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PHYSICAL MODELING OF CAST IRON RADIATOR NIPPLE OPPOSITELY DIRECTED THREAD TURN MILLING

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thread turn milling, simulation, lathe, single cutter, thread, eccentric workpiece fixing.

ABSTRACT

The paper covers a single cutter lathe thread turn milling simulation that significantly reduces physical testing costs. The turn milling process involves a synchronized tool (helical mill), and workpiece rotation with a radial oncoming feed through a mill and workpiece relative movement. The cutting rate occurs by the mill teeth movement over the workpiece. The machining depth in each pass varies from zero to the max value, a common milling process feature. The proposed approach simulates the process parameters through thread turning or incomplete circular groove turning of workpieces attached off-center to a lathe tooling. The proposed turn milling simulation method has reduced the number of machined referenced parts by 710 times. Accordingly, the experimental research period and cost have also been reduced. The research has revealed that the VK6M hard alloy tool life in turn milling with coolant is 50 times longer than the R6M5 HSS tool life while the useful tool life (measured as the number of parts machined within the tool life) for VK6M tools in turn milling with coolant is 50 times higher than that of R6M5 HSS tools.

Introduction

Cast iron sectioned radiators are extensively used for heating of residential and industrial high-rise buildings. The heat transfer fluid temperature in such buildings is up to 130 °C (i.e. in steam heating systems), the operating manometric pressure is up to 1.2 MPa. To ensure structural strength, the minimal test pressure for the radiators is 1.8 MPa.

Cast iron radiators were introduced over a hundred years ago. Initially they were used in steam heating, and then in centralized water heating systems. The classic MS-140 Soviet-design cast iron radiators are installed in many Russian buildings.

The cast iron radiator benefits are high reliability and long service life (over 50 years). A radiator consists of several sections made of high quality foundry iron. Radiator sections are made from high-quality cast iron and connected with nipples from malleable cast iron. Due to a large throat diameter, cast iron radiators are tolerant to poor heat fluid quality. They are suitable for contaminated water commonly used in Russian centralized heating systems. Their hydraulic resistance is low for the same reason. Thick walls and cast iron's chemical properties make the radiators corrosion-resistant. It is a huge benefit

Fig. 1. A radiator nipple

in summer as the water is drained and the dried radiator is exposed to rust. Cast iron radiators are the cheapest option. The only exception are design radiators with complicated cast decorations: they are much more expensive.

Such radiators are manufactured worldwide: in the UK (Gothica); China (KONNER); Germany (GURATEC); Italy (Roca); Turkey (Demir Dokum); Belarus (Minsk); Ukraine (Lugansk); Russia (Bryansk, Cheboksary, Lyubokhna, Nizhny Tagil). Adjacent radiator sections are connected with special parts having oppositely directed threads called “radiator nipples”. They have LH and RH NPT thread on the ends $G1\frac{1}{4}''$. The nipples are made of KCh 30-6f malleable ferrite cast iron (**Fig. 1**).

Cutting oppositely directed threads make the nipple manufacturing process more complicated and labor-intensive.

The threading with a helical tool involving a simultaneous synchronized tool and workpiece rotation was presented by S.I. Skukhtorov and V.N. Khlunov in 1941 in the Manufacturing Engineer magazine [1]. They proposed an efficient thread cutting process with a helical generating surface tool. In the process both a workpiece and a tool are synchronously rotated (D_t and D_{tool} movements, correspondingly) about their respective parallel axes. They also have an approaching motion D_t with the equal axis steps P_o of the tool and P of the surface being machined. The ratio k is constant and equals to one. A thread is cut over the entire length at once and without any axial feed as the $\vec{V}$ and $\vec{V}_D$ surface velocities of a tool point and a point on the surface being machined are oppositely directed at the contact area (**Fig. 2**).

