COMPARISON OF SEMIFINISHED PRODUCT INFLUENCE ON SURFACE DEGRADATION OF FORGING ROLLS

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Abstract. The production of seam tubes is a multi-stage technological process. In the case of exhaust systems, it is mainly a combination of welding and forming technologies. The final quality and state of the pipes generally depend on the chemical composition, microstructure, mechanical and technological properties of the tube blanks. Another factor that is often forgotten in technical and manufacturing practice is the quality, performance and state of tools combined with external factors in the production process. The interplay of all factors, i.e. internal and external, gives rise to a product of the desired quality and characteristics. The technical practice uses a constant set of working conditions for each production technology, often without regard to the state of the sheet metal, the state of the tools does not count with more significant changes and unify the process. While unification is a frequent requirement in the technical sphere, the theoretical assumptions do not always coincide with reality. The article will discuss how choosing the right choice for semi-forging rollers can affect the degradation of the surfaces of these rollers and thus the output quality of the exhaust systems. In this article it is shown that in this analysed case the quality and durability of forging roller degradation clearly affect the internal factors such as different chemical compositions and the microstructure of semi-finished products. As an external factors that have affected the roller life and quality, tool grinding and technology can also be included, which depend on a combination of forces, thermal and corrosive effects acting on the work tool surface.

Keywords: degradation, material, forging rolls.

Introduction

The production of exhaust systems is a multi-stage technological process. Entering into the production process there are blank scrolls from austenitic or ferritic stainless steel. Subsequently, they are divided according to the diameter of the pipe, from which they will subsequently be made. There are several processes at the same time on these production lines, including pipe forming and welding technologies. In the case of exhaust systems it is mainly a combination of welding and forming technologies. Welding of the blank is done either by high-frequency or laser welding. After heating the edge of the steel strip in the dough condition, these are then pressed by the forging rollers. This will result in welding of pipes [1-3].

On the quality and durability of the tubes the chemical composition, microstructure, mechanical and technological properties of the semi-finished tubes have a major influence. Another factor that is often forgotten in technical and manufacturing practice is the quality and state of tools combined with external factors in the production process and compliance with established technological parameters in the forming process during welding of the semifinished product. The interplay of all factors, i.e. internal and external [4; 5], gives rise to a product of the desired quality and characteristics.

As it can be seen, the tools in the forging of semi finished products determine not only the shape, but also the strain of this. The technical practice uses a constant set of working conditions for each production technology, often without regard to the state of the sheet metal, the state of the tools does not count with more significant changes and unify the process. While unification is a frequent requirement in the technical sphere, the theoretical assumptions do not always coincide with reality. An example of this can be the changing the quality of metal semi products for exhaust systems, which affects both the weldability and the formability of the product, and this also affects the lifetime or degradation of the work tools [6-7].

Another factor that affects the quality and life of the tool is the chemical composition and the microstructure of the blank. Aluminium bronzes are often used for forging rollers. Aluminium bronzes are characterized by good mechanical properties, high resistance to fatigue, wear, corrosion resistance and cavitation resistance. They can contain up to 10 % Al, which increases the strength and hardness. If the aluminium content is about 9 % at a eutectic temperature of 565 ºC, it dissolves in copper and the structure of the alloy consists only of crystals of solid solution α. At higher aluminium content eutectoid ($\alpha + \gamma_2$) is formed. Phase γ_2 (Cu_9Al_4) is a hard and brittle electron compound and the alloy is harder and more brittle. The β-phase is an unordered solid solution of the Cu_3Al electron complex with a cubic body centred lattice. In slow cooling it transforms into eutectoid ($\alpha + \gamma_2$). Rapid cooling from the ß-phase region results in martensitic transformation into unordered martensite β ‘. This phase does not, unlike steel, have high strength properties. Subsequent tempering of β-martensite creates precipitate small α-phase needles, which together with the matrix create the so-called tempered β-martensite.

