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Research Article

An Investigation of the Effective Factors in the Shape Rolling Process of a Compressor Blade

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ABSTRACT

One of the most popular forming processes is the shape rolling process in which the desired shape change is achieved by pressing two rollers with a special shape in the opposite rotational direction. In order to improve the product's quality and reduce production costs, accurate analysis of the shape rolling process of the compressor blades as well as the investigation of the effective parameters have been done. First, the shape rolling process of a typical compressor blade was simulated based on the experimental data using the finite element method and Design of Experiment (DOE). Then, the effect of various process parameters, including the thickness and width of the preform, the roller diameter, the thickness and width of the flash channel, and the number of the rolling steps on two objectives, namely the rolling force and the amount of the flash were investigated. The obtained data were analyzed by Analysis of Variance (ANOVA), and the contributory factors of the shape rolling process were identified. The results revealed that all of the considered factors affected the rolling load, but only the initial sheet's width and thickness were the factors with impact on the volume of the flash as the second objective. The required process load decreased by increasing the number of the rolling steps, but the rolling load increased by increasing other factors. Furthermore, increasing the thickness and width of the initial sheet increased the flash volume.

1. Introduction

The shape rolling process is one of the metal forming processes to produce geometrically simple blades or only a single step of twisted blades [1]. Generally, the rolling process increases the dimensional accuracy and surface quality of the blade compared to other blade production methods. Moreover, saving on raw materials, better material flow, higher strain hardening in cold rolling, short processing time, and high production rates are of many advantages of this method. There exists in the rolling process various parameters for which the examination and selection of the appropriate values will result in the production of products with the minimum number of defects or even without any imperfections. The mentioned process parameters include the thickness and width of the initial sheet, the linear and rotational speeds of the rollers, rollers diameters, applied forces on the rollers, and the friction and lubrication conditions [2]. For the moment various studies have been conducted on the rolling blades. James Griffith et al. [3] have proposed a symmetry method for the production of turbine steel blades. This method produces two blades simultaneously due to symmetry, which avoids the deflection of the edges. Medvedev et al. [4] designed and rolled the caliber of two pieces according to the practical

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test and then investigated the blade's rolling parameters by simulation. Lambert et al. [5] performed a study on blade sections and considered the trial and error approach as an important method in optimizing the process parameters. In order to reduce the wear, cost of the mold and raw materials, a simulation was done with DEFORM software. Bound et al. [6] investigated the non-twisting blade types of a compressor and presented a method for preventing the blade warpage during the rolling process. The foregoing process was investigated both practically and numerically by finite element simulation. Mahmoudi et al. [7] studied the pressure distribution and blade warpage in the cold rolling of compressor twisted blades using both the experimental and finite element methods. Finally, the results of the experimental works were compared with those of the theoretical methods. In order to find the net-shape rolling of the compressor blades, Jin et al. [8] studied the geometric accuracy design method of the roller cavity. It was concluded that to have the best design quality, the proposed method is capable enough of designing rolling cavity surfaces. In another work, to have the net shape rolling of the compressor blades, Jin et al. [9] studied the design of roller cavity surfaces and proposed the springback and forward slip compensation models. It was concluded that in order to compensate the forward slip in the process, the relationship between the stacking height and rotation angle can be calculated. Further, the comparison between the experimental tests and numerical simulation revealed that the introduced method is efficient to design roller cavity surfaces.

For the moment the effects of the process parameters, especially the interactions between the parameters, have not been studied comprehensively by scientific methods such as ANOVA. Hence in the present study, the compressor blade of a gas turbine engine of 422 stainless steel, in accordance with Fig. 1, with the geometric curvature of the maximum thickness of 0.7 mm, a width of 11.33 mm and length of 18 mm was studied. The manufacturing process of this blade is such that the upper curvature of the blade is formed by rolling, and then the lower part is obtained by the bending process with a press machine. Then the final form of the blade can be created. In this research, the caliber shape is created only on the upper roller, and the lower roller is considered smooth. After the caliber is designed, the influence of the parameters on the process, the force and the flash amount are extracted using DOE and simulating the proposed processes.

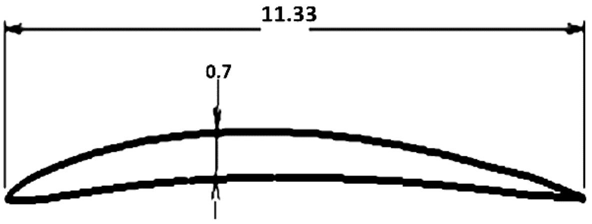

Fig. 1. Blade's cross-section (mm)

