

THE INFLUENCE OF THERMIC AND THERMOCHEMICAL TREATMENT ON THE STRUCTURAL CHARACTERISTICS AND HARDNESS ON DRILLS FABRICATED FROM HS 18-0-1 STEEL

DUMA Sebastian Titus, POPESCU Mihaela

"Politehnica" University of Timișoara, Faculty of Mechanics, Bd. Mihai Viteazul Nr. 1,
300222 e-mail : sduma@eng.upt.ro; mpopescu@mec.upt.ro

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Abstract: Drills and drilling units made from a large range of basic materials are used for manufacturing individual parts and systems in the automotive industry. In the introductory part the main classes of material for drills are presented. The experimental part focuses on the influence of annealing, quenching, tempering and ferroxylation treatments on structural characteristics and the hardness of HS 18-0-1 steel drills. This will be observed with the aid of optic and electronic microscopy and X-ray diffraction.

1. MATERIALS AND AREA OF USE FOR DRILLS

1.1. Steels

Soft *low carbon steel* bits are used only in wood, as they do not hold an edge well and require frequent sharpening. Working with hardwoods can cause a noticeable reduction in lifespan. They are inexpensive when compared to other tools with a longer life [1,4].

High carbon steel bits are made from high carbon steel and are an improvement on plain steel due to the hardening and tempering capabilities of the material. These bits can be used on wood or metal, however they have a low tolerance to excessive heat which causes them to lose their temper, resulting in a soft cutting edge.

High speed steel (HSS) is a form of tool steel where the bits are much more resistant to the effect of heat. They can be used to drill in metal, hardwood, and most other materials at greater cutting speeds than carbon steel bits and have largely replaced them in commercial applications.

Cobalt steel alloys are variations on high speed steel which have more cobalt in them. Their main advantage is that they hold their hardness at much higher temperatures, so they are used to drill stainless steel and other hard materials. The main disadvantage of cobalt steels is that they are more brittle than standard HSS carbides.

Tungsten carbide and other carbides are extremely hard materials that can drill in virtually all workpiece materials while holding an edge longer than other bits. Due to their high cost and brittleness, they are often used only in tipped tools, in which small pieces are screwed or brazed onto the tip of the bit. However, it is becoming common in job shops to use solid carbide drills, and in certain industries, it has been commonplace for some time [1,2,3].

1.2. Diamond

Polycrystalline diamond (PCD) is among the hardest of all tool materials and is therefore extremely wear resistant. The material consists of a layer of diamond particles, typically about 0.5 mm (0.019") thick, bonded as a sintered mass to a tungsten carbide support. Bits are fabricated using this material by either brazing small segments to the tip of the tool to form the cutting edges, or by sintering PCD into a vein in the tungsten carbide "nib". The nib can later be brazed to a carbide shaft and ground to complex geometries that cause braze failure in the smaller "segments".

PCD bits are typically used in the automotive, aerospace, and other industries to drill abrasive aluminum alloys, carbon fiber reinforced plastics and other abrasive materials, or in applications where machine downtime is especially harmful to profitability.

1.3. Coatings

Black oxide is an inexpensive black coating. A black oxide coating provides heat resistance and lubricity, as well as corrosion resistance. These result in a longer drill life than the typical uncoated high-speed steel drill.

Titanium nitride (TiN) is a very hard ceramic material, and when used to coat a high-speed steel bit (usually twist bits), can extend the cutting life by three or more times. A titanium nitride bit cannot be properly sharpened, as the new edge will not have the coating, and will not have any of the benefits the coating provided.

Titanium aluminum nitride (TiAlN) is another coating frequently used. It is considered superior to TiN and can extend tool life five or more times.

Titanium carbon nitride (TiCN) is another coating and is also superior to TiN.

Diamond powder is used as an abrasive, most often for cutting tile, stone, and other very hard materials. Large amounts of heat are generated, and diamond coated bits often have to be water cooled to prevent damage to the bit or the workpiece.

Zirconium nitride has also been used as a drill bit coating for some Craftsman tools [1,2,3,4].

2. EXPERIMENTS REGARDING THE USE OF HS 18-0-1 STEEL FOR DRILLS

The HS 18-0-1 steel is a highly alloyed steel from the high speed steels category, used for tools. (old symbol Rp3). The chemical composition of this steel is: C = 0,7 – 0,78 %, W = 17,5-18,5 %, Mo = max. 0,6%, V = 1 – 1,2 %, Cr = 3,8 – 4,5 %, [4].