In 1971 V.V. Lotsmarenko proposed a method for determining a generatrix profile of the tool for opposed directions of rotation D_{tool} and D_{wp} [2]. In 1978 “Traub” company (Germany) equipped its turning-revolver machine tools with a dedicated attachment and a tool for external thread milling in brass and light alloys. The tool had a helical generatrix surface.

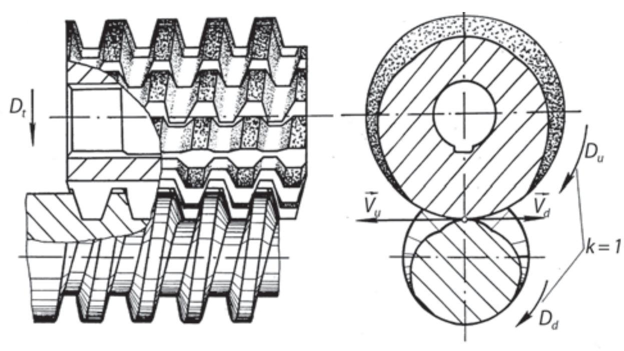

Fig. 2. Thread cutting by a helical tool synchronously rotated with the workpiece

In 1987–1993 V. N. Voronov has developed thread cutting technique with a helical tool [3, 4]. The research has mostly focused on practical implementations of the process. In 1994 E. V. Serova and S. I. Lashnev have developed a geometric theory for creating thread milling tool profiles [4, 5]. D. Yu. Solyankin, A. S. Yamnikov, O. A. Yamnikova [6–8] have investigated the same aspects using 3D simulation with COMPASS 3D CAD software [9].

V. N. Voronov [3, 4] proposed the term “turn milling”. In this process, just like in turning, a workpiece is rotated at high RPM by a lathe while its material is removed with a tool similar to a group thread mill. For the same reason it is clear that the laws of turning and milling cannot be applied to turn milling. There are a number of points requiring further actual experimental research: tool life, cutting force relations.

Hardware-in-the-Loop Simulation

As the above description shows, a turn milling tool is a multi-tooth one. The available experimental data suggest that its service life is extremely long so an experimental approach to determining its service life would take a lot of time, and workpieces. Another difficulty is that the existing equipment would have to be either significantly modernized, or some dedicated equipment would have to be manufactured. Simulation is a way to remove these obstacles [10-18].

Fig. 3 represents an external thread turn milling process.

A D_{mill} diameter mill and a D_{wp} diameter workpiece rotate with equal RPM ($n_{wp} = n_{mill}$) and approach each other at the S_p radial feed. Each mill tooth makes one cut per each workpiece and mill revolution. Thus, in turn milling tooth loading is equal to chip load per revolution $S_z = S_{po}$. Correspondingly, the cut depth is also $t_i = S_{po}$.

Let us consider the turn milling cutting process to develop a simulation method. The analysis of external thread turn milling tool paths [3–6] has shown that a single mill tooth relative path is a R_{tp} radius circle, while $R_{tp} = R_{mill} + R_{wp}$. A single tooth removes a layer with specified length and thickness per each workpiece (and mill) revolution.

To completely machine a thread with the H profile depth the mill (the workpiece) shall make k revolutions:

$$k = \frac{H}{S_{po}}. \qquad (1)$$

To make the experimental research faster and cheaper, we have applied simulation of a turn milling process executed on a lathe with a single-point threading tool.

The experiments have been conducted via physical imitating simulation, when turn milling process has been

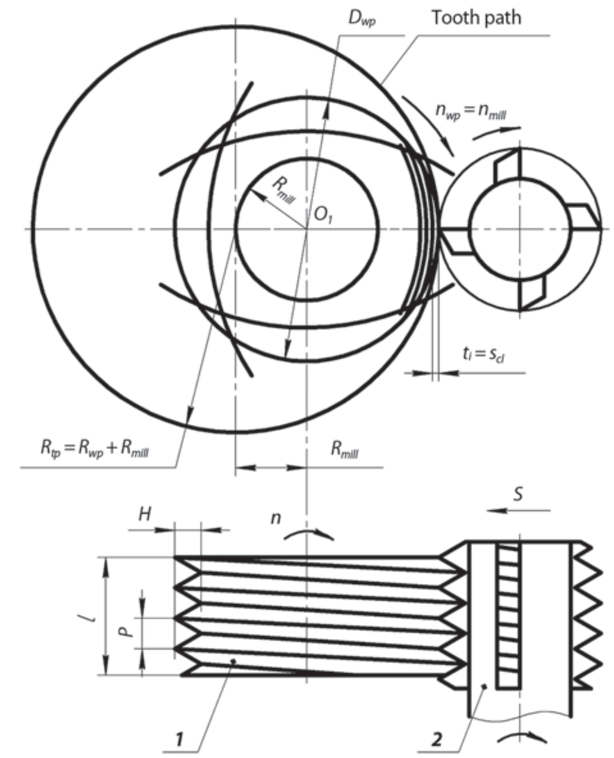

Fig. 3. External thread turn milling

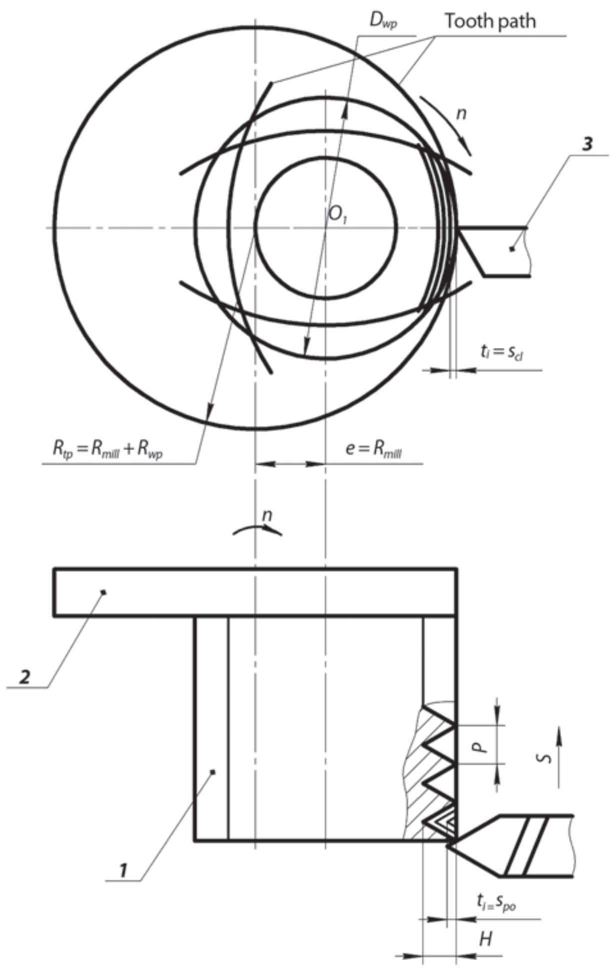

Fig. 4. External thread turn milling simulation

replaced by the milling of eccentrically fixed workpiece (**Fig. 4**).

The workpiece (pos. 1) with its center at O_1 is fixed to the chuck plate (pos. 2), and the chuck plate with the workpiece is rotated about its center O. The single threading tool (pos. 3) is attached to the lathe carriage and is fed.

V. N. Voronov has obtained a parametric mill tooth path equation [3–6]

$$\begin{cases} X_1 = (R-r)\cos\alpha + r\cos 2\alpha, \\ Y_1 = (R-r)\sin\alpha + r\sin 2\alpha. \end{cases} \quad (2)$$

V. N. Voronov has compared this expression to "Pascal snail" curve equation and has concluded that they are identical. Therefore, a relative mill tooth path for the process under consideration (see Fig. 3) shall be a "Pascal snail". Its parametric equation is presented as (2). In implicit form:

$$\left[(x_1+r)^2 + y_1 - 2r(x_1+r)\right]^2 = $$
$$= (R-r)^2\left[(x_1+r)^2 + y_1^2\right]. \quad (3)$$

To provide eccentricity a plate is installed under one of the chick jaws. The plate thickness is

$$b = 1{,}5e\left(1 + \frac{e}{2D_{dp}}\right), \quad (4)$$

where D_{pd} is the primary diameter (workpiece external diameter).

