screws support points at the
four ends of beams cutting each other crosswise, which allows adjustment
of the whole structure, so that the instrument can be levelled and placed in
a perfectly horizontal position.
- Chap. 1, f. 13b: A screw or fastener luožhu 螺柱 is used to arrange the
turning point with regard to the middle of the horizontal plane.

Quadrant
- Chap. 1, f. 17: A screw or fastener (luožhu 螺柱) is applied to block the
alidade.
- Chap. 1, f. 17b: Three screws are mounted to make the axis line coincide
with the plumb line of the instrument.

Sextant
- Chap. 1, f. 20b: A luožhu 螺柱 (screw or fastener) is used to fix the posi-
tion of the axial system (transversal axle and axial system).

Celestial globe
- Chap. 1, f. 23: Setscrews (luoxuanzhuan 螺旋轉) are mentioned on bearing
blocks at both poles on the meridian ring that contain the instrument’s axis.
- Chap. 1, f. 27b: The zenith gauge has a setscrew (luoxuanzhuan) which
allows one to move and fix the zenith.
- Chap. 1, f. 30: Setscrews (luoxuanzhuan) are set at the base to adjust the
level of the instrument.

4. Conclusion
In their conclusion concerning the transmission of European mechanics
into China in the seventeenth and eighteenth centuries, Zhang Baichun and
Tian Miao underline the importance of the aims of the transmitters (the
Jesuit missionaries, using knowledge to win over Chinese scholars) and
receivers (the Chinese scholars interested in practical knowledge useful to
society). Water screws were introduced, but never became popular due to
the inconvenience and high costs of construction and maintenance. As the
Chinese used wedge presses, the Jesuits did not need to promote the

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Western screw presses, but, according to Joseph Needham,\(^45\) the Jesuits were responsible for the introduction of worm gears and the simple wood screw and metal screw. In this context, Verbiest’s introduction of the setscrew into China is a good example of the practical application of one of the five simple machines: the screw used as a specific tool to facilitate raising heavy objects, and thus as a labour-saving device, has considerable practical value.

What is important is that Verbiest was able to demonstrate a visible and useful application of the screw with his own newly constructed instruments. Why so important? The Chinese instruments available on the observatory were fixed instruments. By using screws, the instruments and their parts could be taken apart and moved to other places. After replacement, the whole instrument could be adjusted using the screws, which was not possible with the old Chinese instruments. Verbiest repeatedly points out that these old instruments, because they could not be adjusted, were not in accordance with the celestial circles and not fit for making measurements.

Verbiest used Tycho Brahe’s instruments as prototypes. These instruments were also provided with screws to adjust them and Verbiest applied Brahe’s mounting system to his own instruments. As the Jesuits had just introduced into China the theoretical knowledge of the screw from Western sources, this practical application was most timely for demonstrating its usefulness and mechanical advantages.

The explanation of the screw does not differ from the other explanations in Verbiest’s *Lingtai yixiang zhi*: the technical explanation is very limited and only a few references to the specific instruments are included. The text on the screw is largely based on the Chinese text of Terrenz and Zheng, and on the principles of Stevin (inclined plane), Galileo (screw) and Del Monte (level). Verbiest does not give original theoretical explanations. His text is an intelligent compilation limited to what is usable. The prints to illustrate the principles are taken from Vittorio Zonca, Agostino Ramelli, Jacques Besson, Buonaito Lorini, and some are similar to some in the manuscripts of Francesco di Giorgio Martini. So, overall one might consider Verbiest’s text on the screw to be a description of mechanical technology for practitioners with special reference to astronomical instruments.

Illustrations

Figure 1. Screw as depicted in Verbiest’s *Yixiang tu* 儀象圖, 1674.


NOTE: This picture shows the two applications of worm and wormgear and the three shapes of screws, namely, the cylindrical, spherical screw, and conical screw. These mechanical techniques were introduced by Verbiest into China. We see a spirally threaded shaft and a conic worm. The worm with handle and the application machine (on the left of the print) are based on Vittorio Zonca’s (1588-1603) ‘Vite perpetua che’alza grandissimi pesi’. The other machine (on the right side of the print) is an application of the conic worm in the style of Zonca’s ‘Vite perpetua o martinello’ (Fig. 1a, 1b). The illustrations of the three shapes of screws are copied from the *Yuanxi qiqi tushuo*, section 74 (Fig. 1c).
Figure 1a. Endless screw and winch in Vittorio Zonca’s *Novo Teatro di machine et edificii*, 1607.

