TECHNICAL INSIGHTS

ADVANCED MANUFACTURING

TECHNOLOGY ALERT

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1. AUTONOMOUS INSPECTION SYSTEM FOR AEROSPACE SECTOR

Mechanical parts such as bolts and rivets are used in significantly large numbers in a wide range of industrial sectors such as aerospace, automotive, and so on. These mechanical parts are being used in a large scale in aircraft fuselage shells to turbines. Traditionally, the inspection of these mechanical parts has been carried out manually, thereby making the entire inspection process tedious and time consuming for the workers. There is also a problem of overseeing the errors through manual inspection. To address the above mentioned drawbacks, a research organization in Germany has developed a novel automatic inspection system.

Researchers from the Fraunhofer Institute for Factory Operation and Automation (IFF), Germany, have developed an automatic inspection system for manufacturing industries to employ in the coming years. According to the researchers, workers in the aerospace sector are expected to receive support from this inspection system while they are checking for errors. Researchers from the Fraunhofer IFF have developed this inspection system for Premium AEROTEC GmbH, Germany, a company specializing in the development and production of structures and production systems for aircraft. The inspection system has been field tested in pilot systems that independently inspect every mounted part and joint on aircraft fuselage shells. This inspection system consists of a robotic arm, which is attached with a specially developed sensor head. It has also been equipped with image sensors and 3D sensors, the head is capable of autonomously scanning the fuselage shells. The inspection system is also said to be capable of generating reliable, high resolution measured data on the state of assembly of the parts from any angle. The system extracts the data that is required from 3D CAD (computer-aided design) data and the results containing

the inspection points are specified to the user. The system also uses the data to generate a virtual measured data of the inspected parts in the form of images and 3D point clouds. Every joint and mounted part is represented in the images and 3D point clouds. This digital inspection system that has been developed is not only significantly more reliable but also faster than the manual inspection methods that are currently employed. For instance, the pictures taken with this novel system take only 5 seconds and the evaluation process takes about 3 hours when compared to the conventional system, which takes about 5 to 8 hours for evaluation. The system also inspects all sorts of sizes, effortlessly analyzing volumes of up to 11 m × 7 m × 3 m very precisely and with high resolution.

This system not only detects errors, but also helps the manufacturer in eliminating recurring errors in the long term. The above mentioned feature is achieved through the storage of errors in a database, which are then given to the assembly technicians along with suitable instructions. Due to the various capabilities and advantages, this novel inspection system has opportunties to be adopted in the aerospace industry once it commercialized.

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2. ROBOTIC SYSTEM FOR INCREASING PRODUCTION EFFICIENCY IN AEROSPACE SECTOR

Even with the development of robots for various manufacturing processes in different industrial sectors, aerospace is one industry where the employment of these robots has not thus far been very widely adopted. For instance, the wings of aircraft are still being assembled manually, which results in increased duration and reduced efficiency of the production process. Traditionally,, the assembly of aircraft parts has involved significantly high manual processes and labor, which has resulted in reduced production output. The aerospace industry has been looking for ways to automate the assembly process; and in certain cases it has been a challenge, which is primarily due to the complicated internal structure of the wings (consisting of series of hollow chambers). Researchers have been working on a snake-like robot that is capable of tightening the bolts that are present in the some of the most inaccessible places of the airplane wing.

A research group from the Fraunhofer Institute for Machine Tools and Forming Technology (IWU), Germany, is currently working on developing an automation solution, which is based on a flexible robot with articulated arms that reduces the time and effort required for the assembly of airplane parts. Conventional robots that are currently available in the market tend to not be very flexible to pass through the narrow openings and their rigid arms are not capable of reaching out to the outermost regions of the workspace that usually extends up to 5 meters in length. The robot developed by IWU addresses the above mentioned challenge with the help of articulating arms that consist of eight serie-connected elements thereby allowing it to be rotated or inclined within a narrow radius. The tool is first attached to the series of eight limbs in the robot for carrying out the desired application. This tool can also be replaced with an inspection camera if it is required. The robot arm, which is 2.5 meters in length, is capable of supporting tools that weigh up to 15 kg. Kinematics used to drive this robot is based on a sophisticated mechanism, which also includes a novel gear system. The gear system has been developed by the researchers and they have also filed a patent for the same. A small motor has been integrated into each of the eight robotic arms, and is capable of producing high torque of up to 500 Newton-meters. The reason for using a small high powered motor is because the conventional motors would not be suitable for the robotic arms due to their compact design. Small motors are used in combination with a cord and spindle drive system, which enable the arm to move independently and turn with an angle of 90 degrees. They are expecting to develop the complete version of the robotic system equipped with an eight-part articulated robotic arm by the end of 2014.

