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STUDY ON LOOSENING TORQUE OF THREADLOCKED BONDS

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Abstract: One of the most important parameters of threadlocked bonds is loosening torque, which is a result of complex, time dependent chemical and physical, static and dynamical processes. Compliance of a threadlocker for a certain technical solution basically depends on it. In this paper we demonstrate results of experimental investigations on widely used threadlockers: Loctite 2400, 2700 and AJett 126.Loosening torque as function of curing time was measured on 8.8 galvanized steel screrws with three different threadlocker. Comprehension between thread surface cleaning, thread size, curing time and strength of thread bond was studied. It can be concluded that sensitivity of threadlockers for prior decontamination show significant difference, furthermore environmentally conscious materials saves costs of treatment, but may cause longer curing time, so deeper quantitative understanding of their functioning is needed for a competitive production design and optimization.
Keywords: threadlocking, loosening torque, production design, environmental consciousness

INTRODUCTION

Today adhesives are applied in a wide variety of industry fields like structure bonding, instant bonding, retaining, gasketing, threadlocking, thread sealing, lubrication and protection or surface treatment. In this study we focus on applications when adhesive makes a connection between two surfaces without any relative motion, like the first six item inthe previous list.

Threadlocking by adhesives has at least duplicate advantage in competitive manufacturing: on the one hand it lowers costs, on the other hand it has additional functions beyond preventing loosening, like protection from corrosion, sealing, reducing number of parts and space demand of the whole assembly. If the adhesive is environmentally friendly, this technology has no additional risk to nature and humans furthermore has no additional costs of safe disposal [8,9,10].

Adhesives function like chemical and mechanical bridge between surfaces to be connected. Strength and other features of glued bond are determined by adhesion between molecules of glue and surfaces, and cohesion between molecules of glue. Van der Waals intermolecular forces play key role in generating adhesive and cohesive forces.

Wettability is a highly important technical concept in adhesive technologies. When adhesives get in contact the surface, in ideal case the whole surface is covered by the liquid state adhesive, so after curing adhesive force arise along the total surface. This is the way of forming thebest, strongest bond. In reality this does not happen for at least three different reason.

1. Surface contaminations form a thin layer between the surface and adhesive preventing them from adhering.
2. Surface roughness, inequalities and porosity may also hamper spreading of adhesive even on a clean surface.For example pores can not be filled perfectly with adhesive. So voids may be formed between the surface and the adhesive, where of course adhesive force can not arise. This is related to the next reason.
3. The smaller the viscosity of the adhesive is, the faster and completer it covers the surface. In many cases viscosity of adhesive increases by time, so it loses gradually its ability to wet (maybe in second or minutes).

This is why surface energy of the adhesive and cleaning of surfaces before gluing or thereadlocking influences substantially the strength of the bond [1]. Adhesive strength is a highly complex quantity. Reference [6] describes a fuzzy logic system for estimeting adhesive strength of thin fil coatings of dynamically loaded machine parts. In this paper we consider a static problem, which

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many parameters like frictional coefficient and relative speed plays no role in.

In our experiments we applied anaerobic threadlockers. Curing mechanism of anaerobic adhesives can be scetched as follows:

1. oxygen in the air inhibits the process of curing,
2. when the adhesive becomes occluded from air and get in contact with metal, peroxide molecules start to disintegrate to oxygen radicals,
3. which makes monomers to polymerize,
4. at the end adhesive turns to a solid state polymer which adheres strongly to the surfaces to be bonded together.

Polymerization is a time comnsuming process [2].

Objectives of our research are the followings.

1. Clarify the effect of cleaning (of absence of cleaning) to the strength of the bon din case of different threadlockers.
2. How loosening torque changes during the process of curing.
3. How size of thread influences the loosening torque.

EXPERIMENTAL PLAN AND METHODS

8.8 galvanized steel screws with sizes M10, M16 and M20 were used in our experiments. These are commonly and widely used bonding elements.

