Turbo-Abrasive Machining and Finishing

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Deburring and surface-conditioning of complex machined and turned parts is one of the most troublesome problems faced by the metalworking industry. In many cases parts with complex geometric forms, which are manufactured with very sophisticated computer-controlled equipment, are deburred, edge finished, and surface conditioned with manual or hand-held power tools. This labor-intensive manual handling often has a considerable negative impact on manufacturing process flow, productivity, and uniformity of features on the final product, as well as part-to-part and lot-to-lot uniformity. It has been a long-standing industry-wide paradox that the final surface-conditioning operations utilized on many types of precision parts have nowhere near the level of sophistication of the preceding machining operations. This is something that needs to change.

CONVENTIONAL MECHANICAL FINISHING METHODS

Mass-finishing techniques, such as barrel and vibratory finishing, have long been recognized as the primary tools for metal part deburring and surface conditioning and, as such, have wide application throughout industry. As metalworking techniques have evolved in recent years, it seems that an increasing number of parts require more sophisticated deburring and surface-conditioning methods. Many parts routinely manufactured now have size and shape considerations that preclude the use of conventional mass media finishing techniques. Additionally, manufacturers of high-value parts now prefer manufacturing methodologies in which parts are processed singly and continuously rather than in batches, obviating the possibility that large numbers of parts will be scrapped or reworked due to human error or process maladjustment.

Another important consideration in evaluating current mass-finishing processes is their wet waste effluent stream, the treatment cost of which often approaches the cost of the actual deburring or surface conditioning operations themselves. Industry has long had a strong incentive to seek out mass-finishing methods that could achieve surface-finish objectives in a dry abrasive operation. In contrast with current methods turbo-abrasive finishing (TAM) operations are completely dry and produce surface effects rapidly in single-part operations. (Some parts lend themselves to multiple-spindle or multiple-fixture operations when single-part processing is not an important quality-control objective.)

TURBO-ABRASIVE FINISHING

The TAM method provides manufacturers with the ability to utilize a high-speed precision final machining and finishing method that can accommodate the current trend toward continuous processing of individual parts. Many larger and more complex rotationally oriented parts, which pose a severe challenge for conventional mechanical-finishing methods, can easily be processed. Many types of nonrotating parts can also be processed by fixturing them on disklike fixtures.

Increasingly complex parts are being fashioned in today’s four and five axis turning and machining centers. TAM technology provides the method in which needed surface improvements can be made on these types of parts with a minimum of direct labor and tooling costs. TAM as a surface-conditioning method is a blend of current machining and surface-finishing technologies. Like machining processes the energy used to remove material from the part is concentrated in the part itself, not the abrasive material interfacing with part surfaces, and like many surface-finishing processes material removal is not accomplished by a cutting tool with a single point of contact, but by complete envelopment of the exterior areas of the part with abrasive materials. As a result deburring, edge finishing, surface blending and smoothing, and surface conditioning are performed on all exterior exposed surfaces, edges, and features of the part simultaneously. Many metal parts that are machined by being held in a rotational work-holding device (for example, chucks, between centers, rotary tables, etc.) are potential candidates for TAM processes, and in many cases, these final deburring and surface-conditioning operations can be performed in minutes if not in seconds.

PROCESS BENEFITS

- Very rapid deburring, radiusing, and surface conditioning of complex parts, replacing or minimizing manual deburring procedures with controllable machining processes.
- No part-on-part contact or impingement.
- Reduces manual process or cycle times from hours to minutes.
- Uniformity. Complete abrasive development of parts means all exposed exterior surfaces and features will be free abrasive machined. Unlike processes with hand-held tools or directional streams of abrasive media, all features of the part are processed uniformly and simultaneously.
- Repeatability. Part-to-part and lot-to-lot variations can be eliminated or minimized. Uniformity of surface effects on features of parts is also enhanced.
- Compressive stresses and metal improvement can be developed on critical part areas to enhance metal fatigue resistance.
- Special microtextured surfaces can be generated that have enhanced bonding receptivity as substrates to many types of coatings and plating.
- Low-temperature material removal. Unlike many traditional grinding processes, physical characteristics of the outer surface layer of metal are not changed by process-generated temperature shifts on surface of metal.
- Random surface-finish pattern means greater compatibility with coating and plating processes than linear patterns developed with traditional grinding methods.
TURBO-ABRASIVE MACHINING CONCEPT

