

THEORETIC AND TECHNOLOGICAL ASPECTS OF THREAD ROLLING

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ABSTRACT

In this contribution is introduced thread rolling method by means of rolling tools applied on universal machine tool. The thread is regarded as a constructional-technological element of engineering parts such as plugs, shafts, guide-bolts, etc. Rolling process is realized in a technological rolling system where on the start of the process is semi-product and on the output is rolled thread. We have done analysis regarding to requirements on material properties, shape a dimension of an initial semi-product for rolling. Reached parameters of rolled threads are quantified and circumstantiated by results of experiments. The contribution contains practical recommendation concerning thread rolling usage in a manufacturing process of engineering parts.

1. INTRODUCTION

Thread rolling runs among three non-powered discs with toroidal thread profiles that are swing out upon lead angle. Profiles of discs are moved among themselves upon third of lead. We have done analysis of theoretical aspects related to half-finished product, rolling conditions and rolled thread.

2. TECHNOLOGICAL PROPERTIES OF SEMI-PRODUCT MATERIAL

Thread rolling is realized via cold forming. With this fact bears specific requirements on material properties that can be expressed by tensile strength, yield point and modulus of elasticity.

For appreciation of material behavior upon thread rolling is often necessary to consider specific deformation dependencies on appropriate loading curves that comport with material creeping.

For thread rolling are specified these basic requirements on material of half-finished product

$$R_m \leq 900 \text{ MPa} \quad A_{10} > 8\%.$$

However, these conditions were many times overcome practically. Rolling property of material as a technological property is not definitely quantified until these days. Thus, usually for a concrete case is necessary to make an initial analysis. Considering to stated facts is possible to express rolling property concerning definite standard material similarly like upon machinability.

Thread rolling on hardened parts is usually made before hardening. If functional requirements require thread part to be soft then inductive annealing follows. Upon parts that are case-hardened can be on thread section left so-called case-hardening allowance which would be removed after case-hardening. Then will succeed hardening. Thread is rolled as last operations of production.

3. POSSIBILITIES OF THEORETICAL DIAMETER DETERMINATION OF SEMI-PRODUCT

Diameter of semi-product is necessary to set up so that upon rolling would be available as much material as it is required for full profile creation. Rolling process is significantly influenced by technological conditions, namely by speed and rolling environment. Upon absence of material points of thread are not fully created. Upon excess of material points of thread are over-rolled, rolling tool is overloaded and can happen an axial extension of thread part and due to lead deviation. Diameter of semi-product can be technologically identified as theoretical value, nominal value and limiting deviations.

Value of a theoretical diameter of semi-product d_{pt} can be expressed by virtue of characteristic dimensions of rolled thread. Material volume that rolling tool pushes out from semi-product body must be equal to material volume that runs out over the surface of semi-product – volume equivalence. Practically (with certain approximation, of course) we sometimes operate with equivalence of surfaces in the axis profile of thread – area equivalence.

Upon determination of theoretical diameter d_{pt} we usually proceed of theoretical profile of thread. For metric thread is the theoretical profile marked on picture No. 1.

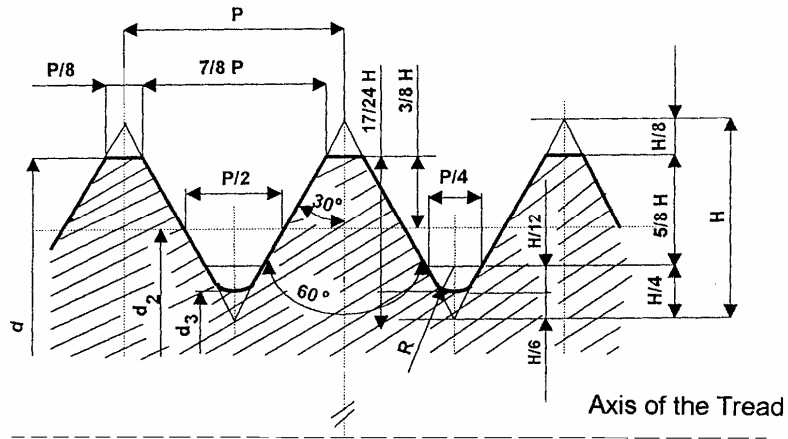


Fig. 1. Theoretical profile of metric thread ČSN 01 4008, ČSN 01 4013

- d - major diameter of the thread [mm]
- d_2 - pitch diameter of the thread [mm]
- d_3 - minor diameter of the thread [mm]
- P - lead of the thread [mm]
- H - depth of basic profile [mm]

Upon presumption of area equivalence we proceed of ratios that are stated on picture No. 2. Surface of thread in the axis profile S_z can be expressed as :

