Optimization of Two Way Helical Abrasive Flow Machining using Taguchi Method

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ABSTRACT

The problems in the activities of events in manufacturing processes is to sustain productivity while keeping pace with new materials of high strength, complexity in shape and size, and higher demand for product accuracy and surface finish. The solution to the above problems cannot be achieved through conventional processes (e.g. turning, drilling, milling and plastic forming). Finishing operations usually cost approximately 15% of the total machining cost in a production cycle of the manufacturing plant.

Keywords- Abrasive Jet Machining (AJM), Ultrasonic Machining (USM), Water Jet and Abrasive Water Jet Machining (WJM and AWJM), Electro discharge Machining (EDM) are some of the Non Traditional Machining (NTM)

1. INTRODUCTION

In the modern metal working industry the finishing processes are the most time and cost consuming ones. Moreover the complex finishing processes require the manual handling which is very slow and sometimes these repetitive works are detrimental for the health of the workers too. Modern difficult to machine materials, there manufacturing and complex designs of precision parts pose special machining and finishing challenges. AFM is one of the processes capable of addressing the above mentioned challenges. This process replaces a lot of manual finishing processes leading to more standardization of manufactured parts, hence there inter-changeability, mass production and reduced costs. Helical-AFM will improve the surface geometry and material removal.

Since in the AFM process, abrading medium conforms to the passage geometry, complex shapes can be finished with ease. Dies are ideal work-pieces for the AFM process as they provide the restriction for medium flow, typically eliminating fixturing requirements. The uniformity of stock removal by AFM [29] permits accurate 'sizing' of undersized precision die passages. The original 2µm Ra (EDM finish) is improved to 0.2µm with a stock removal of (EDM recast layer) 0.025mm per surface.

2. NEED OF PRESENT WORK

Various tools and dies used for extrusion of aluminium or plastic profiles are often polished manually. Also manual deburring leads to health and safety problems like, Carpal Tunnel Syndrome and “white fingers”(permanent numbness) due to continuous exposure to vibrations of hand-held tools. For such applications to reduce the finishing time and cost with better surface finish abrasive flow machining finds a suitable application [1] which is non-traditional machining process. Abrasive flow machining(AFM) is a type of such non-traditional machining processes.

AFM is becoming popular day by day. More intricate surface features the abrasive fine finishing processes use a large number of random cutting edges with indefinite orientation and geometry for effective removal of material with chip sizes smaller than those obtained during machining with tools having defined edges. Because of the extremely thin chips produced, abrasive machining allows better surface finish, close tolerances, and the surface generation. In AFM, semisolid media, consisting of an abrasive and a polymer-based carrier in a typical proportion, is extruded under pressure through or across the surface to be machined. The abrasive grains are held tightly in place at this point and the media becomes a grinding stone, which conforms to the passage geometry. The AFM process offers both automation and flexibility in final machining operations as an integral part of the complete manufacturing cycle.

3. METHODOLOGY UESED IN CONCEPT

Taniguchi [51] has concluded that high accuracies cannot be achieved by conventional machining methods in which material is removed in the form of chips. However, the conventional machining processes normally involve the use of energy from electric motors, hydraulics, gravity etc and rely on the direct physical contact between tools and work piece. On the contrary, NCM processes utilize energy such as that from electromagnetic forces, electrochemical etc.

In the present work the effects of different process parameters, such as number of cycles, concentration of abrasive, abrasive mesh size and media flow speed, on material removal, surface finish of different materials using Helical Abrasive Flow machining (HLX-AFM) are studied. The dominant process parameter found is concentration of abrasive, followed by abrasive mesh size, number of cycles, and media flow speed. Experiments [29] are performed with brass, aluminium and Mild Steel as test specimen. The machined surface texture is studied using scanning electron microscopy. It has been noticed that abrasive jet machining (AJM), water jet machining (WJM), and ultrasonic machining(USM) give almost comparable accuracy and possesses nearly similar capabilities but have no solution when the task requires better accuracy, high efficiency, economy and consistency .

