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Hexapod Octahedral Machining System, an Advanced Machine for Making Things

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Abstract

Increased productive machines are required in the industrial business to achieve higher productivity and accuracy. Enhanced performance in the field of sophisticated machine tools is seldom accomplished without increased design complexity, lower operating flexibility, and higher expense. These disadvantages have sparked innovation in India, where most R&D efforts are focused on minor improvements to existing machinery. The hexapod actuator is used in conjunction with a space frame, which is an octahedral frame.

Keywords: *Hexapod Actuator, Lower Operating Flexibility, Industrial Business, Enhanced Performance*

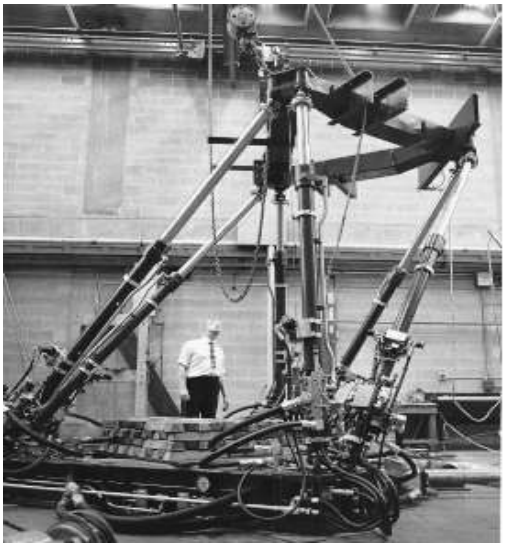
INTRODUCTION

The machine tool industry is primarily reliant on stacked axis computer numerical control (CNC) machines, which operate as many as six positioning axes separately to produce a certain spindle position and orientation (X,Y,Z, roll, pitch, and yaw). The CNC may control up to six different motions, each of which is conducted separately and results in a goal position. A more accurate instrument was required by the industrial industry. Small businesses' capacity to improve the quality of manufactured items grew dependent on the development of a high-precision, low-cost machine tool. Octahedral hexapod machine with better precision, rigidity, and speed, as well as reduced pricing, easier assembly, and wider accessibility. This was only achievable because to the computer's ability to manage six actuating struts simultaneously.

THE PRINCIPLE OF HEXAPOD STRUCTURES

Stewart platform idea, which is most typically utilised for flight simulators, was imaginatively combined with hexapod constructions. The hexapod actuators resemble the Stewart platform, which was created in the 1950s. The stewart platform is a six-actuator equilateral triangle hanging in an octahedron frame (strings). Two threads are hooked to the control devices at each corner of the vertices of the top triangle and run down to the base of the octahedron frame. The operator can operate the platform using the 6DOF control system.

The hexapod mechanism is housed within and coupled to the octahedron's upper three corner blocks (nodes). The machining forces are steered towards the nodes as a result of this configuration. The octahedral hexapod machine's hexapod actuators are made up of six extendable struts pivotally placed in pairs at one end to face the octahedral frame's top nodes. The struts are also pivotally attached to the other end of the machine spindle to move the work platform. The struts are a ball screw system that allows the platform to be raised, lowered, or tilted in an endless number of configurations within the given range. The lengthening or shortening of strut length adjusts the spindle location in the hexapod. This is done using a control system that is controlled by a computer utilising design software. As a result, the machine has no traditional X, Y, or Z way members or axes for machine motion; instead, six extendable struts do the task with extreme accuracy.