Some of the potential applications for this robot are automated assembly of aircraft wings (a traget application), in automobile manufacturing, and also in the power plant design. Some of the advantages of this robotic system are that in reduces the manufacturing time in the aerospace sector and also increases the adoption of robotic system in this sector. Due to the above mentioned capabilities and advantages, this robotic system has opportunties to be adopted on a large scale by various industrial sectors on commercialization by 2016.

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3. ATOMIC LAYER DEPOSITION EQUIPMENT WITH ROLL-TO-ROLL PROCESSING

Flexible electronics has key opportunities in fields such as displays, body worn electronics, photovoltaic (PV) cells, and sensors. However, in applications where organic materials are used, rapid product degradation can occur when exposed to moisture and air. This is a major challenge, which is addressed by novel encapsulation technologies. As the devices are thin and bendable, thin film moisture barrier technology is used. According to Frost & Sullivan analysis, atomic layer deposition (ALD) results in high-quality moisture barrier films. ALD is a thin film deposition technology where a chemical reaction between the substrate and specific chemical leads to the formation of a thin film. However, continuous printing processes are required to produce flexible electronics, such as roll-to-roll processing on a cost-efficient mass scale. Thus, a manufacturing process that can apply ALD in a roll-to-roll process is required.

Finland-based Beneq Oy has come up with innovative roll-to-roll ALD equipment that can be used for research as well as scaled to industrial use in a cost-effective manner. The equipment, WCS 500, can help drive accelerated commercialization of roll-to-roll ALD processes for an effective moisture barrier in printed electronics. Roll-to-roll processing addresses key needs in the marketplace by enabling the manufacturing of printed electronics in a fast and cost-effective manner. Devices such as organic light-emitting diode (OLED) displays and flexible PVs require efficient thin film barrier films deposited by the ALD process. Beneq's WCS 500 incorporates these two processes, which can not only be used for research, but also industrial-scale production.

The WCS 500 can handle various types of substrates, such as polymer films and other flexible substrates, and the thickness of the ALD coating can be varied. The flexible substrate (web) is moved inside the equipment using rollers while an ALD coating head emits the precursors on a processing drum. In this way, a continuous ALD process is achieved. Unwind and rewind rollers regulate the speed of movement of the substrate. ALD simultaneously takes place through

nozzles fitted inside the vacuum chamber. Beneq's system uses two precursors that are delivered inside the vacuum chamber to react and form the thin film on the surface of the substrate.

Beneq's WCS 500 can coat webs up to 500 millimeters wide, which makes it useful for large area printed electronics. By being able to use roll-to-roll process for barrier film generation, customers can lower the cost of manufacturing and have a high throughput. The equipment has a web speed of up to 2 meters/minute and a yearly throughput of 400,000 square meters, which enables industrial-scale production.

The WCS 500 can be used for research, pilot production, as well as industrial-scale production. As a result, the customer need not invest in different equipment. Moreover, a continuous process where ALD is just one part saves the manufacturing time of end products. The product has opportunities to be a key enabler for the commercialization of ALD technology for printed electronics.

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4. PATENT ANALYSIS OF MILLING PROCESS

The milling process is used in a variety of industrial applications where there is a need for high accuracy, complex shaping, and removing large amounts of material. Milling machines are used to produce planar surfaces, cutouts, and slot or hole features. Contoured surfaces--which include rack and circular gears, spheres, helical, ratchets, sprockets, cams, and other shapes--can also be readily cut with CNC (computer numerical control) mill machines. A milling machine consists of an array of standard support blocks, work clamps, and other work piece holding fixtures. They enable carrying out milling operations with minimal fixture and equipment investment. The milling process plays a key role in the production of any tool and die work, prototyping, and other low-volume manufacturing. For carrying out mass production of any parts or products, special purpose milling machines are employed. These types of machines are typically used to combine milling operations with boring, drilling, tapping, and other operations. The major types of milling machines that are currently employed in a wide range of industrial sectors include column and knee machines, bed type milling machines, and special purpose machines.

From patents profiled in exhibit 1, it can be seen that the current research activities include a focus on developing milling machine technology for different milling applications, such as milling asphalt pavement, rice milling, or milling dental items. The patents also indicate interest in improving the functionality of milling machines or the milling process; such as optimization of cutting forces in the milling process, developing milling machine cutter apparatus,or milling machine drive mechanisms.