Mechanical Non-Traditional Machining-

Ultrasonic machining (USM) and water jet machining (WJM) is typical examples of single-action, mechanical, nontraditional machining processes. Machining occurs by MA in USM while cutting is adopted using a fluid jet in case of WJM. The machining medium[9] is solid grains suspended in the abrasive slurry in the former, while a fluid is employed in the WJM process. The introduction of abrasives to the fluid jet enhances the cutting in case of abrasive water jet machining (AWJM) or ice particles during ice jet machining Mechanical non conventional machining can be classified as given in the flow chart. Machining occurs by MA in USM while cutting is adopted using a fluid jet in case of WJM. The machining medium[9] is solid grains suspended in the abrasive slurry in the former, while a fluid is employed in the WJM process. Machining occurs by MA in USM while cutting is adopted using a fluid jet in case of WJM. The machining medium[9] is solid grains suspended in the abrasive slurry in the former, while a fluid is employed in the WJM process. Machining occurs by MA in USM while cutting is adopted using a fluid jet in case of WJM. The machining medium[9] is solid grains suspended in the abrasive slurry in the former, while a fluid is employed in the WJM process. process capability one get idea that how much work to done in this field to improve the level. An advantage of SPC over other methods of quality control, such as "inspection", is that it emphasizes early detection and prevention of problems, rather than the correction of problems after they have occurred.

Thermal Non-conventional Machining

Thermal machining removes the machining allowance by melting or vaporizing the work-piece material. Many secondary phenomena relating to surface quality occur during machining such as micro-cracking, Many secondary phenomena relating to surface quality occur during machining such as micro-cracking, Many secondary phenomena relating to surface quality occur during machining such as micro-cracking, Many secondary phenomena relating to surface quality occur during machining such as micro-cracking, formation of heat-affected zones. The source of heat required for material removal can be the plasma during electro discharge machining (EDM) and plasma beam machining (PBM), photons during laser beam machining (LBM), electrons in case of electron beam machining (EBM), or ions for ion beam machining (IBM). Many secondary phenomena relating to surface quality occur during machining such as micro-cracking, formation of heat-affected zones. The source of heat required for material removal can be the plasma during electro discharge machining (EDM) and plasma beam machining (PBM), photons during laser beam machining (LBM), electrons in case of electron beam machining (EBM), or ions for ion beam machining (IBM).

Chemical and Electrochemical Machining

Chemical milling (CHM) and photochemical machining (PCM), also called chemical blanking (PCB), use a chemical dissolution (CD) action to remove the machining allowance through ions in an etchant. Electrochemical machining (ECM) uses the electrochemical dissolution (ECD) phase to remove the machining allowance using ion transfer in an electrolytic cell. Many secondary phenomena relating to surface quality occur during machining such as micro-cracking, The introduction of abrasives to the fluid jet enhances the cutting in case of abrasive water jet machining (AWJM) or ice particles during ice jet machining Mechanical non conventional machining can be classified as given in the flow chart. Machining occurs by MA in USM while cutting is adopted using a fluid jet in case of WJM.

One Way AFM Process

One way AFM process [29] apparatus is provided with a hydraulically actuated reciprocating piston and an extrusion medium chamber adapted to receive and extrude medium unidirectionally across the internal surfaces of a work-piece having internal passages formed therein, as shown in [fig.1.4.1]. Fixture directs the flow of the medium from the extrusion medium chamber into the internal passages of the work-piece, while a medium collector collects the medium as it extrudes out from the internal passages. The extrusion medium chamber is provided with an access port to periodically receive medium from the collector into extrusion medium chamber**.**

- **Two-Way AFM Process**

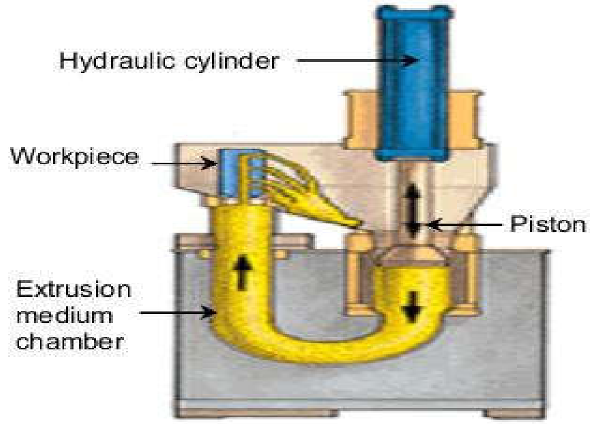

Figure. One Way AFM Process

Two way AFM machine has two hydraulic cylinders and two medium cylinders. The medium is extruded, hydraulically or mechanically, from the filled chamber to the empty chamber via the restricted passageway through or past the work-piece surface to be abraded (Fig.1.4.2). The introduction of abrasives to the fluid jet enhances the cutting in case of abrasive water jet machining (AWJM) or ice particles during ice jet machining Mechanical non conventional machining can be classified asgiven in the flow chart. Machining occurs by MA in USM while cutting is adopted using a fluid jet in case of WJM. The introduction of abrasives to the fluid jet enhances the cutting in case of abrasive water jet machining (AWJM) or ice particles during ice jet machining **.**

