Computer Numerical Control (CNC) Production Tooling and Repeatable Characteristics on Ten Remington Model 870 Production Run Breech Bolts

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Key Words: class characteristics, computer numerical control (CNC), impressed toolmarks, production run group, striated toolmarks and subclass characteristics.

ABSTRACT

Comparisons were made to determine if the Computer Numerical Controlled (CNC) process used to manufacture shotgun breech bolts would produce sufficient Subclass Characteristics on the bolt faces to be attributable to the working surfaces of the tool groups used within a single Production Run. Of additional interest was if these characteristics could be traced through an entire CNC Production Run leaving the sufficient transfer of individual markings to be considered unique in nature.

INTRODUCTION

A product created through the economically profitable use of leading edge technology will more than ever govern the future of the firearm industry. This will be accomplished by blending man and machine to create technologically advanced production methods for new items as well as being incorporated into the old favorites of the firearm industry. In order for a firearm and toolmark examiner to deal with the idiosynchroncies encountered, present and future manufacturing techniques must be understood.

During an orientation tour of twelve firearm manufactures in the northeastern United States, it was noted the majority used Computer Numerical Control (CNC) equipment somewhere within their manufacturing process. The term CNC covered a wide variety of self-contained computer operated machines which performed the multiple facets of machining and finishing operations. Their use varied from a product totally created by CNC to none being used at all. (The instances where manufactures did not utilize some form of CNC were producing components required to meet very specific customer designated tolerance allowances.) At the cost of hundreds of thousands of dollars per unit, the industry constantly evaluated which phase of production would be most economical for CNC use. Many manufacturers had implemented CNC operations, only to replace that CNC with manpower and incorporate a different system into another phase of production. In many instances the CNC's proved slower than machinists and were best incorporated to perform specific functions. The resulting cost savings allowed two production shifts of employees in support of three CNC manufacturing shifts. The third shift only required a skeleton workforce made up of programmers and minimal support personnel.

The accepted life expectancy of a CNC machine was five years. By the end of that cycle, the machine became no longer economically feasible to maintain and so obsolete replacement parts were unavailable. The factor of an approximate five-year cycle was found to be a marker within the industry and often used as an earmark for change related to production line operation.

CNC's were employed in a wide variety of locations within the production process. In some instances CNC's were used for "Hogging" large amounts of metal from parts with the finishing work being accomplished using machines and techniques perfected during the 1930's and 1940's. (8)(9) Other manufacturers did just the opposite, with the hogging accomplished by employees and precision work done by CNC. To further complicate the field of CNC's, some parts were CNC produced either by sub-contractors or at corporate owned facilities in Europe, the Americas, or Asia, then shipped and integrated into production assembly facilities in the United States.

The Remington Arms Company, Inc., Ilion, New York, was one of the firearms manufacturers visited. Remington was found to be no different from other manufacturers in the utilization of CNC's. Over the years, Remington had installed CNC systems, only to determine that in some instances time lost due to breakdowns and waiting for parts was economically unjustifiable. The ineffective CNC's were replaced by tooling machines with the human touch and different CNC's were incorporated into other phases of production. At the time they were visited, Remington was employing approximately 600 workers, with the third shift accounting for only 75 to 80 of those employees.

As an example, the CNC Remington used to produce Model 870 shotgun breech bolts accepted 85 work-pieces for processing at one time. These 85 pieces were termed a "Production Run". A production run was the smallest denominator used in the flow of production line units through the manufacturing process. Specific functions for the CNC to accomplish were programmed into the computer control unit. These programming instructions covered the milling, grinding, drilling, tooling, and finishing of all 85 breech bolts within the production run during a single cycle. The functions included the forming of external angles, locking lug slots, firing pin channels, firing pin retainer holes, extractor plunger spring holes, extractor slots, ejector grooves and breech faces. The CNC while accomplishing these functions performed it's own internal quality control tolerance checks. If the CNC detected any function exceeding a +/- .0025 inch acceptable tolerance, the machine automatically shut down and went into standby waiting mode until the operator took over control. To aid the operator, the CNC maintained a complete record of the machining functions performed. These records provided the operator with a method of determining what activated the shutdown and the corrective action needed. (8)

