



e-ISSN: 2319-8753 | p-ISSN: 2347-6710

IJRSET

International Journal of Innovative Research in
SCIENCE | ENGINEERING | TECHNOLOGY



INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH

IN SCIENCE | ENGINEERING | TECHNOLOGY

Volume 13, Issue 5, May 2024

ISSN INTERNATIONAL
STANDARD
SERIAL
NUMBER
INDIA

Impact Factor: 8.423

9940 572 462

6381 907 438

ijirset@gmail.com

www.ijirset.com

Effect of Surface Treatment on Friction of MP35N Fasteners

Anoop Kumar A¹, Ivin Shibu², Srinath J³, Amaljith T H³, Dr. Christopher Solomon S³, Dr. Anoop Kumar S⁴

¹Graduate Engineer, Bureau of Indian Standards, Kochi Branch Office, Kerala, India

²Assistant Professor, Dept. of Mechanical Engineer, Mount Zion College of Engineering, Kerala India

³Materials and Mechanical Entity, Vikram Sarabhai Space Centre, ISRO, TVM, India

⁴Associate Professor, Dept. of Mechanical Engineering, SCT college of Engineering, Kerala, India

ABSTRACT: Ultra-high strength fasteners are used in aerospace applications for specific critical requirements. An ultra-high strength nickel cobalt based multiphase alloy which is highly durable, namely MP35N, is used in this study. MP35N is an excellent anticorrosive material for usage in fasteners. Friction plays a pivotal role in fasteners for determining the torque tension characteristics in a joint. If the friction is high, higher torque is required to produce a required level of preload in the fasteners. Friction in fasteners at two locations assumes significance: thread friction and bearing friction. Thread friction is the friction between the threads of bolt and nut, while bearing friction is the resultant friction at the interfaces between washer & bearing face of nut/bolt, and between washer and flange surface. To reduce friction, different lubricants are applied based on requirement. Passivation is generally used to provide a uniform oxide layer for corrosion resistance. Silver is generally used for high temperature applications as a lubricant, and SMAG is a solid lubricant coating developed by VSSC, ISRO, for high temperature applications. Friction characterization was carried out on different surface conditions of MP35N studs and nuts in the foll006Fwing surface combinations: passivated-passivated, silver-passivated, silver-silver, silver-SMAG had been investigated along with A286 washer in passivated condition and also 15CDV6 washer in cadmium plated condition. Friction factor was evaluated at various preloads. It is found that the friction factor of silver coated studs and SMAG coated nuts is much lower when compared with the passivated studs and nuts.

KEYWORDS: MP35N, SMAG, Multiphase alloy, Passivated, A286, 15CDV6, Cadmium plating, Friction factor, Torque, Preload, Metallography, SEM, EDS

I. INTRODUCTION

Fasteners are machine elements that can be easily installed and removed with hand or power tools [1]. Screws, bolts, nuts, and rivets are common types of fasteners. Selecting the right fastener material from the vast array of materials available is an important requirement and requires careful consideration of the material properties such as strength, corrosion, toughness, fatigue behaviour, in addition to the service conditions like temperature, vibration, etc. For most of the critical aerospace applications, ultra-high strength fasteners having strength higher than 1800 MPa are required to be used due to their high strength and toughness [12]. For most of the applications, they must be capable of withstanding heavy loads and hot service conditions, in addition to having adequate ductility. However, these fasteners are likely to be prone to corrosion, hydrogen embrittlement, and poor stress corrosion cracking resistance, which may require additional coating/surface modification. Hence, selection of a proper material assumes significance. For newer developments in launch vehicles, ultra-high strength fasteners suitable for the application are being developed.

MP35N is an age-hardenable nickel-cobalt base alloy that has a unique combination of properties such as ultra-high strength, good stress corrosion cracking (SCC) resistance, withstand high temperatures, hydrogen embrittlement, toughness, ductility, and outstanding corrosion resistance. It is produced by Vacuum Induction Melting (VIM) and Vacuum Arc Re-melting (VAR). MP35N is usually melted in a vacuum atmosphere to avoid contamination due to oxidation and also further purify the metals by eliminating trapped gases from the melt [3]. No surface coating is required for preventing it from corrosion because it is an excellent anticorrosive material MP35N is generally used in passivated condition to maintain a thick oxide layer responsible for corrosion resistance and uniform corrosion characteristics. This material has been chosen to develop the ultra-high strength fasteners for the new developments.



