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History of Science and Medicine

Automation & Muslim Scientists!

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Automation fascinates everyone! It's now almost ubiquitous; sparing no area of life; watches & clocks, toys, kitchen & household gadgets, communication equipments, transport services and hospitals and laboratory equipments all have plenty of automation! With power of electricity and computers automation has seen logarithmic growth explosion! But when did real and substantial automation begin? Many will say that it perhaps began in the last century or at the most a century prior; without electricity no question of automation; nothing could be farthest from truth!

Greek scientists had done some initial work. The work was primitive and rather insignificant! Then with Islam came greatest enthusiasm ever for education and research. We see astonishing substantial accomplishment in 9th century on automation! To achieve this of course great grand work began as soon as Muslims established peaceful huge governments with very rich treasury! Muslims organized everything from Arabic numbers to algebra! Now V was not 5 and X 10! They established "House of Wisdom" hosting galaxy of numerous teachers and scientists! Monumental translation services were started preserving almost total knowledge data base available at that time in Greek, India and China. Then careful and meticulous scrutiny took place. Unsubstantiated, junk and myths were rejected paving the path to solid and healthy growth in all spheres of life including modern sciences. Muslim rulers were extremely generous in funding research projects, sponsoring scientists & researchers and translating all the material available to date! With utmost devotion, tranquility, peace and prosperity, big ban of sciences occurred spanning 10 most glorious and glittering centuries when Europe was in dark ages! Unfortunately religious hatred and intolerance led Western media and scholars to hide those 10 magnificent centuries and prevented people of the world from seeing great embryogenesis of sciences! A false impression was created as if Islam hinders education and research. Even today through psychological warfare based on fabrications and puppet characters; this wrong impression is repeatedly strengthened and consolidated! They not only did not give due credit to Muslim scientists but went on to distort the names of great researchers and scientists without whom, Europe may still be lingering in dark ages. This constitutes highest degree of hypocrisy and ungratefulness in sharp contrast to the Islamic values of morality and ethics. In Islamic era of growth there was comprehensive integrated growth of soul, mind and body on one hand and self, family and society on the other hand! Muslims did not discriminate based on faith, color and place etc.

In Islamic society several individual and groups of scientists devoted their life toward mechanical engineering and automation. We will briefly mention two of them here; first an unusual constellation of great scientists in one family known as "Banu Moosa" comprised of 3 sons and their father Moosa bin Shakir. They did outstanding remarkable work on mechanical engineering and automation in 9th Century! The second individual

is al-Jazari in 12th-13th century. Both these created sophisticated machines containing valves, gears, pumps, pipes using propelling powers of gravity, water and air. The automatic robotic movements can be seen in the form of clocks of various types containing humanoid, peacock, elephants robots and also in various water raising machines.

Banu Moosa: Moosa bin Shakir and his 3 sons; their names, in order of seniority, were Muhammad, Ahmad, and al-Hasan. Muhammad was mainly a specialist in geometry and astronomy, while Ahmad worked mainly on mechanics and al-Hasan excelled mainly in geometry.

The "Banu Moosa" were fully patronized by great Muslim ruler al-Ma'moon Rashid, who generously paid them celebrity salaries and appointed talented teachers for the grooming of the three sons. Ma'moon himself had been enthusiastic aficionado of the sciences. He got this spark from teachings of Quran and life of the Prophet Muhammad (s.a.w) as he was one of the most respectful students of Imam Malik who used to teach at Masjid Nabawi in Madina. Tender support, genuine care in highly spirited and most human atmosphere created a magnificent research atmosphere that led to Muslims scientists to found all modern sciences including mechanical engineering.

