From manual grinding to CNC automation – a major step forward for the rod mill

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Abstract

This paper sets out to describe the transition of a hitherto intensely manual grinding operation to what has now become an automated process placing little demand upon the skill of the operator thus removing a significant likelihood for error. The project presented considerable challenges on a number of fronts taking the application of touch trigger probing into previously uncharted territory. Indeed the forming of precision shapes in solid tungsten carbide rollers by means of special diamond grinding wheels was hitherto a “black art” known only to those in the rod rolling industry. Furthermore the introduction of CNC automation into an area where craftsmanship had remained unrivalled for several generations called for a delicate approach to the issues of technique, training and manning. However, the investment was considered wholly worthwhile and justifiable by considerable improvements in quality, efficiency and not least, in operator safety.

1 Introduction

In modern day engineering parlance the term Closed Loop Machining is normally taken to mean the highest level of CNC automation whereby a machine tool equipped with a measuring device is programmed to locate the true position of a component feature and then to calculate any deviation from the expected value. Data gathered in this way may then be utilised to modify a subsequent tool path by, for example, correcting a value in the stored tool offset table thus improving the final accuracy of the machined component. Sometimes referred to as In-Process Gauging such techniques enable the part-programmer to hold tighter tolerances and are often regarded as the optimisation of machining accuracy made possible only by the advent of advanced CNC systems coupled with the touch – trigger probe. On examination however we find that the closed loop principle is by no means new.
Clearly, metal-cutting operations have always been controlled by the output of a measuring device, albeit indirectly by the use of a measuring instrument, typically a micrometer, followed by an appropriate adjustment to the machine tool. Such ongoing corrections were normally carried out by the operator with whom would rest sole responsibility for the end result, a principle that is far less clear in the modern day machine shop.

Explained here in the simplest terms is the concept of closed loop machining on a manual machine tool -

![Figure 1: A manual feedback loop of the simplest kind](image)

and on a CNC machine tool equipped with measuring devices -

![Figure 2: The concept of closed loop machining](image)

A significant change brought about by CNC technology has been the removal of the human element from this fundamental feedback loop.
2 The component

The component is the primary tool used in the production of rolled steel rod commonly referred to in the industry as a disk. These cylindrically shaped rollers fashioned in tungsten carbide are stocked in large numbers and maintained in-house by a continuous cycle of re-grinding and replacement thus meeting the demands of the rolling mill on a round-the-clock basis. Used arbitrarily in identical pairs, the discs come in a variety of diameters and widths, a standard diameter bore being a common feature throughout the range.

Supplied to the tool room as "virgin disks" each pair must be prepared for use in the rolling mill. First they are precision ground to a matching outside diameter. Next the required radii are cut in the periphery by means of a preformed diamond compound wheel of which the tool room holds more than fifty varieties. Critical dimensions for this operation are the depth of the profile as measured from the outside diameter and the longitudinal position of the profile as measured from the edge of the disc the tolerance in each case being +/− 10um (+/− 0.0004")
3 The existing method

A detailed survey of the existing method was carried out from which the main observations were as follows -

- Three manual grinding machines were operated on a 24/7 basis by a team of ten skilled personnel.
- Purpose built by Wendt of Germany the twin spindle machines were some 20 years old but nevertheless the basic components were in reasonable condition.
- Intermediate checks by shadowgraph called for the disc to be removed from the arbor and subsequently replaced several times during the grinding operation.
- The existing guarding offered little or no protection from undesirable substances produced by the grinding process.

The survey concluded that the physical attributes of the machines were worthy of retention but the outdated manual control system could be much improved by the application of CNC. Equally strong was the opinion that the basic grinding techniques, well proven over many years, should in principle be adhered to. The decision was reached that two of the three machines would form the basis of an extensive retrofit to be carried out during the coming months during which production capacity would be maintained by keeping two machines in almost continuous use.

4 The new concept

In close cooperation with the owners a specification for the re-engineering of the two machines was drawn up as follows:

- A complete mechanical refit including new drives, ballscrews, guideways, linear scales etc
- A complete electrical refit based on the Siemens 840D CNC system.
- A fully interlocked enclosure having coolant and air filtration systems qualifying for CE marking
- Pre-written Part-Programs to cater for the whole range of discs
- Fully automatic operation including "intelligent" detection of the disk type and final inspection of the ground profile
- A simple, user-friendly interface prompting for key choices but requiring only the minimum operator input
- Wheel and work measurement routines facilitated by touch-trigger probes
- In the interests of economy the regrinding process must remove only the minimum stock necessary to bring the disc within tolerance
- The system must be capable of recognising and subsequently forming the complete profile in a new solid (or virgin) disc.
5 The rebuild

The cast iron beds consisting of a substantial pair of ribbed castings with integral guideways were re-ground and machined to accept two Siemens IFT6 AC servomotors driving precision ballscrews for the X and Z axes by means of Centa planetary reduction gearboxes. Both axes were fitted with high resolution linear feedback scales.