However, the friction is high for passivated MP35N fasteners, that is higher torque is required to produce a required level of preload in the fasteners [4]. Providing higher level of torque is particularly challenging for higher sizes. Therefore, to reduce the nut factor, different types of coatings are used.

Surface coatings are typically applied to alter the surface properties of a metallic substrate, to improve its anticorrosive properties, to reduce friction and provide functional aspects as part of the finishing process. The most commonly used techniques are electroplating, chemical vapour deposition, and physical vapour deposition. Chemical deposition methods typically involve a fluid precursor, which deposits a thin film after undergoing a chemical reaction to leave a solid layer. The physical deposition method, on the other hand, uses mechanical, electromagnetic, or thermodynamic methods to produce a thin film. In electroplating, an electrical current passing through the solution causes objects at the cathode to be coated by the metal in the solution.

Silver-plated fasteners are widely used in the aerospace industry where lubricant cannot be used or where fasteners are assembled into materials where galling is a serious risk. Silver coatings have been used as both corrosion inhibitors and dry lubricants. Silver belongs to a family of soft coatings and can easily shear to reduce friction [7]. Silver can be used as a lubricant at room temperature as well as at higher temperatures because it can withstand higher temperatures. The SMAG coating is a dry film lubricant consisting of sodium silicate, MoS₂, antimony trioxide and graphite, which was developed by the Vikram Sarabhai Space Centre, ISRO, Thiruvananthapuram, Kerala, India. Sodium silicate acts as a binder and MoS₂, antimony trioxide, and graphite act as lubricants [6]. This helps reduce wear on the parts and reduces the coefficient of friction. Passivation is used as a basic anticorrosive coating in fasteners, which is an oxide layer coated on the surface [2]. Cadmium coating is typically applied to the fasteners and provides technical benefits such as crack resistance, good lubricity, solder ability, salt water corrosion resistance [5].

The objective of this study is to characterize the friction in MP35N fasteners with different surface conditions for finalizing the ideal condition for torquing. Conducted various tests such as Torque Tension Test, Optical metallography to characterize the surface and SEM & EDS evaluation to study the tribo-mechanism.

II. EXPERIMENTS

The material used in this study is MP35N, the typical properties and chemical composition are in the table 1 and table 2.

Table 1: Tensile Properties of aged MP35N

UTS (MPa)	YS (MPa)	%El	%RA	HARDNESS (HRC)
1793	1586	8	35	46-50

Table 2: MP35N Chemical Composition

Element	% wt.
C	0.02
P	0.015
Si	0.15
Ni	33-37
Co	Bal.
B	0.010
Mn	0.15
S	0.10
Cr	19-21
Mo	9-10.5
Ti	1
Fe	1

2.1 Surface Treatment and Characterization

The studs used for the purpose of this study were MP35N M20 × 1.5 mm×72.5mm and the nuts were MP35N M20 × 1.5 mm. As discussed, earlier studs and nuts had been studied in 3 different surface conditions: passivation, silver, and SMAG were the coatings that were used in this work, which act as lubricants.

2.1.1 Passivation

Passivation was carried out by chemical treatment. The specimen was allowed for ultrasonic bath for 12 minutes with 50% acetone and 50% isopropanol. After cleaning, the samples were immersed in 75 mL of 10.5% HNO₃ at 35°C for 150 min. The HNO₃ solution used for passivation was prepared from analytical-grade HNO₃ and ultrapure water.

2.1.2 Cadmium Plating

Cadmium was plated on the 15CDV6 washer. Cadmium plating was carried out by three stages. The first stage was Pre-treatment, in this stage degreasing to remove grease oil, de-scaling to remove scale rust and other corrosion, then cadmium plating was carried out at a current density of 11.5Amp/dm² for a duration of 20 minutes. Finally post-treatment (baking) was carried out to remove the hydrogen embrittlement.