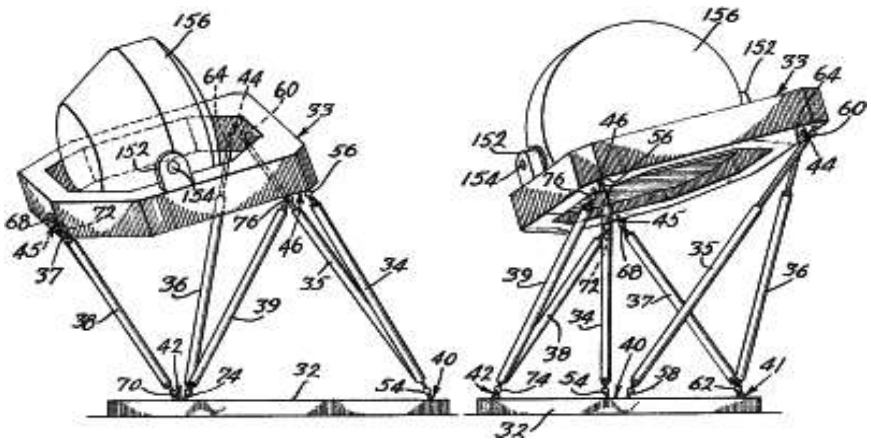


WORKING OF OCTAHEDRAL HEXAPOD MACHINE

The hexapod actuator has a highly tuned kinematics system with six axes of freedom and a high stiffness to weight ratio. There are no typical parts in the octahedral hexapod machine, such as column slides, etc. The work platform may be moved through a whole axis of working zone by setting the rate of motion and length of each strut.

The octahedral hexapod machine is made up of six ball screw driven linear actuators connected to a self-contained octahedral structure at one end and a moving platform with a spindle motor and cutting tool at the other end through ball and socket connections. The top ball joints coupled to the octahedral structure are organised according to the Stewart platform idea such that the forces through strut pairs roughly meet at the vertices of an equilateral triangle. On the spindle platform, the lower ball joints are evenly spaced.

Even a basic single-axis movement of the machine necessitates the precise coordination of all six struts. The machining load is shared by all the struts working together. Each strut's movement is controlled by a computer. G and M codes control the controller. The servo and spindle motors are controlled by a computer system that has the needed speed selectively and often, all at the same time, to execute a predetermined tool path. All high-speed computations are performed by the computer and sent to a servo amplifier, which amplifies the signal before sending it to the servo motors. Motion control techniques are used in the computer system to create six axis simultaneous output and to reduce mistakes caused by servo lag, thermal problems, and other factors.



The software allows for a 2 to 3 micron precision in following the specified course. The programme maps and saves the real-time faults in files called personality files. The personality files map the various mistakes, requiring no sophisticated on-machine calibration. Encoders provide feedback to the computer.

CONSTRUCTIONAL FEATURES

Strut Assembly:

The octahedral hexapod machine is made up of six ball screw driven linear actuators connected to a self-contained octahedral structure at one end and a moving platform with a spindle motor and cutting tool at the other end through ball and socket connections. The top ball joints coupled to the octahedral structure are organised according to the Stewart platform idea such that the forces through strut pairs roughly meet at the vertices of an equilateral triangle. On the spindle platform, the lower ball joints are evenly spaced.

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Sphere Drive:

The spherical drive is a unique ball and socket combination. Because of the symmetry of the ball and socket design, loading, wear, and temperature expansion are always concentric. Shear lubricant on a large surface provides effective damping. Calibration is a simple process. The inside of the ball is hollow, and it houses a brushless D.C. motor, a radial encoder, and two ball nuts. The key components are

well-protected from harm and foreign matter.

A ball screw strut runs directly through the sphere's middle. The motor is positioned so that the driving forces emanate from the sphere's centre. The socket is a little ring with a ball within. A simple restraining device in the socket protrudes into a groove in the sphere stretching from one point to another to prevent the ball from rotating as a reaction to a drive torque.

Bifurcated Ball:

Bifurcated refers to a split or division into two sections. In a ball and socket joint, a pair of struts share a ball to prevent them from rotating in relation to one another. The ball is made up of two separate hemispheres that have been joined together. Each hemisphere is related to the other.

The reference point for estimating strut length is the centre of the ball. This is exactly calculated by measuring the distance between the sphere drive's centre and the bifurcated ball's centre. The socket is small, and the ball is magnetically trapped in the tiny socket. The tremendous shock forces dislocate the joint while causing little structural damage.