2. Caliber's Design

The compressor blade's cross-section is asymmetric, and the left and right halves are different in their thickness. Because of the aforementioned reason, during the rolling process the segment is diverted towards the zone where there is a slight reduction in thickness. On the other hand, the piece is asymmetric in another direction, and the upper part of the blade has a curvature while its lower surface is flat. Hence the piece is bent upward while rolling. These two irregular twists cause the warpage of the compressor blade after rolling. Therefore, the calibration symmetry method was used to eliminate the warpage of the two rolled sides processed simultaneously [6]. James Griffith et al. introduced the initial idea of caliber design [3]. They rolled the two blades together to remove deviations from each side. The design of the caliber was in such a way that the two blades were transversely connected with less thickness. In this case, the pressure on the rollers was high, and there was a possibility of tearing in the workpiece. In another study, Bowden et al. [6] designed the caliber in a way that the compressor blades were bonded with each other from the thick part. In such circumstances, the pressure applied to the middle of the roller reduces. Furthermore, in the proposed method the rapid wear and stress concentration of the rollers were prevented by removing the middle groove on the roller. Two previous methods were designed for a blade with two curvatures. However, in the present study the design should be made for the blade with a curvature at the top. Fig. 2 indicates an adequate representation of the rolled compressor blades.

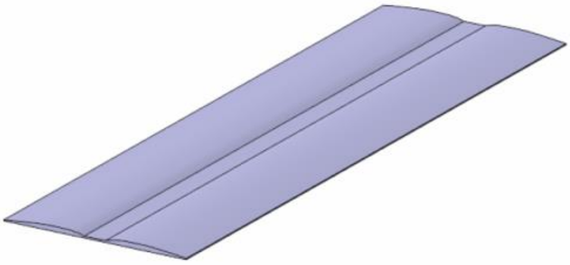

Fig. 2. An adequate sample obtained from compressor blade rolling.

In the rolling blades, the metal flow and the speed of each point of the workpiece's cross-sections are different due to the non-uniformity of the roller diameter for different parts of the cross-sectional area of the workpiece. Besides, the workpiece getting out from the caliber has a special complexity. The precise control of these structures depends not only on the accurate design of the caliber but also on its position in the space between the two rollers. In order to determine the adequate position of the caliber, a method should be selected in which the mean linear velocity on the roller with concavity (upper roller) equals the mean linear velocity on the smooth roller (lower roller). Therefore, the average linear speed of both rollers should be equal, and then the actual diameters of both rollers should be the same. For this purpose, the distance between the 45 pairs of different points with equal spacing on the caliber cross-section of the upper roller was considered, as shown in Fig. 3, and then the average value of these 45 pairs of points was calculated. The average value of the points equaled 0.472 millimeters. By using this value, the roller diameter would equal 0.9144 mm. If this value is considered to be 1 and the roller diameter equals 122.4 mm, then the upper roller diameter will be 122.4 mm. However, for the lower roller the subject diameter was reduced by 1 mm. Hence the lower roller diameter would equal 121.4 mm. Since the lower roller surface is flat, it does not need to be divided. As a result, the actual diameter of the two rollers and that of the mean linear velocity on them are the same. Fig. 3 shows the designed caliber.

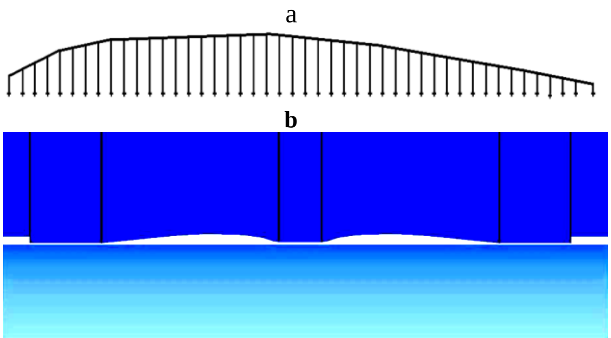

Fig. 3. a) Caliber curvature average points (upper roller), and b) The designed caliber.

3. Tensile and Ring Compression Tests

Stainless steel 422 is the material used for the primary sheet. The chemical composition of the subject material was shown in Table 1. In order to obtain the input parameters of FE analysis the stress-strain curves from ref. [10] were used as shown in Fig. 4. Moreover, the AISI D2 tool steel is the material used for the rollers.

Table 1. Chemical composition [10]

W	1.2-6	C	90.13
S	0.03	Cr	10.5-12
P	0.03	Ni	1.5-1.8
Mn	0.6	Mo	0.35-0.5
Si	0.6	V	0.18-0.3

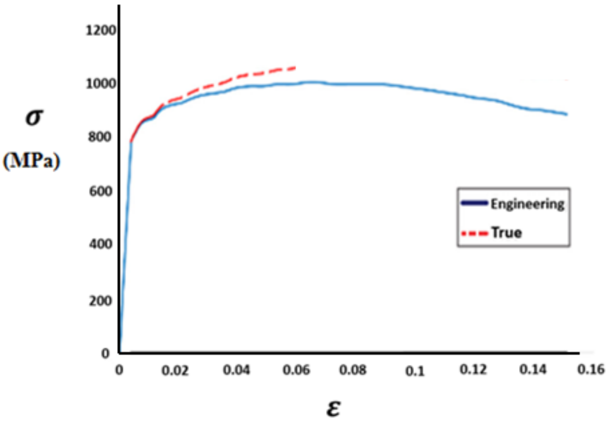

Fig. 4. Stress-strain curves [10].

