TESTING SURFACE ROUGHNESS AFTER DIFFERENT TECHNOLOGICAL PHASES OF PROCESSING NIMONIC 80A

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ABSTRACT
Surface roughness is the totality of microgeometric irregularities on the surface of an object and it is caused by various factors, from which the most important are machining and processing techniques. This characteristic of the material is very important, especially in the case of high-quality materials designed for the demanding conditions of exploitation.
In this work the tests of surface roughness Nimonic 80A were carried out. The tests were performed after the different tehnological phases during processing of Nimonic 80A using Sutronic 10 instrument. This instrument work on the principle of ultrasound which measures the aritmetic value of Ra, i.e. parameter for determining the surface roughness.

1. INTRODUCTION
The roughness of a particular machined surface is an important measurable characteristic of the quality of final products in the metal industry. It is present regardless of the processing method used in the production process. All functional surfaces of the product are the result of the application of certain production technology. Products with very good surface quality can also achieve plastic processing, especially when it comes to cold plastic processing. However, processing in the warm or hot state is characterized by a rougher surface, which requires additional machining.
Superalloys, and therefore Nimonic 80 A superalloys, are severely deformable alloys and with each technological operation a different surface texture is formed, ie. different surface roughness values. Therefore processing is not continuous and after every operation visual inspection of the surface is carried out and, if necessary, the roughness is measured to provide insight into the state of wear of tools and processing plants.Also, roughness affects the mechanical properties of the material, resistance to wear, corrosion, etc.
This paper presents the measurement of surface roughness in individual stages of the technological process of production of Nimonic 80 A by determination of averagearithmetic deviation of R_a as the commonly measured roughness parameter.

2. ROUGHNESS MEASURING
Surface roughness is measured by means of devices for measuring various roughness parameters such as: arithmetic deviation R_a, mean height roughness R_z, maximum height of roughness, etc.
The surface roughness is determined by the following methods [1]:

- direct or contact methods,
- comparison techniques,
- a non-contact methods,
- three-dimensional measurement.

Roughness measuring devices are used for rapid measurement the depth of roughness on the surface of a test specimento show the average roughness depth R_z and the mean roughness value R_a in µm.The devices can be both manual and stationary [2].

2.1. Roughness classes

The usage of individual roughness parameters are changed over the years. This was due to the development of methods and devices for measuring. Vertical roughness parameters were the first parameters measured. Among them, R_a parameter took the dominant role. It is still widely used today. Based on this parameter, the surface roughness is classified into 12 roughness classes, Table 1. The lower value for R_a indicates the finer quality of the treated surface.

Surface roughness is a consequence of the production process and the result of the treatment process. Table 1 shows the different treatment methods and their effect on the surface roughness [3].

Table 1. Effect of different treatment methods to the surface roughness [3]

Surface roughness classes	**N1**	**N2**	**N3**	**N4**	**N5**	**N6**	**N7**	**N8**	**N9**	**N10**	**N11**	**N12**	
***R_a* [µm]**	**0,025**	**0,05**	**0,1**	**0,2**	**0,4**	**0,8**	**1,6**	**3,2**	**6,3**	**12,5**	**25**	**50**	**100**
MANUAL PROCESSING													
-Coarse rasping									■	■	■	■	■
-Fine rasping						■	■	■	■				
CASTING													
- in the sand												■	■
- in the mold									■	■	■	■	
- pressure casting						■	■	■	■	■	■		
FORGING													
- warm, free													
- top-stamping									■	■	■	■	■
- cold-stamping							■	■	■				
ROLLING													
- warm									■	■	■	■	■
- cold				■	■	■	■	■	■				
SANDBLASTING											■	■	■
GAS CUTTING									■	■	■		
TURNING													
-harsh								■	■	■	■	■	■
-fine							■	■	■	■			
PLANING													
-harsh										■	■	■	■
- fine							■	■	■	■			
MILLING													
- harsh								■	■	■	■	■	
- fine					■	■	■	■					
GRINDING													
- harsh							■	■	■	■	■		
- fine			■	■	■	■	■						
POLISHING													
- mechanical			■	■	■	■							
- electric	■	■	■	■	■								

Products with very good surface quality can be obtained by forming, especially when it comes to processing in the cold state. However, processing in hot and cold condition poses a challenge in terms of high surface quality, and products are generally characterized by rough surface, or poor surface quality and higher dimensional tolerances. A representative process of hot working is free forging, which is performed on forging machines with the help of simple tools, usually by repeating the operation of compacting between flat surfaces. The expansion and elongation of the material in all horizontal directions is freely between the working surfaces of the tool, resulting in parts with significantly larger dimensional deviations and rougher surfaces.

However, compared to other metal processing technologies, forging has no alternative because it provides the ability to produce relatively complicated parts with significantly better mechanical and structural properties, high strength and dynamic strength.

Therefore, the functional surfaces of the material previously formed by free forging are subsequently processed by cutting technology. The required quality of forgings during free forging is ensured by the proper selection of the forging temperature and the degree of forging, that is, the degree of deformation as the basic forging parameters [4].

2.2. Roughness tester

To measure surface roughness in manufacturing plants, a visual comparative standard called the Rugotest is often used, which allows an expert to evaluate surface roughness by comparing it with an etalon.

