THE HELIX-TOWER BY KONRAD ZUSE AUTOMATED CON- AND DECONSTRUCTION

Thomas Bock
Technische Universität München, Munich
thomas.bock@bri.ar.tum.de

Nora Eibisch
Technische Universität München, Munich
nora.eibisch@bri.ar.tum.de

Abstract
In this Paper we present a continuously extendable and retractable tower construction: The Helix-Tower by Konrad Zuse. From 1989 onwards Zuse worked on the design of the height-adjustable tower. In 1993 Zuse had accomplished the prototype HT1 on a 1:30 scale to test the construction. In 1992 he started sketching up a second model (HT2) on a 1:10 scale, which was planned to be the forerunner of an initial experimentary tower on full scale. The prototype can be extended to a height of 270 cm; the full-scale tower had been schemed to reach 120 m. The analysis of archival documents and reports by witnesses revealed that Zuse intended his tower to be used for wind power installations, for observation and for radio transmission. The prototype of the Helix-Tower, and therefore the only existing model to experience the function of the HT, together with his estate has been at the Deutsche Museum in Munich since 2006.

KEYWORDS: automated con- and deconstruction, Robot Oriented Design, Helixturm

INTRODUCTION

Konrad Zuse (1910–1995) is known as an inventor of the modern computer. However, Zuse had many other accomplishments on different fields of engineering that are not known to the public yet. In the mid-1980s, Zuse started thinking about the construction of buildings that could withstand strong storms. In his opinion a solution would be to construct a building that could vary in its height. From 1989 onwards Zuse worked on the design of an auto-extendable and -retractable tower construction, the so-called Helix-Tower. The first prototype had a scale of 1:30 and was named HT1 (Figure 1, 2). Siemens Corp. fabricated its parts from surplus material. In 1993 Zuse had fully accomplished the prototype HT1 in his workshop and started to test its functionality. In order to resolve several technical weaknesses of the HT1 Zuse sketched up the blueprints of an improved version of the Helix-Tower on a 1:10 scale, the so-called HT2. This was planned to be the forerunner of a first tower on full-scale. Zuse's death in 1995 halted the further development of the Helix-Tower.