The main alloying elements are iron, manganese and nickel. Iron with a content of up to 3 % softens the structure of the alloy and precipitation hardening of the matrix. Manganese increases hot and cold formability, improves corrosion resistance and increases strength. The manganese content is up to 3 % max. Nickel in the range (1-6) % increases the strength characteristics due to the CuFeNi intermetallic phase precipitation, but reduces toughness [8].

The aim of the paper was to show the influence of the input semi finished product on the origin and development of degradation processes for forging rollers.

Description of the situation

The forging rollers are degraded during surface deformation (Fig. 1). These altered surfaces then affect the quality of the exhaust pipes produced, Fig. 2.

Fig. 1. **Example of surface degradation of forging roller**

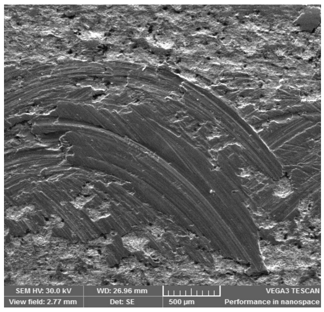


Fig. 2. **Changing surface geometry of pipe**

Experiments and methods

Two bronze forging rollers were used for the experiment. Both forging rollers were subjected to the same loading conditions and were used to produce the same number of tubes before they were decommissioned. The difference is in the kind, and hence the chemical composition of the semi-product. Rollers 1 and 2 were analyzed. It was possible to compare their chemical composition, structure, mechanical properties, and degradation of the surface of the rollers and thus discuss how the input semi-product influences the quality of the final product, in this case the exhaust pipe.

Roller 1

Roller 1 is an aluminium bronze forging roller with the trade name MZ6H. This roller, before being decommissioned, completed N cycles and was N-1 machined by turning. Turning was followed by grinding to match the condition requirements of the roller. Since this is a non-tested material, a spectral analysis was performed using the hand held spectrometer and the metal analyzer DELTA, Table 1.