2.1.3 Silver Plating

The silver coating was carried out by electroplating. After degreasing, acid etching, alkali wash, and a water break test were carried out. Then Wood's Nickel strike was carried out, in which a thin layer of nickel is coated to provide proper adhesion to silver [9]. Again, an alkaline dip is carried out to remove the oxide layer. Silver plating was carried out at a current density of 1 A/dm² for a duration of 10 minutes [10]. The image of optical metallography is illustrated in Fig. 1. It shows the cross-sectional morphology of the silver-plated nut. It can be seen from Fig. 1 that the thickness of the silver coating is in the range of 8.8 μm to 10.21 μm. The thickness of the coating does not change significantly in the observation range.

The image of SEM is illustrated in Fig. 2. It also shows the cross-sectional morphology of the nut after silver plating. The EDS image gives the material proof of silver-plating. It can be seen that there is no spalling in any of the tested coatings. Based on these observations, we believe that the coating is sufficiently uniform.

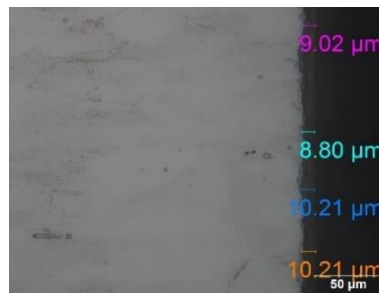


Fig.1: The cross-sectional morphology of nut in optical metallography of the fastener after silver plating.

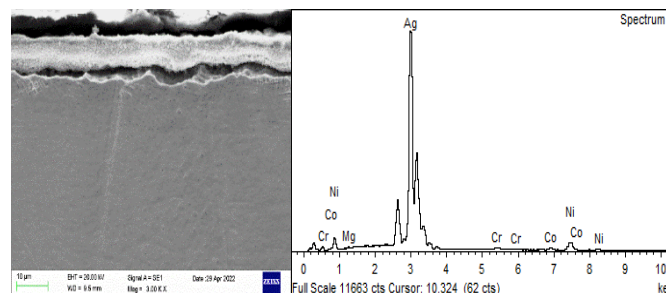


Fig. 2: The cross-sectional morphology of nut in SEM and EDS of the fastener after silver plating.

2.1.4 SMAG Coating

The SMAG coating was prepared using a spraying technique. SMAG coating was only applied on the inner thread of the nut. Molybdenum disulphide powders, graphite and antimony trioxide were uniformly dispersed in sodium silicate adhesive. After precleaning, drying, and masking, the mixture is sprayed onto the surfaces of fasteners by a spray gun, then the applied SMAG coating was dried at room temperature. After unmasking, the coating was cured by heating in a hot air oven. The image of optical metallography is illustrated in Fig. 3. It shows the cross-sectional morphology of the SMAG coating. It can be seen from Fig. 3 that the thickness of the SMAG is in the range of 7.8 μm to 7.9 μm. The thickness of the coating does not change significantly in the observation range.

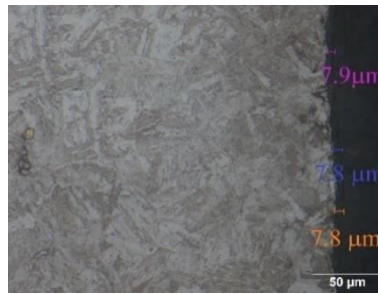


Fig. 3: The cross-sectional morphology of nut in optical metallography of the fastener after SMAG coating

The image of SEM is illustrated in Fig. 4. It also shows the cross-sectional morphology of the nut after SMAG coating. The EDS image gives the material proof of the SMAG coating. It can be seen that there is no spalling in any of the tested coatings. Based on these observations, we believe that the coatings is sufficiently uniform.