SOURCE: Zonca (1607), fig. 1, ‘Vite perpetua che’alza grandissimi pesi’.
The Archimedes Project: Database Machine Drawings:
http://dmd.mpiwg-berlin.mpg.de/author/dmd/database/resultpage?
table=ded&format=resultpage&theauthor=Zonca,Vittorio&
Figure 1b. The conic wormdrive in Vittorio Zonca’s *Novo Teatro di machine et edificii*, 1607.

SOURCE: Zonca (1607), fig. 2, ‘Vite perpetua o martinello’.
The Archimedes Project: Database Machine Drawings:
http://dmd.mpiw-berlin.mpg.de/author/dmd/database/resultpage?
table=ded&-format=resultpage&theauthor=Zonca,Vittorio&-
Figure 1c. Three screw shapes as depicted in Johann Schreck and Wang Zheng’s (Yuanxi) qiqi tushuo, 1628.

SOURCE: (Yuanxi) qiqi tushuo.
Figure 2. Applications of screws as depicted in Verbiest’s *Yixiang tu*, 1674.

NOTE: Applications of setscrews can be seen at the bottom right. The plate is copied from Agostino Ramelli’s ‘Macchine per rompere un inferriata’ (fig. 2a). The applications of setscrews at the bottom left are illustrations of screw clamps, box spanners, pincers and cable fasteners. These applications can be seen in the mss. of Francesco di Giorgio Martini (1439-1502) (Fig. 2b).
Figure 2a. Setscrews as depicted in Agostino Ramelli’s *Le diverse et artificiose machine*, 1588.

Figure 2b. Applications of screw clamps, box spanners, pincers and cable fasteners as depicted in Francesco di Giorgio Martini’s *Trattato di architettura civile e militare*, 1478-1486.

SOURCE: Martini (1481?), p. 134.

NOTE: Another is in *un codice di machine civili e militari della collezione Santini*. Some of the Santini codices are reproduced in Bettini (2009), fig. XIV.14r, p. 648, and fig. LI 50r, p. 660.
Figure 3. Applications of screws as depicted in Verbiest’s *Yixiang tu*, 1674.


NOTE: Original Western source not found.

Here we see applications of different types of screws: as screws with gimlet points, with grips, and button headed setscrews. Some screws can fix or adjust mechanical devices; others go deeply into the surface of spherical objects (globs).
Figure 4. Two setscrews as depicted in Verbiest’s *Yixiang tu*, 1674.

NOTE: Illustration copied from Buonaito (Bonaiuto) Lorini’s (1537/38?-1611) treatise on fortification, book 5, nr. 1, illustration of chapter 3 (Fig. 4a).
Figure 4a. Screws as depicted in Buonaiuto Lorini’s *Fünff Bücher von Vestung Bauwen*, 1607.

SOURCE: Lorini (1607), book 5, nr. 1, illustration of chapter 3.
Figure 5. The spindle hoist and a drawing of the inclined plane as depicted in Verbiest’s Yixiang tu, 1674.


NOTE: Illustration of a spindle hoist, copied from Buonaito (Bonaiuto) Lorini’s treatise on fortification, book 5, nr. 1, illustration of chapter 4 (see Fig. 5a). At the top, there is Stevin’s illustration (see Fig. 5b) based on the inclined plane. This is a didactic drawing which Verbiest added to explain that the mechanical system of the spindle hoist relies on the law of the inclined plane.
Figure 5a. The spindle hoist as depicted in Buonaiuto Lorini’s
Fünff Bücher von Vestung Bauwen, 1607.

Das Dritte kupffer des 5. buchr.