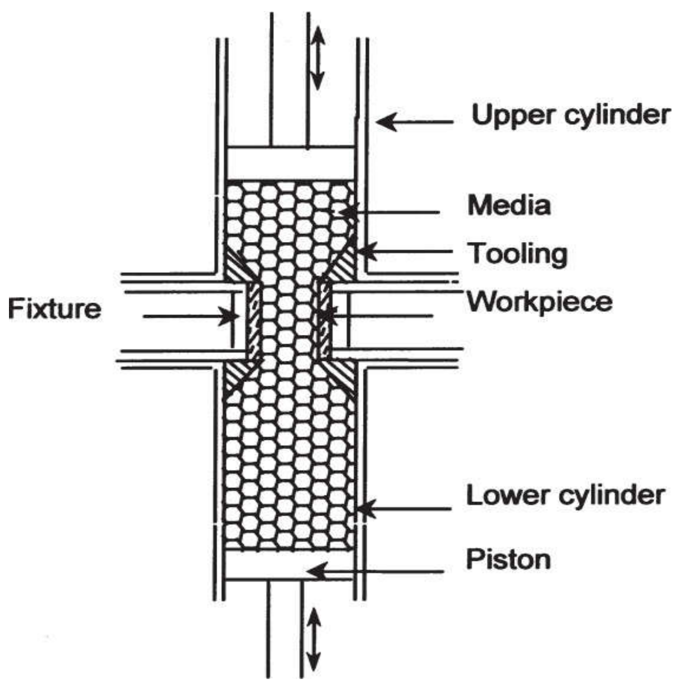

Figure. Two Way AFM Process

Orbital AFM Process

Orbital AFM concept is to provide translational motion to the work-piece. When work piece with complex geometry translates, it compressively displaces and tangentially slides across the com-pressed elastic plastic self-formed pad (layer of visco-elastic abrasive medium) which is positioned on the surface of a displacer which is roughly a mirror image of the work-piece, plus or minus a gap accommodating the layer of medium and a clearance. A small orbital oscillation (0.5 to 5 mm) circular eccentric planar oscillation is applied to the work-piece so that, at any point in its oscillation, a portion of its surface bumps into the medium pad, elastically com-presses (5 to 20%) and slides across the medium as the work-piece moves along its orbital oscillation path. As the circular eccentric oscillation continues, different portions of the work piece slide across the medium.

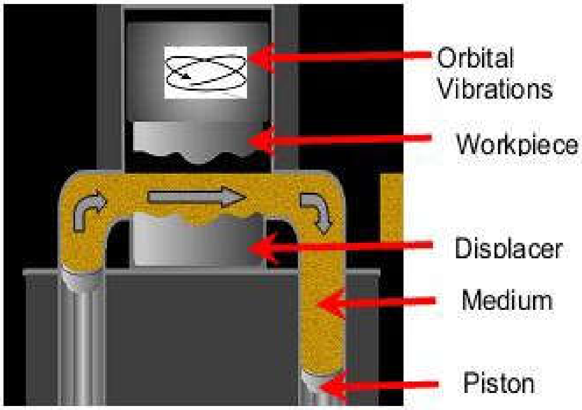

Figure (a) Before start of finishing [25]