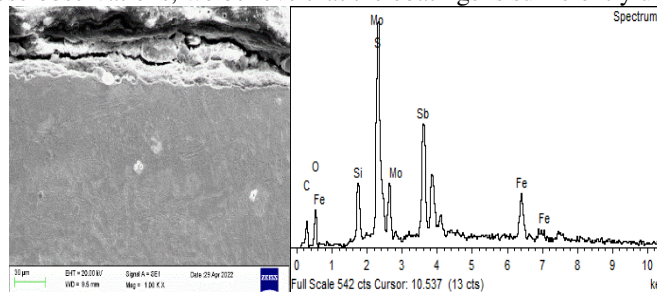


Fig. 4: The cross-sectional morphology of nut in SEM and EDS of the fastener after SMAG coating.

2.2. Torque Tension Testing Evaluation

Torque tension tests were done at varying preload from 43kN to 215kN. Different combinations of MP35N studs and nuts had been tested as shown in table 3.

Table. 3: Different combinations of studs, nuts and washers

Sl. No.	Stud	Nut	Washer
1	Passivated	Passivated	15CDV6 washer in cadmium plated condition
2	Silver plated	Passivated	
3	Silver plated	Silver plated	
4	Silver plated	SMAG Coated	
5	Passivated	Passivated	A286 washer in passivated condition
6	Silver plated	Passivated	
7	Silver plated	Silver plated	
8	Silver plated	SMAG Coated	

For testing, a Schatz automated torque tension machine was used. The test setup is given in Fig. 5. The equipment has a preload force transducer and a thread friction torque transducer. A force transducer with a capacity of 300 kN and a torque transducer of 5000 Nm were used. Washer Sledge used were XH67 of M20 size and M20 M250 fabricated adaptor is used for constraining the motion of studs.

The automated torque tension machine was programmed step-wise, i.e., the machine torques the nut to 10% YS and stops for 5 seconds, and then again torques to 20% YS and stops for 5 seconds, and this continues up to 50% YS. After that, the machine un-torque the assembly. The machine records the reaction torque, the preload, the thread friction torque, and the bearing friction torque. The system computes nut factor, bearing friction, and thread friction from the measured data [11]. The test is repeated for three samples and average of them is taken for all combinations. The nut factor is determined from the tightening torque/clamp force relation using the formula [8]:

$$K = \frac{T}{F d}$$

The coefficient of friction between threads is [8]:

$$\mu_{th} = \frac{T_{th} - \frac{P}{2\pi}}{0.577d_2}$$

The coefficient of friction between bearing surfaces is [8]: $\mu_b = \frac{T_b}{0.5 \times D_b \times F}$

d – Nominal thread diameter

F – Clamp force

T – Tightening torque

K – Nut factor

P – Pitch of the thread

μ_{th} – Coefficient of friction between threads

μ_b – Coefficient of friction between bearing surfaces under nut or bolt head

T_b – Bearing surface friction torque

T_{th} – Thread torque

d_2 – Basic pitch diameter of thread

D_b – Diameter of bearing surface under nut or bolt head for friction



Fig5: Schatz Torque Tension Testing Machine.

III. EXPERIMENTAL RESULTS

From the average of the results obtained from the torque tension test, preload Vs torque, preload Vs nut factor, preload Vs bearing friction, and preload Vs thread friction were plotted.

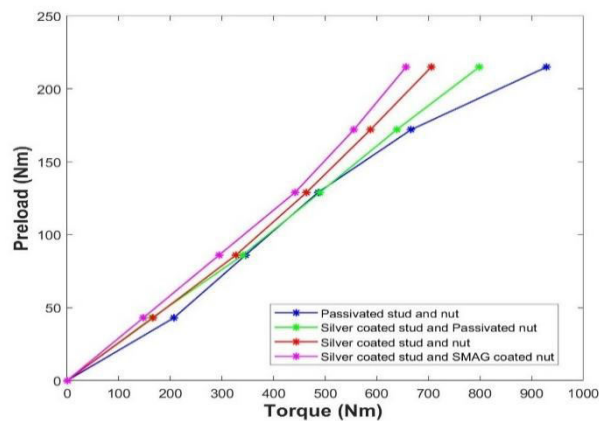


Fig. 4: Preload Vs torque with passivated A286 washer.