A ring test was used to obtain the accurate value for the coefficient of friction between the jointing surfaces of the rollers and the workpiece. The purpose of the ring test is to obtain the friction coefficient and investigate the effect of different lubricants on friction in the forming processes. The proposed method started using the calibration curves [11] and considering 6:3:2 ratio for "height: inner diameter: outer diameter." The thickness, inner diameter, and outer diameter of the ring were considered to be 6.67 mm, 10 mm, and 20 mm, respectively. For this test, two similar ring samples were used, which were produced under the same conditions of machining and grinding as well as the same levels of quality. The lubricant was made using Iranol oil with a viscosity of 30 m^2/s. In this test, a 100 tons Time Group press, in the open form, and a precision stopper were used to accurately control the press. Fig. 5 demonstrates the sample rings before and after the ring compression test.

In this test, both rings were pressed up to the same size. The height and internal diameter of the rings were changed to 4 mm and 10.3 mm, respectively. By replacing the values of the height and inner diameter in Eq. 1, the changes in thickness and diameter were obtained.

$$\%\Delta D=\frac{D-D_1}{D}\times 100$$
$$\%\Delta H=\frac{H-H_1}{H}\times 100 \qquad (1)$$

ΔD% is the reduction percentage of the inner diameter, ΔH% shows the reduction percentage of the height, D is the initial inner diameter, D_1 is the final inner diameter, H refers to the initial height, and H_1 is the final value of the height. According to Fig. 6, by replacing the numbers obtained from the calibration curves the friction coefficient was calculated to be 0.2.

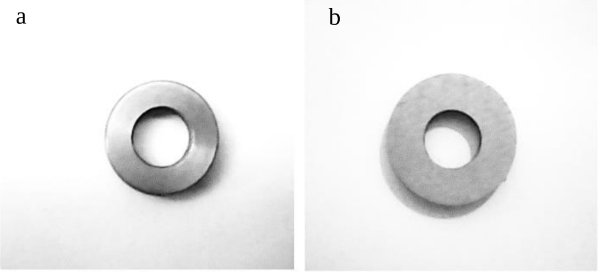

Fig. 5. Ring test, a) before the test, and b) after the test.

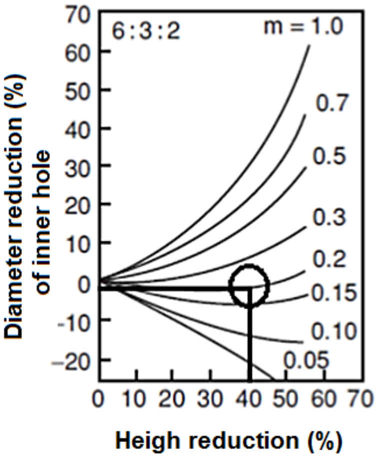

Fig. 6. The calibration curves for the ring compression test and the obtained point form tests [11].

4. Finite Element Simulation of Blade Cold Rolling

Finite element simulations were performed by DEFORM 3D. The rollers were supposed to be rigid, and the preform was considered deformable-tetrahedral mesh type was used for the preform simulation. However, as the rigid body is not meshed by software, the rollers do not need to mesh. The meshing type of the initial form of the sheet, which enters the plastic region together with the size and number of the elements, determines the accuracy of the analysis. In order to select the proper size of the elements, the definition of mesh sensitivity was used. For this purpose, several simulations with identical conditions and a different number of elements were performed, and the value of the rolling force was recorded. The required force diagram was plotted according to the number of the elements in Fig. 7. According to the diagram, it was found that the increase in the number of the elements or reduction in the size of the elements leads to the increase of the rolling force to a certain extent. In addition, it becomes uniform and almost constant in a special range of the number of elements. According to the sensitivity diagram of the mesh, the rolling force does not change significantly from the 24000 numbers of the elements or the element size of 0.12. As a result, the foregoing number of the elements was used in the analysis.

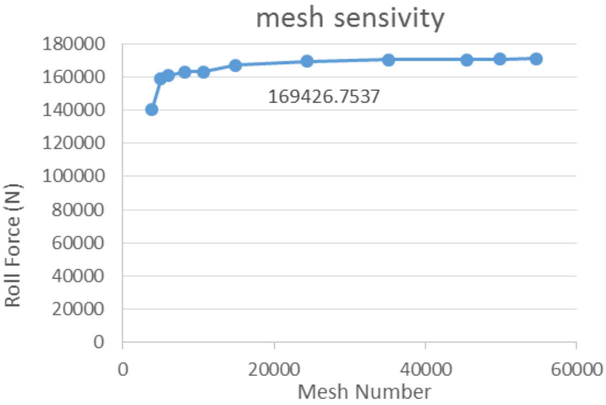

Fig. 7. Sensitivity curves for the number of the elements.