The CNC computer controlling the production cycle was programmed with tool identifying numbers to recognize the tools to be utilized from an internal central tool repository. The programmed tool numerical designations for a production run was divided into "Tool Groups." Programming the tool number allowed a specific tool to perform functions in more than one tool group. For example: The manufacturing of an 85 unit production run may call for twelve tool groups, consisting of up to 30 tools per tool group. The tools are retrieved, delivered, used, and returned by a conveyer sequence controlled by the computer program. Such things as tool wear, tool deformity or tool breakage are controlled and calibrated by the CNC as part of the quality control checks performed after each operation. Tool life can not be controlled by a given number of performed functions but rather determined by the tolerance calibrations of the checks performed on the tool and the work it has performed. (8)

RESEARCH METHODS

Kansas is no different from any other rural; hunting orientated state and a significant percentage of casework involves the use of shotguns. In addition, a review of published Association of Firearm and Toolmark Examiners (AFTE) Journal articles and other forensic sources revealed a limited number of references relating to the use of CNC equipment in the industrial production of metal products. Research addressed in this paper attempts to provide usable information related to both.

The Remington Model 870 (M 870) slide action shotgun was selected over other popular shotgun models because it has been in continual production since 1950, with representation in all the popular hunting, trap and skeet gauges utilizing the same breech bolt configuration. (2) The Model 870 Law Enforcement is also frequently issued as a backup long gun to state, county and local law enforcement agencies in Kansas. (Note: The 870's listing in the twenty-second Edition of Blue Book of Gun Values covers over five full pages of model variations.) (7)

Tests of shotgun performance were conducted from the shoulder fire position in a controlled environment using two Remington M 870, 12 gauge shotguns. Shotgun "A" was a Model 870 Law Enforcement, with a 20 inch barrel and 16 inch magazine spring, and Shotgun "B" was a Model 870 Wingmaster, with a 25.5 inch barrel and 16 inch magazine spring. After a thorough cleaning of each shotgun, fifteen different 12 gauge shotshell loads from four common manufactures were selected from the Standard Ammunition File and test fired. The test firings were completed using the original bolt assemblies. Comparisons of the tests were made to determine which fired shotshells, from which shotgun, transferred the best representation of breech face impressions to the primer faces. These comparisons resulted in the selection of Federal, 2¾ inch, 7½ shot, one ounce, game load (red box) shotshells fired from Shotgun A as the combination to be used for research firings.

Ten M 870, 12 gauge, breech bolt assemblies were acquired from the Remington Arms Company, Inc. The breech bolt assemblies contained breech bolts that were selected at random from a single 85 unit CNC production run. These assemblies included the locking blocks, firing pins, firing pin springs, firing pin retaining pins, extractors and extractor springs. They were all Remington Part Number - 22860, Polished Chrome Plated Breech Bolt Assembly. (8)

Upon receipt of the bolt assemblies from Remington, it was learned the ten received consisted of four Standard and six Marine Magnum bolts. Remington advised all ten breech bolts were work-pieces from the same CNC production run. The only difference between the two types of assemblies was an additional amount of metal had been removed during the facing operation of the marine magnum breech bolts. The amount of metal removed was to accommodate a thicker layer of finish material on the marine magnum models, for additional protection in harsher operational environments. The allowable difference for thickness of bolt face tolerance was .316 to .314 inch for the marine magnum bolt versus .317 to .315 inch for the standard bolt. (8) (Note: The difference of units produced within a CNC production run provides another example of the variants which may occur in CNC manufacturing. This resulted from the programming of the tool group functions based on production requirements.)

For identification purposes each breech bolt assembly was randomly given a number from I through IV and M-I through M-VI. Thirty test fire shotshells were selected from the same lot number and each etched with a number signifying the bolt used, shotgun used, and orders of firing (i.e. M-I-A-3). To ensure conformity, each breech face was cleaned using cotton tipped applicator and ethyl alcohol. A Mikrosil casting and measurements were taken of each breech bolt face. The breech faces were again cleaned and caution was taken to ensure no other contact was made with the breech face prior to test firing.