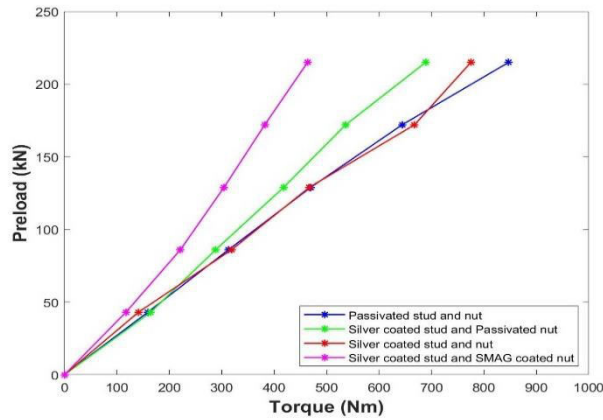


Fig. 5: Preload Vs torque with cadmium plated 15CDV6 washer.

Fig. 4 and 5 show a preload versus torque plot with a passivated A286 washer and a cadmium-plated 15CDV6 washer. From the graph, it is clear that the torque required for achieving 215kN is much lower in the silver-plated stud and SMAG coated nut with cadmium plated 15CDV6 washer whereas the torque is almost 50% higher in the passivated stud and nut with passivated A286 washer. The torque required to achieve 215kN for silver plated stud and passivated nut is slightly less than that of passivated stud and nut, whereas for silver-plated stud and nut, it was slightly less than for silver-plated stud and passivated nut in both combinations.

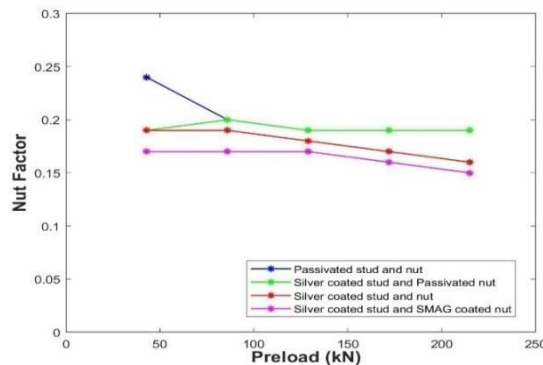


Fig. 6: Preload Vs nut factor with passivated A286 washer.

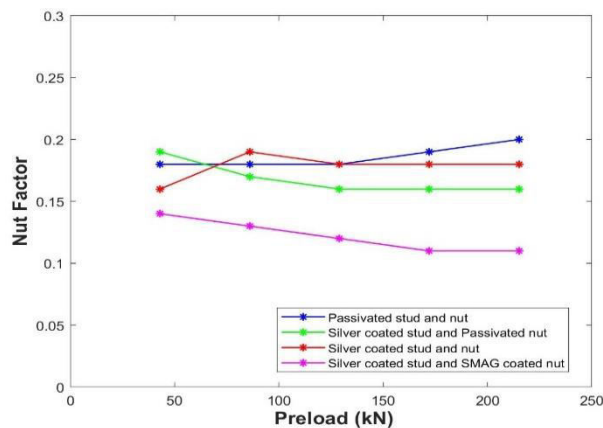


Fig. 7: Preload Vs nut factor with cadmium plated 15CDV6 washer.

Fig.6 and Fig.7 show the plot of preload versus nut factor with a passivated A286 washer and a cadmium plated 15CDV6 washer. The nut factor is the combined effect of bearing friction and thread friction. Passivated stud and nut with passivated A286 washer have a much higher nut factor, whereas silver plated stud and SMAG coated nut with cadmium plated 15CDV6 washer have the least nut factor. For silver plated stud and passivated nut, the nut factor was less than that of passivated stud and nut.

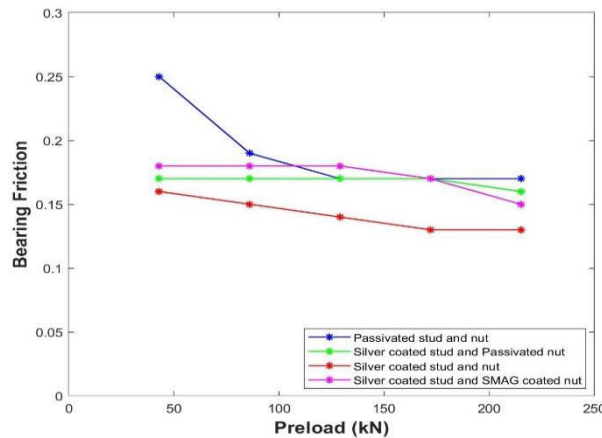


Fig. 8: Preload Vs bearing friction with passivated A286 washer.