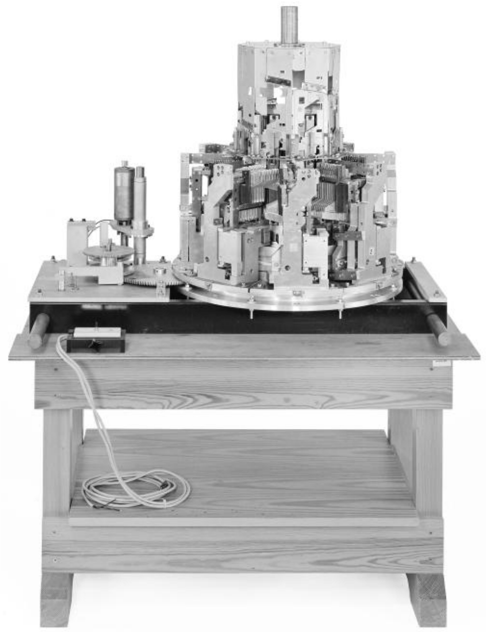


Figure 1: The HT1, retracted

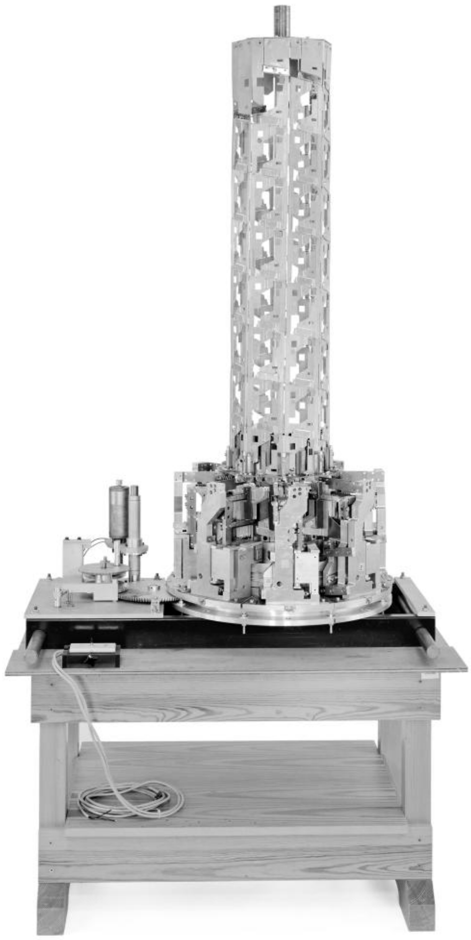


Figure 2: The HT1, extended

TOTAL SYSTEM DESCRIPTION

The Helix-Tower is an assembly of metal components, a purely mechanical automaton. The extendable or retractable mast is formed from a multiplicity of shell segments arrayed one behind the other forming a helix. The shell segments are stored in radially positioned magazines (Figure 4). The construction is powered and controlled by a single pinion, which withholds control surfaces to initiate the construction of the tower. As the tower erects, the components connect through an especially designed shape. The extension of the building follows the same process as the retraction. The Helix-Tower is designed for high top-heaviness to stabilize the tower. The extraction of the tower is executed via motor drive. However, its weight is sufficient to power the retraction via gravity. The continuous extraction/retraction is obtained absolutely mechanically. The tubus is built from identical shell segments. The number of these segments determines the height of the tower. The tubus has a constant diameter, governed by the number of magazines. The more magazines mounted, the larger the diameter. Only the angle of the shell segments has to be adjusted. Its elementarization and modularization is what distinguishes the Helix-Tower from other related patents: The tower can be built in a short time with a few workers from easily transportable building-components without a crane or scaffolding. The building-components can be mass-produced and are composed in a modular conception. The tower-construction is of versatile utility.

Figure 3: HT1, building components of the central unit; from the left to the right: cam disk, central cylinder and stator, outer rotor cylinder and inner rotor cylinder, guideways for the cam followers, copyright A. Bunz

