Nano Coating Application for Corrosion Reduction in Oil and Gas Transmission Pipe: A Case Study in South of Iran

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Abstract. Corrosion healthy in equipment of big industries such as oil industries as well as the quality of its transmission is an important and basic problem which disregarding of this phenomenon causes to stop production and consequently cost repairing. In this paper a kind of nano-composite coating is used to prevent atmospheric corrosion and under insulation corrosion. This coating that consist of 30 percent of acrylic resin water based and 70 percent of nano-composite as well as the nanometer tunnel (the thickness of tunnels is only a few nano meters) covers the surface completely, so that there is not any microscopic space for air penetration (percolation). In addition to the hydrophobic properties will remove the moisture from the insulation surface. Thus this nano-coating insulation prevents from reaching moisture oil and gas transfer pipeline, also this type of insulation is semi-transparent. In the other hands, its space beneath is visible each time. In order to test this nano-coating, GM9540P test this has been approved as environmental corrosion test was used. After the first stage of test, the surface without coverage was corroded entirely, but the coated part was tested successfully without any effect of corrosion after 24 stages. Although there are numerous ways and materials to create resistance against corrosion, but insulation and anti corrosion properties aren't considered synchronous; the coverage used in this test includes both properties.

Keywords: no-composite coating; atmospheric corrosion; under insulation corrosion; oil and gas transfer pipeline.

1. Introduction

In Iran, according to our climate and climate variability, there are many corrosive areas. It's interesting to know the Persian Gulf and Omen sea waters, are one of the most corrosive waters in the world. Equipments in the water work, including fixed facilities such as jetties and the oil platforms & mobile devices such as tankers, naval frigates and forest's are put under severe corrosion. Iran's central dessert, and industrial environment North's rainy atmosphere. And south's entremets heat and dust conditions provide suitable field of corrosion for facilities. There's no doubt corrosion costs are high in the industry.

For example and based on statistics, cost of corrosion in oil and gas sector in Iran was estimated about 511.7 million dollars in 1979. Iran annually spends 1.5 to 2 million dollars on replacement of corroded pants in this industry. Mean while, pipe is extremely important and special attention must be exposed due to its high potential corrosion. Existence of 17 thousands of kilometers of high pressure gas transmission lines and 79 thousands of kilometers of gas pipeline network clarifies the importance of this discussion. Also, transmission of oil and gas production from domestic sources and central Asia's oil resources to refineries and also transmission of petroleum products to country's provinces' are done by 14 kilometers of pipeline. As was stated aloof, atmospheric corrosion and under. Insulation corrosion are two major reasons of corrosion problems in different industries especially oil, gas and petrochemical industries. [1].

2. Corrosion under Insulation

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For Corrosion under insulation is considered one of the largest and the most the most expensive problems for various industries. Annually, it costs many factories and industries a f fortune to build new systems. Corrosion under insulation occurs in the contact area between the metal and insulation.

Because this type of corrosion is difficult to detect, it can be very dangerous compared to other types of corrosions. Because the insulation must be removed for inspection of metal surface under insulation, Detection of corrosion under insulation is very difficult and costly. Corrosion of pipes, tanks and equipments that occurs under the insulation, in most cases is due to the type of insulation used.

Now we should find the root of problem.

Corrosion under insulation is occurred in presence of oxygen and water . When water & oxygen are present in the metal surface, corrosion occurs due to the metal dissolution (an odic effect).

This chemical process is balanced by reduction of oxygen. The rate of corrosion under insulation depends on type of insulation, the availability of oxygen, the impurities of water, temperature and heat, transfer properties of metal surface and the condition of metal surface of being dry or wet. {2}

In absence of oxygen, corrosion is neglect able {3}

Although carbon and low alloy steels typically have the lowest corrosion rates in alkaline environment, but Ned chloride ions (-cl) under the cover causes a local hole localized pitting.