As part of this work, testing was performed at the Institute "Kemal Kapetanović", using Sutronic 10 by Taylor-Hobson, which measures the mean (arithmetic) value of the roughness R_a, Figure 1. The device operates on the principle of ultrasound. This is a pocket electronic instrument which is easy to handle. The device scans the surface in a few seconds and shows the value of the parameter of surface roughness R_a. The measuring range of the device is 40 μm and the measurement speed is 2 mm/s [4].

Figure 1. Sutronic 10 device for measuring surface roughness

Above mentioned device was used to measure surface roughness on Nimonic 80A superalloy samples after the following processing operations: primary forging, planing, re-planing, rolling, machining, thermal processing (recrystallization annealing + precipitating annealing) and grinding.

3. ROUGHNESS TESTING AFTER TECHNOLOGICAL TREATMENTS

The surface roughness depends on the production process and subsequent surface treatment process. The surface of the finished superalloy product must meet the specified requirements of the materials. Also, the surface must be of high quality during the processing of these materials becasue all irregularities and surface defects can cause damage and cracks of the material that cannot be repaired.

The technological scheme of experimental production of superalloy rods is given in Table 2.

Table 2. The sequence of technological operations

Nr.	Technological operation	Description of the operation	The final cross section
1.	Primary forging - hydraulic press 200 t with flat tools	- Preheating at 600 °C - Heating at 1050 °C together with the furnace - Holding for 20 min - Heating to 1170 °C - The forging press with flat tools with a degree of reduction up to 10%	square 44x450 mm
2.	Planing the surface on the planing machine	-Cutting the head - Planing the surface from all four sides	square 37x380 mm
3.	I Secondary forging in the press	- Preheat at 600 °C - Heating to 1050 °C - Held at this temperature for 20 min. - Forging on a straight tool press	square 35x400 mm
4.	II Secondary hammer forging 250kg	- Preheat at 600 ° C - Heating to 1050 °C - Held at this temperature for 20 min. -Forging hammers with the flat tools	square 25x550 mm
5.	Planing the surface on the planing machine	- Planing the surface from all four sides	square 20x550 mm
6.	Rolling Rolling mill SKET Ø 380 mm	- Heating of rolling bars at temperature 1170 °C - Rolling in the temperature interval from 950 °C to 1150 °C - The rolling speed is about 1 m / s.	Ø15 mm

Standard heat treatment or recrystallization annealing at 1080 °C / 8 hours was performed on rolled bars. Mechanical test tubes were made from annealed rods. At the end the precipitating annealing (720 °C / 16 h, air cooling) of test tubes was performed.

The appearance of the semi-finished products after individual technological operations is given in Figures 2 to 9.

Figure 2. Billets after forging in the press

Figure 3. Billets after planing

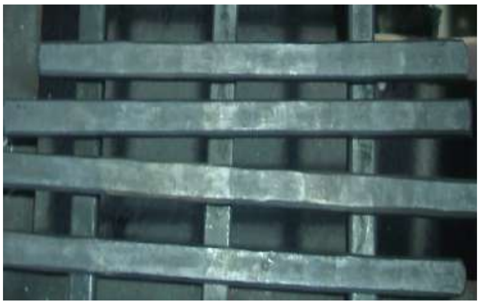

Figure 4. Rods after hammer forging

Figure 5. Rods after planing

Figure 6. Rods after rolling

Figure 7. Rods after thermal treatment

Figure 8. Machined rods

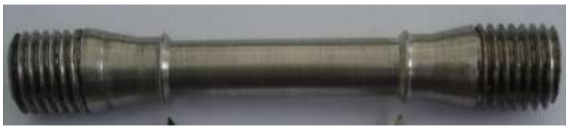

Figure 9. Tubes for mechanical testing after thermal treatment

Surface roughness measurements were performed after all stages of processing and machining and results are shown in Table 3.

Table 3. Results of roughness measurements [4]

Technology	Average arithmetic value of roughness R_a, μm	Class of roughness
Primary forging	4,875	N9
Planing	0,7	N6
Forging in the press	5,125	N9
Forging on a hammer	3,05	N6
Planing	1,25	N7
Rolling	3,875	N9
Thermal treatment recrystallization annealing	3,75	N9
Machining	1,375	N7
Thermal treatment recrystallization annealing	0,475	N5

Polishing	0,2	N4

4. CONCLUSIONS

Surface roughness is a very important measurable characteristic of the quality of final products in the metal industry. Surface roughness is a consequence of the manufacturing process and the subsequent surface treatment process. Processing in hot and warm conditions presents a challenge in terms of the quality of the surface to be treated. It is generally characterized by a rougher surface, that is, a poor quality of the treated surface and higher dimensional tolerances.

The surface roughness condition is usually defined only by the parameter R_a. Based on the arithmetic mean of R_a, surface roughness is classified into twelve roughness classes.

The smaller number of classes reflects the finer quality of the surface being worked.

Discarding products at the end of the technological process, especially those that are expensive and poorly deformable slows down and increases the price of the entire production.

The highest value of roughness was obtained for this superalloy after forging and the lowest value after the final polishing, which is in accordance with the literature.

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