The experimental part focuses on the influence of chemical and thermochemical treatments on structural characteristics and hardness of HS 18-0-1 steel drills.

HS 18-0-1 steel samples were annealed, quenched, tempered and ferroxed. The initial status of the material was called 'forged'.

Figure 1 presents the cyclogram of the secondary thermic treatment inflicted on the samples [3]. The transformations suffered by the material are as follows:

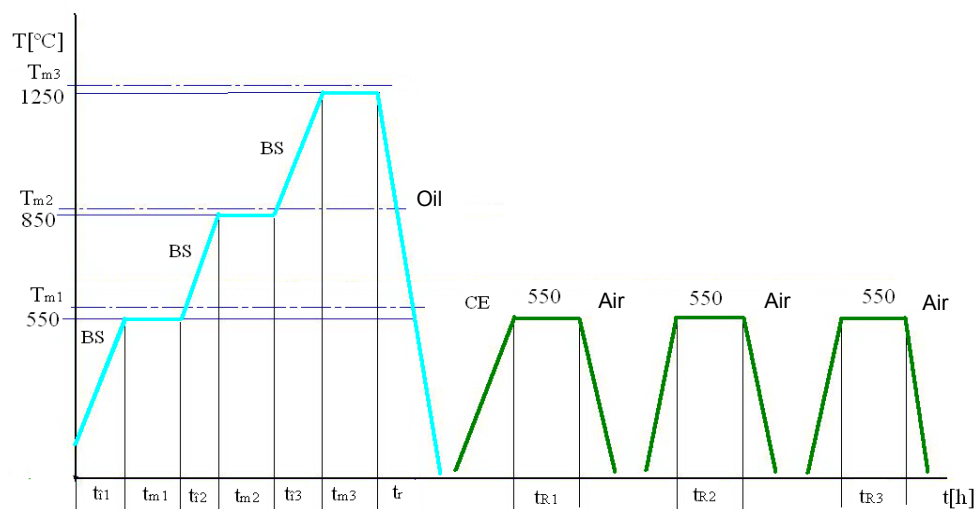


Figure 1. The cyclogram of the secondary thermic treatment applied on the HS 18-0-1 steel

Heating transformations

The heating for austenitizing in order to quench high speed steels is made at high temperatures (1200- 1300°C). This ensures that a large quantity of carbides are

decomposed and dissolved in austenite enriching it, and after cooling enriching the martensite [2,3].

These temperatures are much higher than the eutectoid temperatures of carbon steel used for tools. The components of the alloy (which are α -gene) increase the temperatures of critical points A_{c1} and A_{c3} forming carbides reducing the susceptibility of overheating the austenite expressed by its granulation (the susceptibility of overheating the austenite increases with the increase of carbon dissolved in it).

Quenching transformations

Because of the high austeniting temperatures, carbon and alloy components that lower the martensitic transformation point M_s , the austenite becomes stable and exists for a longer time, preventing it from fully transforming into martensite resulting in residue called residual austenite. Thus quenched high speed steels contain residual austenite, undissolved carbides and a small quantity of martensite. The presence of residual austenite in the structure prevents us from reaching a maximum hardness after quenching.

Tempering transformations

During the tempering process the diffusion intensifies because of the heating resulting in a loss of hardness at about 300°C after carbon separation. Continuing with the heating process the diffusion of the iron and alloy components is favored resulting in the precipitating of granular carbides that endow the structure with greater hardness. Thus, the austenite has a lower concentration of carbon and alloy elements leading to an increase of temperature for martensitic transformation points, enabling the transformation of residual austenite in tempering martensite connected with an increase in hardness. The maximum hardness is obtained at 550°C and is called "secondary quenching" [1,2,3,4].

After applying the secondary thermal treatment the samples were metallographically prepared and analyzed with the aid of optic and electronic microscopy. These testing machines can be found in the Mechanics College, Welding and Material Science in Timisoara. (figure 2 optic microscope, figure 3 electronic microscope).



Figure 2. – Optic microscope



Figure 3. - Scanning electron microscope

The structural determining have been also performed with X-rays diffraction at the „DRON 3” diffractometer with molybdenum radiation $\lambda = 0,71 \text{ \AA}$, at $U = 40 \text{ kV}$ and $I = 30 \text{ mA}$. In order, to compare the structural status the diffraction were performed in the same conditions.