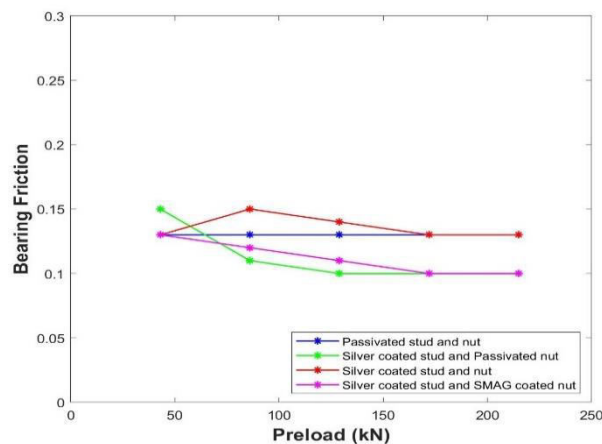


Fig. 9: Preload Vs bearing friction with cadmium plated 15CDV6 washer.

Fig.8 and Fig.9 show the plot of preload versus bearing friction with a passivated A286 washer and a cadmium plated 15CDV6 washer. In the passivated nut and the SMAG coated nut, the bearing face is the same. From Fig.8 and 9, the average value of bearing friction for passivated MP35N and passivated A286 interface is the same. Similarly, the average value of bearing friction for passivated MP35N and cadmium plated 15CDV6 is the same. The bearing friction was lowest in the cadmium plated washer as compared to the passivated A286 washer.

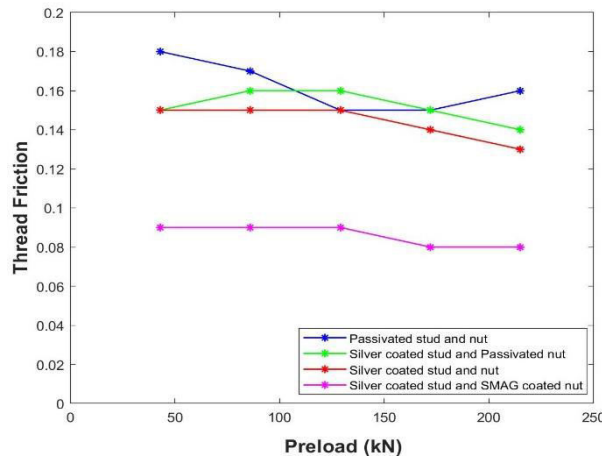


Fig.10: Preload Vs thread friction with passivated A286 washer.

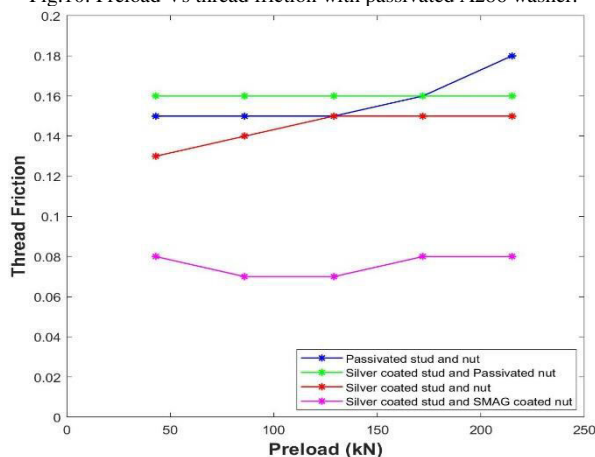


Fig.11: Preload Vs thread friction with cadmium plated 15CDV6 washer.