If the sulfur and nitrogen oxides, which are acidic, penetrate through the impurities inside the water or air inside the insulation, or if the water is acidic General Corrosion occurs. Some times impurities of water or air, specially nitrate ions No3 cause external stress corrosion crack SCC under the cover in carbon or low alloy steels. Mentioned phenomena, especially when the processes of being alternatively dry and humid environments increase the concentration of impurities, is more significant {3}.

The problem comes from this fact that due to the conditions of the insulation, pipes , tanks and the other equipments suffers from corrosion under insulation. Understanding this problem is simple. Difference in Temperature is always observed between the insulation and its field , where the insulation is applied . Regardless of how tightly the insulation wrapped around pipes or imposed on it , in the space between the two , there's high temperature difference, because in this part high temperature suddenly placed in contact with the lower one. Thus condensation is achieved.

The most basic rule in beat transfer is that the heat transfers to the cold region. Warm air holds more moisture than the cold one. When the warm air quickly cools in contact with the insulation , the heat transfer rate is reduced and moisture is released or in other words, condensation occurs, and thus by emergence of moisture and oxygen in the air , rust and corrosion occurs.

Insulation on the metal surface prevents moisture evaporation and in this case insulation acts as a carrier and more the moisture accumulated in one area to other areas and causes the corrosion formed in a region to be moved elsewhere. Surface covered with traditional insulation such as fiberglass and rock wool traps moisture and prevents the evaporation.

Traditional insulation contain coloride , and if this exposed to the moisture , the coloride with the moisture can be appear on the surface of metals such as oil and gas pipeline and due to corrosion, in can be creates holes or cracks on the surface.

Research conducted by Exxon Mobil Chemical co. on the order of Europe Federation of corrosion in September 2003 shows that the most significant factor of extension of holes in refineries and chemical inductions due to the corrosion process, is not general but is due to the corrosion under the insulation.

Also 40 to 60 percent of maintenance costs related to the corrosion of pipelines is because of corrosion under the insulation.

3. Effects of Coating

Corrosion under all types of insulation is possible.

Type of insulation just affects the speed and quality of the corrosion. {5} the main effect of coating in this type of corrosion. is providing adequate circular space for assembly and remaining the water or dust

phenomenon in the southern oil region in Iron .{4} water can be funded from eternal recourses such as rain or liquids resulted from condensation .

Chemical composition and coating's properties are involving in corrosion, too. Covering material cam absorb water, makes suitable condition for electro chemical reactions. In addition, the chemical compounds such as chloride and sulfate inside the coating, can play a role as an electrolyte, causing accelerated corrosion. Also if coating doesn't have appropriate overlap and dust particles pass through it, this causes and accelerates corrosion process.

4. Analysis

4.1. Cost per Foot Analysis
There is almost always some uncertainty about the best time to terminate a bit run and begin tripping operations. If the lithology is somewhat uniform, cost per foot calculation can be used as a criterion. In this case the best time to terminate the bit run is when the lowest cost per foot is achieved. However, when the lithology is not uniform, this procedure will not always results in the minimum total well cost. In this case, an effective criterion for determining optimum bit run is obtained only after enough wells are drilled in the area to define the lithologic variations. For example it is sometimes desirable to drill an abrasive formation with an already dull bit and then place a sharp bit in the next shale section. Alternatively, it may be best to terminate a bit run in order to place a hard formation bit in an extremely hard abrasive section [3].

Costs are usually broke into two categories: (1) Fixed costs and (2) Variable operation costs [3]. The usual objective when drilling a well is to drill for the lowest overall cost. At first sight, this may seem like a requirement to drill as fast as possible, since many of the costs, such as the rig day rate, wages, etc., are time dependent. However, some costs are fixed, for example the cost of the bit, and it may not always be economic to pay a very high cost for a bit that drills somewhat faster, particularly if the other costs are low [1].Unless the bit run is to be terminated for a specific reason, such as logging or casing the well, the cost of each bit run can be minimized by calculating the cost per foot as the hole gets deeper. This is done by summing the fixed and time-dependent costs and dividing by the total footage drilled during the bit run [4]:

When it is run in hole with the new bit, the cost already incurred of the new bit and spent time to run in hole, but have drilled no distance. Cost per foot is therefore infinite. However, as soon as when begin drilling, the factor "Feet drilled this bit run" begins to increase, and so the cost per foot decreases. As drilling continue, the fixed costs remain constant, but the time related costs increase, as does the footage drilled. Initially, the fixed costs are greater than the time-related costs, but eventually the time-related costs begin to dominate the top line of the expression. In the real situation, the bit gradually wears, and so the number of additional feet drilled per additional hour gets less as time increases. The time-related costs continue to increase steadily, however, and so eventually the cost per foot reaches a minimum and then begins to rise again. It is at this minimum value that reached the minimum cost per foot for the bit run, and should therefore replace the bit.

Finally, note that the Cost per Foot calculation can be used even if the bit run has to be terminated for other reasons. In this case, all that needs to be done is to find the set of conditions that give the minimum cost per foot at the depth where the bit run is to be terminated [1].

4.2. Optimizing the Rock Bit Runs
Next investigated whether the bits might have been run with different operating conditions to produce a saving in time or cost. The procedure consisted of a step-by-step approach investigating different parameters in sequence.

4.3. Optimization of Hydraulics:
The bit runs were repeated using different bit nozzles and different mud flow rates. The data are shown in Table 3. Regarding the mud flow rates (for any particular nozzle size), as long as the maximum pump pressure or flow rate are not exceeded, it is generally true that the more hydraulic power that can be delivered to the hole bottom, the better it is. However, this view neglects the possible adverse effects of excessive flow rate on pump wear and on hole washout. Therefore adopted the view that the best conditions were those that gave high ROP without excessive flow. The values predicted by the simulator coincided in all cases with the values reported

from the field. As for the nozzle sizes used, they were all optimal except for run number five, for which it was found that the best set of nozzles was 13/32" (instead of 16/32"). At a flow rate of 550 gpm, these gave an ROP of 20.5 ft/hr, with a bit HSI of 13.6 HP/sq in. The time consumed when using this nozzle size was 64.4 hrs, a saving of 4.5 hrs. The cost dropped to $ 3,264,972 (- $ 9,201).

4.4. Optimization of WOB and Rotary Speed:

The next step consisted of altering the combination of weight on bit and rotary speed to see if some time could be saved in this area. In general, it was found that better results were obtained with lower weight on bit and higher rotary speed, typically in the range of 10,000 – 20,000 lb. WOB with rotary speeds of 130 – 140 rpm. Total savings of more than $90,000 were predicted.

The findings point to the use of higher rotary speed and lower weight, a combination that tends to increase bearing wear over tooth wear, and hence encourages the driller to risk bearing failure and consequent cone loss. Under the optimized conditions, the simulator gave bearing wear values of at most 5, which are in the safe range. Bearing failure is, however, notoriously difficult to predict, and it may well be that experience has taught drillers to err more on the side of caution by reducing rotary speed and instead maintain ROP by corresponding increases in weight on bit.

4.5. Optimization of Bit Types:

Finally the possible advantages of using bits of types are investigated other than the tungsten carbide inserts bits that were used in the field. This is the least certain part of the prediction because had to assumed that the relative rates of penetration could be predicted and wear of different types of bit in the range of formations that constitute the interval to be drilled

Overall, milled tooth bits appear attractive, principally because they have high rates of penetration and were assumed to cost less than half the price of a TCI bit ($2,800 vs. $6,500). PDC bits have generally high rates of penetration, but are expensive (this bits were assumed to cost $25,000). In several cases, they were shown to produce cost savings, but note that the interval contains a substantial proportion of sandstone, and if underestimated the wear rate of the PDC bit in abrasive formations, the recommendation may be in error. Again, a counsel of prudence would probably incline towards choosing a TCI or milled tooth bit, and it should be noted that the real well was in fact a wildcat, so caution would have been in order. Finally, the behavior of natural diamond bits was checked, but, as expected, they are expensive and their rates of penetration are too low to be interesting. [7]

In summary, the estimated savings obtained by optimizing hydraulics, weight on bit and rotary speed using the same (TCI) bits as were used in the field were $94,000. The total saving estimated by substitution of milled tooth bits using optimized conditions were $216.000 while the corresponding value for PDC bits was $165,000. Final optimization show in figures 3-5.

5. Bit Run Optimization Method

All the bits used in the original bit runs were of tungsten carbide insert type. The first 2600 ft of the lithology was drilled using a 17 1/2" bit and mud density of 9 ppg. At the depth of 2600 feet, a 13 3/8" casing was set, mud density was increased to 10.2 ppg and 12 1/4" bit was used. Table 3 shows the 4 bit runs coupled with their resultant cost per foot and overall well cost. As it can be seen, drilling this section takes 163 hours and imposes a cost of about 325000 dollars.[8]

6. Results and Discussion

The first step consisted of comparing other bits cost per foot results to find a more economic case. Results are shown in table 4 where, regarding bit types, only the first bit run was recognized optimized. Runs number 2, 3 and 4 could yield a lower cost per foot using milled tooth bits because they have higher rate of penetration and also cost less than half the price of a tungsten carbide bit.

Since Tungsten carbide bits have more bit wear tolerance, they may seem more efficient to be used for drilling harder rocks. However, the distance to be drilled in the fourth section (hard lime stone) is not that long to justify higher cost of the bit.[9],[10]

Table 4, 5 and 6 show the overall well cost and savings made due to optimizations for the studied bit runs. Table 3 compares original and optimized drilling operation in terms of time taken. Having made these optimizations, 55262 $ of the total well cost is saved which is about 15% of the original well cost.

7. Conclusion

1. Recovery and removal cost of insulation systems is very high, and traditional insulation create proper environment to absorb moisture and corrosive agent which are effective in corrosion.

2. Nano technology defines an easy way for corrosion inspection with out the need to remove insulation, which reduces significantly the costs and problems of corrosion under insulation on pipelines, tanks and other equipments.

3. It can be concluded from the several performed tests that the nano – composite thin layers of coating are so compressed that the porosity is very low and corrosion causes can not penetrate the layers.

4. This coating has very effective penetration on cavity surface group which coating operation is alone on them.

8. References

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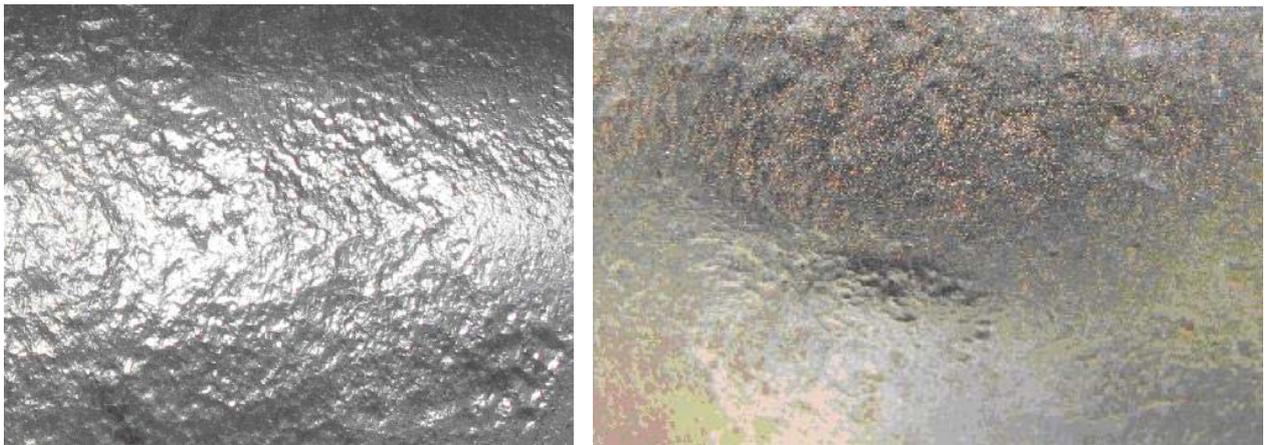Fig. 1-2: Corrosion under insulation in maroon desalting plants