In figure 4 the microstructure (optic microscopy) of the forged and annealed sample is presented and figure 5 presents the corresponding diffractogram [1,2].

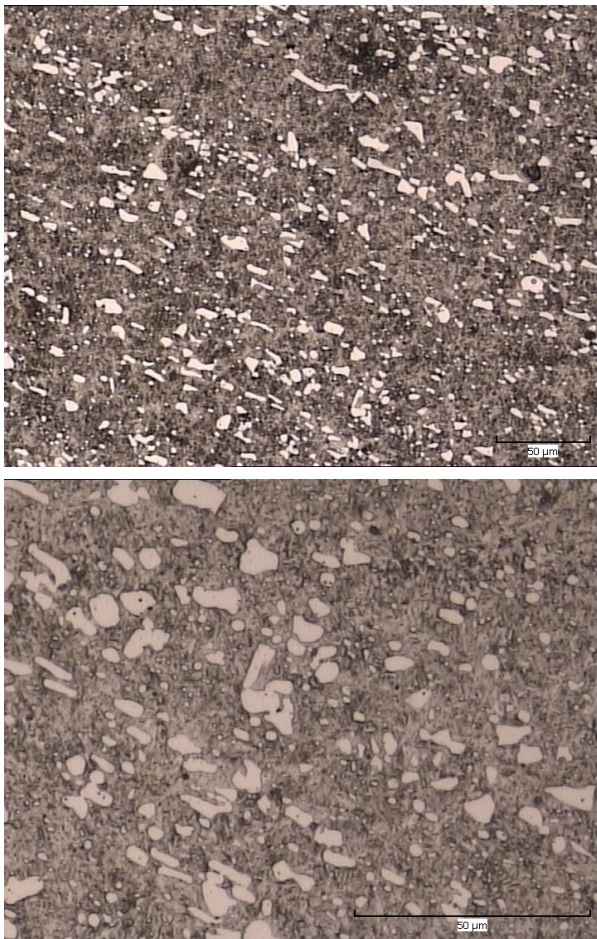


Figure 4. HS 18 – 0 – 1 steel – forged + annealed (Sorbite and, primary and secondary carbides)

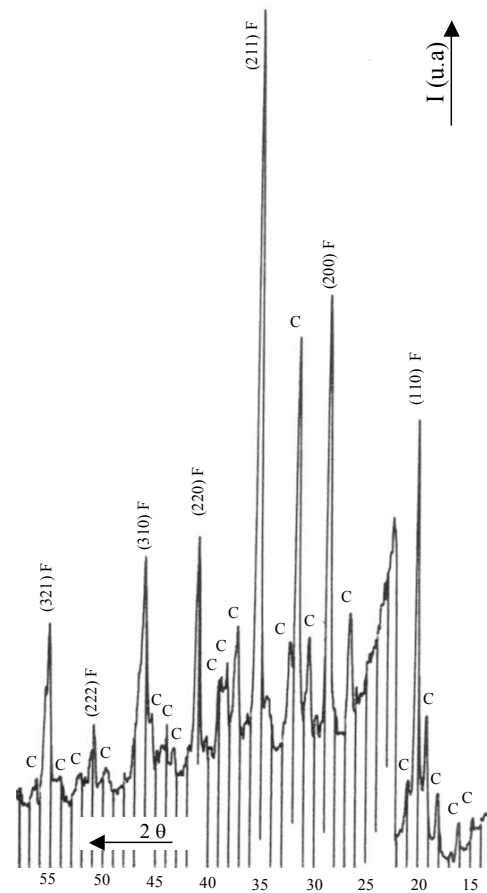


Figure 5: The diffractogram of the annealed status. (F-ferrite, C - $\text{Fe}_3\text{W}_3\text{C}$ carbides)

Under close observation the annealed structure is made out of sorbite and primary and secondary carbides. The linear arrangement of carbides is due to forging.