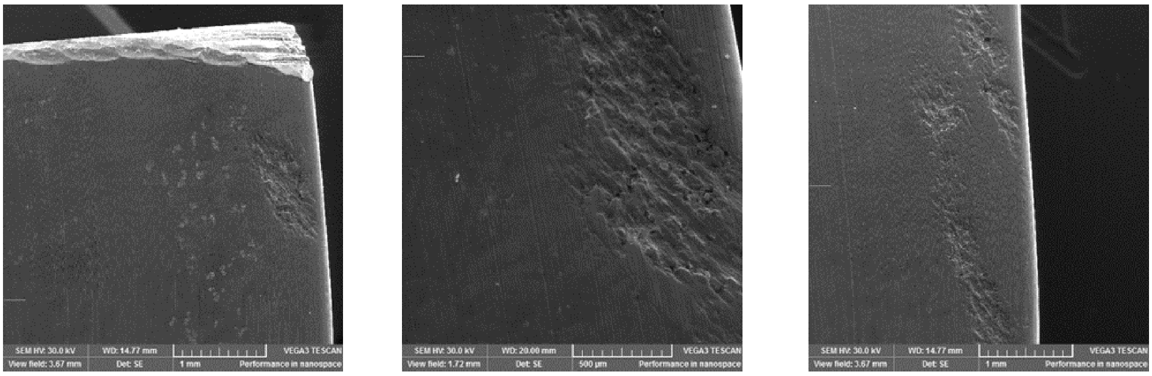
Table 1

Chemical composition of roller 1, spectral analysis

Element	Cu	Al	Fe	Mn	Ni
wt. %	81.07	13.91	3.56	1.43	0.03

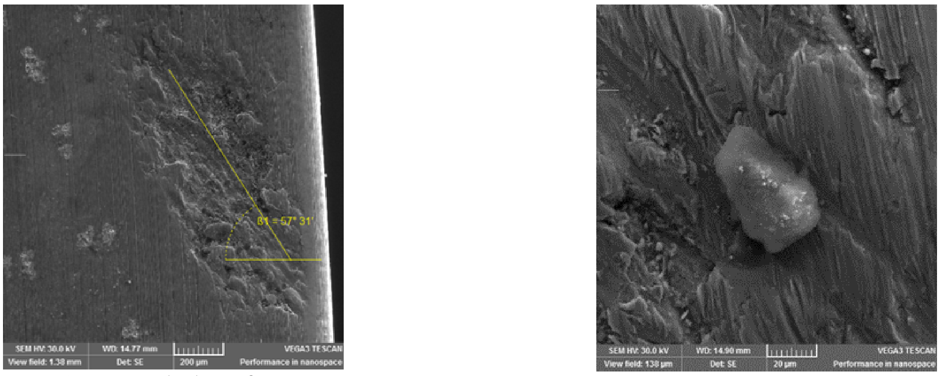
A macroscopic analysis of the roller was performed on the electron microscope TESCAN VEGA 3 using the BRUCKER analyzer and the software ESPRIT 1.9.

On the surface of the cylinder 1 there is a change in the surface geometry in the vicinity of the working edge (Fig. 3). Scraps were recorded, which were oriented in one direction at an angle of approximately 60º (Figure 4a). Their origin is related to abrasive wear during forming of stainless steel pipes.



a) Surface b) Detail c) Working edge

Fig. 3. **Roller 1, Surface dagradation**



a) Degraded surface b) Rounded Particle

Fig. 4. **Roller 1, Abrasive wearing**

In these areas of wear, rounded (Fig. 4b) and sharp-edged particles appeared (Fig. 5). These particles left traces of movement on the surface of the roller.

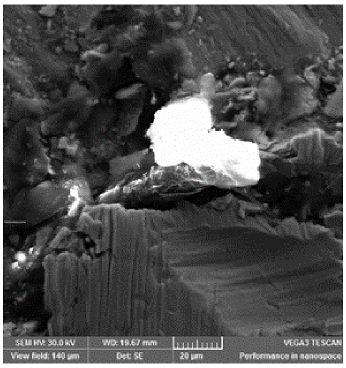


Fig. 5. **Roller 1, sharp-edged particle**

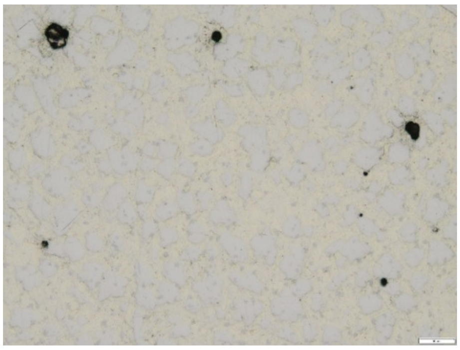
Table 2

Roller 1, particles, spot EDX analysis

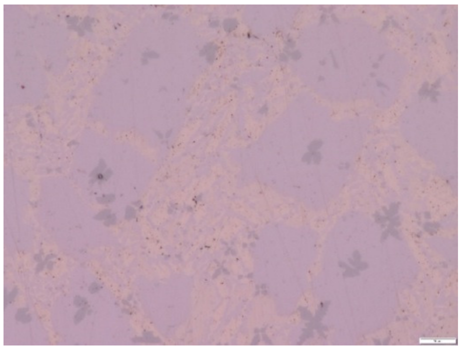
Element	**O**	**Al**	**Cr**	**Mn**	**Fe**	**Ni**	**Cu**	**Si**	**Mg**	**Ca**
wt. %	53.2	6.9	0.24	0.9	1.8	2.3	14.8	2.0	1.8	16.2

Microscopic analysis: For the microscopic analysis of both cylinders the OLYMPUS LEXT 3000 confocal laser microscope and the OLYMPUS BX51M light microscope were used.

In Fig. 6a, we see the microstructure of the material of roller 1, where the relatively large pores are unevenly distributed. The aluminium bronze structure, with the aluminium content of more than 9 %, consists of a mixture of α-phase and eutectoid ($\alpha + \gamma_2$), Fig. 6b.



a) Porosity



b) Microstructure, detail

Fig. 6. **Microstructure, roller 1**

Roller 2

Cylinder 2 is a designation for a bronze alloy forging cylinder with the trade name AMPCO 25. The results of the spectral analysis are shown in Table 3.