The plots of preload versus thread friction with a passivated A286 washer and a cadmium plated 15CDV6 washer are shown in Fig.10 and 11. From the graph, it's clear that the thread friction is least in the silver plated stud and SMAG coated nut and higher in the passivated stud and passivated nut. Fig.10 and 11 the thread interfaces are same and hence the thread friction is almost consistent in both cases

IV.CONCLUSION

Silver plating and SMAG coating had been carried out on MP35N M20x1.5 studs and nuts to analyse the effect of friction due to different surface treatments. Surface characterization of all the coatings was also conducted. Nut factor, bearing friction and thread friction were evaluated for all the surface conditions.

The following are the conclusions drawn from the analysis,

- Silver plating on stud and nut doesn't give any significant change in nut factor as compared to passivated stud and nut; cost of silver plating is also higher as compared to passivation.
- Considerable reduction in thread friction for silver plated stud with SMAG coated nut is observed; the percentage of reduction is 50% when compared to passivated stud and nut. This reduction in thread friction is due to the lubricity of SMAG coating.
- Bearing friction is observed to be less between cadmium plated 15CDV6 washer and passivated MP35N interface. Almost 35% reduction in bearing friction was observed. This is because of, cadmium act as a lubricant.
- Nut factor is observed to be higher in passivated studs and nuts interfaces with passivated A286 washers and least in SMAG coated nut and silver-plated stud with cadmium plated 15CDV6. The percentage of reduction observed was 40%.

REFERENCES

- [1] Q. Zou, T. S. Sun, S. A. Nassar, G. C. Barber, A. K. Gumul. "Effect Of Lubrication on Friction and Torque-tension Relationship in Threaded Fasteners": STLE/ASME International Joint Tribology Conference, IJTC2006-12090.
- [2] A. Ornberg, J. Pan, a., z M. Herstedt, b, C. Leygraf, "Corrosion Resistance, Chemical Passivation, and Metal Release of 35N LT and MP35N for Biomedical Material Application": Journal of The Electrochemical Society, 154 (9), C546-C551 (2007).
- [3] A. Ishmaku, K. Han, "Characterization of cold-rolled and aged MP35N alloys": Elsevier, Materials Characterization 47 (2001) 139 – 148.
- [4] Junbo ZHOU, Jianhua LIU, Huajiang OUYANG, Zhenbing CAI, Jinfang PENG, Minhao ZHU. "Anti-loosening performance of coatings on fasteners subjected to dynamic shear load": Springer, Friction 2017 ISSN 2223-7690 .
- [5] Neethu P, Sankaravelayutham P, Dr. Rajeev N, "Nut Factor Analysis of Aluminium Ivd Coated and Cadmium Electroplated High Strength Fasteners": International Research Journal of Engineering and Technology (IRJET 2017), Volume: 04 Issue: 06, 807-809.
- [6] Bożena Pietrzyk, Sebastian Miszczak, Lukasz Kaczmarek, Marek Klich. "Low friction nanocomposite aluminum oxide/MoS2 coatings prepared by sol-gel method": ELSEVIER, May 2018, Volume 44, Issue 7, Pages 8534-8539.
- [7] Giuseppe Tronci, Matthew B. Marshall. "Understanding the behaviour of silver as a low friction coating in aerospace fasteners": ELSEVIER, Tribology International, August 2016, Volume 100, Pages 162-170.
- [8] ISO 16047:2005(E); Standard Practice for Fasteners -Torque/clamp force testing.
- [9] ASTM 558-79; Standard Practice for Preparation of Nickel Alloys for Electroplating.
- [10] ASTM B700-08; Standard Specification for Electrodeposited Coatings of Silver for Engineering use.
- [11] John H. Bickford, Introduction to the Design and Behavior of Bolted Joints, Fourth Edition, Non-Gasketed Joints.
- [12] M. Hemmilä, R. Laitinen, T. Liimatainen, D. Porter, Mechanical and technological properties of ultra-high strength Optim steels: Rukki, 1-7.



INTERNATIONAL
STANDARD
SERIAL
NUMBER
INDIA



INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH

IN SCIENCE | ENGINEERING | TECHNOLOGY

 9940 572 462  6381 907 438  ijirset@gmail.com



www.ijirset.com

Scan to save the contact details