# Influence of Deformation Temperature and Time on the Mechanical Properties of Pulsation Deformed Stainless Steel

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## ABSTRACT

Pulsation forging of metallic materials (also referred to as stresscycling) is a novel forming method based on the application of a variable pulsation frequency during the metal forming process. This paper presents some new results obtained after pulsation forming of steel grade Cr18Ni10. The previous works given by the present authors suggested that the value of summary deformation of 25 % (at the pulsation frequency of 30 Hz) was obtained with the very good compromise of yield strength ($R_{p\ 0,2}$), tensile strength ($R_m$), elongation ($A_5$) and contraction (Z). Value of geometrical parameter $\Theta$ of 20 % or the highest value of $\Theta$ is found to improve the flow of material at pulsation forming process in a sense of the lower plastic deformation heterogeneity. The experimental results were given with respect to the effect of deformation temperature (from 1193 to 1123 K) and deformation time (from 2 to 10 sec.) at constant heating temperature (1373 K) and constant pulsation frequency (30 Hz) on mechanical characteristic ($R_{p0,\ 2}$; $R_m$; $A_5$; Z) of stainless steel grade Cr18Ni10. The relationships between strength – plastic values and geometrical parameters $\Theta$ were also investigated.

**Key words:** pulsator, pulsation forging, pulsation frequency, geometrical parameter $\Theta$ - barrel ratio of the samples, deformation temperatures, deformation times, mechanical properties

## 1. INTRODUCTION

The scheme of a pulsator installed at the Department of Metal Forming (Faculty of Metallurgy, Technical University in Košice, Slovakia) is shown in the literature /1/.

Pulsatory forging, as one of the non-conventional forming methods, can be classified into the category of technological processes where the energy of vibration systems is utilized with a frequency effect. The original idea for a volume forming method using pulsatory forging technology was proposed in 1999, within the international project EUREKA E! 2336. It is a process where a tool applies a force to a formed material, while the immediate value of the force oscillates around a mean value, which can remain constant or can increase or decrease during the process. Pulses can be generated by different mechanisms of hydraulic, electromagnetic, or mechanical principles.

## 2. MATERIAL AND EXPERIMENTAL METHODS

Cylindrical specimens were used with the dimensions $h_0$ = 30 mm, $d_0$ = 20 mm using the apparatus installed at the Department of Metal Forming, Technical University in Košice, Slovakia

The chemical composition of the experimental steel is shown in Table 1. The experimental conditions are summarized in Table 2.

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**Table 1**
Chemical composition of steel grade Cr18Ni10 [mass %]

| Steel | C | Mn | Si | Cr | Ni | Ti | P | S |
|---|---|---|---|---|---|---|---|---|
| **Cr18Ni10** | 0,03 | 1,2 | 0,5 | 18,6 | 10,8 | 0,26 | 0,008 | 0,023 |

**Table 2**
Experimental procedure

| Heating temperature [K] | Deformation temperature [K] | Pulsation frequency [Hz] | Note |
|---|---|---|---|
| 1373 | 1098 | 30 | The specimens after pulsation forming were water quenched |
| | 1123 | | |
| | 1148 | | |
| | 1173 | | |
| | 1198 | | |

The basic mechanical characteristics ($R_{p\,0,2}$, $R_m$, $A_5$, Z) after forming and quenching of the specimens were searched in accordance with STN 42 0321 Standard. The following dependences were obtained:

- Strength and plastic values as a function of summary deformation;
- Strength and plastic values as a function of ratio Θ;
- Strength and plastic values as a function of deformation temperature;
- Strength and plastic values as a function of deformation time.

## 3. EXPERIMENTAL RESULTS AND DISCUSSION

The strength and plastic values achieved using the pulsation forging method and quenching of cylindrical specimens are shown in Fig. 1 and Fig. 2, respectively, as a function of the summary deformation.

The maximum values of $R_{p\,0,2}$ at pulsation frequency of 30 Hz were achieved at summary deformations from 20 to 25 %. The maximum values of $R_m$ at pulsation frequency of 30 Hz were achieved at summary deformations from 5 to 10 % and from 20 to 25 %. The course of maximum plastic values coincides with the tensile strength case (summary deformations from 5 to 10 % and from 20 to 25 %).

The strength and plastic values as a function of ratio Θ at pulsation frequency of 30 Hz are given in Fig. 3 and Fig. 4 and their variations were found to be similar to the results shown in Fig. 1 and Fig. 2. (Mechanical characteristics as function of summary deformations.)