Shotgun A was thoroughly cleaned prior to test firing. All tests were conducted in the same controlled environment from the shoulder fire position. Each group of three was fired at the same time. After the firing of a three round test firing, the breech bolt assembly was removed and the next bolt assembly placed in the shotgun. The order of fire was based on the random number assigned to each breech bolt assembly. Each group of three was loaded with the first shotshell being inserted through the ejection port, chambered and the remaining two inserted into the magazine tube. The original bolt slide of Shotgun A was used for both ammunition selection and test firings.

To aid comparative microscopic examinations the extractor marks were indexed. Extractor alignment in relation to a chambered shotshell was constant at the three o'clock position. As shotshells were cycled for firing, the position of headstamp markings could not be controlled; however, the extractor position at the three o'clock was true to each breech bolt assembly. By using this positioning as a marker, the extractor marks were rotated to approximately the twelve o'clock position for all microscopic examinations. This fixed point of reference became extremely important when comparing multiple firings to the relationships between magnified primer faces, breech bolt faces, Mikrosil casts and photographs.

FINDINGS

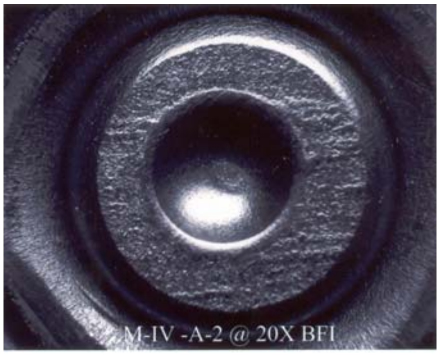
The focus of research was to determine if a self-contained, computer generated, multi-tooling machine would create markings of a nature comparable to assembly line machinist manufacturing and if they did occur, could these marks be separated into graduated levels for identification. It was determined the utilization of CNC's within the manufacturing process to create bolt faces does produce sufficient subclass and individual characteristics to provide uniqueness to each within a production run. However, factors other than tooling and machining were found to influence the impressions left on the primer faces and have the potential of altering the initially impressed markings.

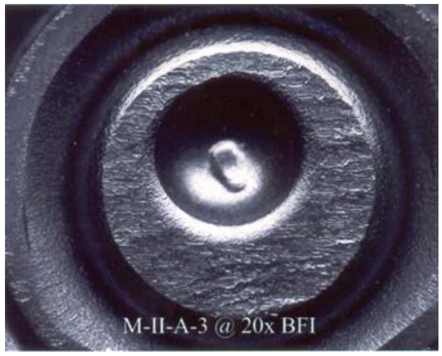
The marks found could be grouped by related categories. A Production Run Group was considered to be an area of disturbance made up of Subclass Characteristics appearing in the same locations on all test fires. These grouped subclass characteristic markings were consistent with having been created by the overall machining process. Production run groups were general in nature and categorized by reoccurring at relatively the same locations on all primer faces. The marks creating a production run group changed in shape from one group to the next because they were not the result of design. These subclass characteristics were located on the surface area within the production run groupings at reoccurring locations. The production groupings of subclass characteristics consisted of carryover from one breech bolt to the next in general forms but not in detail. (4) The subclass characteristics occurred on the tool working surfaces, or surfaces produced by these tools, that were manufactured consecutively. This was because there was less likelihood of change in the tools working surface in the short duration than would be expected from the same tool being used over a longer period of time. (5) Individual Characteristics were irregularities or imperfections produced during the manufacturing process and were not transferred from one group to the next. These marks were unique, distinguishing the firing representative from those of all the other test fire groups. (3)

To evaluate the transfer of markings from the different groupings of breech bolts to the shotshell primers, comparisons of each of the test fire groups were made. These resulted in the identification of two areas, which remained constant throughout the examination of the ten breech bolts. The production run groups occurred in the areas of approximately two to four o'clock and five to seven o'clock. Although the actual form and shape varied, these were areas of disturbance detected on all the test fires.