Figure 8 illustrates the meshed preform, and Fig. 9 shows the dimensions of the preform. The required information was entered into the software and the directions of the preform as well as roller movement were determined. Then, the contact conditions were specified between the parts, and finally, the simulations were performed. The rolling process was done in several steps. First, the sheet was deformed towards the near-final shape to facilitate the final step in deforming and creating the final form. Fig. 10 illustrates the design of each step of the three-step blade rolling, and Fig. 11 shows the three-step FE model of the blade rolling and the cross-sectional area of the part coming out.

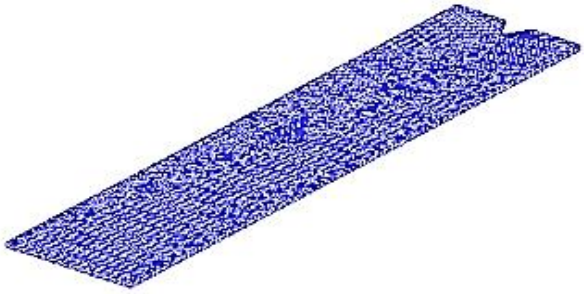

Fig. 8. Meshed preform.

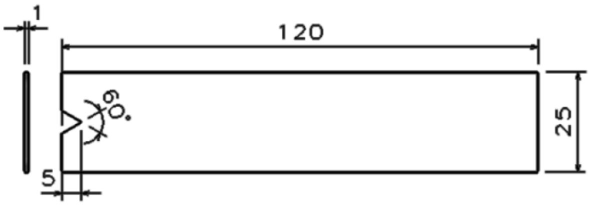

Fig. 9. Initial sheet dimensions.

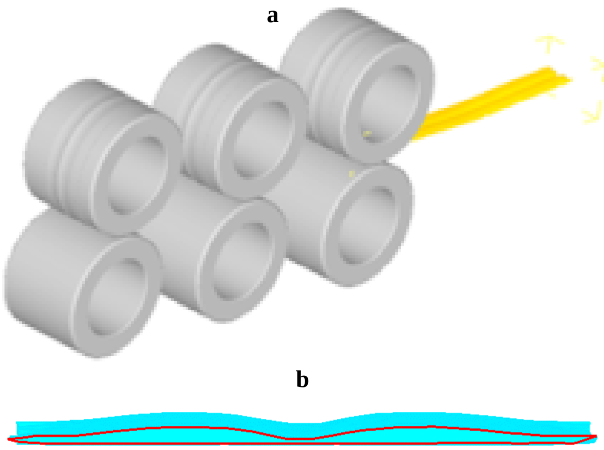

Fig. 10. a) Simulation model for the three-step rolling process, and b) the exiting section of the blade.

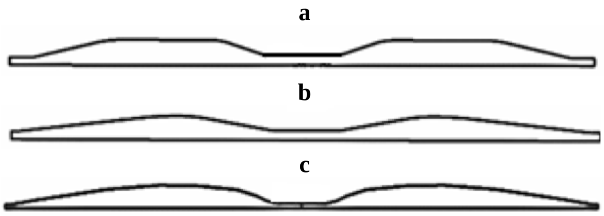

Fig. 11. Design of different steps in the cold rolling process of the compressor blade, a) first step, b) second step, and c) third step.

5. Design of Experiments with ½ Fraction of 2^k Design

Factorial designs have gotten an extensive application in multi-factor experiments. The purpose of these designs is to study the simultaneous effect of several factors on the desired responses. Certain types of factorial designs considered in the present investigation have a significant practical value due to their extensive use in research activities and being the basis for other designs. The most usual case is the two-level of k factor [12]. The factorial designs are used when the number of the experiments is high. ½ fraction of 2^k design includes 2^{k-1} experiments and is usually nominated as the half fractional factorial design, which was used in this research. Six factors, i.e., the width and the thickness of the preform, the roller radius, the width and the thickness of the flash channel, and the number of the rolling steps were studied, and 2(6-1), namely 32 experiments were designed. The test factors and related levels were listed in Table 2, and the obtained FE results of the mentioned experiments were presented in Table 3.