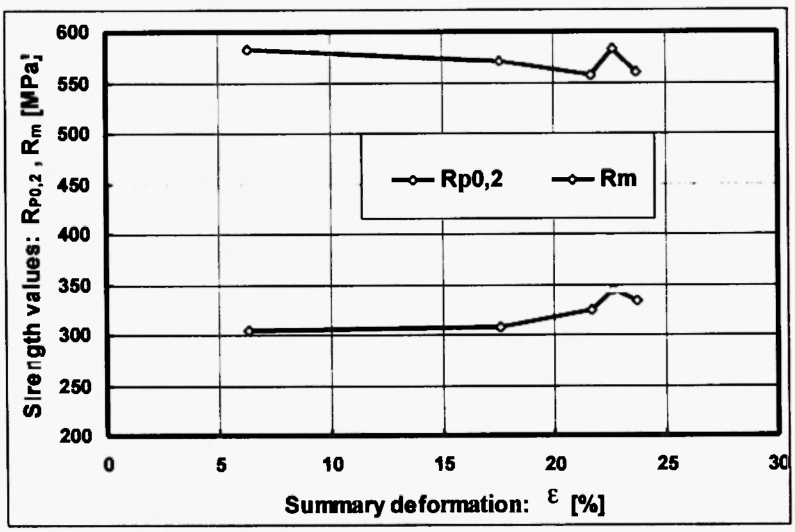


**Fig.1:** Strength values as a function of summary deformation (f = 30 Hz)

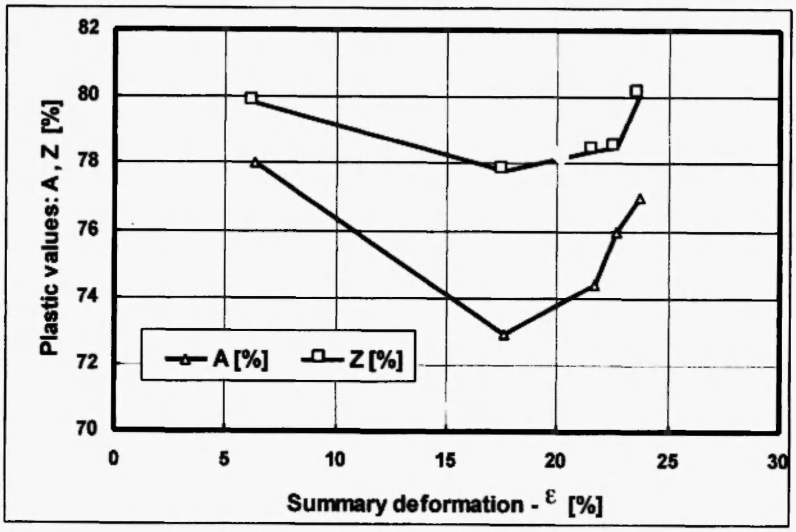


**Fig. 2:** Plastic values as a function of summary deformation (f = 30 Hz)

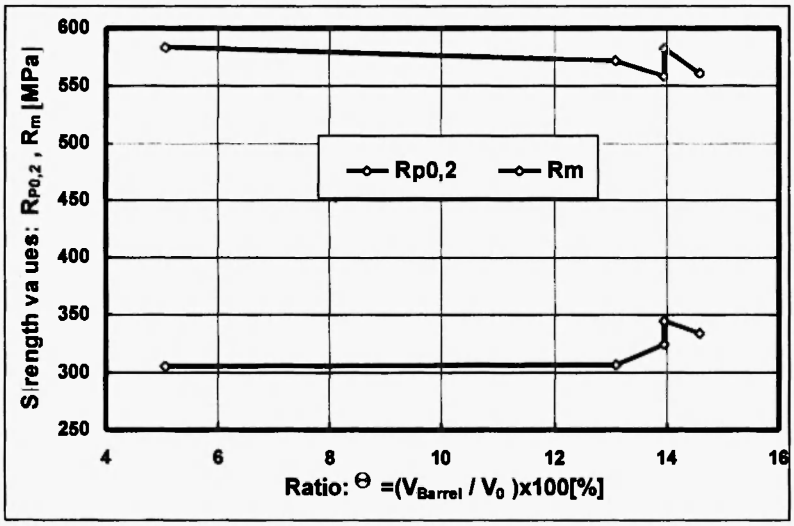


**Fig. 3:** Strength values as a function of ratio Θ (f = 30 Hz)

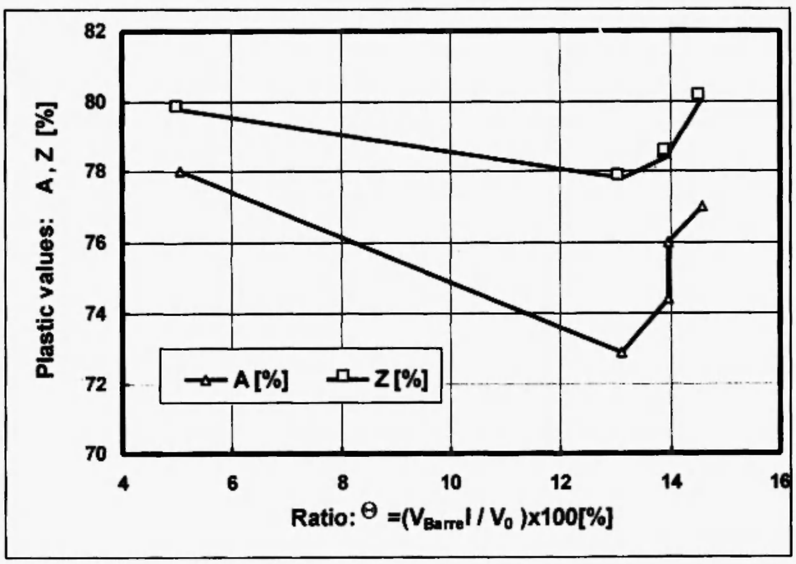


**Fig. 4:** Plastic values as a function of ratio Θ (f = 30 Hz)

According to /2/, the parameter Θ increases with increasing frequency (growth of deformation non-uniformity). However after exceeding the pulsation frequency of 20 Hz the growth of the barrel ratio significantly decreases. The effect of the parameter Θ on strength properties appears to be very small. Good plastic properties are also found for cases where $\Theta = 5$ and $\Theta > 14$.

Strength and plastic values as a function of deformation temperature at pulsation frequency of 30 Hz are shown in Fig. 5 and Fig. 6, respectively.

The utmost decrease of mechanical properties at deformation temperature 1193 K was found (mainly yield point and investigated plastic characteristics). However, the present authors maintain the view that the decrease of mechanical characteristics is not so significant.

Tested mechanical properties as a function of deformation time, at pulsation frequency 30 Hz, are shown in Fig. 7 and Fig. 8, respectively.

The utmost decrease of $R_{p\ 0,2}$ at deformation times from 2 to 4 sec., plastic values at deformation time 4 sec., were found. The $R_m$ value appears to be almost independent of deformation time.