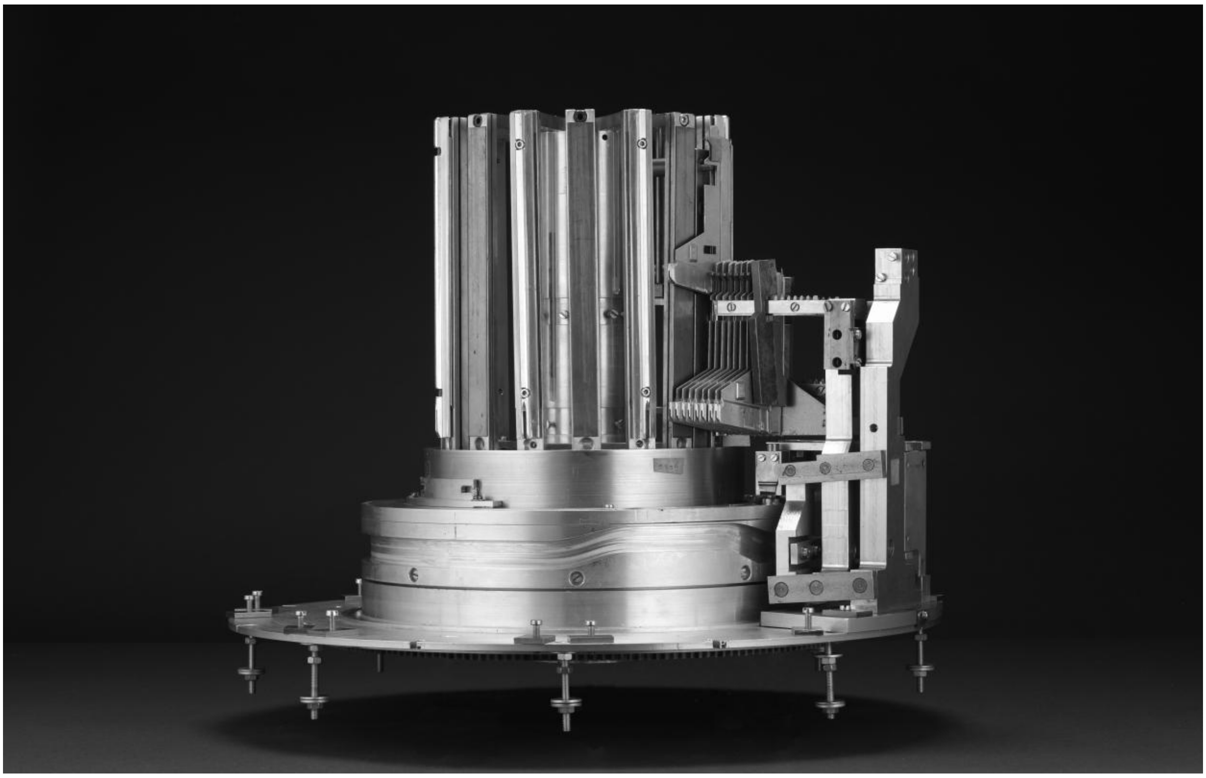


Figure 4: HT1, central unit, one magazine mounted, copyright A. Bunz

The HT1 is composed of 6295 individual parts. Its main components are available eight times or in multiples of eight. The cross-section of the tower forms an octagon (Figure 9). The prototype, scaled 1:30, is extendable to a height of 2.7 m (Figure 2). A HT1-Building on scale 1:1 would be 51 m high. The HT2, designed on a scale of 1:10, would reach a height of 76.8 m on full-scale. Most of the HT2's parts appear in multiples of 12 and its cross-section forms a dodecagon (Figure 8). The HT2 has only been partially realized: Only one conveyor chain and four shell segments exist. The differences between HT1 and HT2 are shown in the patent applications (DE 4119466 and DE 19609749, see www.depatisnet.de for further details). Konrad Zuse had planned a real tower at an elevation of 80-120 m.

SUBSYSTEMS

Central unit of the HT1

In the central unit of the tubular structure a lifting device or unit is located. The unit is equipped with a stator and a rotor (Figure 3-5). On the stator eight short and eight long levers are mounted via 32 rectangular connectors (Figure 6). At the lower end of each lever a ball bearing is located. The ball bearing connects to a cam disk, which surrounds the central cylinder. This cam disk initiates the back and forth movement of the levers. At the upper end those levers are connected to lifting arms that move horizontally. The lifting arms lie in vertically movable carriers: 8 short and 8 long cam followers (Figure 7) connect with control surfaces via ball bearings. The control surfaces are located at two rotor cylinders, an outer- and an inner one. Those two have a fixed connection to the cam disk. The joint movement of the central unit governs an up and down movement of the cam followers and a back and forth movement of the lifting arms.

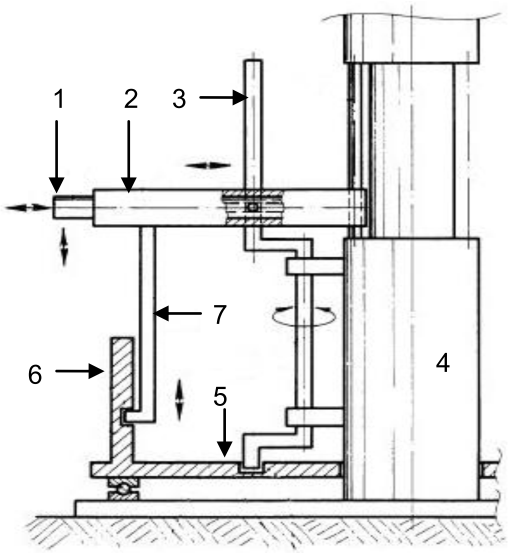


Figure 5: HT1, central unit, in: Patent DE 4119466
1: lifting arm; 2: carrier; 3: lever (see figure 6); 4: stator; 5: cam disk with control surface; 6: rotor with control surface; 7: cam follower (see figure 7)

Figure 6: HT1, long lever, CAD drawing

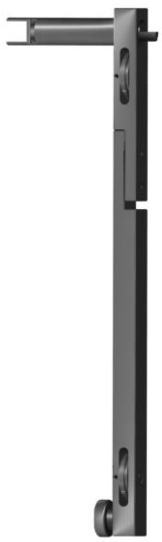


Figure 7: HT1, cam follower, CAD drawing

Magazines of the HT1

The movements described above are coupled with a ring (rotor), which encircles the central cylinder. This rotor has two control surfaces for controlling the movement of the magazines containing the shell segments (Figure 4). Each of these magazines is connected to the rotor via two ball bearings, attached to the control surfaces. As the rotor is turning, three out of six rack-pairs of a magazine move backward and forward. This way the shell segments that hang in the racks are transported out of or into the magazines.