Table 2. Test factors and related levels

Factor	Level 1	Level 2
Sheet thickness (mm)	0.8	1.2
Sheet width (mm)	24	26
Roller radius (mm)	49	73.5
Flash channel thickness (T), (mm)	0.1	0.3
Flash channel width (W), (mm)	3.6	7.6
Number of rolling steps (N)	2	3

Table 3. DOE and response variables

No.	T(mm)	W(mm)	R(mm)	T(f), (mm)	W(f), (mm)	N	F(ton)	$f(mm^2)$
1	0.8	24	49	0.1	3.6	2	12.80	0.86
2	1.2	24	49	0.1	3.6	3	13.60	0.90
3	0.8	26	49	0.1	3.6	3	15.30	1.38
4	1.2	26	49	0.1	3.6	2	17.00	1.46
5	0.8	24	73.5	0.1	3.6	3	16.50	0.80
6	1.2	24	73.5	0.1	3.6	2	20.60	0.88
7	0.8	26	73.5	0.1	3.6	2	20.60	1.39
8	1.2	26	73.5	0.1	3.6	3	18.10	1.61
9	0.8	24	49	0.3	3.6	3	12.70	0.82
10	1.2	24	49	0.3	3.6	2	16.00	0.84
11	0.8	26	49	0.3	3.6	2	15.00	1.35
12	1.2	26	49	0.3	3.6	3	14.90	1.40
13	0.8	24	73.5	0.3	3.6	2	14.60	0.80
14	1.2	24	73.5	0.3	3.6	3	17.00	0.86
15	0.8	26	73.5	0.3	3.6	3	18.90	1.42
16	1.2	26	73.5	0.3	3.6	2	19.00	1.57
17	0.8	24	49	0.1	7.6	3	24.10	0.90
18	1.2	24	49	0.1	7.6	2	12.70	0.92
19	0.8	26	49	0.1	7.6	2	14.80	1.29
20	1.2	26	49	0.1	7.6	3	15.50	1.54
21	0.8	24	73.5	0.1	7.6	2	18.00	0.84
22	1.2	24	73.5	0.1	7.6	3	20.00	1.06
23	0.8	26	73.5	0.1	7.6	3	23.80	1.33
24	1.2	26	73.5	0.1	7.6	2	13.00	1.48
25	0.8	24	49	0.3	7.6	2	14.20	0.82
26	1.2	24	49	0.3	7.6	3	14.15	0.93
27	0.8	26	49	0.3	7.6	3	14.50	1.48
28	1.2	26	49	0.3	7.6	2	17.54	1.50
29	0.8	24	73.5	0.3	7.6	3	17.50	0.85
30	1.2	24	73.5	0.3	7.6	2	23.60	0.90
31	0.8	26	73.5	0.3	7.6	2	22.20	1.148
32	1.2	26	73.5	0.3	7.6	3	22.97	1.163

The parameters listed in Table 3 are as follows: T: sheet thickness, T(t): flash channel thickness, W: sheet width, W(f): flash channel width, R: roller radius, and N: number of rolling steps. Rolling load (F) and flash cross-section area (f) are considered as the two response factors.

The force values for each experiment were obtained directly by FEM, and the most significant force obtained during the rolling process was considered as the final force in the analysis. Fig. 12 shows the two examples of forces on upper rollers for the two-step and three-step rollings.

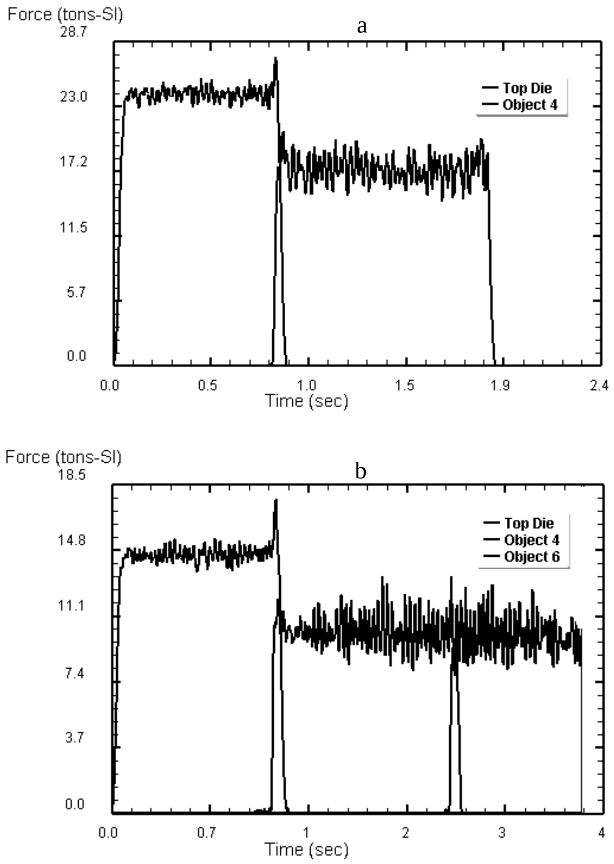

Fig. 12. Rolling force curves, a) two-step rolling, and b) three-step rolling.

The value for the flash's cross-section area cannot be obtained directly by FE. Therefore, the surface area of the analyzed cross-section was calculated by exporting it to SolidWorks software. Then, the obtained values for the flash's cross-section were directly used in the calculations. The values for each output were shown in Table 3.