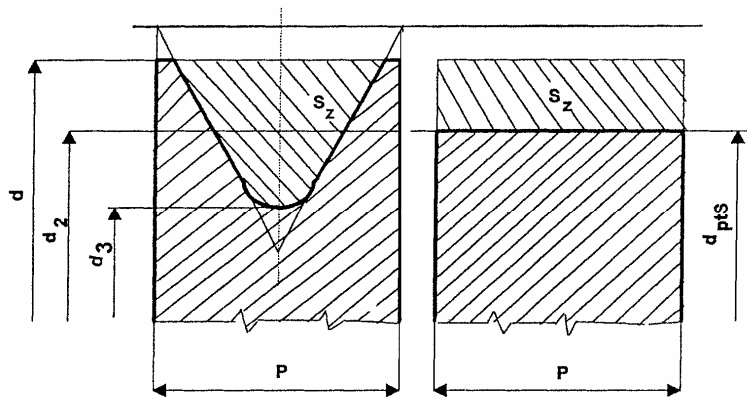


Fig. 2. The calculation of teoretical diamater of semi-product d_{pts} through area equivalence
 S_z - area of thread in the axis profile

$$S_z = 0,31726 P^2 \text{ [mm}^2\text{]} \tag{1}$$

Theoretical diameter of semi-product d_{ptS} is determined as follows :

$0.5 (d - d_{ptS}) \cdot P = 0,31726 P^2$ after modification we can write :

$$d_{ptS} = d - 0,63425 P \text{ [mm]} \quad (2)$$

For example : for M10 ($P=1,5$; $d_2=9,026$ mm) is $d_{ptS} = 9,04822$ mm

Upon volume equivalence we proceed of ratios that are stated on picture No. 3. Volume thread in the axis profile V_z is for $S_{zn} = S_z \cdot \cos \varphi$ expressed as :

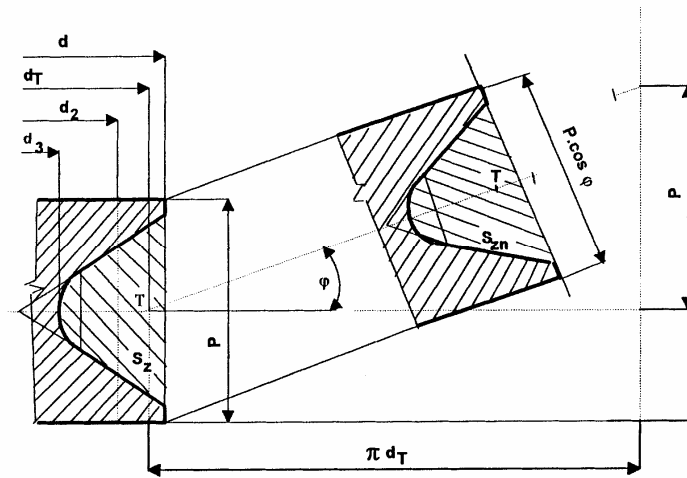


Fig. 3. The calculation of teoretical diameter of semi-product d_{ptV} through volume equivalence

S_z - area of thread in the axis profile [mm²]

S_{zn} - area of thread in the base profile [mm²]

d_T - diameter of the position centre gravity T in the area S_z [mm]

φ - angle lead of thread on the diameter d_T [°]

$$V_z = \pi \cdot d_T \cdot S_z$$

For example stated above is :

$$d_T = d - 0,46924 P$$

$$S_z = 0,31726 P^2$$

After modification we can write :

$$V_z = (d - 0,46924 P) \cdot 0,99670 P^2 \quad (3)$$

Theoretical diameter of semi-product for volume equivalence d_{ptV} is expressed by virtue of equality of thread volume in the axis profile V_z and corresponding material volume of semi-product V_p :

$$V_z = V_p = 0,25 \pi (d^2 - d_{ptV}^2) P$$

$$d_{ptV} = [d^2 - 1,26903 d \cdot P + 0,59547 P^2]^{0,5} \text{ [mm]} \quad (4)$$

For example, for M10 ($P=1,5$; $d_2=9,026$ mm) is $d_{ptV} = 9,07548$ mm

4. CALCULATION OF NOMINAL VALUE OF SEMI-PRODUCT DIAMETER

In production proceeding is necessary to specify nominal value of semi-product diameter d_{pM} and relevant limiting deviations. Regarding technological conditions of thread rolling is generally valid :

$$d_{pM} < d_{pt}$$

For example, supplier of thread-rolling die heads Narex a.s. Prague and some other authors recommend for calculation of nominal value of semi-product diameter for metric thread following equation :

$$d_{pM} = d - 0,67726 P \quad (5)$$

This value is really close to d_{ptS} value determined according to (2).