The required arc length of the tooth to workpiece contact has been obtained by changing of the eccentricity.

Thus, the workpiece shall be rotated about the O center point. A single threading tool (pos. 3) is attached to the lathe carriage and is fed. It means that the lathe simulates the turn milling tool movements (same relative movement path radius; similar intermittent machining with the same cycle length; same single cutter path length, same contact length.) The cutting modes and conditions (rpm, feed, depth of cut, cooling) are the same as for the turn milling.

In turn milling process each mill tooth is a thread chaser. As a single workpiece is machined, each single threading cutter of the chaser cuts one thread vee at the corresponding helical surface sector. Therefore, for the simulation the machining of a single thread vee at the corresponding workpiece sector would be identical (in terms of the cutting path and the single threading tool wear rate) to a single workpiece turn milling. Thus, to reduce the number of workpieces, and the testing time it is advisable to cut as many thread vees as possible on one and the same workpiece. This can be obtained by multi-pass thread turning with longitudinal feed. At every pass the depth of cut t_i shall be equal to the chip load per revolution S_{cl} used in the turn milling process. After the multi-pass machining of a single thread surface sector the workpiece is rotated about its axis by the angle equal to the mill tooth angular pitch, and the next sector is machined, and so on. In this way a one workpiece machining would be identi-

Table 1. **Average tool wear in the thread turn milling process**

Mean tool wear U, m	Cutting path length, m			Number of reference parts		
	R6M5		VK6M	R6M5		VK6M
	No coolant	Coolant	Coolant	No coolant	Coolant	Coolant
20	10	35	74	42	148	316
35	20	60		84	254	
50	30	90	5312	127	381	22860
70	50	125	5605	211	529	24124
85	60	150	6303	254	635	27126
100	70	185	13096	296	783	56359
115	80	210	18786	388	889	80851
130	90	255		381	1080	
150	110	310	19950	466	1313	85855
165	130	350		550	1483	
180	135	419	20806	572	1775	89541

Table 2. **Testing Results**

Values	Threading		
	R6M5		VK6M
	No coolant	Coolant	Coolant
Tool path length per one reference part L_i, m	0.236	0.236	0.236
Tool life ΣL_i, m	135	419	20806
Tool life mean square deviation σ_l, m	17.3	74.459	1739
Tool life T, min	4.09	12.69	630.5
Tool life CV	0.128	0.177	0.11
Number of reference parts machined within the efficient tool life, N, psc.	572	1775	89542
Wear limit U_{np}, mm	0.18	0.18	0.18
Specific wear U_0, m/m	1.333	0.429	0.0086
Specific wear per part U_0, m/psc.	0.314	0.101	0.002

cal (in terms of a single threading tool wear rate) to turn milling of N workpieces.

$$N = \frac{zl}{P}, \quad (5)$$

where l — the thread length; P — the thread pitch; z — the number of machined sectors (equal to the mill teeth number).

Experimental Results

The proposed approach has been applied to an experimental study as follows.

Sample material: KCh-6F cast iron, HB 130–200. An NPT G 1 1/4" thread has been machined. The $OD =$ = 41.9 mm, the pitch is P=2.309 mm, the height of engagement H= 1.48 mm, the thread length l= 30 mm.

Tool: a thread chaser (in accordance to GOST 18875–73) type 1, face angle: $\gamma = 0°$, clearance angle: $\alpha = 12°$. Cutting head material: R6M5 HSS, HRC 63–65, and VK6M hard alloy.