6. Results and Discussion

The experimental data should be analyzed by statistical methods so that the validity of the results is scientifically verified, and also decisions are not made based on personal judgment. In this section, the obtained response variables (forces on rollers and cross-section areas of the flash) were analyzed using such parameters as effect graphs, main factors, and interaction effects.

6.1. Forces on rollers

6.1.1. ANOVA

In this section, data analysis was performed on the rolling forces using ANOVA. The F-test method was used, which means that if P-value is lower than the α factor (assumed to be 0.05 in these experiments), the considered factor is effective with more than 95% probability; otherwise, the factor is not effective.

According to the ANOVA results presented in Table 4, from the total of the main factors and interactions, the total effectiveness of the six main factors was 88.23%. The factors included the width and the thickness of the preform, the roller radius, the thickness and the width of the flash channel, and the number of the rolling steps, the remaining 11.77% was related to interactions. The roller's radius had the most significant effect, so that 60.5% of all was related to this factor. Afterward, the effectiveness of the width and thickness of the preform, the number of the rolling steps, and the thickness and the width of the flash channel were in the order of higher to lower, respectively. In general, all main factors affect the rolling force. Furthermore, the thickness of the first sheet and the number of the rolling steps (T*N) have the most significant effects among all interactions.

6.1.2. Main effects of parameters

The main effects plot for the rolling force has been illustrated in Fig. 13. It can be inferred that:

- Considering the preform thickness factor, the minimum level is 0.8, and the maximum level is 1.2. Stated alternatively, increasing the thickness of the preform leads to an increase in the rolling force.
- Investigating the preform width factor shows that the 24th level is the lowest force and the 26th level is the highest force.

- Focusing on the roller radius, the rolling force will increase as the roller radius increases. As shown in Fig. 14, among all factors, the roller radius has the most considerable influence on the rolling force.
- Enhancing the thickness and width of the flash channel will increase the rolling force.
- As the number of the rolling steps increases, the thickness reduction of each step decreases; as a result, the rolling force will reduce.

Table 4. ANOVA for rolling force data

Factor	Degree of Freedom (DF)	Sum of squares (SS)	F	P
Main effects	6	330.406	152.88	0
T	1	31.928	88.64	0
W	1	41.611	115.52	0
R	1	226.620	629.13	0
T(f)	1	6.031	16.74	0.002
W(f)	1	2.401	6.66	0.027
N	1	21.815	60.56	0
Way interaction	15	40.461	7.49	0.001
T*W	1	4.315	11.98	0.006
T*R	1	4.287	11.90	0.006
T*T(f)	1	2.936	8.15	0.017
T*W(f)	1	0.482	1.34	0.274
T*N	1	12.495	34.69	0
W*R	1	2.707	7.52	0.021
W*T(f)	1	0.225	0.62	0.448
W*W(f)	1	0.977	2.71	0.131
W*N	1	1.945	5.40	0.043
R*T(f)	1	3.596	9.98	0.010
R*W(f)	1	3.010	8.36	0.016
R*N	1	1.234	3.43	0.094
T(f)*W(f)	1	2.011	5.58	0.040
T(f)*N	1	0.100	0.28	0.610
W(f)*N	1	0.141	0.39	0.545
Error	10	3.602	-	-
Total	31	374.469	-	-

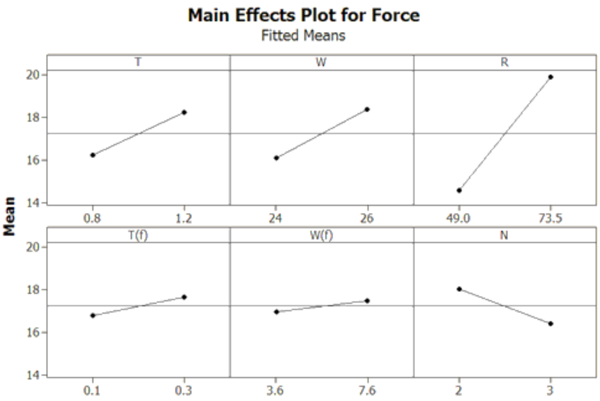

Fig. 13. Main effects of the parameters on the rolling force.

6.1.3 Parameters interactions

The graphs of the effects of the parameter interactions on the rolling forces have been shown in Fig. 14. If these graphs are parallel, there will be no interactions between the two involved factors, but when the lines of these graphs are not parallel with each other, there is a sign of interaction between the studied factors. By analyzing the interaction graphs, it was inferred that:

- The number of the rolling steps and the thickness of the preform have the most significant effect on the rolling force. In the case of the preform thickness of 0.8 mm, the force will rise by increasing both factors, i.e., the roller radius and the preform width. The width and the thickness of the channel and the number of the rolling steps do not have much effect on the rolling force. However, in the case of the preform thickness of 1.2 mm, the rolling force increases along with all the factors except for the number of the rolling steps. In this case, the interactions of the roller radius and preform thickness lead to the highest force.
- In the case of the preform thickness of 1.2 mm, the force decreases sharply by increasing the number of the rolling steps.
- In the case of the preform width of 24 mm, the force rises by increasing both parameters, i.e. the roller radius and the thickness of the flash channel. Moreover, the rolling force will reduce by increasing the number of the rolling steps. Furthermore, by increasing the flash channel, there will be no effect on the amount of the rolling force, and within the 26 mm width of the preform, the interaction effects will be in the same order.
- In the case of the roller radius of 49 mm, the width and the thickness of the flash do not affect the rolling force. However, the relative force increases in the radius of 73.5 mm while the number of the rolling steps in the two conditions mentioned above will reduce the amount of the force similarly.
- In the case of the thickness of 0.1 mm for the flash channel, increasing the channel width does not affect the amount of the force. However, in the case of the thickness of 0.3 mm, increasing the width of the channel can lead to the rise of the amount of the force, while increasing the number of the rolling steps in the aforementioned two thicknesses will reduce the amount of the rolling force.

- Increasing the number of the rolling steps in two different thicknesses of the channel will reduce the amount of the force.

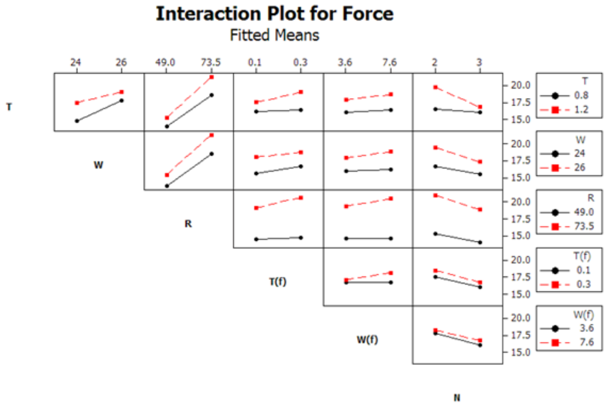

Fig. 14. The effects of the parameters' interactions on the rolling force.

6.2. Flash cross-section area

6.2.1. ANOVA

Analyzing the variance of the data for the cross-section of the flash was performed based on the sum of the squares technique (Table 5). It was inferred that the percentage of the main factors is 91.6% of the total factors. Among the main factors, the width of the preform had the most significant effect. The total squared of the thickness and the width of the channel, the number of the rolling steps, and the radius of the roller were respectively less among the six main factors. Moreover, the P-values of the mentioned main factors were higher than the error value of α, and these factors were ineffective in the size of the cross-sectional area; in other words, they were not meaningful. Finally, all other factors (both main and interactive) were not effective except for the preform's width and thickness.

6.2.2. Main effects

Figure 15 shows the main effect diagrams of the parameters on the cross-section of the flash. By studying the main effect diagrams, the following results are obtained:

- As the preform thickness increases, the cross-section area of the flash increases as well.
- The preform width has the most significant effect on the flash creation. By increasing the preform thickness, more flash is produced. Therefore, in the designing step, the width of the preform is considered to be less than the width of the caliber.
- Increasing the radius and width of the flash channel does not have much effect on the increase in the cross-section area of the flash.
- By increasing the thickness of the flash channel (according to the design of the flash), the cross-section area of the flash decreases.
- Increasing the number of the rolling steps leads to a more precise cross-section. However, it has less effect on the flash creation.

Table 5. ANOVA for the flash cross-section area

Factor	Degree of Freedom (DF)	Sum of squares (SS)	F	P
Main effects	6	2.376	40.87	0
T	1	0.073	7.58	0.02
W	1	2.274	234.09	0
R	1	0.002	0.27	0.616
T(f)	1	0.019	2	0.187
W(f)	1	0.001	0.11	0.742
N	1	0.004	0.5	0.495
Way interaction	15	0.12143	0.83	0.637
T*W	1	0.00351	0.36	0.561
T*R	1	0.00394	0.41	0.539
T*T(f)	1	0.01069	1.10	0.319
T*W(f)	1	0.00057	0.06	0.814
T*N	1	0.01012	1.04	0.332
W*R	1	0.00261	0.27	0.616
W*T(f)	1	0.00037	0.04	0.849
W*W(f)	1	0.03843	3.96	0.075
W*N	1	0.00049	0.05	0.827
R*T(f)	1	0.01012	1.04	0.332
R*W(f)	1	0.02697	2.78	0.127
R*N	1	0.00158	0.16	0.695
T(f)*W(f)	1	0.00381	0.39	0.545
T(f)*N	1	0.00513	0.53	0.484
W(f)*N	1	0.00310	0.32	0.585
Error	10	0.097	-	-
Total	31	2.594	-	-

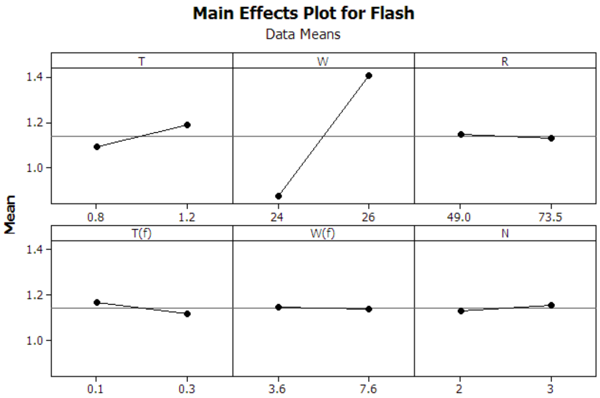

Fig. 15. Main effects of the parameters on the flash cross-section area.

