Centreless Precision Grinding of Camshafts as an Automated Operation

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ABSTRACT

The development of a microprocessor-controlled centreless grinding station has opened the way for the production of automobile camshafts - from raw casting to precision-finished part - as a fully automated operation. This results in manufacture to finer tolerances, with part-to-part consistency and a floor-to-floor time of half that needed for alternative production methods. Shafts with a grinding length of up to 700 mm can be processed.

Centreless grinding, in which the workpiece is not axially constrained, has steadily taken over from turning for first-stage (roughing) operations in the production of automobile camshafts. There are important technical and economic reasons for this. No straightening operation is needed, while the resulting improved geometric accuracy and closer tolerances obtained afford the best possible basis for later machining operations. The production rate is also faster. In practice, first operation attainments include a roundness of 10-20 μm, parallelity of 3-25 μm and a diameter tolerance of 40 μm.

However, in automotive camshaft production, centreless grinding has tended not to be used beyond the roughing operation because intermediate operations have traditionally been carried out under axial constraint. By rearranging the manufacturing sequence and using a procedure in which the workpiece is located from the shaft bearing journals, for example when grinding the cams, a basis was established for a start-to-finish centreless grinding operation for making these components. Because of the absence of any intermediate machining operation between centres, machining allowances could be reduced to yield the additional potential production advantages of shorter grinding times and reduced grinding-wheel wear.

While this established the basis for higher

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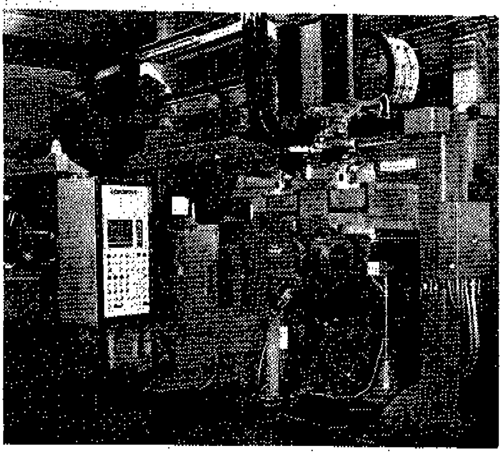

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Fig. 1

productivity, the requirements of a finish-grinding operation are infinitely more exacting than those of the first-stage treatment, typically a roundness of approximately 1.0 μm, parallelity of 5.0 μm and diameter tolerance of 8.0 μm are called for. This imposes substantial demands not only on the precision capability of the machine itself but on achieving absolute control over the variables involved, in particular compensation for wheel wear. The Lidköping 660 centreless grinding station (Fig. 1) provides for fully automated operation under microprocessor control, and incorporates its own electronic gauging for quality monitoring and self-adjustment of the operation.

In essence the station comprises a multi-wheel grinding unit, rack-type loading and unloading magazines, workpiece traverse- and gauge-sensor, the relative operations of which are integrated under a single microprocessor control system. The combination of gauge sensor and microprocessor first enables each processed workpiece to be checked against a set of memorised values as a quality control, then causes the derived date to be used for automatic machine adjustment as needed, including dressing of the grinding wheels and compensation for abrasive removed during the dressing operation.

Rigidity - A Key Factor

Ultra-rigidity of the machine and accuracy of feed are key factors in any system's reliability under close-tolerance metalworking conditions. Weighing ten tonnes without ancillaries, the 660 has a maximum grinding wheel width of 700 mm and a drive capacity of up to 100 kw, enabling a broad range of workpiece weights and sizes to be accommodated. Dual support bearings on both the grinding wheel and regulating wheel spindles (Fig. 2), coupled with the adoption of a fixed work centreline, provide for the stability of the grinding gap that is vital to this type of operation. Grinding wheel headstock movement is effected by a d.c. servo-motor operating through a backlash-free pre-loaded ball screw which, under electronic control, enables the headstock to be positioned to an accuracy of better than 0.3 μ both forward and backward. The feed rate is steplessly variable between 0.001 and 10.0

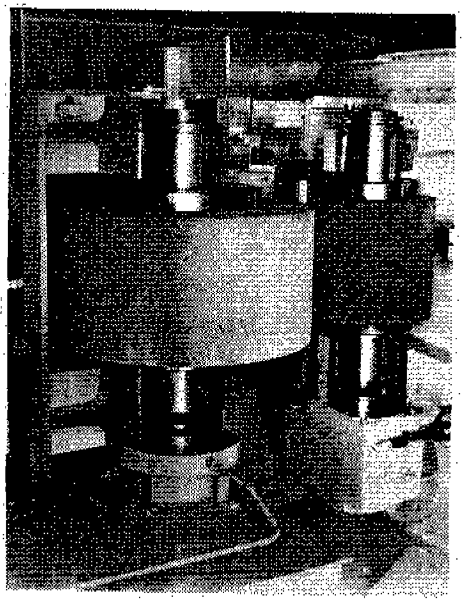

Fig. 2

mm/s. Regulating wheel-speed is maintained constant by tachometer and electric braking, the motor acting as a generator if it is over-run as the grinding operation starts up. The precision of this system is complemented by the use of hydrostatic guideways which reduce frictional effects and wear to a minimum.