The headstock carrying the work spindle in hydrostatic bearings and the hydraulic work-clamping unit were re-conditioned and a PLC controlled lubrication system provided for the slideways and ballscrews. Up rated drive motors were provided for the workhead and for the two grinding spindles. In order that the installation would meet the health and safety requirements of the customer’s plant and qualify for CE marking a full enclosure was designed with safety interlocks in place at all access points. An integral centrifugal oil mist filter unit was installed to clear the air of harmful residue from the grinding process.

A high pressure recirculating coolant system was fitted with powerful jets supplying the grinding wheels so minimising the build up metal on the surfaces. In addition multiple outlets served as a wash-down for the residual tungsten carbide particulate which is then removed from the coolant by means of hydro-cyclone filtration system, a system which facilitates recovery of the scrap metal for recycling. A control pendant carrying the Siemens 840 D CNC along with an auxiliary control panel, various indicators and the Renishaw probe interfaces was suspended by a universal arm thus allowing the operator to position himself in front of the window so maintaining visual contact with the operation aided by internal lighting. For ease of work piece loading the sliding door was pneumatically operated and a footswitch provided for the hydraulically clamped arbor. Clearly, the required accuracy of $\pm 10$ microns could only be maintained by overcoming the effects of uncertainties such as thermal change and wheel wear. On this issue metrology specialists, Renishaw were consulted and subsequently put forward a system utilising touch trigger probes from their standard product range. For measurement of the grinding wheels a TSR motorised tool setting arm was mounted above the workhead thus allowing the probe to be retracted from the working envelope when not in use. The integral TS20 probe carried a 5mm cube stylus accessible to both the topping wheel and the form grinding wheel. In the role of work measurement probe was a LP2H SS with a 2mm ruby ball stylus. Such was the configuration of the machine that this multi-directional touch-trigger probe could only be mounted adjacent to the large grinding wheel, a position where it would
be subject to coolant and grinding debris during operation. However, the double
seals of the SS specification probe provided a reliable solution.

Controlled by a customised software package in conjunction with the
facilities of the Siemens 840 D the probing equipment enabled development of a
system of in-process gauging coupled with automatic offset adjustment.

6 The new process

Software design began
by the cataloguing of
every type of disc used in
the rod mill.
Dimensional data
describing each disc and
the associated form
grinding wheel was
collated into a CNC
resident look-up table
and cross referenced with
a number of key
parameters.

Next the advanced
facilities of the Siemens
840D were utilised to
create an interactive user
screen offering to the
operator a simple
selection sequence whereby the type of disc to be ground and details of the
operation are input.
Options available to the operator by means of the input screen are as follows –

- Discs Type? A, B or C
- Profile type? 35 selections
- Type of grinding operation? Light / Heavy
- Datum the probes and wheels on start-up? Yes/No
- Use automatic tolerance control? Yes/No
- Skip the intermediate inspection? Yes/No
- Is this a virgin (new) disk? Yes/No
- Grind the top only? Yes/No
- Grind the profile only? Yes/No
- Grind the second profile only? Yes/No
- Carry out a final inspection of the disc and log the results? Yes/No
Figure 8: The operator interface

The selection sequence ends when the operator is invited to double-check his entries before pressing a confirmation key. At this point the look-up table is accessed and the relevant data transferred to R parameters. An operator message is then issued requesting the appropriate profile wheel to be mounted. A disc is then loaded upon the hydraulically clamped arbor, the safety door closes and the main part-program \textit{MAIN.MPF} is started. The function of \textit{MAIN.MPF} is outlined by the flow diagram shown by Figure 7

Chart 1: A section of the data look up table

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Figure 7: This flow diagram illustrates the sequence of operations.
7 CNC Programming

Using conventional NC code supplemented by the extended programming language of the Siemens 840D to provide functions such as calculation and designed to perform a specific task. Numbering some twenty-five in total the logical selection a family of parametric sub-routines were written (*.SPF) each routines were called by a master main program file (MAIN.MPF) which drew parametric data from a stored look-up table and from the operator interface.

Measurement functions were executed by customised versions of the standard issue probe cycles from Renishaw. A complete summary of the programming strategy used is available on request.

![Diagram of machine elements]

Figure 8: Layout of the machine elements
8 Conclusions

The considerable benefits of this development quickly became clear during the commissioning period and on the authors’ last visit optimisation was ongoing.

- Discs can now be ground in a single operation where previously two or more set-ups and several measuring operations were necessary.
- Two CNC machines are now satisfying a demand that previously called for three manual machines.
- Both machines can be controlled by a single operator
- Working conditions are improved, the environment is cleaner, safer and less noisy. Physical effort is reduced.
- A less stressful grinding technique which was previously impracticable on manual machines is made possible by CNC. By applying multiple passes with a precisely controlled in-feed the wheel life is increased with better accuracy and finish. There is no penalty on cycle time.
- Advanced in-process gauging with data logging ensures that quality standards are achieved on virtually every component with systems in place to warn of deterioration due to wheel wear etc: