5. CONCLUSION AND SCOPE FOR FUTURE WORK

5.1. CONCLUSION

The applications of electroless nickel composite coatings have been widening in many fields because of their desirable surface properties. Therefore, it becomes very important to investigate the development and advancement of these coatings to cater for the needs of the globe. Moreover, understanding of the coating behaviour and their sensitivity is encouraged with the sole purpose of improving the characteristics of the coatings. The main purpose of this work was to determine whether use of surfactants helped in improving coating characteristics and enhancing coating performance. The effect of surfactants on the characteristics of electroless nickel composite coatings, particularly Ni-P-nano-TiO$_2$ coatings has been elaborately studied.

Electroless Ni-P-nano-TiO$_2$ was successfully coated on mild steel substrate. Taguchi method was used to optimize the coating parameters for effective coating process. This analysis helped in arriving at optimal coating parameters in order to enhance the corrosion behaviour of electroless Ni-P-nano-TiO$_2$ coatings. It was found that pH parameter had the most substantial influence on corrosion rate. The optimal parameter combination for minimized corrosion rate was Temperature of 88°C, pH of 6, bath loading of 0.5 dm$^2$/l, and nano-TiO$_2$ concentration of 2 g/l.

The conclusions obtained from a complete assessment of the effect of surfactants on electroless Ni-P-nano-TiO$_2$ composite coatings are briefly discussed. It was found that nano TiO$_2$ particles had a significant influence in enhancing the properties of the coating but their effect was not completely realized as the particles got agglomerated in the deposit. So, two types of surfactants – anionic and cationic were introduced to the plating bath in order to prevent the agglomeration of nano TiO$_2$ particles. TiO$_2$ nanoparticles have been successfully co-deposited in Ni-P matrix in the presence of SDS and DTAB surfactants at various concentrations in terms of CMC. It was
observed that the addition of these surfactants at the levels of $1.5 \times \text{CMC}$ of SDS and $1 \times \text{CMC}$ of DTAB prevented particles to agglomerate in the electroless plating bath, leading to fine deposition and better uniformity. This revealed that the surfactant type and concentration significantly impacts on the properties of composite coatings. The co-deposited TiO$_2$ content had maximum values of 6.95 wt. % & 4.88 wt. % at the concentrations of $1 \times \text{CMC}$ DTAB and at $1.5 \times \text{CMC}$ SDS respectively which were better than TiO$_2$ content obtained without surfactants. This resulted in considerable improvement in surface morphology, corrosion, scratch resistance, microhardness, and wear behaviour of composite coatings at optimal level of surfactant concentration which is revealed by the following observations.

- The investigations on the surface morphology of electroless Ni-P-nano-TiO$_2$ coatings reveal that uniform distribution of TiO$_2$ was observed at an optimum concentration of DTAB ($1 \times \text{CMC}$) whereas nodular structures of Ni-P along with presence of TiO$_2$ were observed for the SDS surfactant.
- The corrosion resistance of Ni-P-nano-TiO$_2$ coating at optimal concentration of DTAB ($1 \times \text{CMC}$) was considerably increased compared to Ni-P-nano-TiO$_2$ deposits obtained with SDS and without surfactant.
- The scratch resistance of the composite coatings with DTAB surfactant at ($1 \times \text{CMC}$) was higher than coatings obtained with SDS and without surfactant as proved by the higher critical load and lower penetration depth resulting in improved adhesion of the coatings.
- In the presence of surfactants, microhardness of the composite coatings had improved significantly. The maximum microhardness value was measured as 789 HV$_{100}$ for SDS and 829 HV$_{100}$ for DTAB at optimum surfactant concentrations.
- The wear resistance of the Ni-P-nano-TiO$_2$ composite coatings had also been increased by the addition of SDS and DTAB surfactants. For DTAB at $1 \times \text{CMC}$ concentration, the specific
wear rate drastically decreased compared to Ni-P-nano-TiO$_2$ deposits obtained with SDS and without surfactant.

In general, addition of surfactants to the EN plating bath has been proved to improve the quality of the electroless deposits. With nano composite coatings having superior properties, the surfactant plays an important role in enhancing the utilization of the materials to a great extent. Therefore, effects of surfactants on the characteristics of electroless Ni-P-nano-TiO$_2$ deposits have been extensively studied. Consequently, effects of concentrations and type of the surfactants on the characteristics of the Ni-P-nano composite deposits, such as surface morphology, composition, wear and corrosion behaviour, and the structural changes were analysed. Among various concentrations of surfactants experimented, 1 × CMC of DTAB and 1.5 × CMC of SDS have been found to be optimal concentrations at which significant improvements were observed in surface characteristics of Ni-P-nano-TiO$_2$ composite coatings. In particular, DTAB at 1 x CMC concentration showed most desirable set of properties. Apart from identifying the optimal levels of surfactants to be used for applications of Ni-P-nano-TiO$_2$ coatings, the studies have also analysed the degree of sensitivity each surface characteristic has to that particular surfactant.

5.2. SCOPE FOR FUTURE WORK

- In the present study, typical anionic and cationic surfactants were used to improve the coating efficiency of electroless nickel composite coating process. Other types of surfactant such as Zwitterionic and non-ionic could be tried out.
- Similar study on other substrates like magnesium, aluminium can also be conducted as they find wide applications in many industries.
- Other solid particles like graphene oxide can also be codeposited similar to nano TiO$_2$ in presence of surfactants which is used in many tribological applications.
• Corrosion resistance of the electroless nickel composite coatings in other corrosive media (acidic) along with stirring is worthy to be investigated.

• High temperature wear behaviour of the electroless nickel coatings could be investigated since the composite coatings may find high temperature applications.

• The transmission electron microscopy analysis can be performed on the electroless nickel structures to investigate the atomic arrangement at different surfactant concentrations.