There was sufficient subclass information within the ten breech bolt assemblies to deduct a probable production relationship. The shotshell primer depicted in Photo 1 (Test Firing M-IV-A-2 @ 20x) was placed at one end, Photo 2 (Test Firing M-II-A-2 @ 20x) in the middle, and Photo 3 (Test Firing IV-A-2 @ 20x) was positioned tenth.

Within the subclass characteristic markings, sufficient finite details were observed to establish individual agreements that were considered to be unique. Sufficient markings could be isolated within a test group to identify each test to the others of the group based on comparison lineups. These identifying marks were found at different locations around the primer face of each representative group. Many of the individual markings in one group, when compared to shotshells of another test firing, fit within the parameters of the subclass characteristics while other marks were individual to the new group.





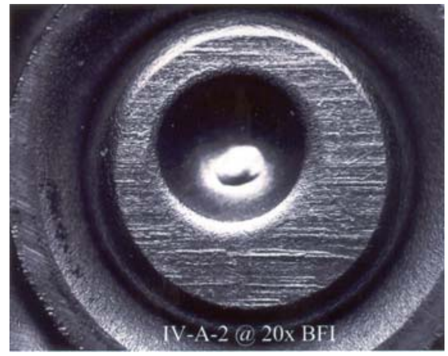
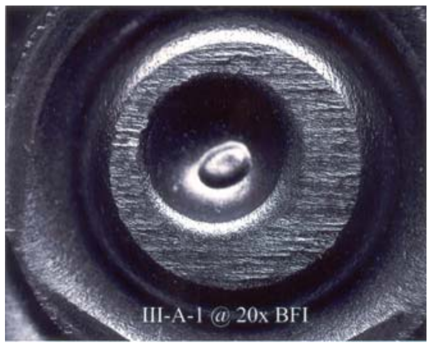
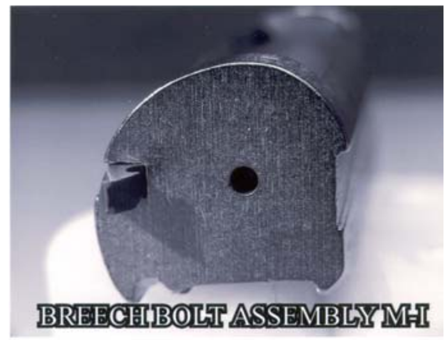


