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# Main Aspects Regarding the Screw-on Torque Diminishing when Using the Fine Pitch Screw

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## Abstract

*Romanian special standards – according to international (ISO) ones – show metric threads of common use for this kind of screw elements (bolts, nuts); there are a lot of standardized and un-standardized variants and also for any mechanical threaded pieces. In usual practice, the threads are executed with normal (standard) pitch. Other cases, when fine pitch in choose, there are some functional behaviour, besides all the dimensional particularities. All these cases, the screw-on torque are significantly diminished given the situation of standard pitch use.*

*The paper delivers here a theoretical analyze of functional thread characteristics and also brings some other lucrative results for mechanical design practice.*

**Key words:** *screw-on torque, thread characteristics, thread friction, pitch*

## Preliminary Considerations

The threaded joints are some of the most used assemblies for mechanical structures thanks to their multiple advantages. Among these, the costs and simplicity of execution or some other lucrative properties recommend threaded connections for many joint solutions.

These assemblies can be designed in two fundamental solutions:
- using two conjugate parts, with inner and outer threads;
- using screw dedicated machine elements, on bolt-nut pair type.

Both of fastening threads comprise metric threads (coarse or fine) and inch threads, on right or left hand [1], [6], [8] and [9].

Romanian Standard STAS 510-74 (accorded to ISO normative) gives o lot of metric thread options, in the large domain of **M2.5**…**M140** [7], [8], [9]. Here is chosen the sample domain of this analyze, from **M10** to **M24**. The M15 and M17 sizes were excluded, as irrelevant.

## Theoretical Fundamentals

The Machine Elements theory shows the way of screw-on torque calculus; the toque moment ($M_{ts}$) can be considered by two fundamental parts: a part of torque ($M_{tf}$) is dedicated to frictional

consumption in the threaded zone, the second part ($M_{tf}$) is dedicated to the bearing zone (of the nut, bolt, shoulder or any equivalent part).
Put in equation, this composite torque means:

$$M_t = M_{tf} + M_{bf} \tag{1}$$

This study means to analyze the first torque part, $M_{tf}$, its behavior when other than normal thread pitch has to be used. It goes without saying a torque decrease, but, how deep? Which are the main influences?

The thread sizes selected are: **M10, M11, M12, M14, M16, M18, M20, M22** and **M24**.
It's well known that frictional part of the torque $M_{tf}$, for the bolt-nut contact, can be expressed by equation:

$$M_{tf} = F_o \cdot \frac{d_2}{2} \cdot \mathrm{tg}\left(\alpha_m + \varphi'\right) \tag{2}$$

The angular values of helix angle $\alpha_m$ refers at thread slope (fig. 1. *a*) and $\varphi'$ is the frictional reported angle (fig. 1. *b*). Their equations are also, well known:

$$\alpha_m = arctg \frac{p}{\pi \cdot d_2} \tag{3}$$

and

$$\mu' = arctg \frac{\mu_t}{\cos \frac{\beta}{2}} \ , \tag{4}$$

where $d_2$ is average thread diameter, $\mu_t$ is threaded zone friction factor and $\beta$ is the 60° angular profile for all metric **ISO** threads [7], [8], [9].