Head Unit:

The hexapod actuator's platform may accommodate a variety of head units. A system is created to supply power and communications to the head. A slip ring secures the head unit and is automatically locked and released at the head exchange station. The spindle and platform may automatically swap quills and head units.

Spindle Motor:

The hexapod actuator features a variable speed spindle that is powered by a specific D.C. motor. The motor has the ability to deliver power at high spindle speeds (typically 4KW at 60,000rpm). Air-cooled ceramic bearings are employed due to the spindle and motor's high speeds. To clear chips and convey cutting fluid mist, the entire head unit is air-cooled, and the exhaust is spun into a vortex around the cutter.

The quills that hold the tools are locked and unlocked automatically using the power of the hexapod actuator. The tool exchange station has a number of quills. The motor is controlled by a hybrid drive that responds to encoder inputs.

IMPORTANT PROPERTIES OF OCTAHEDRAL HEXAPOD MACHINE:

Stiffness:

Anyone can see that the machine isn't very stiff just by looking at it. However, upon closer inspection, we will notice how stiff the mechanism is. Due to its design geometry, hexapods are naturally stiff. Triangles, the strongest geometric structure, are used well in the mechanisms, which is a geodesic dome.

The machine frame is made of an octahedron construction, which has a great stiffness. The actuator creates a stiff truss that is five times more rigid than a traditional machine. Six struts make up the hexapod. Each strut works by applying force to the frame, either pushing or pulling it. Because there are no beams, as in a traditional machine, all deflection in the actuator causes only direct axial stresses, and the structural material is extremely robust under axial loads.

Struts have a propensity to collapse under compression stresses, however the critical buckling load is related to the 4th power of the strut diameter and inversely proportional to the square of the strut length. For additional rigidity, smaller diameter struts are employed. Hexapod solely handles axial forces rather than bending stresses. By applying forces near to the pivot joint and resolving them to a common focal point, the bending moment can be reduced.

Another distinguishing aspect of this machine is that it is self-enveloping, which means that the cutting forces are contained inside the structure and that no force is required to ground it, eliminating the need for a particular foundation. Pre-loading ball screws and linkages enhance rigidity even further. The design rigidity is typically in the range of 35,000 kg/m.

Accuracy:

The machine's rigidity also enhances precision. The hexapod actuator employs a sphere at its node point to precisely specify its centres. Each strut pair concentrates on the common place where forces are resolved without creating ending moments. Because hexapod structures are lighter in construction, there is less wear and tear between the sections, resulting in less backlash on axis reversal and smoother movement profiles. The rotational or tilt phases cause the majority of faults in multi-axis systems; however the strut length may be easily controlled when tilting in a hexapod. This machine also has error aping mechanisms built in, thus real-time errors may be reduced with proper calibration.

Speed:

Very rapid accelerations can be accomplished by lowering the mass of the moving elements. Hexapod actuators hold just the tool-head and the work is installed on the lower platform, requiring speeds of up to 40 inches per second to move the workpiece as well as the heavy bed.

Scalability:

These mechanisms may be scaled up and down to fit a wide range of applications, including micro assembly and surgery, as well as six-degree-of-motion milling, drilling, turning, welding, inspection, and assembly. The hexapod may grow to any size it wants.

Dexterity:

Dexterity translates to skill. This is a crucial aspect of the hexapod. The extension contraction ratio of the strut and the articulation possible in the links in hexapod design. By passing each fragment through the centre of a sphere containing a motor operating a roller screw, dexterity is achieved. Wide angles of movement preserved at tool platform with bifurcated ball joints, linking pair of strut together with specific magnetic sockets to keep the sphere attached to the tool platform. It has a 1 cubic metre working volume with 6 axes (35 cubic feet). The head tilt pan is plus or minus 450 degrees.

Cost:

The cost might be cheaper than that of comparable CNC machines. These devices are simple to assemble and provide a nice balance between machine size and real workspace. The system is made up of six similar pieces, allowing for easy installation, maintenance, and decreased inventory and labour costs. Software makes calibration easier.