5. LIMITING DEVIATIONS OF SEMI-PRODUCT DIAMETER, SHAPE AND SURFACE ROUGHNESS

Limiting deviations of diameter should correspond to requirements of rolling process but also to real possibilities of economical machining accuracy on machining tool. Roughly can be recommended so as limiting deviations should have toleration appropriate to tolerance zone marked as h9.

Semi-product will be provided by entering and outgoing cone due to easier enter of thread discs as well as due to limitation of entering profiles abrasion on discs. Function of outgoing cone can be replaced by appropriate necking-down. It depends on structure of the part. Recommended shape and surface roughness of semi-product for rolling are stated on picture No. 4.

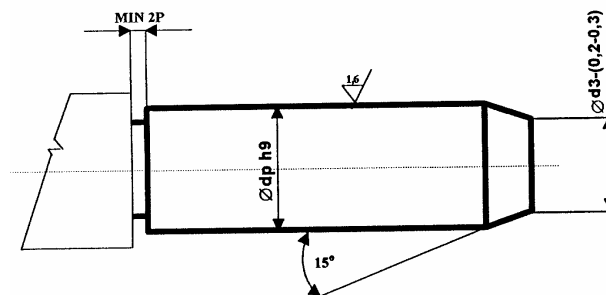


Fig. 4. The form and roughness of semi-product recommended for the metric thread rolling

6. EXPERIMENT AND ITS CONDITIONS

Thread rolling is performed upon relatively high rolling speed when an optimal state of material creeping is achieved. Upon low rolling speed unfavorable extension of thread body as well as imperfect plastic flow in thread top are reached. Rolling speed also has a significant influence on rolling discs abrasion, on quality of rolled thread and rolling productivity.

For example, for metric thread rolling at steel up to $R_m = 700$ MPa is recommended rolling speed 40 till 80 $m \cdot min^{-1}$, for aluminum alloys 70 till 100 $m \cdot min^{-1}$. Thread rolling M10 upon speed 60 $m \cdot min^{-1}$ is realized at 1910 turns/min. Usage of such high turns on standard machining tool may causes some problems. It is necessary to operate with lower turns.

Application of rolling environment bears on high forming speeds that lead to high amount of heat formation. An optimal temperature of rolling discs should be between 30 till 45°C.

Recommended rolling environment is oil OR P 32 CF (P3), for example, with flowage of 5 till 20 $dm^3 \cdot min^{-1}$ in dependency on technological conditions and size of rolled thread.

On author's workplace were done partial comparison of functional parameters of metric thread M7 upon application of cutting and rolling technologies.

Technological conditions:

Machine tool	General-purpose lathe SV 18R
Material	steel 12 050.1
Thread cutting ČSN 24 1540	screw die head, automatic size II (M6 – M14) cutting speed – 8 $m \cdot min^{-1}$ cutting emulsion
Thread rolling	thread-rolling die head Zhv 6 – 10 rolling speed 12 $m \cdot min^{-1}$ oil OR P 32 CF

For microstructure and strain hardness appreciation of thread profile metallographic samples have been processed. Prepared samples were pressed to preparation plastic, cutting surface was grinded by metallographic grinding papers and polished by diamond pastes. The surface was etched by 2% solution of nitric acid dissolved in ethyl alcohol (etching agent Nital). Valuation and foto-documentation of microstructures were done on light microscope ZEISS NEOPTON 2 upon magnification 50-times and 100-times. Micro-hardness was measured by device M-400 LECO upon 25g loading for the duration of 15 seconds. Grain size was determinated by virtue of comparison method according to ČSN 42 0462. Metallographic pictures cut and rolled thread are stated on picture No. 5.

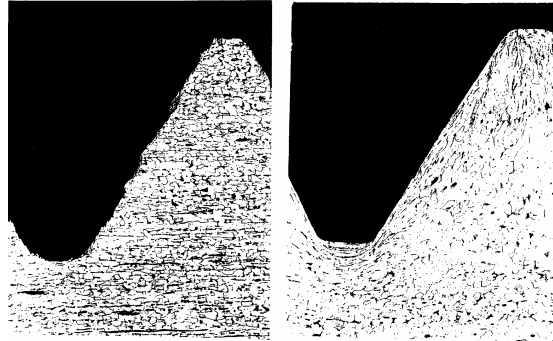


Fig. 5. The microstructure of thread profile - metric thread M7 - scaled up 100 x
a) cut thread b) rolled thread

7. RESULTS OF EXPERIMENTS

On cut thread – pict. No. 5 – microstructure consists of mixture of very fine grains of ferrite (light) and pearlite (dark). These grains have size no. 9 according to ČSN 42 0462., it means mean diameter is 0,015 mm. Fibrousness of the structure is apparent, it is result of rolling process. Extended non-metallic inclusion are directed facing the plastic flow of material. On functional surface of the thread are evident disparity and fractures of cutting process. Thread cutting was not attached with clear plastic deformation of surface layer. This fact was confirmed by microhardness which was measured at hollow of thread, value HV 0,025 = 190.