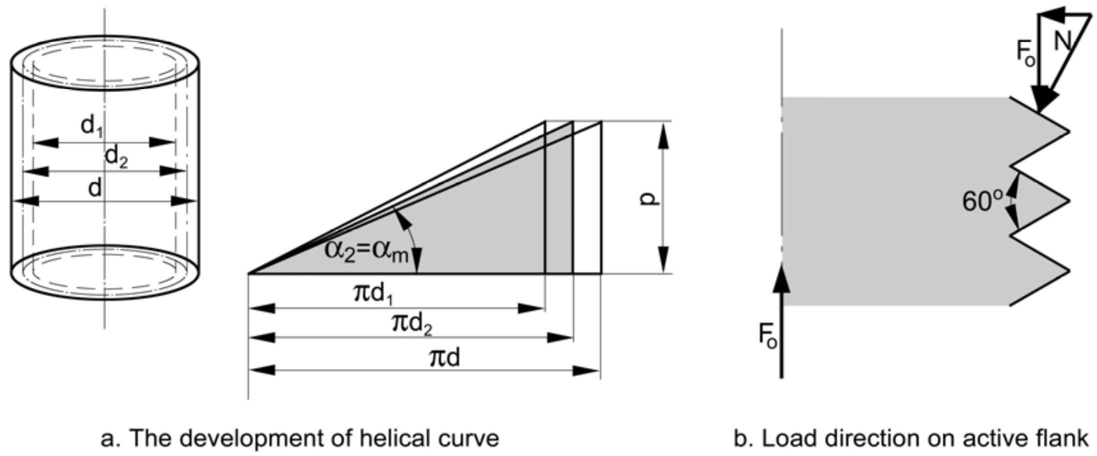


**Fig. 1.** The development of the helical curve of the medium thread cylinder and the load direction on the active flank of the thread

Every thread size of the upper domain in analyze has a few pitch values as option; each of them determines different values of the $\alpha_m$ helix angle. More than this, the angular sum $\left(\alpha_m + \varphi'\right)$, that must be next determined, depends of $\mu_t$ friction factor.

For the following iterative calculus there are 3 friction factor values to consider here: $\mu_t$ =0.11, 0.13 and 0.15, which are correspondent of some usual thread surface roughness. For each case, there are $\varphi'$ calculated values.

The firs step of determination brings as result the values of $\alpha_m$, $\varphi'$ and $\left(\alpha_m + \varphi'\right)$ angles, for any size of domain. The table 1 shows only a sample, brought for **M20** dimension.

**Table 1.** Calculated values of particular angular elements

| Standard thread size | Thread specific dimension | | | Frictional reported angle, $\varphi'$, calculated for following $\mu_t$ values, [grd]: | | | Angular sum $\left(\alpha_m + \varphi'\right)$, calculated for following $\mu_t$ values, [grd]: | | |
|---|---|---|---|---|---|---|---|---|---|
| | $p$ | $d_2$ | $\alpha_m$ | $\mu_t$ =0.11 | $\mu_t$ =0.13 | $\mu_t$ =0.15 | $\mu_t$ =0.11 | $\mu_t$ =0.13 | $\mu_t$ =0.15 |
| **M20** | **2.5** | 18.376 | 2.480 | 7.239 | 8.537 | 9.827 | 9.719 | 11.017 | 12.307 |
| | 2 | 18.701 | 1.950 | | | | 9.189 | 10.487 | 11.777 |
| | 1.3 | 19.026 | 1.438 | | | | 8.677 | 9.975 | 11.265 |
| | 1 | 19.350 | 0.942 | | | | 8.181 | 9.479 | 10.769 |
| | 0.75 | 19.513 | 0.701 | | | | 7.940 | 9.238 | 10.528 |
| | 0.5 | 19.675 | 0.463 | | | | 7.702 | 9.000 | 10.290 |

## Considerations on the Screw-on Torque

The thread-frictional part of the screw-on torque, expressed by relation (2) can also be put in a synthetic form [7]:

$$M_{tf} = k_t \cdot F_0 \qquad (5)$$

The *thread constant*, $k_t$ – in [mm] – is exclusively dependent [7] on thread dimensional characteristics:

$$k_t = \frac{d_2}{2} \cdot \mathrm{tg}\left(\alpha_m + \varphi'\right) \qquad (6)$$

For each typo-dimensional size (**M10**…**M24**), its values can be separately calculated. Certainly, as smallest the thread pitch in use, the most reduced constant $k_t$ values to get. And, by consequence, *the most reduced screw-on torque values are got*.