Title	Publication Date/Publication Number	Assignee	Inventor	Abstract
Asphalt milling machine control and method	August 5, 2014/ US 8794867 B2	Trimble Navigation Limited	Jeroen Snoeck, Richard Paul Piekutowski	An asphalt milling machine control is provided for an asphalt milling machine of the type which mills an asphalt pavement surface over which the machine travels. The machine has a milling machine body, and a rotatable milling drum mounted on the lower portion of the milling machine body, the bottom surface of the milling drum contacting the asphalt pavement surface to mill the surface to a design elevation. The machine further includes a plurality of machine body supports which are adjusted to raise or lower the height of the milling machine body and the rotatable milling drum with respect to the asphalt pavement surface. This defines the elevation of the surface that results from milling with the drum. The control includes a floating plate, mounted to the side of the milling machine and the rotatable milling drum, or a pair of floating plates mounted to either side of the machine, for sliding over the surface adjacent to the area to be milled. The floating plates have associated sensors and are vertically movable with respect to the machine body and the rotatable milling drum. The control includes a GNSS receiver on the machine body for determining the two dimensional coordinates of the floating plate or plates. The control includes a memory which stores a map of the unmilled asphalt pavement surface, and data defining a desired design surface. The control includes a sensor for detecting the relative vertical position of the floating plate with respect to the machine body and an inclinometer. Finally, the control includes a processor, responsive to the GNSS receiver, the inclinometer, and the sensors. Cross checking of various measurements may be made to determine error conditions.
Milling Machine	June 4, 2014/CN 203620673 U	Guangxi Luzhai County Huaguang Machinery Manufacturing Co., Ltd.	Lin Jianwu	The utility model discloses a rice mill, involving machinery manufacturing technology; which includes a feed hopper connected with the inlet, live shells from the rice mill and rice milling machine fixed shell composed chamber, mounted on the milling spindle and the sleeve in the interior of the spindle on the meter roller, said spindle being on the inlet section of the meter unit is provided with feed means; the rice mill feed means comprises a sleeve in the rice mill feed tube on the spindle, opened a feeding tube through the hole on the rice mill feed; said meter machine is provided with a feeding tube to control the rotation of the outer wall of the adjustment lever. The utility model can solve paddy rice mill feed rate caused by uneven size and easy to swallow feed chamber shell wall wear.
Milling machine having six (6) axis motion system	April 17, 2014/WO 2014058874 A1	D4D Technologies, Llc	Rod Duncan, Mark Quadling, Henley Quadling, Chris PARTEE, Adam TIBBITTS	A milling machine for a dental item comprises a six (6) axis motion system. A workpiece is fixed in space. Each of a pair of opposed tool spindles operates in 3DOF, with an x-axis (laterally, left or right) being along an axis of each working tool, a rotational (theta (θ)) axis (rotationally in or out), and a z-axis (up or down). On each respective side of the block, the x-axis rides on a θ-axis, and the θ-axis rides on the z- axis. Each z-axis supports a first carriage adapted to move up or down along the z-axis, and the first carriage supports a motor having a shaft. The shaft's rotational axis is the θ-axis. A second carriage is mounted on the shaft for rotation about the θ-axis. A spindle assembly is mounted on the second carriage for lateral (left or right) movement along the x-axis carried by the θ-axis.

Title	Publication Date/Publication Number	Assignee	Inventor	Abstract
Method for optimizing cutting forces in a milling process and computer-controlled milling machine using the same method	March 7, 2013/ WO 2012153157 A3	Pécsi Tudományegyetem	Balázs TUKORA	The present invention relates to a computer-controlled milling machine comprising a milling tool (210) for machining a workpiece, a measuring unit (230) for measuring the cutting forces exerted by the milling tool (210) to the workpiece, a simulation module (240) for simulating the milling process to determine a contact area between the workpiece and the milling tool (210) by using a multi-dexel representation of the workpiece, a prediction module (250) for receiving the milling force measurements and the simulated geometrical data, and for generating predicted cutting forces from the measured cutting forces and the simulated cutting forces, and a control unit (220) for receiving the predicted cutting forces and for adjusting the operational parameters of the milling process according to the predicted cutting forces so as to reach optimum values for the actual cutting forces acting to milling tool (210).The invention also relates to a method of optimizing cutting forces in a milling process using the aforementioned computer-controlled milling machine.
Cutter apparatus of milling machine	September 27, 2011/ US 8024999 B2	Kia Motors Corporation	Yong Ha SHIN	A cutter apparatus of a milling machine includes: a transmitting means in an X-axis direction provided with a spindle and a motor delivering rotation power to the spindle; a milling cutter rotatably arranged at one side of the transmitting means so as to cut a work piece; and a tool holder interposed between the spindle and the milling cutter and connecting the milling cutter to be able to eccentrically rotate in a Y-axis direction. Since the necessity of a transmitting means in a Y-axis direction can be eliminated, a mechanical structure can be simplified and a problem of restriction of addition of a model and modification of a work piece can be solved.
Milling machine drive mechanism	June 17, 2010/US 20100150680 A1	Bor-Huah Cherng	Bor-Huah Cherng	The present invention provides a milling machine drive mechanism. The milling machine drive mechanism includes a main shaft, a gear assembly, and a machine shaft. The gear assembly includes a first gear and a second gear. The first gear is pin-jointed to the main shaft, so as to rotate with the main shaft. The second gear is operatively connected to the first gear. Wherein, the main shaft drives the second gear to rotate through the first gear. The main shaft is pin-jointed to the main shaft, so as to rotate with the second gear.
Vibratory milling machine having linear reciprocating motion	March 18, 2010/CA 2804420 A1	Longyear Tm, Inc., Jing James Yao, Robert Eugene Able, Thomas J. Oothoudt	Jing James Yao, Robert Eugene Able, Thomas J. Oothoudt	A continuous mining method includes operating a vibratory milling machine having a milling head, a base, and a milling tool to oscillate the milling head in a substantially linear reciprocating fashion relative to the base to move the milling tool along a milling axis; and advancing the vibratory milling machine in a work piece in a cutting direction and wherein milling axis is oriented at an attack angle relative to the cutting direction, the attack angle being between about 0 and about 40 degrees.