In experiments three different threadlockers were applied: a medium strength threadlocker Loctite 2400, and two high strength threadlocker Loctite 2700 and AJett 126.

Experiments were performed without prior cleaning of threads, and also applying cleaning with Loctite SF 7036 cleaner.

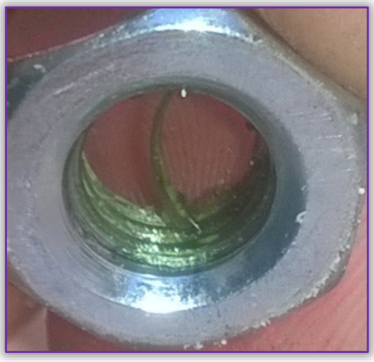

Figure 1. Screw and nut disassembled (example)

Loosening torque was measured after 6 different time intervals: 0.5h, 1h, 3h, 24h, 72h, 168h (h means hour). It means that threadlocked screw-nut pairsa were disassembled after a prescribed curing time (Figure 1). 12 measurements were performed for a certain threadlocker-thread size-curing time case. Salient values were omitted if existed, and mean value was calculated.

Experiments were performed at room temperature without termostating.

RESULTS

Results were taken into account if loosening torque exceeded 5 Nm. Under 5 Nm disassembling was possible by hand..Table 1 summarizes which cases were applicable for evaluation.

Before measurement results it is worth to mention two observations what are not studied here in details:

- During disassembly srew and nut heated up significantly. This is because of mechanical energy fed into the system during twisting away transformed to heat.
- Fracture of threadlocker gives qualitative information on relative strength of adhesive an cohesive forces. If cohesive forces are stronger then threadlocker separates from at least one of surfaces. If adhesive forces are stonger, then small pieces of threadlocker was observable on surfaces of both screw and nut.

Table 1. Threadlocker-thread size-curing time combinations resulting more than 5 Nm loosening torque. Letter „n” means that even after 168h (one week) loosening torque did not reach 5 Nm.

Threadlocker	Size	Without cleaning	With cleaning
Loctite 2400 (medium strength)	M10	n	n
	M16	24h, 72h, 168h	24h, 72h, 168h
	M20	0.5h, 1h, 3h, 24h, 72h, 168h	0.5h, 1h, 3h, 24h, 72h, 168h
Loctite 2700 (high strength)	M10	3h, 24h, 72h, 168h	1h, 3h, 24h, 72h, 168h
	M16	1h, 3h, 24h, 72h, 168h	1h, 3h, 24h, 72h, 168h
	M20	0.5h, 1h, 3h, 24h, 72h, 168h	0.5h, 1h, 3h, 24h, 72h, 168h
AJett 126 (high strength)	M10	not studied	not studied
	M16	1h, 3h, 24h, 72h, 168h	1h, 3h, 24h, 72h, 168h
	M20	not studied	not studied