It is quite explicit that the torque diminishing (reduction) – when using a fine pitch of the thread, replacing the standard pitch – is similar to the thread constant values diminishing. The effective *rate of torque reduction* is calculated by formula:

$$\rho = \frac{M_{tf,standard\ pitch} - M_{tf,fine\ pitch}}{M_{tf,standard\ pitch}} \ [\%] \qquad (7)$$

Than, it's naturally right to consider the equation (5) and the *rate of torque reduction (ρ)* can be put in a similar form:

$$\rho = \frac{k_{t,standard\ pitch} - k_{t,fine\ pitch}}{k_{t,standard\ pitch}} \ [\%] \qquad (7')$$

After all de calculus steps are done, the torque reductions are determined, for all the thread sizes considered in this paper. The table 2 presents the calculated values of thread constant $k_t$, and rate of torque reduction (ρ) for those frictional values.

Here are selected – as representative samples – only some of these results for typo-dimensions of **M18**, **M20**, **M22** and **M24**.

**Table 2.** The calculated values of thread constant $k_t$, and rate of torque reduction ($\rho$)

| Thread size | Angular factor $(\alpha_m + \varphi')$, for | | | Medium diameter, $d_2$ [mm] | Thread constant, $k_t$, calculated for [mm] | | | Torque reduction rate, $\rho$, calculated for [%] | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | $\mu_t$ =0.11 | $\mu_t$ =0.13 | $\mu_t$ =0.15 | | $\mu_t$ =0.11 | $\mu_t$ =0.13 | $\mu_t$ =0.15 | $\mu_t$ =0.11 | $\mu_t$ =0.13 | $\mu_t$ =0.15 |
| **M18** | 0.177 | 0.200 | 0.224 | 16.376 | 1.149 | 1.638 | 1.834 | - | - | - |
| | 0.166 | 0.189 | 0.213 | 16.701 | 1.386 | 1.578 | 1.778 | **4.3** | **3.7** | **3.1** |
| | 0.156 | 0.179 | 0.202 | 17.026 | 1.328 | 1.524 | 1.720 | **8.4** | **7.0** | **6.2** |
| | 0.146 | 0.169 | 0.192 | 17.350 | 1.267 | 1.466 | 1.666 | **12.6** | **10.5** | **9.2** |
| | 0.141 | 0.164 | 0.187 | 17.513 | 1.235 | 1.436 | 1.637 | **14.8** | **12.3** | **10.7** |
| | 0.136 | 0.159 | 0.183 | 17.675 | 1.202 | 1.405 | 1.617 | **17.1** | **14.2** | **11.8** |
| **M20** | 0.171 | 0.195 | 0.218 | 18.376 | 1.571 | 1.792 | 2.003 | - | - | - |
| | 0.162 | 0.185 | 0.208 | 18.701 | 1.515 | 1.730 | 1.945 | **3.6** | **3.5** | **2.9** |
| | 0.153 | 0.176 | 0.199 | 19.026 | 1.455 | 1.674 | 1.893 | **7.4** | **6.6** | **5.5** |
| | 0.144 | 0.167 | 0.190 | 19.350 | 1.393 | 1.616 | 1.838 | **11.3** | **9.8** | **8.2** |
| | 0.139 | 0.163 | 0.186 | 19.513 | 1.356 | 1.590 | 1.815 | **13.7** | **11.3** | **9.4** |
| | 0.135 | 0.158 | 0.182 | 19.675 | 1.328 | 1.554 | 1.790 | **15.5** | **13.3** | **10.5** |
| **M22** | 0.167 | 0.190 | 0.214 | 20.376 | 1.701 | 1.936 | 2.180 | - | - | - |
| | 0.158 | 0.182 | 0.205 | 20.701 | 1.635 | 1.884 | 2.122 | **3.9** | **3.7** | **2.7** |
| | 0.150 | 0.173 | 0.197 | 21.026 | 1.577 | 1.819 | 2.071 | **7.3** | **6.0** | **5.0** |
| | 0.142 | 0.165 | 0.189 | 21.350 | 1.516 | 1.761 | 2.018 | **10.9** | **9.0** | **7.4** |
| | 0.138 | 0.161 | 0.185 | 21.513 | 1.484 | 1.732 | 1.990 | **12.8** | **10.5** | **8.7** |
| | 0.134 | 0.158 | 0.181 | 21.675 | 1.452 | 1.712 | 1.962 | **14.6** | **11.6** | **10.0** |
| **M24** | 0.171 | 0.195 | 0.218 | 22.051 | 1.885 | 2.150 | 2.404 | - | - | - |
| | 0.156 | 0.179 | 0.202 | 22.701 | 1.771 | 2.032 | 2.293 | **6.0** | **5.5** | **4.6** |
| | 0.148 | 0.171 | 0.195 | 23.026 | 1.704 | 1.969 | 2.245 | **9.6** | **8.4** | **6.6** |
| | 0.141 | 0.164 | 0.187 | 23.350 | 1.646 | 1.915 | 2.183 | **12.7** | **10.9** | **9.2** |
| | 0.137 | 0.161 | 0.185 | 23.513 | 1.611 | 1.893 | 2.175 | **14.5** | **12.0** | **9.5** |