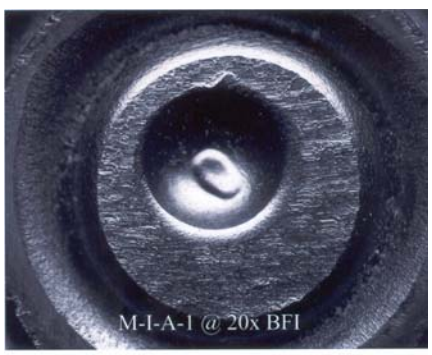
Figure 1: Grannular Breech Face Marks

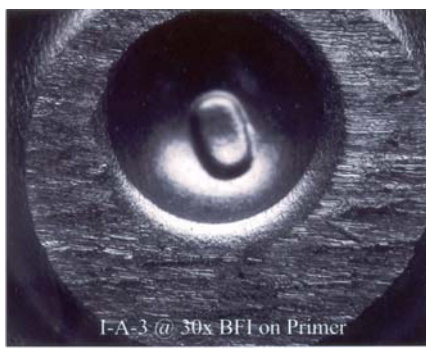
Figure 2: Striated and Impressed Marks

Figure 3: Parallel Impressed Marks









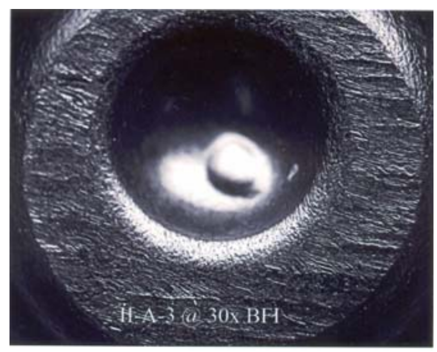


Figure 4: Standard Bolt Face

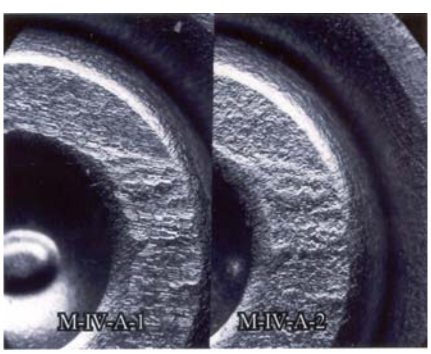
Figure 5: Standard Bolt Marks

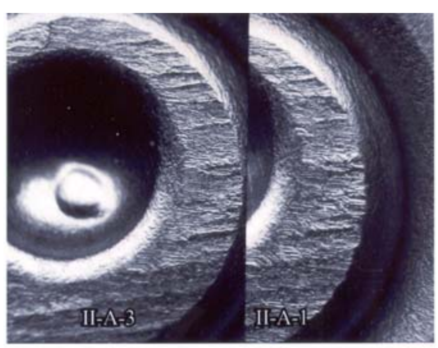
Figure 6: Marine Bolt Face

Figure 7: Marine Bolt Face Marks

Figure 8: Impressed and Striated Marks

Figure 9: Movement of Impressed Marks





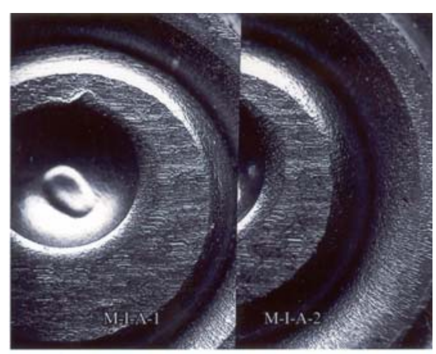


Figure 10: May Not Always Occur

Figure 11: Marks Move With Each Firing

Figure 12: Marks May Appear Repetitive

Details present on the primer faces were sufficient to allow the bolt and the corresponding Mikrosil cast to be compared. However, in some instances this was done with difficulty due to the limited amount and condition of markings being impressed at the time of firing. This was found to be especially true with bolts M-III, M-V, and M-VI that were re-fired in an attempt to obtain better markings, but with limited improvements.

OVERLAPPING TOOLMARKS

While conducting the research examinations, two areas of concern were encountered. The first was if there would be a difference in bolt faces between standard and marine magnum bolt assemblies and if these differences would result in detectable variances in markings impressed within a firing.

Visually the standard and marine magnum breech bolt faces appeared to be slightly different; however, the toolmarks impressed during firings did not indicate a significant difference. The standard faces had a predominance of vertical parallel toolmarks. (Photo 4, Bolt Face III, and Photo 5, Test Firing III-A-1 @ 20x) While the marine magnum bolts had the appearance of a smoother granular surface with less vertical parallel marks. (Photo 6, Bolt Face M-I, and Photo 7, Test Firing M-I-A-1) A review of the machine program records provided by Remington showed approximately an additional .001 inch was removed from the marine magnum surface during a second process. (8)

Upon initial evaluation of the test firings it was believed the ten breech bolt assemblies selected from the production run consisted of three different face surfaces; granular impressed (Photo 1), striated and impressed (Photo 2), and parallel impressed (Photo 3). However, it was determined the breech bolt assembly was actually moving, which allowed the breech face to drag across the primer face. This movement was occurring immediately after the shotshell head impacted. The movement in all cases in which it occurred was in a downward direction (twelve to six o'clock) with a slight turn right at the bottom of the movement toward seven o'clock. The initial IMPRESSED TOOLMARK became a STRIATED TOOLMARK as soon as movement began. (4) Primer faces with both the impressed or striated toolmarks could be found within the same test fire groups. (Photo 10, Test Firings M-IV-A-1 vs. M-IV-A –2)

There were sufficient impressed or striated toolmarks observed on the shotshell primer faces for them to be separated into categories. The method, in which these toolmarks were created, coupled with the production run groupings of subclass characteristics and individual characteristics present were used to reach a probable relationship within the CNC run. These categories were:

1. The Impressed Toolmarks found in Photo 1 represent the markings left at the time of impact. The subclass characteristics of the production run group show an example of those discussed, with sufficient individual characteristics to demonstrate uniqueness.