CHARACTERISTICS OF LOADING OF HEXAPOD ACTUATORS

In a traditional machine tool, machining forces are imposed on a workpiece largely through bending strength. Bending is a structurally inefficient technique in which a large section of the material is under tension or even at no stress, basically carrying no load.

A truss effect is created by a triangular load pattern, in which all stresses are axial and all material in each truss member is evenly strained. As a result, no inefficient material exists. As a result, constructions built on trusses look fragile or inefficiently strong to the untrained eye. Even while bending constructions are weaker and less rigid than equal amounts of material in a truss arrangement, they appear to be more resilient.

Because a force P resolves into 1/6th P at each leg, the hexapod machines may be so stiff while appearing to rotate. Machine thrust is conveyed as massive bending moments in traditional machine structures, requiring a great amount of material to resist. This property allows hexapods to be extremely stiff and unyielding despite their little weight, allowing for faster speeds and accelerations.

MERITS OF OCTAHEDRAL HEXAPOD MACHINE OVER CONVENTIONAL MACHINES

Traditional machines include a bed, base slides, column, and other components that rely largely on the supporting framework. The octahedral hexapod machine is self-

contained, consisting merely of an octahedral frame and six actuating struts.

- Because all deflection in the actuators causes only direct axial tension or compression, and structural materials are most stiff under axial stresses, this construction is five times more rigid than traditional machines.

- A hexapod contains no traditional beams; hence, there are no bending strains.

- Because of their small weight, these machines move significantly faster than traditional machines.

- Hexapod has built-in personality files that automatically map the error.

- The hexapod construction differs from typical machines in that it does not require a particular base and may be placed in areas inaccessible to normal machines, such as unstable floors and ships.

- When compared to traditional machines, the hexapod provides more rigidity and precision. The precision is within.01mm. It is also dependent on the programme.

- Hexapod features a basic modular design that makes maintenance easier. It also cuts the cost of the machine by 30% compared to a comparable traditional machine.

- Faster delivery of higher-quality components.

- Improved precision reduces inspection time.

- The fully automated system eliminates downtime.

- Six degrees of freedom

- Increased dependability and the ability to map mistakes and rectify them automatically.

- Due to the small weight, there is less wear and tear.

CONCLUSION

This technology has the potential to have a significant influence on a number of manufacturing industries. It has given the machine tool industry a new level of capability and accuracy from which to expand. It offers the potential to do so at a cheaper cost and with more consistency. The octahedral hexapod machine has a

large market potential since we are still reliant on CNC, and I am confident that this machine will replace the old style of machining with a new way of machining.

REFERENCES

1. Kim HS (1999) Design and control of Stewart platform based machine tool. PhD dissertation, Graduate School, Yonsei University, South Korea

2. Lebret G, Liu K, Lewis FL (1993) Dynamic analysis and control of a Stewart platform manipulator. J Robot Syst 10(5):629–655

3. Dohner JL, Kwan CM, Regerlbrugge ME (1996) Active chatter suppression in an octahedral hexapod milling machine: a design study. Proc SPIE 2721:316–325.

4. Ren G, Lu Q, Hu N, Nan R, Peng B (2004) On vibration control with Stewart parallel mechanism. Mechatronics 14:1–13

5. Dasgupta B, Mruthyunjaya TS (1998) Closed-form dynamic equations of the general Stewart platform through the Newton-Euler approach. Mech Mach Theory 33(7):993–1012

6. U. Saranli, W. J. Schwind, and D. E. Koditschek, “Toward the Control of a Multi-Jointed, Monoped Runner,” in Proceedings of the IEEE International Conference On Robotics and Automation, Leuven, Belgium, May 1998, vol. 3, pp. 2676–82.

7. G. Gabrielli and T. H. von Karman, “What price speed?,” Mechanical Engineering, vol. 72, no. 10, pp. 775–781, 1950.

8. Lin H, McInroy JE (2006) Disturbance attenuation in precise hexapod pointing using positive force feedback. Control Eng Prac 14:1377–1386

9. H. Goldstein, Classical Mechnanics, Addison-Wesley, 1980