Then, using these results we transcript all on graphics, shown in figures, as follows: figure 2 for threads **M10** and **M12**, figure 3 for **M14** and **M16**, figure 4 for **M18** and **M 20** and figure 5 for **M22** and **M24**.

The calculated values of the screw-on torque – for all threads in domain **M10-M24**, standard and fine pitches – pointed out the following aspects:

- the torque values (thread friction part) are in proportion to thread constant, $k_t$, as much as its reduction rate;
- using a fine pitch thread instead of standard (normal) pitch always determines a screw-up torque diminish;
- in proportion of finest thread pitch choice, frictional torque is more diminishing;

- the calculated torque reduction rate found values ($\rho$) are in the field of 2% to 17%; these limits were established for thread friction factor in domain of 0.11 to 0.15;
- the average values of the torque reduction rate are in the following fields:
  - if $\mu_t = 0.11$, reduction rate is $\rho = 5…15\%$;
  - if $\mu_t = 0.13$, reduction rate is $\rho = 4…12\%$;
  - if $\mu_t = 0.15$, reduction rate is $\rho = 3…10\%$;
- if the thread friction factor is smaller – values towards $\mu_t$=0.7…0.8, corresponding on fine thread rugosity – the torque reduction rate will increase to 20-25%;
- if these statistic determination will be extended to some other ISO thread dimensions, the variation keep the same rule.