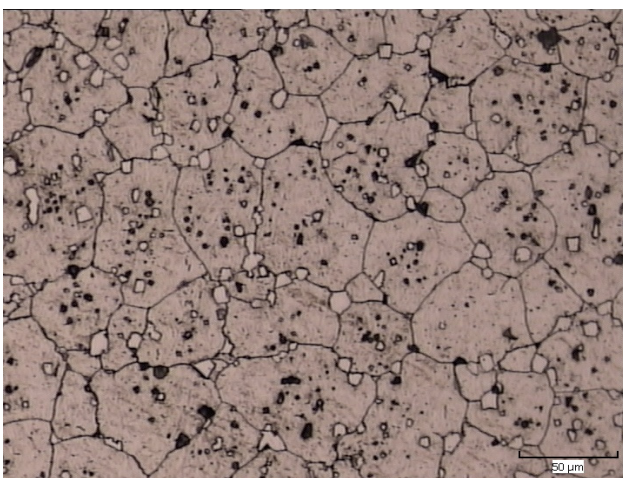


Figure 6. HS 18-0-1 steel - quenched

Figure 6 displays the quenched sample microstructure (optic microscopy): it is noticeable that the quenched structure is made of austenite, un-dissolved carbides and a certain amount of martensite. The diffractogram of this sample confirms the microscopic analysis (figure 7) [4].

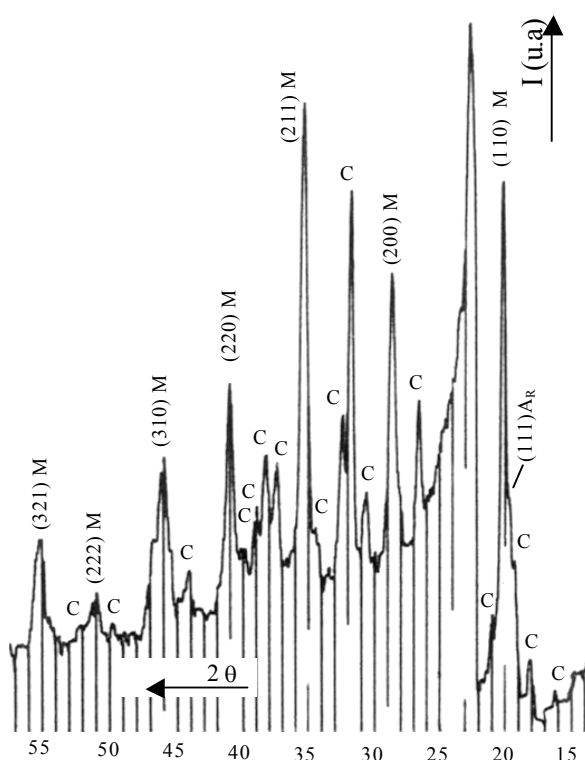


Figure 7: The diffractogram of the quenched status (M -quenching martensite, A_R - residue austenite, C - Fe_3W_3C carbides)

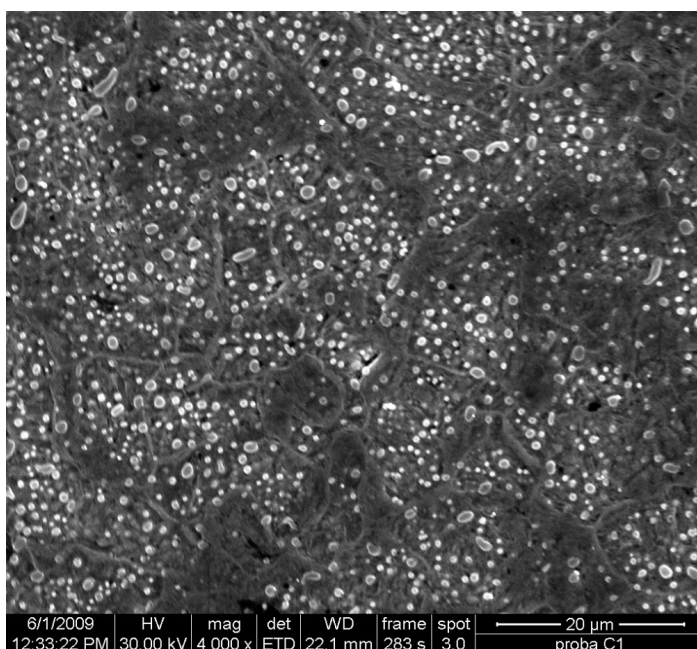


Figure 8. HS 18-0-1 - quenched and tempered at 550 °C (x4000)

If a reduced quantity of residual austenite is pursued a negative temperature treatment is imposed before the high-tempering treatment [1,4].

In order to mark the transformations after the tempering process at 550°C, especially the precipitating of fine granular carbides, the quenched and annealed sample was put under electronic microscopy (x4000).

Figure 8 displays the microstructure of the quenched and tempered sample during 3 stages of one hour at 550°C and in figure 9 its corresponding diffractogram. It is observed that its structure is made out of nonstructural martensite (hardenite and tempering martensite) and fine carbides [2,3].