Microstructure of rolled thread consists of mixture of very fine grains of ferrite and pearlite. These grains have size no. 8 according to ČSN 42 0462., it means mean diameter is 0,022 mm. Also this microstructure has outstanding texture highlighted with non-metallic inclusions extended facing the plastic flow of material upon rolling. Functional surfaces of rolled thread show markedly higher surface quality than in case of cut thread.

Thread rolling is guided with plastic deformation of material that raises a strain hardness of surface layers. For viewed thread are values of micro-hardness at hollow of thread profile compiled at diagram on picture No. 6.

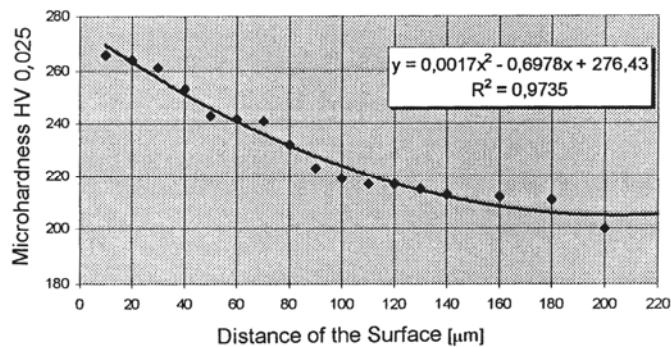


Fig. 6. The microhardness HV 0,025 - distance dependency of the surface from the bottom of thread profile - M7

Strain hardness due to plastic deformation upon thread rolling is shown at area of hollow till distance of 0,2 mm from surface. In distance of 0,01 mm from surface the micro-hardness achieves a maximal value of 266, it means approx. 1,3 multiple of micro-hardness of the material that was not affected by plastic deformation. Hardening on sides of thread profile shows lower values, micro-hardness in distance of 0,01 mm from surface is HV 0,025 = 220 and in longer distances is not apparent.

8. CONCLUSION

Rolling of external threads has at nowadays production technology of rotary shaft parts significant use considering reached productivity and production quality. Rolled threads show important improving of functional parameters compared to cut threads. Among these parameters belong namely continuous run of fibers, higher strength of thread profile, lower roughness value, higher dimensional accuracy and as well as higher abrasion and corrosion resistance. Application of thread-rolling die heads on standard, respect. numerically controlled machine tools allow production of these parts in one setting. Requirement on rolled thread would be suitable to specify already at construction documentation.

9. REFERENCES

- [1] KŘÍŽ, R. – VÁVRA, P. : Mechanical engineering guide. 7-th volume. SCIENTA, Ltd., Prague. 1996
- [2] VÝKRUTA, J. : Thread rolling by thread-rolling die heads. SNTL Prague. 1964
- [3] SVOBODA, K.: Thread rolling tools. Technik, 1988, volume V, no.1, p. 14 - 15.
- [4] Thread-rolling die heads. Instruction guide. NAREX a.s. Prague

TEORETSKI I TEHNOLOŠKI ASPEKI VALJANJA NAVOJA

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REZIME

Primena glava za valjanje na standardnim mašinama obezbeđuje izradu navoja na veoma efikasan način.

U ovom radu prikazana je metoda valjanja navoja pomoću alata montiranih na univerzalne mašine alatke. Navoj se tretira kao konstrukciono-tehnološki element jednog enžinjskog dela. Proces valjanja ostvaruje se u tehnološkom sistemu valjanja gde je na ulazu poluproizvoda na izlazu iz sistema valjani navoj. Urađene su analize sa aspekta zahteva u odnosu na materijal, oblik i dimenzije početnog polufabrikata. Dobijeni podaci su kvantifikovani i potvrđeni kroz eksperimente. U radu su date i praktične preporuke u vezi primene metode valjanja navoja u metalnoj industriji.

Rad je struktuiran u sledeća poglavlja: 1.) Uvod, 2.) Tehnološke karakteristike materijala polufabrikata, 3.) Mogućnosti teoretskog određivanja prečnika polufabrikata, 4.) Izračunavanje nominalne vrednosti prečnika polufabrikata, 5.) Granična odstupanja prečnika polufabrikata, oblika i hrapavost površine, 6.) Eksperiment i uslovi eksperimenta, 7.) Rezultati eksperimenta, 8.) Zaključak

Tehnologija valjanja spoljnih navoja dostigla je visok nivo u proizvodnji metalnih delova. Valjani navoji odlikuju se sa niz prednosti u odnosu na navoje dobijene skidanjem strugotine; kvalitetan tok materijala, bolje mehaničke osobine valjanog profila, veća tačnost i kvalitet, veća otpornost na habanje.