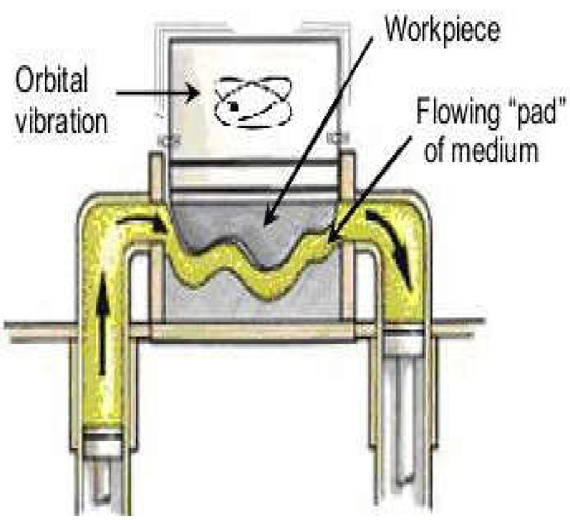

Figure (b) while finishing

Orbital AFM can be applied to many different work-pieces from many different industries from precision ground aerospace components to cast aluminium wheels. Coining dies used to make proof coins can be polished from a 0.5 µm before surface to an amazing 0.01 µm after

In helical abrasive flow machining process there are three parts of the nylon fixture i.e. upper part, middle part and lower part. Drill bit is attached in the inner hole of work piece and this drill bit is held stationary. Lower and upper fixtures are tapered for proper media flow. The major difference between AFM and Helical-AFM machines is its tooling. In AFM machine, circular fixture plate allows the medium to flow as cylindrical slug. So, the abrasive intermixing (or reshuffling) purely depends on medium self-deformability. The abrasive particles follow the shortest contact length; hence, the material removal is less. The abrasive particles follow the shortest contact length; hence, the material removal is less. The abrasive particles follow the shortest contact length; hence, the material removal is less.In Helical-AFM, abrasive intermixing depends not only on medium self-deformability as in AFM but also on the pressure from the drill bit. In the present study there are three types of helix are used i.e. two-start drill bit, three-start drill bit and a spline with the use of three different materials and comparison of the surface finishing between them. The abrasive particles follow the shortest contact length; hence, the material removal is less. In Helical-AFM, abrasive intermixing depends not only on medium self-deformability as in AFM but also on the pressure from the drill bit.

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In Helical-AFM, three types of flows that occur in finishing zone (fig.1.6a,b and c) and remixing of medium at exit from the finishing zone(flow along the flute, axial flow, and scooping flow) [34]. Due to the combination of different flows, the work piece-abrasive contact length is no longer a straight line, rather it

1. Flow along the flute

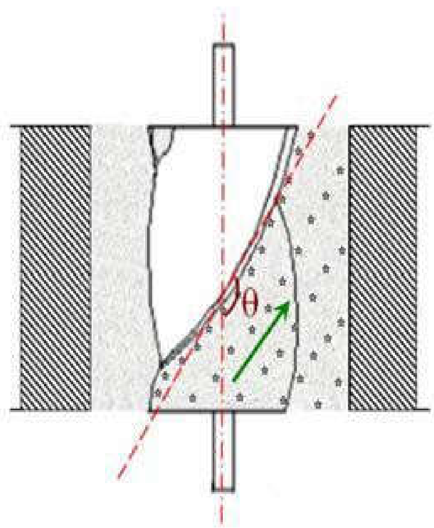

Figure. Flow along flute [28]

2- Reciprocating axial flow motion

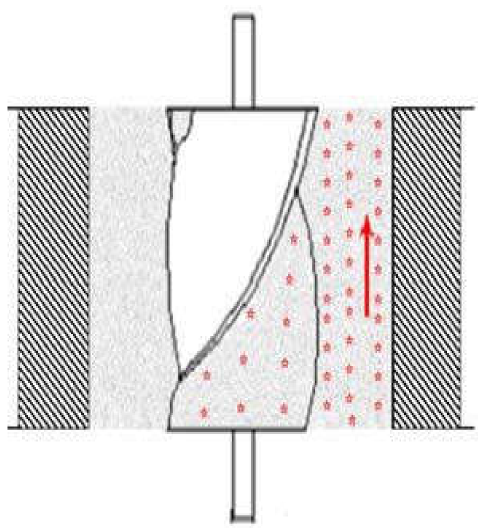

Figure. Reciprocating axial flow motion [28]

