Experimental research on the durability of the cutting tools for cutting-off steel profiles

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Abstract. The production lines used for manufacturing U-shaped profiles are very complex and they must have high productivity. One of the most important stages of the fabrication process is the cutting-off. This paper presents the experimental research and analysis of the durability of the cutting tools used for cutting-off U-shaped metal steel profiles. The results of this work can be used to predict the durability of the cutting tools.

1 Introduction

Cold-formed steel profiles are found in a wide range of products, with a wide variety of shapes and sizes, in almost all aspects of contemporary life [1,2,3,4]. The industrial use of these profiles started only in the second half of past century. In recent years the use of these profiles also expanded to achieve proper strength structures of buildings.

Light profile metal systems with complex sections are also commonly used for the production of curtain walls. Advanced technologies for corrosion protection have led to increased competitiveness of cold-formed steel profiles in domains where, until recently, their use was restricted due to high corrosion risk [5,6].

The development of manufacturing technologies by cold plastic deformation allowed to increase the thickness from 3 mm to 25 mm [1]. Increasingly used to manufacture profiles, the steels with flow limits of which these profiles are obtained have flow limits within the (250 ÷ 550) MPa range [1, 2].

The shapes of cross sections for cold-formed profiles are usually more complex than those of hot rolled and welded sections, such as sections I or U. Usually, cold-formed sections have symmetric, or asymmetric shapes, usually with additional stiffeners at the end areas, or even intermediate stiffeners [6]. As shown in Figure 1, cold forming can be used to manufacture different simple or complex sections.

One of the very important operations in the production flow of cold-formed profiles is their cutting-off, which is affected by the tool wear. Generally, the wear should progress gradually and should be easily monitored. However, during the cutting-off process, the tool wear is hard to predict. Thus, in this paper, since productivity is important, the durability of a tool for cutting-off U-shaped metal profiles is investigated.

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Fig. 1. Cold-formed sections [2].

2 Experimental methodology

The tool for cutting-off U-shaped metal profiles from zinc plating metal sheets investigated in this paper (Figure 2) is part of the length cutting subassembly of a production line for U-shaped metal profiles. This line manufactures UD-30 metal profiles used for dry-wall, at 80 mm width and 0.5 or 0.6 mm thickness, at standard lengths of 3 or 4 meters.

The tool is made of hardened HS 6-5-2 and tempered to 63~65 HRC, and the metal profile is made of S250 zinc plating metal sheet.

Fig. 2. Tool for cutting-off U-shaped metal profiles.

Figure 3 shows photos of profiles cut with the tool. The profiles in Figure 3.a have been cut-off when the tool was new, and those shown in Figure 3.b have visible defects after cutting-off with a used tool, as a result of pronounced wear of the tool.

The production line (Figure 4) has a maximum work speed of 60 m/min, the rolls train being driven by a SIEMENS DC engine with an output of 12.5 kW.

The actual speed of the profile is translated using a digital encoder that sends impulses to a specialized computer which synchronizes the tool with the speed of the line.

Fig. 3. U-shaped profiles cut: a. at the beginning of the cutting process; b. with tool with a high degree of wear.

Fig. 4. The production line.

The tool holder assembly is supported by two linear guides. The translational motion is performed by a ball bolt-and-nut assembly, which it’s driven by a 3.2 kW servomotor. The tool is placed in this assembly, fixed by a ram port connected to a hydraulic cylinder making a back-and-forth race in about 0.7 seconds, which results in the actual cutting-off of the U-shaped profile.

Figure 5 shows schematically the stages of the experimental research.

Fig. 5. Stages of experimental research.

To measure the tool wear, initially, a grid size of $3\times3\text{ mm}^2$ was designed on the rake surface and several points were marked, where maximal wear was expected (Figure 6). The measurements were performed 3 times for each marked zones and were used 4 tools. The cutting-off process is done at high speed which leads to forming crater wear along the cutting edge of the tool, h_a , or flank wear on the rake surface. To determine the wear progress, after each N_i ($i=1 \div 4$) cutting cycle, the production line was stopped and the crater depth along the cutting edge of the tool was measured using a SINOWON WMM 3D video microscope (Sinowon, China) as shown in Figure 7.

The values of the wear in the four most important zones of the tool, resulted from the measurements, are presented in Table 1. It should be noted that the values presented in Table 1 represents the average for three measurements and the corresponding standard deviation.

Fig. 6. Initial picture of the grid on the tool.

Fig. 7. Wear measurement with a SENOWON 3D microscope.

Table 1. Wear in four zones of the tool

Number of cycles		Wear [mm]			
		Zone 1 (grid 6)	Zone 2 (grid 8)	Zone 3 (grid 11)	Zone 4 (grid 13)
N1	188000	0.104±0.001	0.012±0.001	0.052±0.001	0.194±0.002
N2	298000	0.165±0.001	0.012±0.001	0.07±0.001	0.275±0.002
N3	415000	0.196±0.001	0.02±0.002	0.093±0.002	0.294±0.001
N4	726000	0.212±0.002	0.036±0.001	0.106±0.001	0.301±0.001

Figure 8 shows the main effects plot for the tool wear and the corresponding measurement zone. As shown in Figure 8 the wear increases with increasing number of cycles; on the other hand, the wear decreases in the zones approaching the tip of the tool, which is used to cut the bottom of the metal profile. As shown in Figure 8 and Table 2, the greatest impact on the tool wear is the zone 4 wear, used for cutting-off the side of the U-shaped profiles.

Fig. 8. Main effect plot for the wear of the tool.

Table 2. Wear of the tool in the 4 zones (average values for four tools)

Level	Zone	Cycles
1	0.16925	0.0905
2	0.02025	0.13075
3	0.08025	0.15075
4	0.266	0.16375
Delta	0.24575	0.07325
Rank	1	2

Table 3. Analysis of Variance for Means

Source	DF	Seq SS	Adj SS	MS	F	P
Zone	3	0.137979	0.137979	0.045993	105.69	0
Cycles	3	0.012274	0.012274	0.004091	9.4	0.004
Residual	9	0.003917	0.003917	0.000435		
Total	15	0.154169				

3 Conclusions

This paper shows the wear that occurs using a tool for cutting-off U-shaped metal profiles at different cycles.

On the active surfaces of the tool it develops abrasion wear because of the existent oxides on the surfaces of metal profiles and chipping wear as a result of the “hits” made at the cutting-off.

The wear is more pronounced at the sides of the tool tip, where the cutting-off of the edges of the profile is done, and less obvious in the zones where it cuts the bottom of the profile.

The analysis of the wear process showed that, after about $(700\sim800)\cdot10^3$ work, fatal wear occurs, which requires, after stopping the production line, that the tool is sharpened or replaced. The cutting knives can be sharpened on the rake surface until its active height is enough for the cutting-off process.

The research results provides the necessary information to reduce the number of waste and to ensure a good productivity of the manufacturing process by the knowledge of the tool durability for cutting-off U-shaped metal profiles.

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