Besides their proper scientific work, Banū Mūsā were also patrons of translation of Greek scientific works! They funded and supported the work of scientists, such as Thābit ibn Qurra (d. 901). They spent a large amount of their wealth in advancing the intense scientific and intellectual activity in Baghdad. Their book *Kitāb al-hiyal* (The Book of Ingenious Devices) is an outstanding contribution in the field of mechanical sciences. This treatise, in the form of a catalogue of machines, is a large illustrated work on mechanical devices including automata. The book described a total of 100 devices and how to use them. Some of these inventions included: valves, float valves, feedback controller, automatic flute player, a programmable machine, trick devices, self-trimming lamp. The work was first partly translated and interpreted into German by Eilhard Wiedemann and Franz Hauser. It was translated and annotated in English by Donald R. Hill, and its Arabic original text was edited by Ahmad Y. al-Hassan. A total of 100 devices are taken up and explained in great detail in the book. 73 of these are related to trick vessels and the others consist of 15 automatic control systems, 7 water jets, 3 oil lamps, one bellow and one lifting mechanism system. Their application is generally based on aerostatic and hydrostatic pressure principles. The systems are more advanced than earlier ancient ones in that they can even satisfy contemporary technologic requirements. The book provides the first examples of various mechanic elements, technical drawings, logic and command systems and especially automatically controlled systems. About eighty of the devices are trick vessels; the remainder includes lamps, alternating fountains, and a clamshell grab, identical in design to its modern counterpart. The trick vessels display a bewildering variety of effects: for example, a pitcher into which liquids of three different colours are poured in succession -when the tap is opened they discharge in the order in which they were poured; or a basin that is replenished when small amounts of liquid are extracted from it, but is not replenished if a larger amount is taken. These effects, and many others, are obtained by switching mechanisms operated by small variations in aerostatic and hydraulic pressures, and by the use of automatically activated conical valves. The purpose of these devices was partly didactic and partly to amuse. They appear trivial to us, but the Banū Mūsā's mastery of delicate controls was unsurpassed until fairly recent times.

In his study of *Kitāb al-hiyal*, Atilla Bir examines Banu Musa's inventions and devices, analyzing each one as a system incorporating various mechanisms. Then, basing his analysis on various logical relationships and linear and non-linear blocks, he obtains the corresponding block diagrams. This method of establishing the workings of the systems and explaining their behavior is very much in accordance with the principles of modern systems analysis and as such will be fully understood only by those who are familiar with modern control engineering. While this may seem to be an anachronistic approach, the only interpretative method fully explains how all these devices worked. Also, it does justice to the extraordinary ingenuity and inventiveness of the Banū Mūsā. In his appreciation of Professor Bir's book, the late Donald R. Hill, specialist of Muslim echnology, stated that this modern mechanical analysis of *Kitāb al-hiyal* by Banū Mūsā should appeal to historians of technology to become aware of the present work, and "appreciate the implications of Dr. Bir's methodology"

Abu Iz ibn Razaz al-Jazari: He was born at Jazira a small town in northern Iraq in the year 1136 CE. Al-Jazari excelled in education and made several new inventions, and after the retirement of his father he became chief engineer of the palace. He lived all his life at Diyar-Bakir, Turky and died in the year 1206 CE. Al-Jazari was a rare genius who mastered the science of mechanical engineering at an early age. He was also a scholar, artist, inventor, astronomer and craftsman. He is considered one of the fathers of modern day mechanical engineering because of his fundamental inventions in this field. He is also hailed as the father of robotics because he was first to design an early programmable humanoid robot. Al-Jazari was an accomplished writer and artist. His treatise The Book of Knowledge of Ingenious Mechanical Devices is considered the most outstanding book in mechanical engineering. Gorge Sarton, the historian of science and technology says, “This treatise is the most elaborate of its kind and may be considered the climax of the Muslim achievements in science and technology.” In this book he has given the details of his inventions and has illustrated them with drawings and paintings. This book includes six main categories of machines and devices. Several of the machines, mechanisms and techniques that first appear in his treatise later entered in the vocabulary of European mechanical engineering books. This includes double acting pumps with suction pipes and the use of a crank shaft in a machine, accurate calibration of orifices, lamination of timber to reduce warping, static balancing of wheels, the use of paper models to establish a design, and casting of metals in closed mould boxes with green sand etc. He also describes methods of construction and assembly in great detail of about fifty machines, so that the future craftsmen could reconstruct them. Al-Jazari was the first engineer to invent the crankshaft and connecting rod system, which is considered the single most important invention after the wheel. This system is used to transform linear motion into rotatory motion, and vice versa, and is central to the modern machinery such as steam engines and internal combustion engines used in cars today.

Al-Jazari invented five machines for raising water from a river or well. It was in these machines where he introduced his most important ideas and concepts. The first two devices used animal power and an open channel with a scoop. The third machine manipulated the water power and a series of gears to lift pots filled with water. In the fourth machine he used a brand new concept of using the crankshaft and connecting rod system to lift the water. The fifth machine was very complex, it utilized a cog wheel, piston and a suction pipe. Creating vacuum for suction and appli-

cation of the double-acting principle were advanced technological achievements eight centuries ago. The modern reciprocating water pumps are not very different from what al-Jazari invented centuries ago.