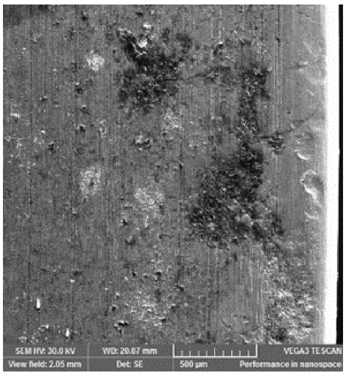
Table 3

Chemical composition of roller 2, spectral analysis

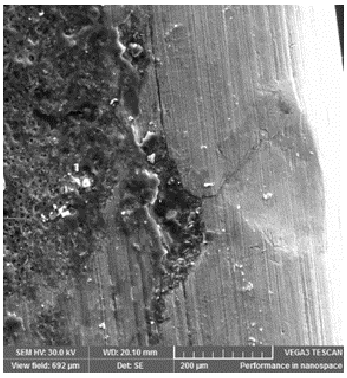
Element	**Cu**	**Al**	**Fe**	**Mn**	**Ni**	**Cr**
wt. %	78.40	14.79	4.56	2.04	0.09	0.13

Compared to the results of the spectral analysis of roller 1, roller 2 has a lower copper content, but a higher content of aluminium, iron, manganese and nickel. It can therefore be assumed that roller 2 should have a higher hardness and resistance to wear on the functional surface.

Macroscopic analysis, using electron microscopy, shows that there has been significant wear on the edge of the tool, which manifests itself as imprints on the working edge and changes the quality and coherence of the surface, Fig. 7.



a) Surface

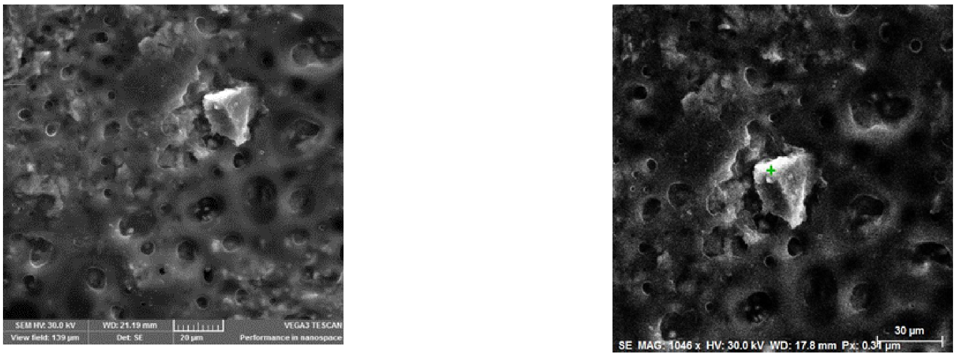


b) Imprint

Fig. 7. **Roller 2**

The imprints are probably due to the change in the strength characteristics at these forging roller areas. At the working edge of the tool, the highest pressure and temperature occur during the manufacturing process.

A detailed analysis of the degraded surface of the roller shows that the material of the roller has been melted (Fig. 8) near the working edge. Its chemical composition by the surface EDX analysis is mainly based on complex oxides of copper and aluminium (Table 4). It can be assumed that melting of this surface occurred during welding, when sparking particles of the molten material from the weld came to the surface of the cylinder. In these areas, sharp-edged particles also appeared, Fig. 8b. According to the EDX spot analysis (Table 5), this particle consists mainly of aluminium oxides.