Fig. 3-4: Initially a layer of coating with a thickness of 30 microns was placed on surface of a piece of pipe with referred standard. Left figure two layers of 30 microns (thickness 60 microns) was placed on the surface

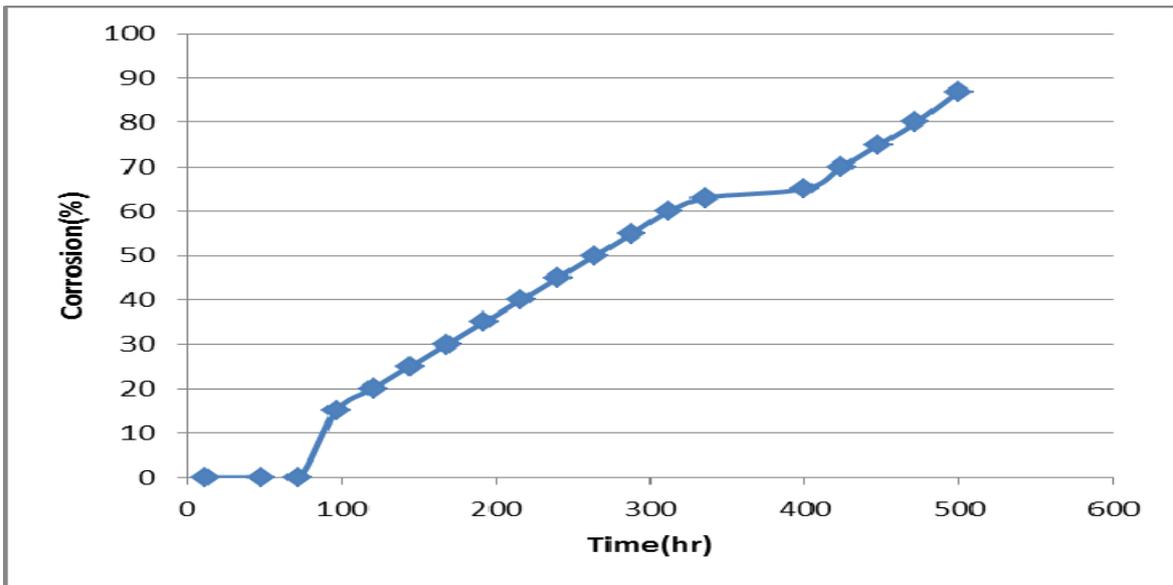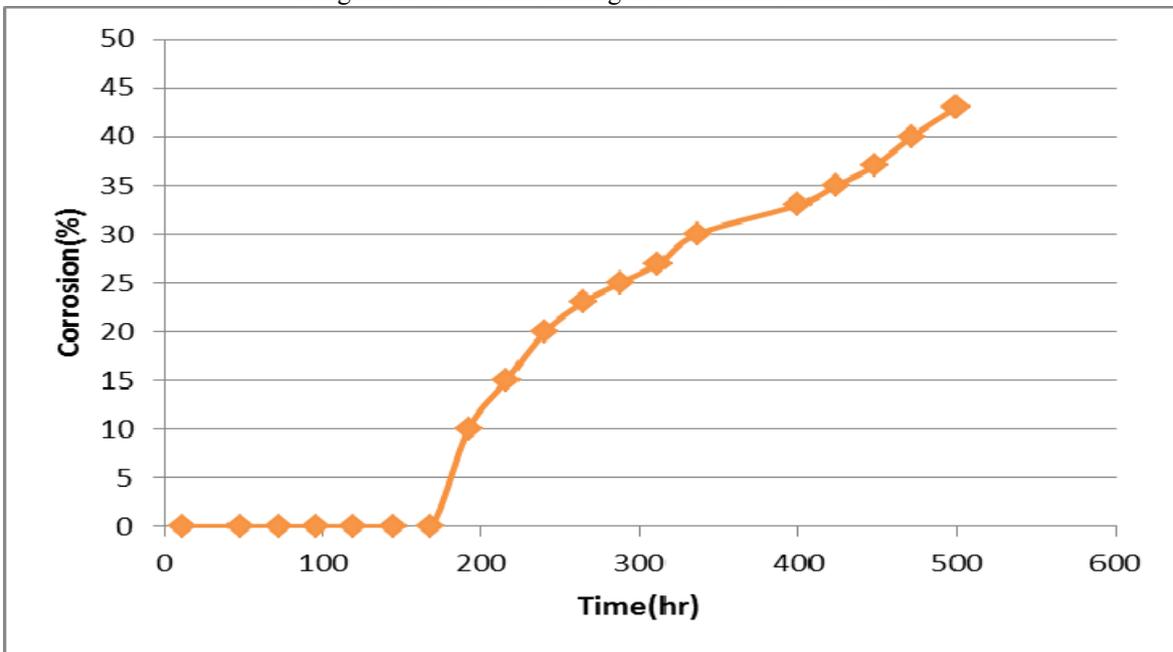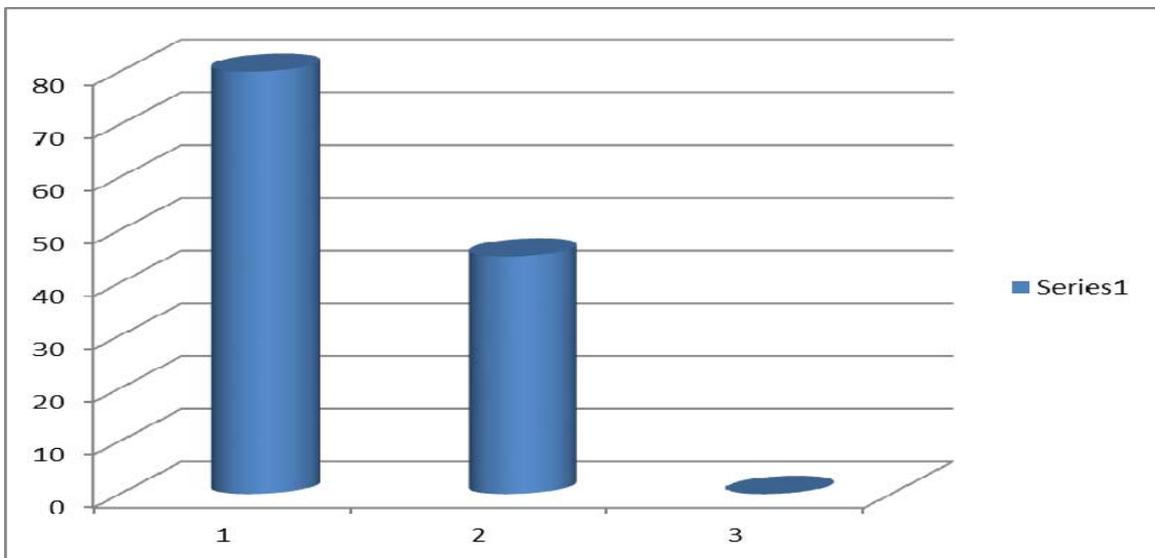Fig. 5: Third stage, two layers of 60 microns(140 microns)