Cutting speed: V=33 m/min, radial feed: S_{po}= 0.1 mm feed per revolution. Both no-coolant mode and machining with Ukrinol-1 coolant have been studied. The tool wear has been measured with a dedicated indicator normally to the machined surface with the tool still attached to the lathe. The indicator's scale factor is 0.002 mm.

The machining has been conducted via the scheme of a turn milling simulation on a lathe [7]. A set of 5 tools has been tested. The thread height exceeding the tolerance being 0.18 mm was chosen as the tool dulling technological criterion.

The existing method [8] has been applied to process the test results. A mean value, a mean-square deviation, and a coefficient of variation have been found for each point on the experimental curves. The experimental results are listed in **Tab. 1** and **2**.

Tab. 2 represents the statistical processing results

From the relations presented in tab. 1 and 2 the following conclusions can be made:

1. The R6M5 HSS tool service life in thread turn milling with coolant is 3 times longer than without coolant.

2. The VK6M hard alloy tool life in turn milling with coolant is 50 times longer than the R6M5 HSS tool life.

3. The operational tool service life (expressed as the number of parts machined within the tool life) for VK6M tools in turn milling with coolant is 50 times higher than that of R6M5 HSS tools.

Conclusions

The proposed hardware-in-the-loop simulation approach enables experimental studies of the turn milling process without designing and manufacturing such complex tools as worm bobs and machine tools retrofitting. It significantly reduces costs and time required to perform experimental research.

The proposed turn milling simulation method has reduced the number of machined referenced parts by 710 times. Accordingly, the experimental research period and cost have also been reduced.

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LINK ANALYSIS OF IRANIAN STEEL INDUSTRY (ISI), USING WEB IMPACT FACTOR (WIF) AND CLUSTERING METHOD

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webometrics, Iranian steel industry, web impact factor, website visibility, link analysis, revised web impact factor.

ABSTRACT

In this paper, ISI Websites are identified and they studied based on the Webometrics methods. The survey aimed to investigate visibility, WIF and the collaboration rate of ISI Websites. In this process in-links, self-links and co-links of the Websites were studied and after analysis the Websites clustered and categorized. Webometric methods are applied and all of the links were analyzed including in-links, Self-links, co-links, number of each Web pages, total WIF and Revised WIF (RWIF). Data collection of 47 ISI Websites was done during March 29 to April 17. The results show that Esfahan Steel Company (ESCo.) Website with 2346 in links was the most visited Website and Shahrood Steel Company (ShSCo.) Website, with 1 in-link had the lowest rate of visibility. Also, Azarbaijan Steel Company (ASCo.) Website, with143 total WIF had the highest rate and Meybod Steel Company (MSCo.) Website with 0.31 total WIF had the lowest rate. On the other hand, ASCo. Website, with 143 rate in this case made the most RWIF and ShSCo. Website, with 0.05 was the last one. In this study 11 Websites were declared as the core Websites. Also co-link analysis results indicated that Websites under study had collaborated in 8 clusters. It is concluded that Website managers and designers outline plans need to improve the quality and content of their Websites and recognizing the factors required by the Website in order to attract links. The final success of a Website is dependent on factors such as quality, size, language, history, content and some other factors and one or two restricted factors cannot be declared as sole reasons for its success. Therefore any research in this field must consider all factors.

1. Introduction

The Web is an enormous source of information, both of a visible kind in the form of the content of Web pages, and also of a more hidden kind, for example through the connections that hyperlinks create between different Web sites and the organizations they represent. The research field of Webometrics tries, among other things, to create new knowledge from this hidden information and to understand what kinds of real world phenomena it may represent. Now, Websites become appropriate tools for presenting professional information in different fields. Websites implement their mission truly which is providing adequate information and performing information services role by providing higher quality information and using easier techniques of informing. Basically it's expected that, the latest information and news of each carrier, profession or organization appear on its Website; of course the way of spreading their information, which with links to other Websites related to the profession or organization emerge, is very important. So, as a result, if the content of Websites be rich and properly distribute the information, it may find a particular place in their