Shell segments as building components of the HT1 (ROD)

When feeding the tower elements to the central unit, the lifting arms of the cam followers will slide into the cut-outs of the shell segments and move them upward. The shell segments are arrayed on top of each other in the form of a helix and linked by special locking mechanisms. The shell segments are slanted in an angle according to the pitch of the helix (Figure 11). The pitch angle of the HT1 approximately amounts to 10 degrees. The angle is defined by the cross section of the HT1: An octagon. The special shape of the shell segments is related to robot oriented design (ROD).

THE ADVANCED MODEL HT2

In the HT2, the shape of the shell segments has been simplified and the shell segments have been made more stable (Figure 10). They have longitudinal profiled and feature cross bars at their top and at their bottom. Storage and transportation of shell segments are performed by three conveyor chains. The segments are engaged at the cross bars by support pins that are attached to the chain links. The cross section of the HT2 is a dodecagon (Figure 8). In the current blueprint all of the main components are available twelve times or in multiples of twelve. Twelve magazines with 384 shell segments were planned. Each magazine was intended to carry 32 shell segments. In comparison to the HT1 with its eight magazines, this reduces the pitch angle and increases the tower's stability. A summary of differences between HT1 and HT2 is listed in Table 1.

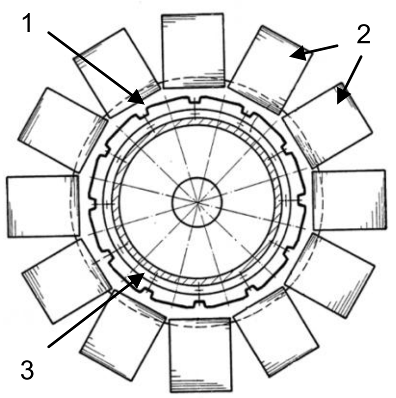


Figure 8: HT2, cross section; in: DE 4119466:
1: shell segments; 2: magazines; 3: rotor cylinder

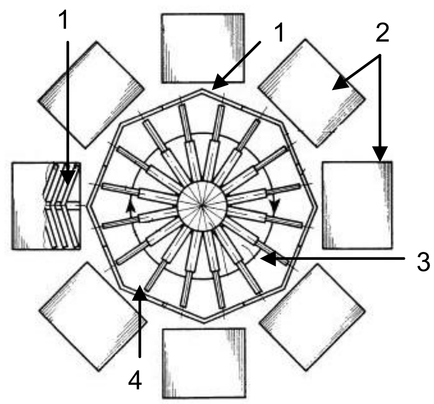


Figure 9: HT1, cross section; in: DE 19609749:
1: shell segments; 2: magazines; 3: stator; 4: lifting arms