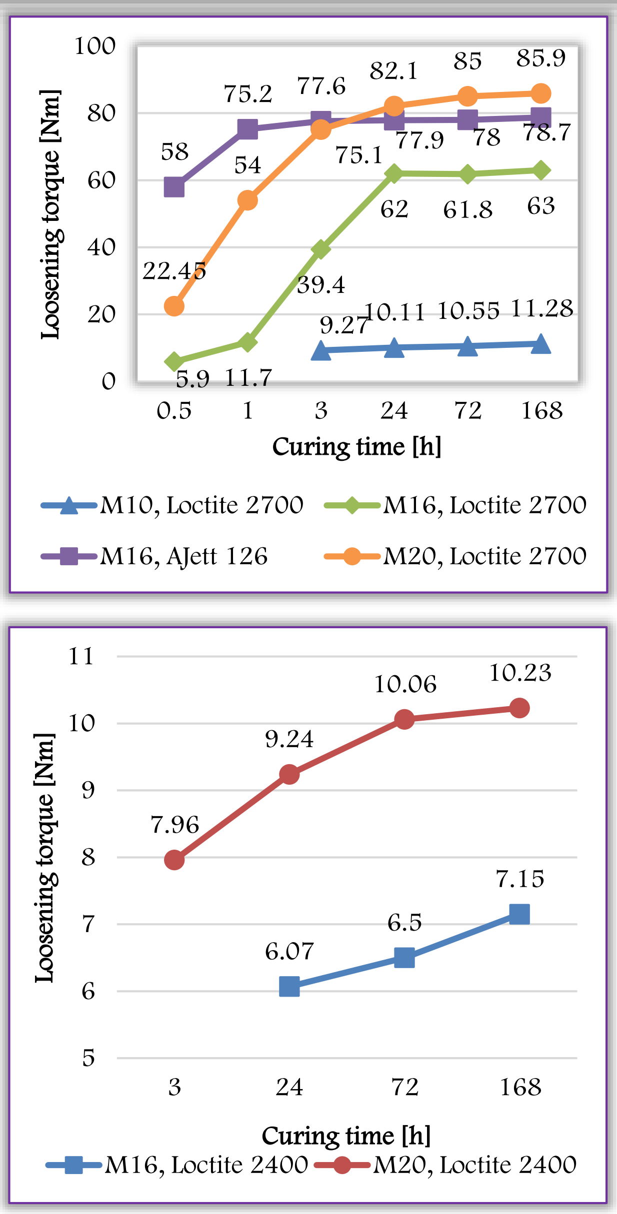

Figure 2. Loosening torque in case of threadlocking without prior cleaning
a) High strength threadlockers,
b) Medium strength threadlockers

Figure 2 demonstrates mean values of loosening torques for experiments in which surface decontamination was not applied. Each curve shows that loosening torque increases with curing time. It is visible that medium strength threadlocker produces almost one magnitude less loosening torque than high strength threadlockers.

On Figure 3 same csases are demonstrated than on Figure 2., but with cleaning before locking with Loctite SF 7036 cleaner. Torques show higher values. Increase in loosening torque depeds on thread size and threadlocker.

At this point we can take some observations:

» Comparing the two high strength threadlocker, is can be stated that AJett 126 provides larger strength than Loctite 2700 in short curin times, but later strengths get close to each other. This can be explained with that Loctite Health and Safety threadlockers cure slower on inactive (e.g. galvanized, like our screws) surfaces.
» Loosening torque increases with thread size as it was expected.