3-Scooping Flow

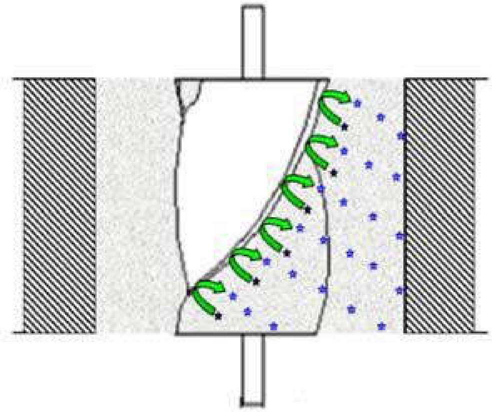

Figure. Scooping flow [28]

4. Finishing zone in Helical-AFM

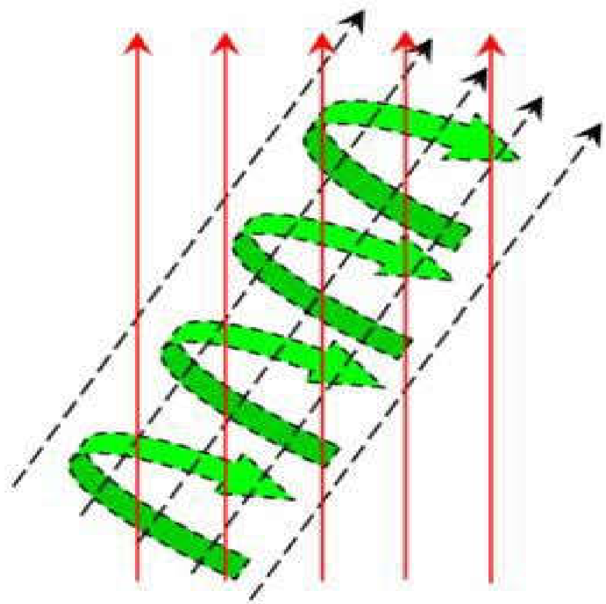

Figure. Three motions (flow along the flute, axial flow, and scooping flow) that can occur in finishing zone [28]

4. APPLICATION OF AFM.

Dies and Moulds

Since in the AFM process, abrading medium conforms to the passage geometry, complex shapes can be finished with ease. Dies are ideal work-pieces for the AFM process as they provide the restriction for medium flow, typically eliminating fixturing requirements. The uniformity of stock removal by AFM [29] permits accurate 'sizing' of undersized precision die passages. The original 2µm Ra (EDM finish) is improved to 0.2µm with a stock removal of (EDM recast layer) 0.025mm per surface

Automotives

The demand for this process is increasing among car and two wheeler manufacturers as it is capable to make the surfaces smoother for improved air flow and better performance. AFM process is used to enhance the performance of high-speed automotive engines. AFM process is capable to finish automotive and medical part and turbine engine components. Internal passages within a turbine engine diffuser are polished to increase air flow to the combustion chamber of the engine. The rough, power robbing cast surfaces are improved from 80-90% regardless of surface complexities.

Medical Equipment & Device Manufacturing

- Food processing
- Semiconductor (front-end) equipment
- Pharmaceutical manufacturers
- Ultra-clean or high purity devices

Polishing surfaces to mirror-like requirements minimizes the amount of microscopic and/or inaccessible areas that enable contamination or entrapment. Ultra-smooth surface finishes greatly diminish the areas of concern for surface absorption,[17] chemical contaminants, foreign particulate and bacteria. Additionally, the AFM process minimizes "flow-retardation" due to machining and/or dies and mould "microgrooves."

Development of Improved Fixturing for Helical-AFM

Fixturing concept largely depends upon the work-piece material and configuration. For the present investigation, work-piece is a hollow cylindrical test specimen, classified as sleeve type component. The fixture is made in three parts. The work-piece is held between first and second , at the interface of two parts and the fixtures plates are clamped together with the help of three countersunk screws allowing the passage (in the work-piece) itself to form the greatest restriction in the media flow path. The threaded holes were kept blind to avoid the possible ingress of abrasive media. The material of the fixture used was Nylon. Good shearing strength, wear resistance, and light weight made Nylon a good candidate for the fixture material.

Nylon Fixture Part

Second part of fixture is also a 102 mm diameter piece of nylon. It holds the work piece at top along with Nylon Fixture Part-1 and has a passage for the flow of media as shown in figure 2.3. On the bottom side it is attached to Nylon Fixture Part-3. The drill bit is held axially mostly inside this part and to this HLX-AFM Part-3 which is a M.S. disc with holes for drill and media is fixed. The fixture is made in three parts. The work-piece is held between first and second , at the interface of two parts and the fixtures plates are clamped together with the help of three countersunk screws allowing the passage (in the work-piece) itself to form the greatest restriction in the media flow path. The threaded holes were kept blind to avoid the possible ingress of abrasive media.

