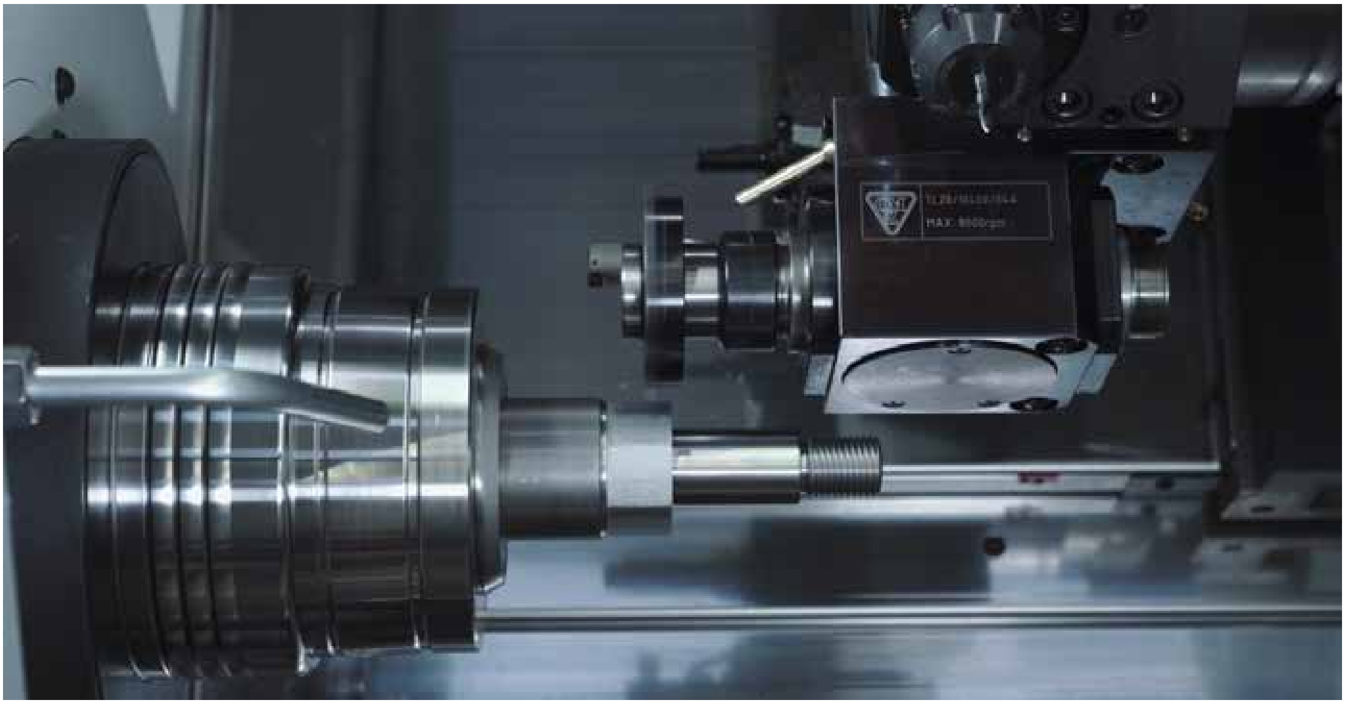
TECH FRONTIERS



Polygon turning – a special machining process

Polygon turning is a special machining process that has made easier secondary operations for the machining of components and parts to required specifications

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I HAPPENED to see an attachment for machining hexagon on a multi-spindle automat way back in the 1980s. This fascinated me and I had made some notes on this. Later when I started my own enterprise, I started working on it to develop this concept into a full-fledged machine for the use of Indian enterprises.

Back then in 80s no one wanted to get associated with a new entrepreneur. Every small thing becomes a challenge, like funds, tooling, support, etc. As this was a new concept no one wanted to come forward to buy this machine. The validation of the machine becomes an issue as we had no purchase order and the specs.

In the general component manufacturing industry, one can find processes for primary operations like cold forging, multi-spindle automats, and single-spindle automats. In recent times, CNC machines with bar is finding a predominant place. These primary processes are very well developed in terms of productivity, quality, and the cost per piece. Not all parts can be completed by the primary operations and it warrants several secondary operations for the parts to be machined to the required

specifications.

When it comes to the secondary operations like drilling, milling, slotting, broaching, and notching, well-developed standard solutions are difficult to find. This is mainly because the secondary operations cannot be categorised and standardised. Each component needs a specific solution.

Trishul Machine Tools Pvt. Ltd has made an effort to categorise these secondary operations and find an economical solution to machine these parts effectively.

The secondary operations can be classified as:

1. Drilling cross holes;
2. Slotting or making a key way; and
3. Making external slots.

These operations require specific solutions, as they cannot be rationalised.

The following operations have been rationalised and Trishul has developed very economical machining solutions for these operations.