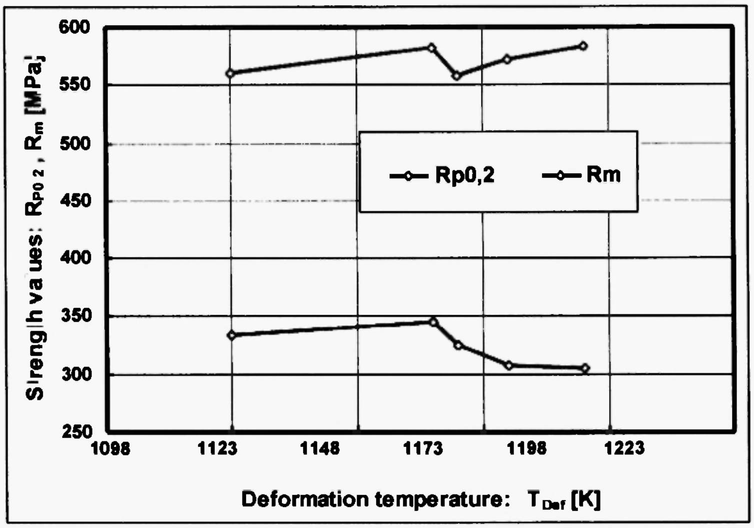


**Fig.5:** Strength values as a function of deformation temperature (f = 30 Hz)

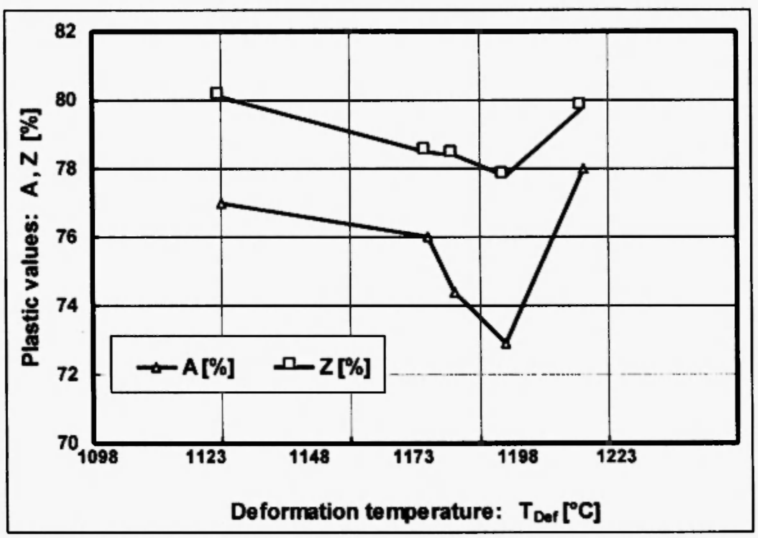


**Fig. 6:** Plastic values as a function of deformation temperature (f = 30 Hz)

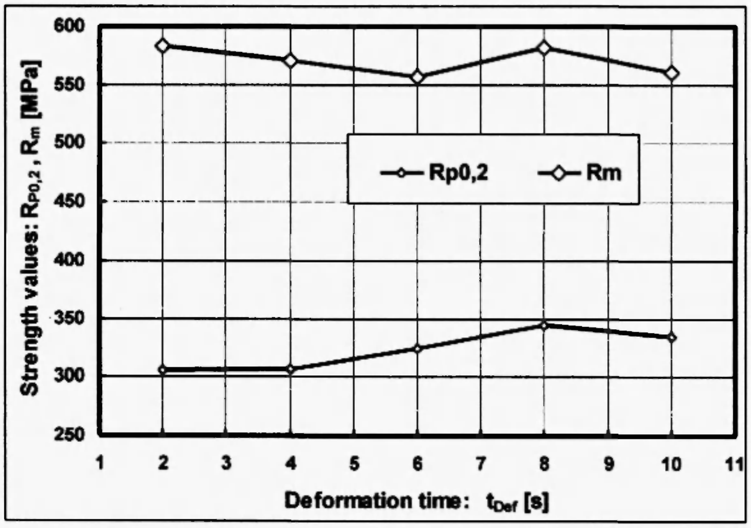


**Fig. 7:** Strength values as a function of deformation times (f = 30 Hz)

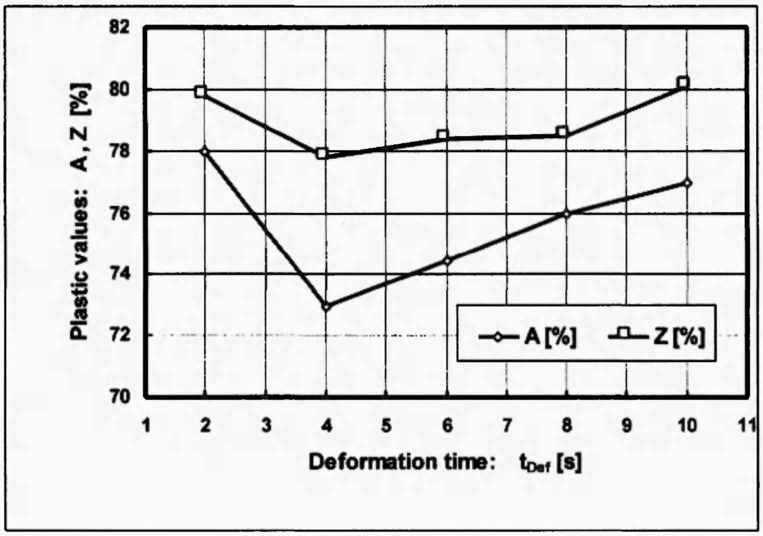


**Fig. 8:** Plastic values as a function of deformation times (f = 30 Hz)

## 4. CONCLUSION

1. After application of the pulsation frequency of 30 Hz at further defined conditions (heating temperature, deformation temperatures, deformation times and quenching of samples after pulsation forging) the following mechanical properties were achieved:

- Yield strength ($R_{p\,0,2}$) from 305 to 345 MPa;
- Tensile strength ($R_m$) from 558 to 584 MPa;
- Elongation ($A_5$) from 72,9 to 78 %;
- Contraction (Z) from 77,8 to 80,1 %.

The variation of mechanical properties is not so significant at various conditions of pulsation forging. Range of defined deformation temperature and time at further defined conditions of pulsation forging suggest a very good level of mechanical properties, high level strength and plastic values / good compromise; high formability, in comparison with conventional forging.

2. The maximum value of $R_{p\ 0,2}$ (345 MPa) at deformation temperature 1163 K and deformation time 8 sec. was achieved. The maximum value of $R_m$ (584

MPa) at deformation temperature 1193 K and deformation time 2 sec. was obtained. Changes of plastic values ($A_5$ and Z) are found to be independent on defined conditions of pulsation forging (deformation temperatures and times) of pulsation forging.

3. The effect of pulsation frequencies (summary deformations) on material properties was searched as a function of deformation temperature and deformation time.

## Acknowledgements:

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