Figure 10: HT2, built in scale 1:10, shell segment, copyright A. Bunz

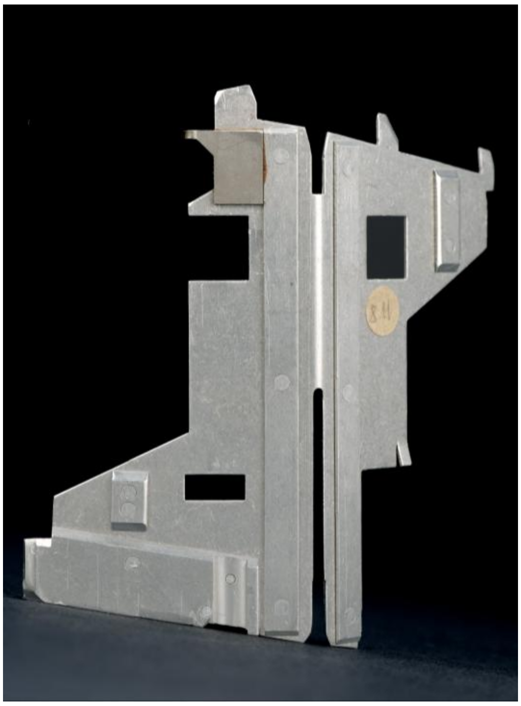


Figure 11: HT1, built in scale 1:30, shell segment, copyright A. Bunz

Table 1: Differences between HT1 and HT2

	HT1	HT2
Scale	1:30	1:10
Shell segements	Bent metal sheets with special cut-outs and supporting elements; Height in scale 1:1 3.60 m	Longitudinal profiles with upper and lower cross bars; Height in scale 1:1 2.40 m
Magazine	Transport and storage of the shell segements by tooth ridges, six tooth ridges arranged in pairs per magazine; shell segments per magazine: 16	Transport and storage of the shell segments by conveyor chains; three conveyor chains per magazine; shell segments per magazine: 32
Central unit	2 rotor cylinders, each 1 control surface	1 rotor cylinder with 2 control surfaces
Modularity	8	12
Height on full-scale	51 m	76.8 m

HT APPLICATIONS ENVISIONED BY KONRAD ZUSE

Zuse thought of three different applications for the extendable and retractable mast: The usage as a look-out, as a radio tower in areas threatened by hurricanes and as a mast for wind energy plants. In June 1991 he applied for a patent with the name *Windkraftanlage*. In April 1994 he applied for a second patent that comprised the invention of the Helix-Tower. This patent is named *Wind turbine with a mast that is extendable and retractable in accordance with the wind speed* (*Windkraftanlage mit einem Mast, der nach Maßgabe der Windgeschwindigkeit auf unterschiedliche Masthöhe aus- und einfahrbar ist*). Both patents contain, besides the description of the tower, the specifications of a wind power plant with exchangeable and retractable rotor blades. The basement of the power plant is not mentioned.

Several contemporary witnesses claim that in the mid-90's some architects were interested in building the tower. In Berlin they planned to build a tower with a restaurant on its top as a tourist attraction. Jürgen Alex, a friend of Zuse wrote in an article for the journal Spektrum der Wissenschaft, 1/1997, that the Fraunhofer-association was pursuing a project related to the Helix-Tower. They planned to build the tower as a monument - 70 m high - at the Ernst-Reuter-Platz in Berlin. However, all efforts in this direction were abandoned after Zuse's death in 1995.