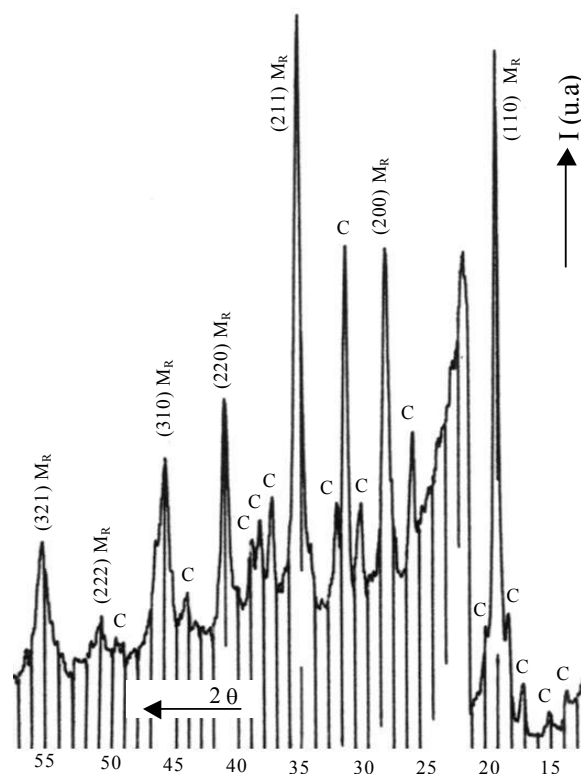


Figure 9. The diffractogram of the status, after tempering 3 (M_R tempering martensite, C - Fe_3W_3C carbides)

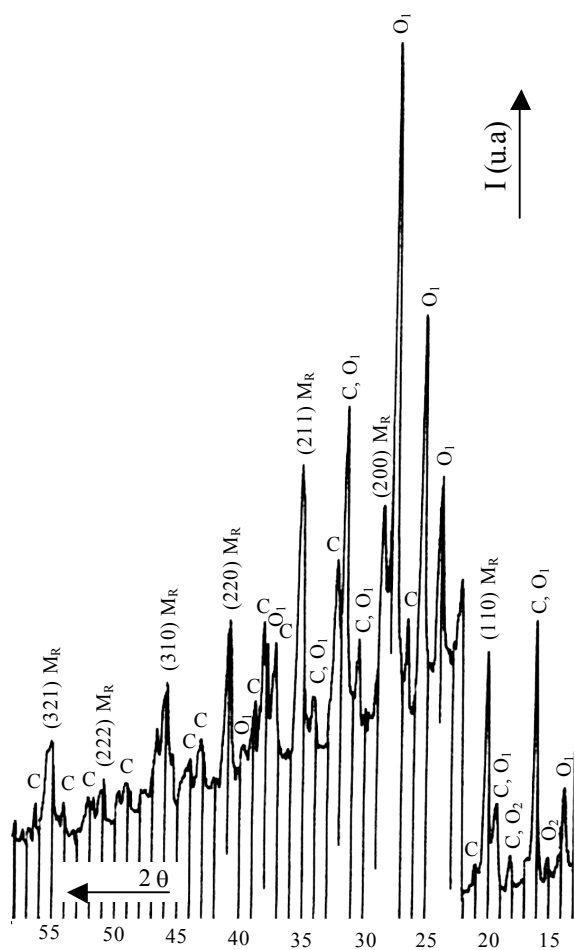


Figure 10. The diffractogram of the ferroxated status (M_R tempering martensite, C - Fe_3W_3C carbides, O_1 - Fe_3O_4 oxide, O_2 - Fe_2O_3 oxide)

Thus, the residue austenite that exists in a very low percentage even in annealed status, grows in quenched status and totally transforms after tempering 2.

Ferroxylation was performed after the second tempering by introducing the specimen into a retort at a temperature of 350°C for 20 minutes. Steam was then introduced at a pressure of 1,2 atm continuing up to 550°C and one hour in the presence of steam. The opening of the retort follows and the cooling of the specimen at 100°C and after this, the final cooling in oil at 50°C [4].

Figure 10 presents the structure after ferroxation. It is formed out of tempering martensite, Fe_3W_3C carbides and iron oxides Fe_3O_4 majoritary and Fe_2O_3 minority.

All samples were sclerometrically analyzed (Rockwell method HRC) and the acquired values included in table 1.