Al-Jazari's genus mind invented a host of new kinds of clocks, which had never existed before. His astronomical clock was a monumental invention; it displayed a moving model of the sun, moon and stars. His biggest model was eleven feet high–it displayed the lunar orbit, the zodiac and solar orbit. The clock had a pointer which traveled across the top and caused the automatic doors to open every hour. His elephant clock was an ingenious creation of several new innovations. It was the first water clock which employed the flow regulator in a closed loop system. This clock indicated hours to match the uneven length of days throughout the year. The float regulation used in the clock had a big implication during the Industrial Revolution of Europe when it was used in the boilers of steam engines; and in other industrial applications.

The candle clock was another original idea. Here he used a candle of uniform weight and cross section whose rate of burning was known. The candle rested on a shallow dish with a ring connected through pulley to the counterweight. As the candle burned, the counterweight pushed the candle upward at a constant rate, which was then calibrated in time. He also designed a mechanical clock powered by water. This clock was successfully reconstructed at the Science Museum in London, England.

Al-Jazari invented the earliest form of programmable humanoid robot. He used this invention to entertain the king in the palace parties. He is also credited with designing a verity of automata, like an automatic gate, door, and musical instruments all powered by water. His creation of water fountains with musical automation was unique; he did this by hydraulic switching, a new invention as well.

In 1206, al-Jazari invented an early crankshaft, which he incorporated with a crank-connecting rod mechanism in his twin-cylinder pump. Like the modern crankshaft, Al-Jazari's mechanism consisted of a wheel setting several crank pins into motion, with the wheel's motion being circular and the pins moving back-and-forth in a straight line. The crankshaft described by al-Jazari transforms continuous rotary motion into a linear reciprocating motion, and is central to modern machinery such as the steam engine, internal combustion engine and automatic controls.

Al-Jazari invented five machines for raising water, as well as watermills and water wheels with cams on their axle used to operate automata, in the 12th and 13th centuries, and described them in 1206. It was in these water-raising machines that he introduced his most important ideas and components. By citing the Byzantine siphon used for discharging Greek fire as an inspiration, al-Jazari went on to describe the first suction pipes, suction pump, double-action pump, and made early uses of valves and a crankshaft-connecting rod mechanism, when he invented a twin-cylinder reciprocating piston suction pump. This pump is driven by a water wheel, which drives, through a system of gears, an oscillating slot-rod to which the rods of two pistons are attached. The pistons work in horizontally opposed cylinders, each provided with valve-operated suction and delivery pipes. The delivery pipes are joined above the centre of the machine to form a single outlet into the irrigation system. This water-raising machine had a direct significance for the development of modern engineering. This pump is remarkable for three reasons:first known use of a true suction pipe (which sucks fluids into a partial vacuum) in a pump. al-Jazari's suction piston pump could lift 13.6 metres of water with the

help of delivery pipes. This was more advanced than the suction pumps that appeared in 15th-century Europe, which lacked delivery pipes. It was not, however, any more efficient than a noria commonly used by the Muslim world at the time.
Water supply system: al-Jazari developed the earliest water supply system to be driven by gears and hydropower, which was built in 13th century Damascus to supply water to its mosques and Bimaristan hospitals. The system had water from a lake turn a scoop-wheel and a system of gears which transported jars of water up to a water channel that led to mosques and hospitals.
Al-Jazari built automated moving peacocks driven by hydropower. He also invented the earliest known automatic gates, which were driven by hydropower. He also created automatic doors as part of one of his elaborate water clocks, He also invented water wheels with cams on their axle used to operate automata. Mark E. Rosheim summarizes the advances in robotics made by Arab engineers, especially al-Jazari, as follows: Unlike the Greek designs, these Arab examples reveal an interest, not only in dramatic illusion, but in manipulating the environment for human comfort. Thus, the greatest contribution the Arabs made, besides preserving, disseminating and building on the work of the Greeks, was the concept of practical application. This was the key element that was missing in Greek robotic science.
al-Jazari invented a hand washing automaton incorporating a flush mechanism now used in modern flush toilets. It features a female humanoid automaton standing by a basin filled with water. When the user pulls the lever, the water drains and the female automaton refills the basin. According to Donald Routledge Hill, al-Jazari described the most sophisticated candle clocks known to date.

Further Reading

1. http://en.wikipedia.org/wiki/Ban%C5%AB_M%C5%ABs%C4%81
2. http://en.wikipedia.org/wiki/Book_of_Ingenious_Devices
3. http://www.muslimheritage.com/article/mechanics-banu-musa-light-modern-system-and-control-engineering
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6. http://en.wikipedia.org/wiki/Al-Jazari
7. http://pl02.donau-uni.ac.at/jspui/handle/10002/323
8. http://www.muslimheritage.com/article/islamic-automation-al-jazari%E2%80%99s-book-knowledge-ingenious-mechanical-devices