The basic concept underlying TAM operations is the placement of a rotating or oscillating metal component or workpiece in a low-speed air-abrasive stream (fluidized bed), which is contained by a specially designed chamber. Surface finishes and effects can be generated on the entire exterior of complex parts, and specially fixed rotational components. (Simple interior channels on some parts can also be processed.) Various surface-finish effects can be obtained by controlling variables of the process such as rotational part speed, part positioning, cycle time, abrasive particle size and characteristics, and others. Additional surface effects can be developed by utilizing processes that make use of sequential abrasive and/or polishing media combinations. Several machine designs have been developed that can accommodate parts as small as 2 to 3 in. (50 mm) in diameter to very large and cumbersome rotational parts up to 4 ft (1.200 mm) in diameter and larger.

HIGH-INTENSITY ABRASIVE EFFECT

Surface-finish effects are generated by the high peripheral speed of rotating parts and the large number and intensity of abrasive particle to part surface contacts or impacts in a given unit of time (200-500 per mm²/sec or 129,000-323,000 per in.²/sec). These factors make this equipment capable of generating one of the highest rates of metal removal to be found in any type of free abrasive surface-finishing operation today. Yet with proper media selection and process adjustments, very refined finishes can be achieved. Parts with an initial surface roughness profile of 2 to 5 µm Rₐ (80-200 microinch Rₐ) have been reduced to 0.2 to 0.4 µm Rₐ (7-15 microinch Rₐ) in a single operation in time cycles of only a few minutes. It should be noted that surface-finish effects developed from this process depart significantly from those obtained from air or wheel blasting. TAM processes can produce much more refined surfaces by virtue of the fact that the rotational movement of parts processed develop a very fine finish pattern and a much more level surface profile than is possible from pressure and impact methods.

RANDOM VERSUS LINEAR GRINDING PATTERNS

Another very important functional aspect of TAM technology is its ability to develop needed surface finishes in a low-temperature operation (in contrast with conventional wheel and belt grinding methods), with no phase or structural changes in the surface layer of the metal. A further feature of the process is that it produces a more random pattern of surface tracks than the more linear abrasive methods such as wheel grinding or belt grinding. The nonlinear finish pattern that results often enhances the surface in such a way as to make it much more receptive as a bonding substrate for subsequent coating and even plating operations.

METAL IMPROVEMENT

TAM processes have strong application on certain types of parts that have critical metal surface improvement requirements of a functional nature. Significant metal improvement has been realized in processes with both abrasive and nonabrasive media. As a result of intense abrasive particle contact with exposed features, it has been observed that residual compressive stresses of up to 400 to 600 MPa can be created in selected critical areas. Tests performed on rotating parts for the aerospace industry that were processed with this method demonstrated a 40 to 200% increase in metal fatigue resistance when tested under working conditions, when compared with parts that had been deburred and edge finished with less sophisticated manual treatment protocols.

LOOSE ABRASIVE TECHNOLOGY

TAM technology makes use of a variety of loose abrasive materials and blends of abrasive and nonabrasive granulates to attain various surface finishes and effects that can vary from abrasive edge finishing and surface smoothing to more refined plate finishes, as well as using an assortment of nonabrasive media for metal improvement processing. The large number of abrasives and specially formulated abrasive blends available makes it possible to produce a wide array of diverse surface-finish effects, even more so when sequential cycles with differing media combinations are utilized.

APPLICATIONS

Some of the applications include high-speed precision, deburring, radius formation, edge finishing, surface enhancement, and metal improvement of all types of rotating components including turbine/compressor disks and other rotating components, gears, impellers, sprockets, machined turnings of all kinds, turbocharger rotors, turbine blade root forms, automotive, textile, engine, electrical, pump marine, electrical, and various consumer items.

SUMMARY

TAM processes can be easily justified in many types of applications where part size and shape considerations make applying other surface-conditioning technologies difficult. The process deburrs and develops needed edge and surface-finish requirements very rapidly.

Significant process characteristics to keep in mind include (1) very rapid cycle times; (2) a high-intensity, small media operation that allows for access into intricate part geometries; (3) a completely dry operation; (4) metal improvement effects; (5) no part-on-part contact; (6) modest tooling requirements; (7) primarily an external surface preparation method—some simpler interior channels can also be processed; and (8) many types of rotating components can be processed—nonrotational components can also be processed when attached to disklike fixtures.

References