Total Process Control

Control of all functions of the work station is effected by a programmable microprocessor (Fig. 3) allowing some operator adjustment to be made, eg on feed rate, within the capacity of the system's built-in operating program. That program is, however, comprehensive. Its basic functions are:

1. Synchronisation of loading and unloading with the grinding operation.
2. Control of wheel dressing sequence, including dressing intervals and wheel-wear compensation.
3. Correction of headstock position.
4. Control of feed strokes and rates, delay times and depth of cut.

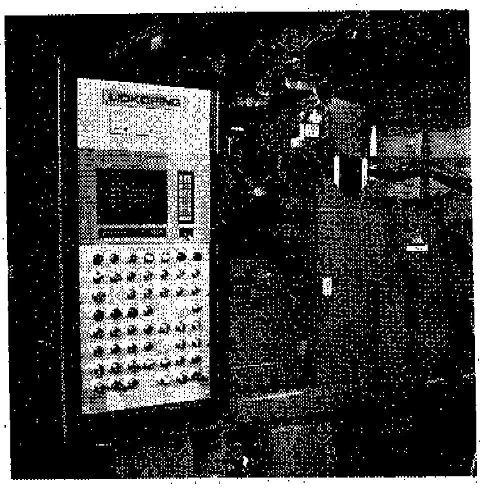

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Fig. 3

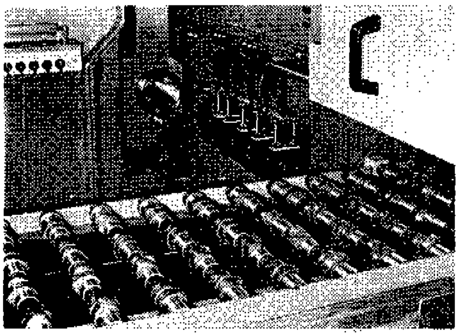

Fig. 4

In addition to these specific functions the controller can be used to carry out analyses needed for process optimisation, which can involve statistical process control, optimization of an adaptive control grinding cycle, or maintaining a constant grinding wheel peripheral speed. The controller has facilities for diagnostics, indicating the status of all position sensors, verifying a working cycle and permitting automatic test cycles to be carried out. A visual display shows the results.

Apart from providing input signals to the process controller for automatic adjustment of processing parameters, the system's electronic/mechanical sensing head (Fig. 4) gauges all five bearing journals of every component after finish grinding, thereby eliminating the need for manual inspection.

Results in Practice

Typical operating experience with the Lidköping 660 automated work station can be summarised as follows:

Rough grinding operation

With average metal-removal requirements of 3-5 mm, floor-to-floor time is about 30 seconds (120 camshafts/h), to yield parts with ground diameters variously of 18.4, 30.4 and 35.4 mm within the tolerances of 40 μm diameter and 20 μm parallelity. Peripheral speed is 60 m/s. Wheel dressing is carried out continuously as grinding is in progress.

Finish grinding operation

With average metal removal requirements of 0.4 - 0.5 mm, floor-to-floor time is approximately 20 seconds. Ground diameters are 18.0, 30.0 and 35.0, the tolerances achieved being: 13-20 μm roundness, 6-10 μm parallelity, and 0.4-0.8 μm CLA surface finish. Peripheral speed is 45 m/s.

In this operation, wheel dressing is carried out at intervals of about 30 cycles, grinding being interrupted for the purpose. The production rate, inclusive of dressing time, is 144 camshafts an hour.

The application of centreless finish-grinding as an automated process will dramatically improve the economics and consistency of results achieved in camshaft production. Its use can also contribute to safety. Built-in protection against wheel bursting and splinter ejection safeguard both the machine operator and the precision components of the work station.

Appendix

Terminology

Centreless grinding
- Grinding operation in which a workblade 'floats' between a grinding wheel and a back-up (regulating) wheel rotating in opposite directions. As opposed to grinding between centres, in which the workpiece is constrained axially between a headstock and tailstock.

'Located from'
- Positioned by reference to a measuring point.

Shaft bearing journal
- Machined portion of an irregularly-profiled shaft which fits into bearings in a machine housing.

Machining allowances
- Excess metal which is of sufficient volume to allow correct dimensions to be attained in a machining operation.

Dressing
- (of wheels). Restoring true concentricity in a turning operation, frequently using a diamond-tipped tool.

Dual support bearings
- Supported by extended bearings on both sides.

Backlash-free
- Without free movement or 'play'. Positively in contact at all times.

Pre-loaded ball screw
- Where a spring- or otherwise compressively loaded ball serves as the engaging element in a threaded drive mechanism.

Steplessly variable
- Literally without discrete pauses.

Tachometer
- Device which measures rotational speed by reference to a fixed point or points on the rotating component.

Hydrostatic guideway
- Sliding bearing having a fluid between the mating faces.

Feed stroke
- Forward/backward movement of a machine component under controlled conditions, eg a piston.

Delay time
- As 'dwell' time. Period of rest during or after an event.

Adaptive control
- Use of derived data to alter or vary parts of an operation.

Surface finish CLA
- International Standard denoting degree of 'polish' as measured under incidental illumination.

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