SOURCE: Lorini, (1607), Fünff Bücher von Vestung Bauwen, treatise on
Fortification, book 5, nr. 1, illustration of chapter 4.
Echo European Cultural Heritage on Line, see picture 295.
http://echo.mpiwg-berlin.mpg.de/ECHOdocuViewfull?mode=
imagepath&url=/mpiwg/online/permanent/library/9X5G8ZZ0/pageimg
&viewMode=images.
Figure 5b. The inclined plane in Simon Stevin’s
*De Beghinselen der Weeghconst*, 1586.

II VERVOLGH.
LAET ons nu d’e’en sijde des driehouckx als BC (ande welcke AB dobbel is) rechthouckich stellen op AC als hier neuen;
Ende den cloot D die dobbel is an E, sal noch met E euestaltwichtich sijn, want ghelijck AB tot BC, also den cloot D tot den cloot E.

Echo European Cultural Heritage on Line, see picture 78.
http://echo.mpiwg-berlin.mpg.de/ECHOdocuViewfull?url=/mpiwg/online/permanent/archimedes/stevi_weegc_085_nl_1586
Figure 6. Explanation of the principle of the lever in Guidobaldo Del Monte's *Mechanicorum liber*, 1577.

References

Traditional Works in Eastern Asian Languages:


*Lingtai yixiang zhi, Yixiang tu* 靈臺儀象志, 儀象圖 (Treatise on Astronomical Instruments at the Imperial Observatory, Illustrations of Astronomical Instruments), by Nan Huairen 南懷仁 [Ferdinand Verbiest], Beijing, 1674.

*Qiqi tushuo* 奇器圖說: see under *(Yuanxi) qiqi tushuo*.


*Xichao chongzheng ji: Xichao dingan (wai san zhong)* 熙朝崇正集; 熙朝定案 (外三种) (“Collection for Revering Orthodoxy in Our August Dynasty”, “Settled Cases in Our August Dynasty” (and Three Related texts)), ed. by Han Qi 韓琦 and Wu Min 吳旻, Beijing: Zhonghua shuju 中外交通史籍丛刊, 2006.

*Yixiang tu* 儀象圖: see under *Lingtai yixiang zhi*.

Traditional Works in Western Languages:

Besson, Jacques (1578), *Theatrum instrumentorum et machinarum*, Lyon: Barthévély Vincent.

Brahe, Tycho (1598), *Astronomiae instauratae mechanica*, Wandersburgi.


Guidibaldi e Marchionibus Montis (1577), *Mechanicorum Liber*, Pisauri.


Ramelli, Agostino (1588), *Le diverse et artificiose machine / del captiano Agostino Ramelli ... ; nellequali si contegnono uarij et industriosi mouimenti, degni digrandis sima speculatione, per cauarne beneficio infinito in ogni sorte d’operatione ; composte in lingua italiana et francese*, Parigi.

Stevin, Simon (1586), *De Beghinselen der Weeghconst*, Leyden: Inde Druckerye van Christoffel Plantijn. (By François van Raphelinghen). Also included in his *Van de Weeghconst* (1605, reedition of 1586), *Wisconstige Gedachtenissen (Mathematical Memories)*, Part IV.


Zonca, Vittorio (1607), *Novo teatro di machine et edificii: per uarie [varie] et sicure operationi; có le loro figure tagliate in Rame é la dichiaratione e dimostrazione di ciascuna; opera necessaria ad Architetti, et a quelli ch di tale studio si dilettano*, Padoua.

**Secondary Sources in East Asian and Western Languages:**


Golvers, Noël (transl.) (1993), *The Astronomia Europaea of Ferdinand Verbiest, S.J. (Dillingen, 1687)*, Nettetal: Steyler Verlag (jointly published by
Ferdinand Verbiest Foundation, Leuven, and Institut Monumenta Serica, Sankt Augustin; Monumenta Serica Monograph Series; 28).


Liu Xianzhou 劉仙洲 (1962), Zhongguo jixie gongcheng faming shi 中國機械工程發明史 (The History of Inventions in Chinese Mechanical Engineering), Beijing: Kexue chubanshe.


Valleriani, Matteo (2010), Galileo Engineer, Berlin: Springer (Boston Studies in the Philosophy of Science; 269).