It is observed that the sclerometrical values coincide with the ones obtained by microscopy and certify the phenomena previously presented [1,2,3,4].

For large diameter drills, in order to save alloyed steel, the active part can be manufactured from high speed steel and the inactive one, which requires tenaciousness, can be made out enhanced carbon steel (C 45 steel for example)

welded together. In these cases the recommended thermal treatment is the following:

- gradually heat the active part in salt baths and cool the whole part in oil;
- global tempering of the tool at 550°C in salt baths or furnaces with forced air convection;
- heating the inactive part in salt baths up to 850°C followed by cooling in water or oil;
- tempering the inactive part by heating the whole piece at 400-500°C.

Table 1. Sclerometrical determinations

No.	Material	Status of thermal treatment	HRC hardness in 3 points	HRC hardness, average
1	HS 18-0-1	Forged + annealed	32, 35, 31	32,66
2	HS 18-0-1	Quenched	61, 62, 61.5	61,66
3	HS 18-0-1	Quenched and tempered at 550 °C	62.5, 64, 63	63,16
4	HS 18-0-1	Quenched + tempered at 550 °C and ferroxated	65, 63, 62.7	63,56

During thermal and thermo-chemical treatments all drills and especially long ones must be held with vertical devices (figure 11 example of device)

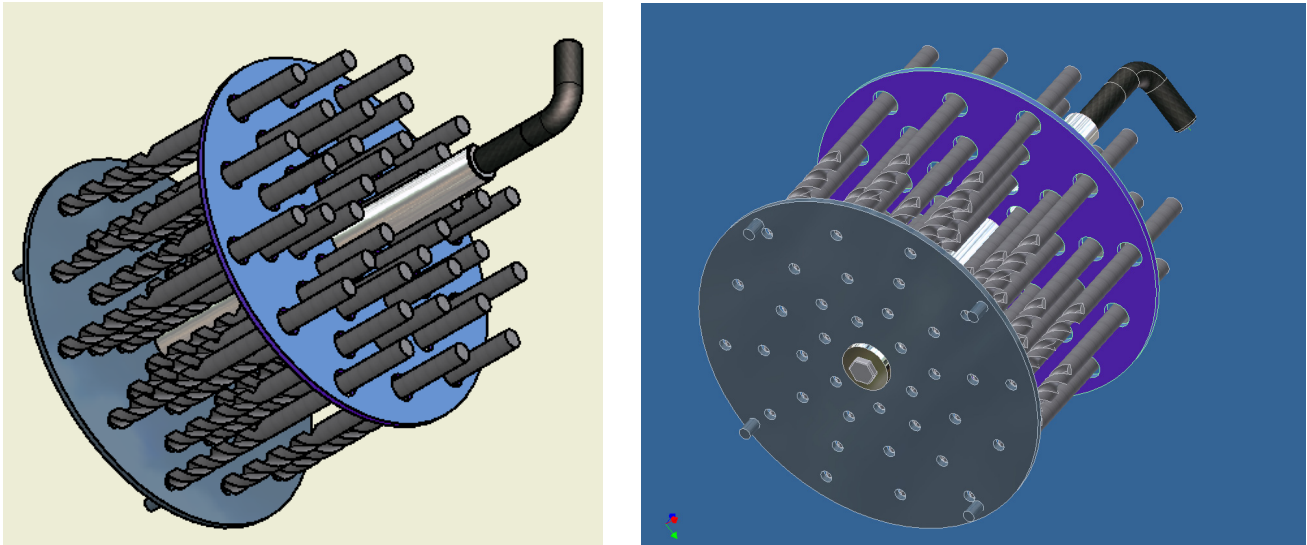


Figure 11. Drill manipulation device

3. CONCLUSIONS

1. HS 18-0-1 steel being thermally treated gradually quenched (salt baths) oil cooled, and tempered in three stages for one hour at 550°C ensures a hard homogenous structure which is thermally stable. (when heated at 550°C they do not soften like other un-alloyed steels). For large diameter drills, in order to save alloyed steel, the active part can be manufactured from high speed steel and the inactive one, which requires tenaciousness, can be made out enhanced carbon steel, welded together.
2. Considering the environments in which HS 18-0-1 steel drills are used, a anticorrosive coating needs to be applied.
3. In special cases when the active parts made out of high speed steel are very burdened they can be coated with titanium nitride to prolong their life up to three times.

4. BIBLIOGRAPHY

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