1. Machining hexagons
2. Machining octagons
3. Machining squares
4. Machining flats
5. Machining tapered flats
6. Machining stepped flats/polygons
7. Slots on the face
8. Machining ratchet teeth, and any other flat surfaces similar to the above.

POLYGON TURNING

Polygon turning is very different from other normal machining operations as this is a generation process.

Process

The tool and the job to be cut are rotating and their interference produces a flat surface. The locus of the point of contact of the two interposing circles, i.e. tool and the job, is an 'ellipse' of minor diameter equal to the across flat size of the component and the major diameter equal to twice the tool diameter and across flat size of the polygon.

Speed ratios

Generally, the tool head and the work head have a speed ratio of 2:1. In special applications ratios of 3:1 and 2.5:1 are also used to generate polygons of three faces and five faces. The speed ratio of 2:1 is the most preferred one as this covers a vast spectrum of engineering applications which have polygon surfaces of even sides, i.e. 2, 4, 6, 8, and 10.

Mechanisms

Trishul model TPT-2S uses speed ration of 2:1 and has a mechanical kinematics link. These are machines with parallel axis and suitable for producing polygons along the axis of the component.

Trishul models TPT-4S and TPT-5S are more suitable for serrations, slots, profiles, such as ratchets and spline along the axis or normal to the axis. These machines have no kinematics link and the spindles are driven by servo motors and have an 'electronic gearbox' function. There is no limitation on the speed ratio of the spindles on this model.

Production of odd numbers and prime numbered serrations, which was otherwise impossible, can be conveniently machined. The electronic gearbox makes the spindle free of the driving elements and linkages; hence the spindle assembly is free to rotate to any angle. The freedom of the spindle to rotate to any angle opens up new arena in machining applications.

Geometries

The machining of starter pinion chamfer, pointing of synchro rings, ratchet teeth on the face, and OD are the new possibilities on the polygon turning machine with electronic gearbox.

Odd numbers and prime numbers are a very common occurrence in these applications, which can easily be addressed.

The locus of point of contact of the tool and the job is an ellipse with the Job A/f being the minor diameter and the thickness of the flat and two times the diameter of the tool being the major diameter. The sides of the polygon generated by the polygon turning process are not flats theoretically. They are segments near the minor diameter of the ellipse.

The flatness of the sides of the polygon is dependent on various factors such as the tool diameter, chordal length of the side of the polygon with respect to the across flat size, the length of overhang, and the number of sides of the polygon.

The other significant factor affecting the flatness on the component is the dynamics of cutting. In general machining processes like turning and milling the dynamic geometry is very close to the designed geometry with a very slight change affected by the feed per tooth or feed per rev. The change becomes highly significant only when cutting threads of high helix angle.

The dynamic geometry of tools in the polygon turning process varies very significantly at every point in the locus of the tool path. It varies from one extreme to the other during the process of cutting. As a result of this the shear efficiency varies significantly from point to point on the surface being cut. In addition to the above the shear section, i.e. the chip section, varies from point to point in the process.

Cutting forces, speed, and materials

Unlike in turning where the disturbing forces are generally uniform throughout the process, in the polygon turning the disturbing forces varies from point to point on the surface being machined owing to the varying dynamic geometry of the tools. The general practice is to cut polygons on the previously turned round parts.

The chip section is a segment of a circle hence it is not uniform. The varying chip thickness is another important factor contributing significantly to the disturbing force. Under these circumstances the stability of clamping and the natural stiffness of the part being machined have to be essentially rigid to resist the cutting forces, which are not uniform in nature.

The polygon turning process being intermittent in nature, the tool is in contact with the job only for 20º-40º in its rotation of 360º. Before the chip can effectively conduct the heat to the tool, the tool is out of engagement and the chip which carries the entire heat is thrown out of the tool surface. The tool travels the rest of the rotation in air, ready to take the next chip. This chip formation is a little different compared to the normal machining and the tool edge remains cool even after prolonged usage. This phenomenon enables us to use higher cutting speeds for the tools. Cutting speeds 35-40 percent more than those recommended are very common.

Machining of tough materials like SS316, SS302, Duplex stainless steel, Inconel, Monel, Hastalloy and Titanium alloys is made lot more hassle free by this phenomenon.

Tool holders

Trishul Machine Tools has standardised on tool holders of ø50 mm, ø80 mm, ø120 mm, ø140 mm, and ø200 mm.

We choose the diameter based on the size of the component, chordal length as a ratio of the A/f size, tolerance on the part, and the permissible flatness error on the part machined. The process of choosing the right diameter of the tool holder is a balance between productivity and flatness. The large diameter tool holder produces a more flat surface, at the same time lower tool diameter tool holders have shorter cycle time. We have design models to predict the flatness error, and we optimise the tool diameter to strike a balance between the cycle time and the flatness error.

With the increase in the manufacture of automotive parts for the domestic and international markets, we will see more and more demand for these machines in the future.