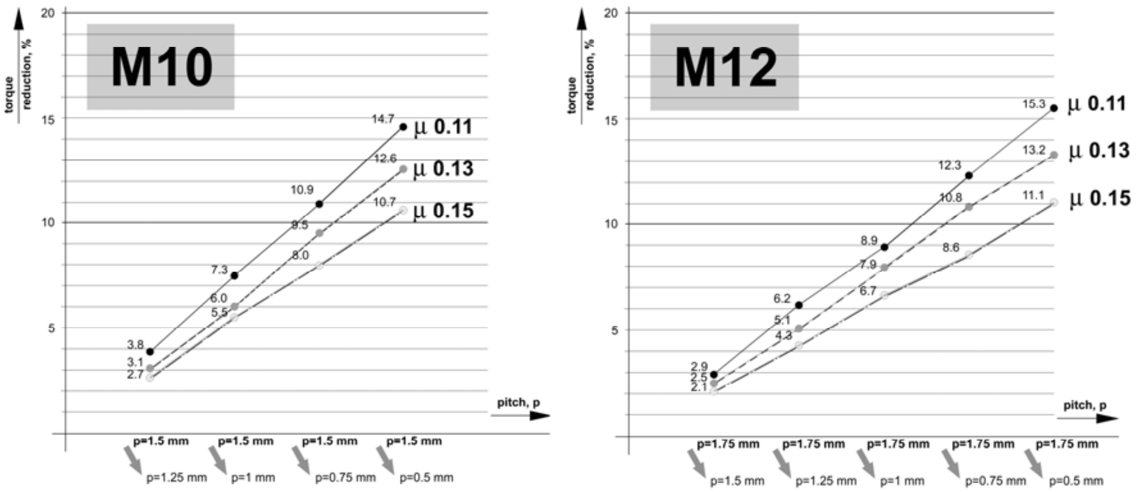


**Fig.2.** The screw-on torque reduction, when using fine pitch for **M10** or **M12** thread

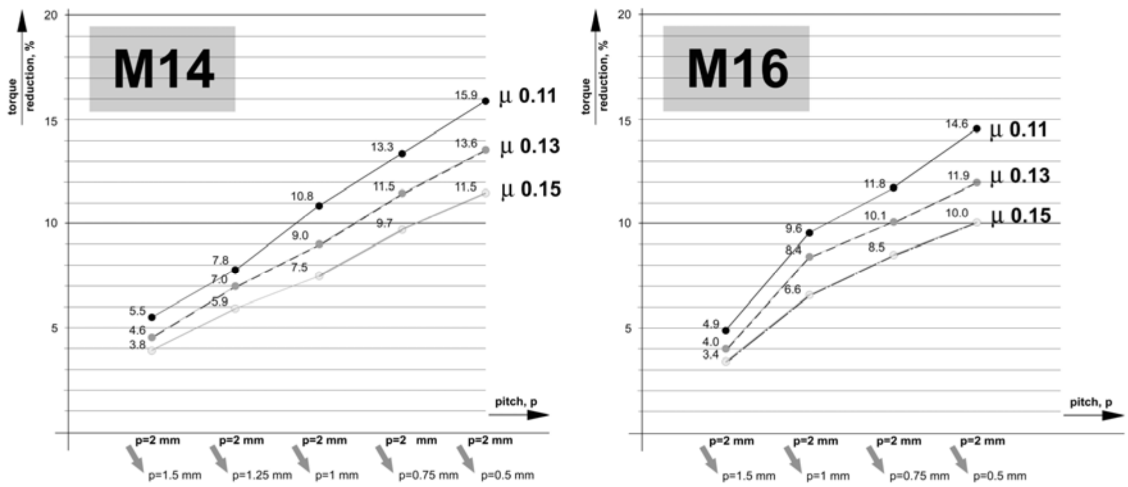


**Fig. 3.** The screw-on torque reduction, when using fine pitch for **M14** or **M16** thread

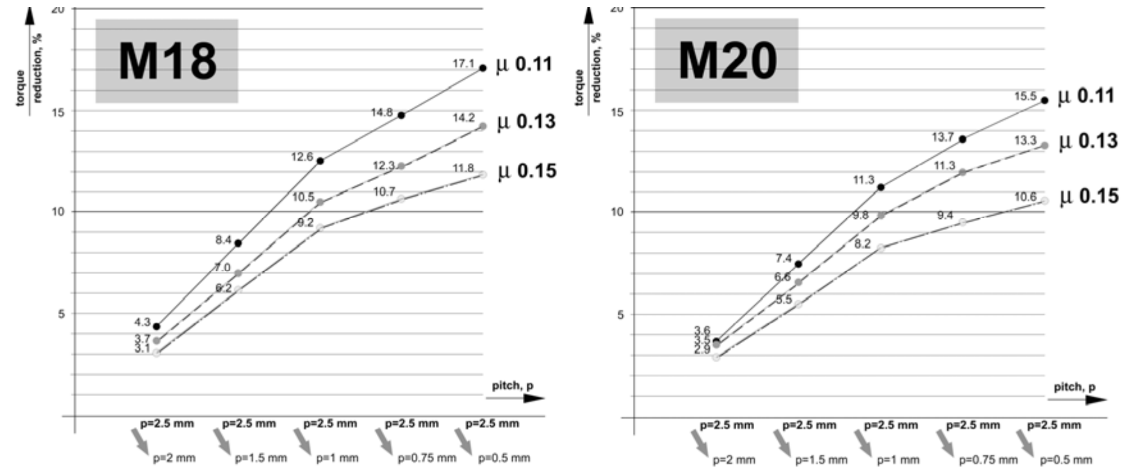


**Fig. 4.** The screw-on torque reduction, when using fine pitch for **M18** or **M20** thread

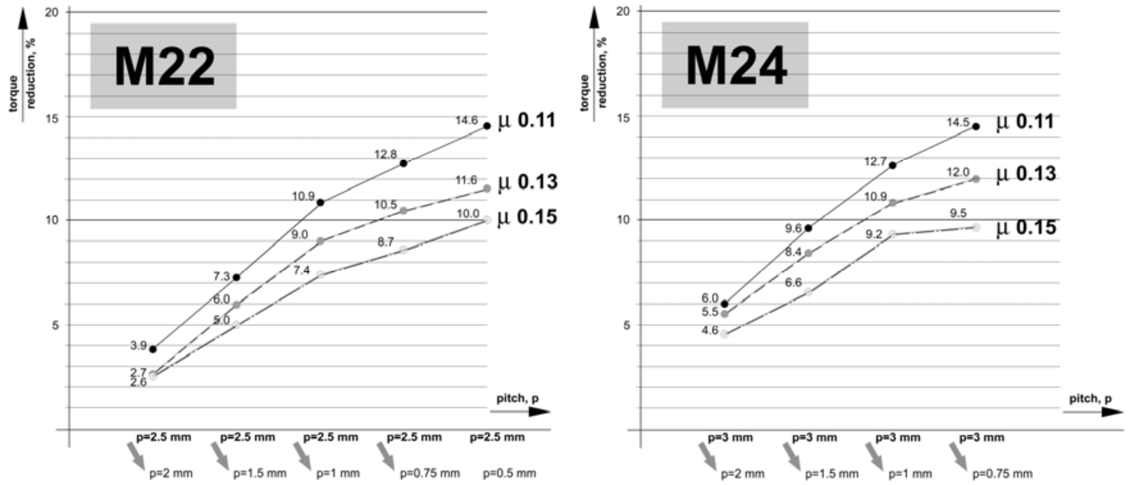


**Fig.5.** The screw-on torque reduction, when using fine pitch for **M22** or **M24** thread

## Conclusion

The analysis of functional thread characteristics, directed on screw-on torque behaviour, brings several relevant conclusions:

- Changing a threaded joint that uses normal pitch with size, but finer pitch, the screw-on torque becomes smaller, as the fineness of the thread pitch is.
- The screw-on torque reduction depends on thread friction factor ($\mu_t$); for usual values from 0.11 to 0.15, torque diminish is in the field of 2% to 17%.
- In the same case, but if the frictional condition corresponds on higher surface fineness, screw-on torque reduction gets to 25%.
- The average values of the torque reduction rate are in the following fields:
  - if $\mu_t = 0.11$, reduction rate is $\rho = 5\ldots15\%$;
  - if $\mu_t = 0.13$, reduction rate is $\rho = 4\ldots12\%$;
  - if $\mu_t = 0.15$, reduction rate is $\rho = 3\ldots10\%$.

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# Aspecte privind diminuarea momentelor de înşurubare a elementelor filetate standardizate echipate cu filet cu pas fin

## Rezumat


*Standardele româneşti de specialitate – în acord cu cele internaţionale (ISO) – tratează filetele metrice de uz general, care sunt folosite în execuţia organelor de maşini tip (şuruburi, piuliţe), în variantele standardizate sau nestandardizate şi a filetelor diverselor piese mecanice.*

*Filetele folositeîn practică sunt executate, cel mai frecvent, în varianta cu pas normal. Variantele de filete cu pas fin au însă, dincolo de particularitatea dimensională, o comportare diferenţiată în exploatare. Momentele de înşurubare aplicate pentru asamblarea acestora sunt, în cazul filetelor cu pas fin, diminuate faţă de cele cu pas normal. Articolul face deci o analiză teoretică a acestor particularităţi funcţionale ale filetelor, aducând apoi o serie de rezultate practice privind calculul momentelor de înşurubare.*