a) Choosed area b) Sharp-edged particle

Fig. 8. **Roller 2, degraded area**

Table 4

Roller 2, chosen area, area EDX analysis

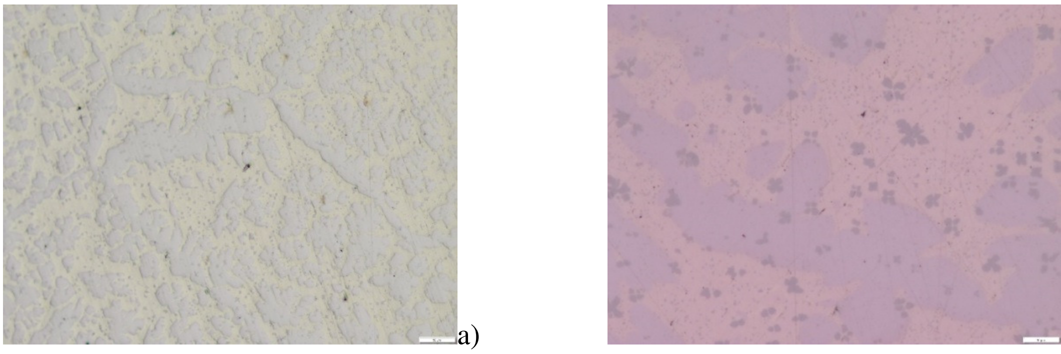
Element	O	Fe	Al	Mn	Si	Cu	Zn	Ni	Mg
wt. %	32.2	7.9	11.2	3.1	0.7	38.5	0.2	5.4	0.8

Table 5

Roller 2, chosen particle, spot EDX analysis

Element	O	Na	Al	Mg	Ca	Cr	Cu	Si	Sn
wt. %	50.3	3.8	29.0	0.4	0.1	0.1	0.4	0.1	0.1

Microscopic analysis: in Fig. 10 we see the microstructure of the material of roller 2. The pores are visible here, but they are substantially smaller than those of roller 1. Details of this structure are shown in Fig. 11b, the microstructure is heterogeneous in phase distribution. Even in this case, it is composed of a mixture of α-phase and eutectoid ($\alpha + \gamma_2$).



a) Porosity b) Microstructure, detail

Fig. 9. **Microstructure, roller 2**

Results and discussion

Both spectral analysis, the REM analysis and microscopic analysis were performed on both forged forging rollers exposed to the same production conditions.

Spectral analysis revealed that both rollers differ slightly from the contents of the individual elements. Roller 1 contained a larger proportion of copper, but less aluminium and iron than roller 2, which increase the strength and hardness in aluminium bronzes.

Macroscopic analysis of rollers using REM showed different degradation of both rollers. For roller 1, degraded areas have been created near the working edge of the tool, the origin of which is related to the abrasive wear of the work surface. In these areas rounded and sharp-edged particles appeared. The degradation of roller 2 was manifested by the formation of imprints at the working edge. The resulting imprints were probably due to a change in the strength at this site, which is related to the chemical composition of the material, the microstructure and the temperature distribution on the roller during the manufacturing process. Further degradation of the surface of the roller was caused by melting of the surface, which was connected with the pipe manufacturing process, respectively with their welding.

The microstructure of both types of cylinders consists of a mixture of α-phase and eutectoid ($\alpha + \gamma_2$). The difference was in the phases, but mainly in porosity. For roller 1, the pores were relatively large and unevenly distributed. Roller 2 also contained pores that were significantly smaller.

Conclusions

The aim of the paper was to show the influence of the input semi finished product on the origin and development of degradation processes for forging rollers. Based on the results, the following can be stated:

- The quality and resistance to degradation of the forging rollers is clearly affected by internal factors such as the chemical composition and the microstructure of the semi finished product. In this case, the difference in the chemical composition and microstructure of the rolls, wherein the porosity is manifested, and a change in the consistency of the material, led to reduction in the resistance to occurrence and development of degradation manifestations.
- There were foreign rounded and sharp-edged particles on the work surfaces of both forging rollers. The presence of these particles is related to grinding of worn grinding wheels on the desired geometric shape. It is therefore necessary to ensure their removal, as they are the source of tool wear, which can be considered as an external factor causing degradation.
- External factors include production technology too, which is a combination of forces, thermal and corrosive influences acting on the work surface of the tool. And the last but not the least, the material of the manufactured pipes, which parameters must be in accordance with the set technological parameters of the production process. The range of material characteristics beyond the specified limits must be reflected in the tuning of the technological process conditions.

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