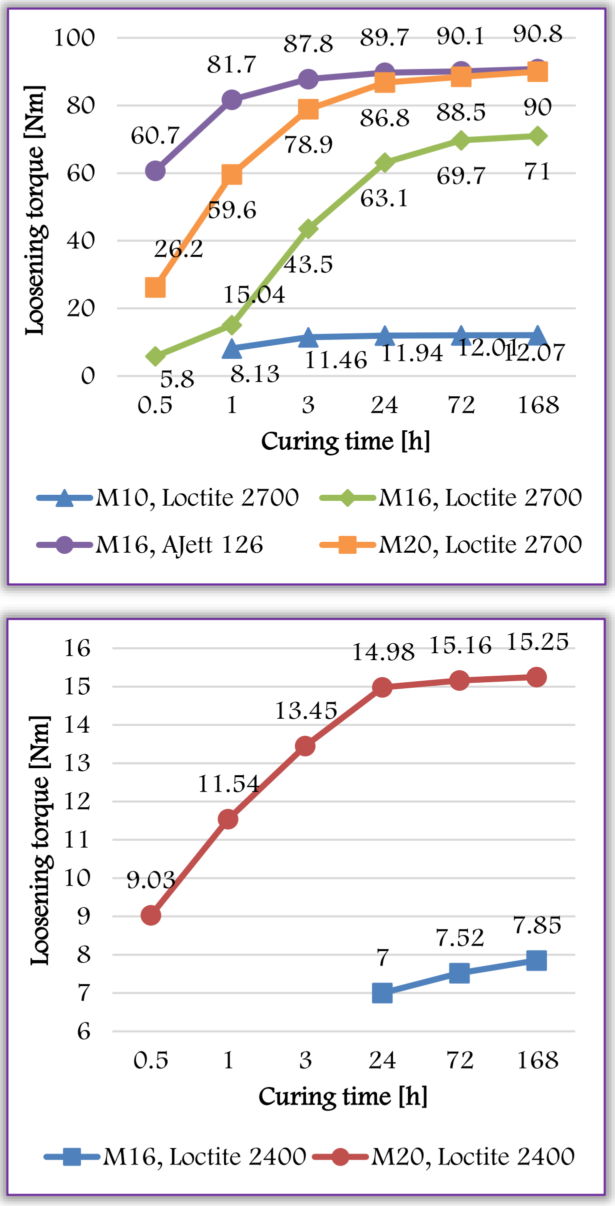

Figure 3. Loosening torque in case of threadlocking with prior cleaning
a) High strength threadlockers,
b) Medium strength threadlockers

Shape of curves are different, but each of them can be more or less approximated with a logarithmic function:

$$f(t) = a \ln t + b, \quad (1)$$

where t is time in hours, a and b are fitting parameters. For high strength threadlockers and for larger thread sizes the approximation is better.

Curve fitting was performed by least square method for cases with at least 5 measurable losening torque. Table 2 shows parameters a, b and R^2, the coefficient of determination:

$$R^2 = \frac{\sum_i (x_i - \bar{x}) - \sum_i (x_i - \hat{x}_i)}{\sum_i (x_i - \bar{x})}, \qquad (2)$$

where x_i are measured values at time instant t_i, $\bar{x}$ means average of x_i-s, and $\hat{x}_i$ denotes values of function resulted from regression. When regression can give account completely of the change of measured values, then $R^2=1$.

In Table 2. coefficients of determination changes from 0.78 to 0.98, five values reach 0.95. It means that our results of time dependency of curing and loosening torque can be well approximated by logarithmic funcion (1), and it is in good agreement with [2]. Generally it can be stated that each threadlockers reach strength guaranteed by manufacturer in 1 or 3 hours, and strength increases with a smaller but not negligible value till the end of one week after assembling.

Table 2. Regressed logarithmic function parameters and coefficient of determination for then selected cases from those demonstrated on Figures 1 and 2

Threadlocker and celaning		Size	a	b	R2
no cleaning	Loctite 2700	M10	2.11	7.78	0.98
	Loctite 2700	M16	37.51	0.50	0.90
	Loctite 2700	M20	36.83	27.04	0.95
	Loctite 2400	M20	3.39	4.39	0.95
	AJett	M16	10.71	62.49	0.78
decontaminated	Loctite 2700	M10	2.41	8.82	0.82
	Loctite 2700	M16	41.47	0.79	0.93
	Loctite 2700	M20	36.67	31.46	0.95
	Loctite 2400	M20	3.73	9.15	0.97
	AJett	M16	16.39	65.49	0.87

CONCLUSIONS

Generally, it is advisable to use cleaner before applying threadlockers. In case of AJett 126 threadlocker the mean value of loosening torque was approximately equal to Loctite 2700 with cleaning. So when using AJett 126 cleaning may be considered to be omitted for the sake of save time and energy.

Our experiments justified that loosening torque increases with thread size. This arises from the simple fact that the larger is the thread size the larger is the contacting surface.

For M16 thread AJett 126 threadlocker was also tested, and showed larger loosening torque.

AJett 126 has the shortest curing time, which has the advantage that curing finishes completely till the end of assembpling, so the bond will not be damaged during storage and transport.

Industrial users are more and more constrained by laws for applying health and safety (H&S) materials without any danger-signal on their data sheets instead of recently widely used materials with risks for health and environment. Loctite 2400 and Loctite 2700 are such H&S materials. The price of safety is usually the longer curing time especially on inactive (e.g. galvanized) surfaces, and any pollution makes weaker the strength of the bond.

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