Figure 12: J-Up system, copyright T. Bock

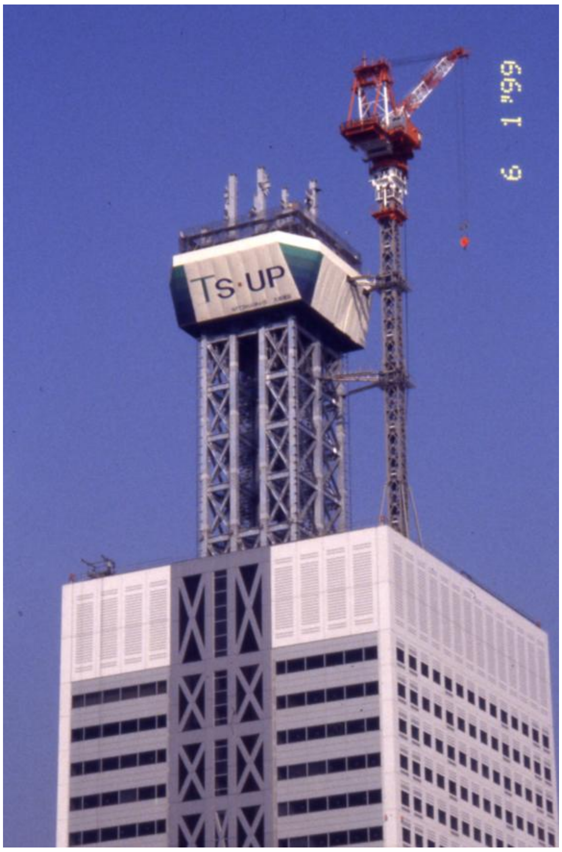


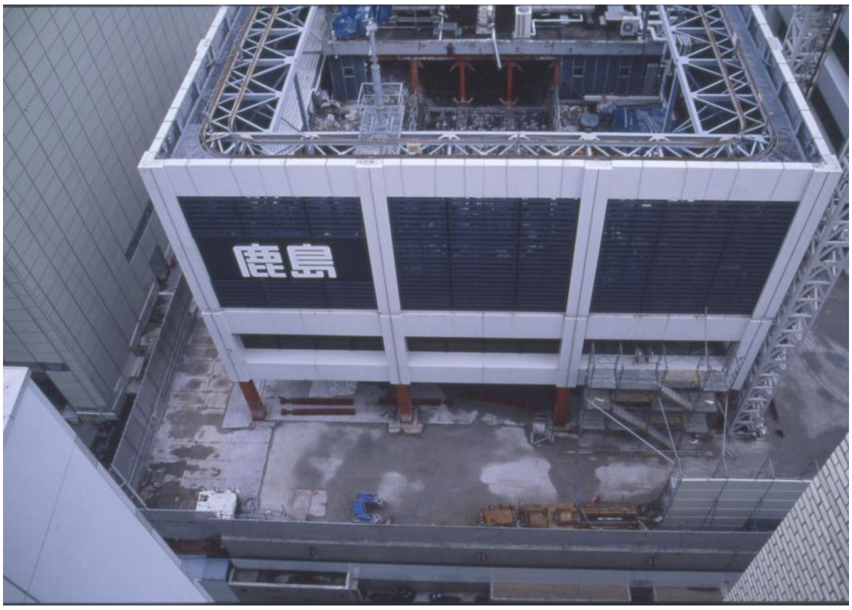
Figure 13: T-Up system, copyright T. Bock

VERIFICATION OF THE HELIX-TOWER BY CONTEMPORARY EXAMPLES OF AUTOMATED BUILDING CONSTRUCTION SITES

Since 1988 major general contractors in Japan investigated the potential complementation of integrated robotic and automated building construction systems. Early prototypic trials (SMART) had been realized in the Shimizu Institute of Technology in Etchujima in 1990. The first actual automated building construction site was the Juroku Ginko project in Nagoya in 1992. The first automated building system of the "Helix-Tower" type was the AMURAD system by Kajima Corporation in Nagoya in 1995. Here a 10 story apartment building had been erected by constructing the roof first and pushing up the whole structure in precast concrete elements (Figures 14, 15). Another application of the AMURAD push up system was a 15 storied office building made of steel in Tokyo. Other automated push up building construction systems are e.g. the Arrow Up by Fujita Corporation in order to build automated car parking facilities and the T-Up by Taisei (Figure 13). Another low cost example of the push up system is the J-Up system by Sekisui House of Sekisui Chemical group (Figure 12). The advantage of the J-Up system was the scaffold-less and crane-less construction by building the roof at ground level, pushing it up using easy to carry hydraulic jacks and repeating same cycle for the upper floors. As Konrad Zuse envisioned in his Helix-Tower all interior finishing works could have been executed in a save and weatherproofed environment. Another verification of Konrad Zuse's ideas is the first automated disassembly of two high rise buildings in down town Tokyo in 2008 (Figures 16, 17).

Figure 14: AMURAD system, copyright T. Bock

Figure 15: AMURAD system, copyright T. Bock



Figures 16, 17: Daruma Oroshi system, Tokyo 2008, copyright T. Bock

CONCLUSION

As a graduate civil engineer, Zuse had developed the Helix-Tower as a lightweight construction. It is superior to related height-adjustable constructions. The systematically designed invention of the Helix-Tower includes an automated process involving the interaction of specifically formed elements. His experience as a structural engineer, Zuse gained during his employment at the Henschel aircraft factory.

Already in 1957 Zuse pointed out the need for automated construction, while he was giving his speech for being awarded the Dr. Ing E. h. at the TU Berlin. Zuse mentioned the "Technical Germ Cell" as a self-reproducing system. Jürgen Alex wrote in his aforementioned article that Zuse thought that the realization of his project would be *a symbol of the principle of his self reproducing systems*. The construction of a building that grows on its own might be a consequence of Zuse's work on "self-replicating-systems", which he first pursued in the 1950's. Zuse was aware of the works of the mathematician John von Neumann. Both of them had the idea of a Technical Germ Cell. This idea traces back to the idea of copying nature by technical means. We do not know whether the structure of the HT was inspired by the structure of the DNA. But we do know for sure that Zuse was excited to read about the discovery of the DNA structure by Watson and Crick in 1953.

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