Figure. Nylon Fixture Part

5. ANALYSIS AND RESULTS DISCUSSION

The experiments were planned by using the parametric approach of the Taguchi's Method. The standard procedure to analyze the data, as suggested by Taguchi, is employed. The average values of the quality/response characteristics for each parameter at different levels are calculated from experimental data. The main effects of process parameters for raw data are plotted. The response curves (main effects) are used for examining the parametric effects on the response characteristics data.

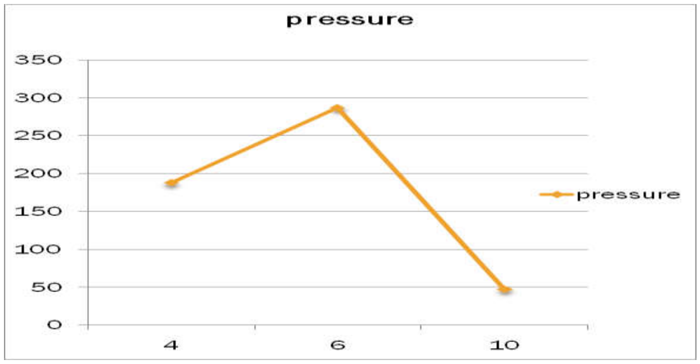

Figure (a) Effect of Extrusion pressure on MR

(ANOVA) of raw data is performed to identify the significant parameters and to quantify their effect on the response characteristics. The most favourable conditions (optimal setting) of process parameters in terms of mean response characteristic is established by analyzing response curves and the ANOVA Tables. The response curves (main effects) are used for examining the parametric effects on the response characteristics.

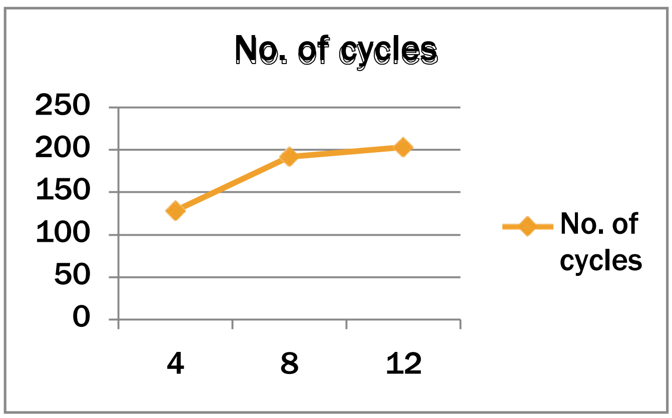

Figure (b) Effect of no. of cycles on MR

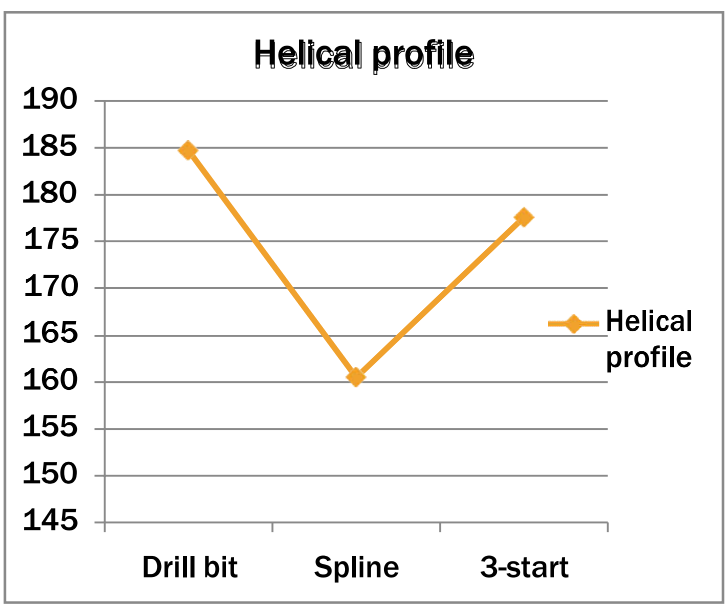

Figure (c) Effect of shape of helix on MR

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