Diagram 1: First case coating of 30 microns thickness

Diag. 2: Second case coating of 60 microns thickness

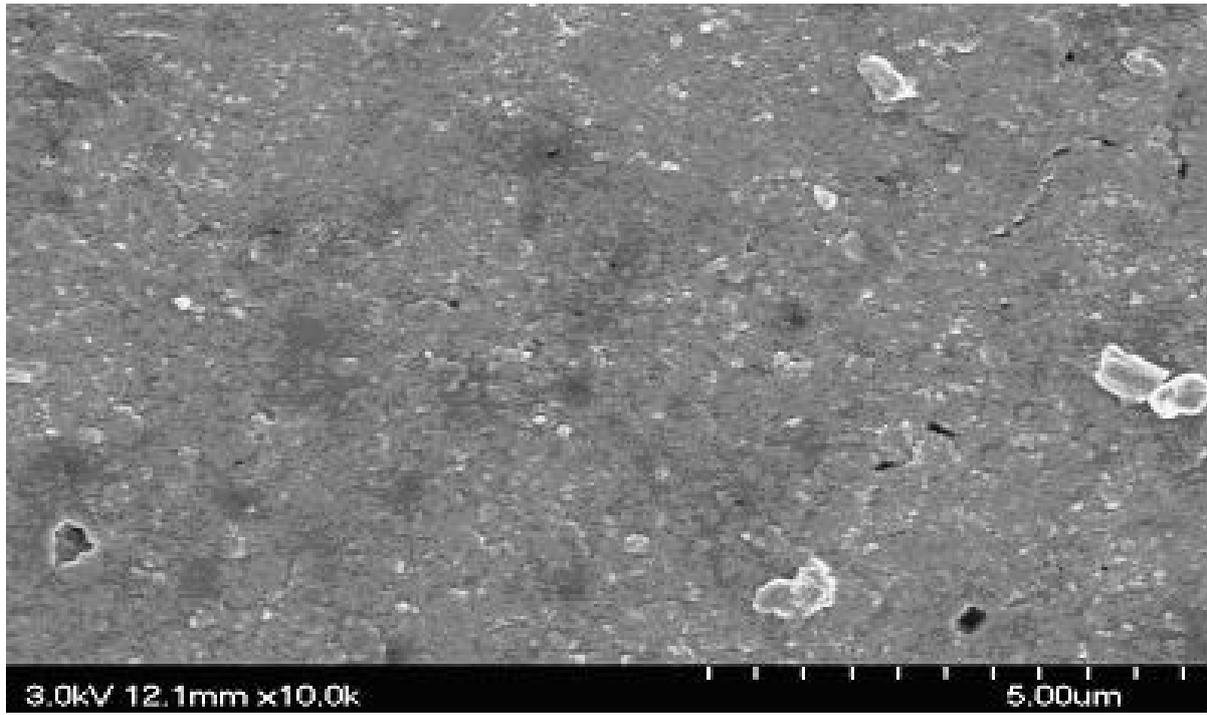Diag. 3: Comparison of three coatings model

Fig. 6: Electron microscopy images(SEM) third mode of approximately 140 microns
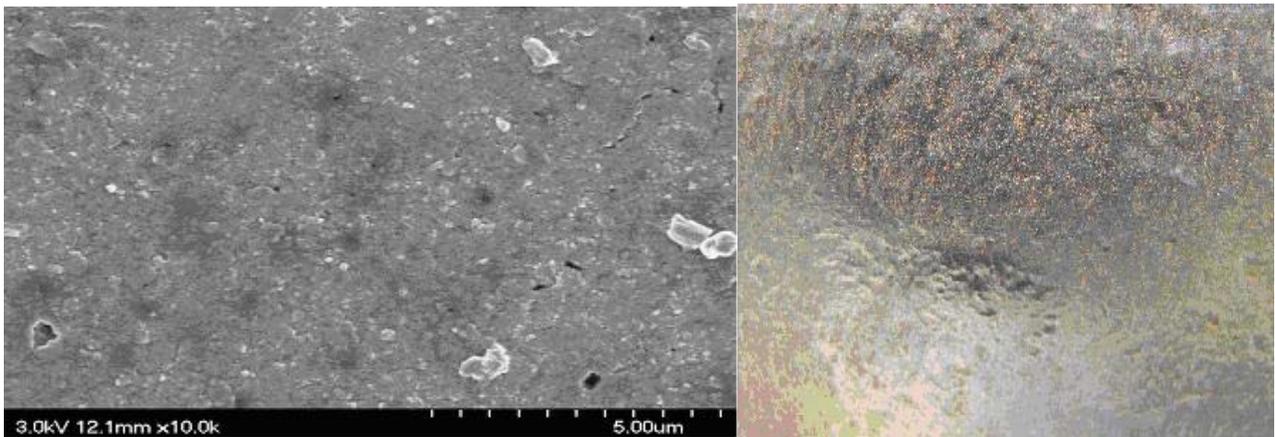

Fig. 7-8: Electron microscopy images(SEM) of second case 60 thickness(right)and without coating(left)