Title	Publication Date/Publication Number	Assignee	Inventor	Abstract
Vacuum system for milling machine	May 11, 2004/US 6733086 B1	Ri Properties, Inc.	Chris McSharry, Thomas R. Campbell	A vacuum system is mounted on a portable milling machine for extracting material cut by the milling drum of the machine from the surface of a roadway. The milling machine includes a frame, a propulsion system for advancing the machine across a surface to be milled, a milling drum mounted on the frame for rotation about its axis, and a conveyor for conveying material cut by the milling drum away from the drum. The vacuum system includes a vacuum pump having an air inlet and an air outlet and a nozzle mounted behind the milling drum having an opening for receiving material cut from the surface by the drum. The vacuum system also includes a material collector having an inlet, an air outlet and a material outlet. The collector is adapted for collecting material entrained in air by the pump through the collector inlet and for discharging such material through the material outlet onto the conveyor. The vacuum system also includes a first conduit and a second conduit. The first conduit connects the nozzle and the inlet of the material collector, and the second conduit connects the air, outlet of the material collector and the air inlet of the pump.
Clamp for holding a workpiece on milling machine table	April 18, 2000/US 6406229 B1	Alpha Manufacturing Co., Inc.	Scott E. Derrick, Scott J Echerer	A clamp for securing an oversized work-piece to a milling machine table using the T-slot on the front surface of a Bridgeport-type milling machine table. The clamp, when attached to the T-slot, extends beyond the table and over it where it can be tightened down on a work-piece to hold it to the top surface of the table. The clamp includes a heel block and a clamp block held in spaced relation by a separation bolt and a tightening bolt. To mill an oversized work-piece, the clamp is inserted into the T-slot and then the separation distance of the clamp block to the heel block is adjusted by rotating the clamp block around the separation bolt until the separation distance is slightly wider than the thickness of the work-piece. The tightening bolt is then used to tighten the clamp onto the work-piece. The nose end of the heel block can be shaped to match the profile of the T-slot or can be modified to allow the nose to be rotated into the slot by rounding its corners. The blocks are formed to allow the tightening bolt to be positioned so that it is more or less close to the separation bolt in order to accommodate work-pieces of different sizes.
CNC milling machine	April 18, 2000/ US 6050760 A	Rambo Machinery Co., Ltd.	Teng A-Tung	A CNC milling machine comprises a main transmission shaft driven by a motor, an upright shaft provided with a transmission wheel set that is actuated by the main transmission shaft, an engagement device having a main shaft which is provided with a connection member which is in turn provided with an engagement wheel set engaged with the main transmission shaft, and a horizontal shaft provided with a gear set mounted thereon such that the gear set is engageable with the main shaft of the engagement device. The upright shaft is actuated to turn via the transmission wheel set so as to enable an upright milling cutter of the upright shaft to carry out the longitudinal cutting of a workpiece. The horizontal shaft is actuated to turn via the engagement wheel set so as to enable a horizontal milling cutter of the horizontal shaft to carry out the horizontal cutting of the workpiece without having to transfer the workpiece.

Exhibit 1 depicts patents related to milling process.

Picture Credit: Frost & Sullivan

Back to TOC

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