6.2.3. Interactions effects

Figure 16 indicates the interaction effects of the parameters on the cross-section area of the flash. By investigating the interaction graphs, the following results are found:

- In all of the two-factor interactions, the two lines are almost parallel. As a result, it can be concluded that the effect of the interactions is insignificant.
- It is inferred from the interactions of the preform thickness with the thickness of the flash channel of the preform that the flash decreases if both of the mentioned thicknesses increase.

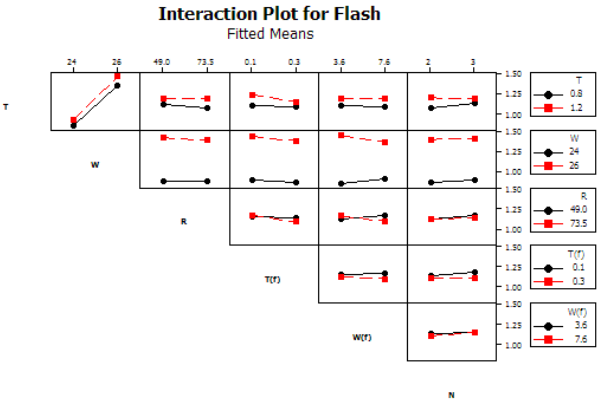

Fig. 16. The effects of the parameters interactions on the flash cross-section area.

7. Conclusions

In the present study, the effect of the process parameters on the amount of the process force and the flash were investigated with the design of the experiments and simulation of the shape rolling process of the compressor blade of a gas turbine engine.

By analyzing the data obtained from the simulations, the following results were obtained by ANOVA, main effects diagrams, and the effects of parameter interactions.

1) The roller's radius, width, and thickness of both the preform and flash channel increase the amount of the applied force on the roller. The roller radius is the most effective factor.

2) The number of the rolling steps reduces the amount of the rolling force.

3) The most effective factor interactions on the rolling force are the interaction of the preform's thickness with its width and the interaction of the roller radius with the preform's thickness, respectively.

4) Increasing the thickness and width of the preform increases the cross-section of the flash.

5) The main factor for increasing the cross-section of the flash is the initial preform width.

6) The interaction effects of all parameters in the cross-section area are not meaningful.

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بررسی عوامل مؤثر در فرآیند نورد شکلی پره کمپرسور موتور توربین گازی

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چکیده

فرآیند نورد شکلی یکی از فرآیندهای متداول تغییر شکل می باشد که با فشار دادن دو غلتک با یک شکل خاص در جهت چرخشی مخالف، تغییر شکل مورد نظر حاصل می شود. به منظور بهبود کیفیت محصول و کاهش هزینه های تولید، تحلیل دقیق فرآیند نورد شکل پره های کمپرسور و همچنین بررسی پارامترهای مؤثر انجام شده است. در ابتدا با استفاده از روش المان محدود و طراحی آزمایش (DOE)، فرآیند نورد شکلی یک پره کمپرسور معمولی بر اساس داده های تجربی شبیه سازی شده، سپس اثر پارامترهای مختلف فرآیند از جمله ضخامت و عرض پیش فرض، قطر غلتک، ضخامت و عرض کانال پلیسه و تعداد مراحل نورد روی دو پارامتر هدف یعنی نیروی نورد و میزان پلیسه مورد بررسی قرار گرفت. داده های به دست آمده با استفاده از آنالیز واریانس (ANOVA) مورد تجزیه و تحلیل قرار گرفت و عوامل مؤثر در روند نورد شکلی شناسایی شدند. نتایج نشان داد که کلیه عوامل در نظر گرفته شده بر میزان چرخش تأثیر می گذارند، اما فقط عرض و ضخامت ورق اولیه بر فاکتورهای حجم پلیسه به عنوان هدف دوم تأثیر می گذارد. افزایش تعداد مراحل چرخش باعث کاهش بار لازم فرآیند می شود اما افزایش عوامل دیگر باعث افزایش بار نورد می شود. همچنین افزایش ضخامت و عرض ورق اولیه باعث افزایش حجم پلیسه می شود.

واژه‌های کلیدی: نورد شکلی، پره کمپرسور، شبیه سازی عددی، آنالیز واریانس