2. The next was a combination of impressed marks and striated toolmarks resulting after primer contact with the breech face. The combination was sufficient to allow a distinction between both types of toolmarks as found in Photo 8 (Test Firing I-A-3).

3. The last grouping represents the transfer of impressed to striated markings, to the degree the striations dominated. These striated markings occurred after initial impact, allowing movement of the bolt face with sufficient force to move the impressed marks to the point metal buildup was left in the form of ridges at the end of the striations. These ridges of metal buildup agreed with established production run groupings of subclass markings at a point slightly below and to the right of production run impressions on the examples. (Photo 9, Test Firing II-A-3 @ 30x)

The movement of the breech bolt assemblies was believed to be the result of possible variances within the grooves of the locking lugs. This allowed limited movement of the bolt as the locking lug disengaged slightly after lock-up and discharge. Production records provided by Remington showed the locking block lock-up height was function tested for 100% compliance after all the breech bolts were assembled. (8)

The problems these marks present to the examiner are:

1. The striations did not occur in every firing. (Photo 10, Test Firings M-IV-A-1 vs. M-IV-A-2)
2. The striations resulted in the movement of tool markings initially impressed on the primer face. (Photo 11, Test Firings II-A-3 vs. II-A-1)
3. These striated marks gave the appearance of being repetitive in nature. However, it was essential to remember the marks resulted from a force occurring after the primer face made contact with the breech face. Within the space confines of the receiver, the path the bolt traveled was not the only factor controlling the creation of the striae. These marks may be compared to the phenomenon of firing pin drag. They may not occur on every firing, but when they do appear the marks may be used as a suitable identification tool. Care should be exercised when evaluating this type of striated marking to ensure an unjustified elimination does not take place. (Photo 12, Test Firings M-I-A-1 vs. M-I-A-2)

GLOSSARY

Class Characteristics: Measurable features of a specimen which indicate a restricted group. They result from design factors, and are therefore determined prior to manufacture. (3)

Subclass Characteristics: Discernable surface features of an object that are more restricted than class characteristics in that they are:

1. Produced incidental to manufacture.
2. Are significant in that they relate to a smaller group source (a subset of the class to which they belong).
3. Can arise from a source, which changes over time. (4)

Individual Characteristics: Imperfections or irregularities produced during manufacture or caused by use, abuse, corrosion, rust or damage to an object. They are unique to that object and distinguish it from all other objects. (3)

Toolmark, Impressed: Marks produced when a tool is placed against another object and enough force is applied to the tool so that it leaves an impression. The class characteristics (shape) can indicate the type tool used to produce the mark. These marks can contain Class and/or Individual Characteristics of the tool producing the marks. Also called Compression Marks. (3)(4)

Toolmark, Striated: Marks produced when a tool is placed against another object and with pressure applied, the tool is moved across the object producing a striated mark. Friction Marks, Abrasion Marks and Scratch Marks are terms commonly used when referring to striated marks. These marks can be either Class and/or Individual Characteristics. (3)(4)

Hogging: A term used for the work performed by tools that rough out work-pieces prior to shaping. They typically have the fastest feed rate of any spiral tool, improve the quality of secondary shaping and extend the life of expensive profile tooling. Also called Rougher Tools. (8)(9)

ACKNOWLEDGEMENT

Without the assistance of Mr. Fred L. Supry, Consumer Affairs and AFTE Technical Representative, Remington Arms Company, Inc., this project would not have been possible. In addition, The Remington Arms Company, Inc. is thanked for hosting a most informative tour of the Headquarters at Ilion, New York and providing assistance and information.

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