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THEORETICAL AND EXPERIMENTAL RESEARCH OF HOT ROLLING OF ALUMINUM STRIPS FOR SOLAR COLLECTOR

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ТЕОРЕТИЧНЕ ТА ЕКСПЕРИМЕНТАЛЬНЕ ДОСЛІДЖЕННЯ ГАРЯЧОЇ ПРОКАТКИ АЛЮМІНІЄВИХ СМУГ ДЛЯ ОТРИМАННЯ СОНЯЧНОГО КОЛЕКТОРА

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ТЕОРЕТИЧЕСКОЕ И ЭКСПЕРИМЕНТАЛЬНОЕ ИССЛЕДОВАНИЕ ГОРЯЧЕЙ ПРОКАТКИ АЛЮМИНИЕВЫХ ПОЛОС ДЛЯ ПОЛУЧЕНИЯ СОЛНЕЧНОГО КОЛЛЕКТОРА

Abstract. The article investigates the process of rolling aluminum strips with aluminum wire inside for the solar collector components. The closure of coal mines, the constant rise in the cost of oil and gas compel to refer to the methods for producing renewable (alternative) energy. An urgent problem is the enhancement of solar manufacturing technologies in order to improve the quality and reduce the cost of products. The article presents the results of experimental and theoretical studies of the hot rolling process of aluminum strips with aluminum wire between them for internal collector channels. The velocity fields were researched; dependence on the rolling load changes for different degrees of deformation was obtained.

It was found that for obtaining high-quality welding strips with wire between them the degree of deformation should be more than 35%. The comparison of the dependencies obtained experimentally and with the theoretical calculations was carried out, which showed a high degree of similarity. The comparison of the dependences obtained experimentally with the theoretical calculations was carried out, which showed a high degree of reproducibility, repeatability and similarity. Scientific novelty of the research lies in the parameters justification of hot rolling process of two aluminum strips with aluminum wire between them for partial welding of aluminum strips. These results can be used in industrial processes for the parts production of solar collectors in alternative energy. This study was supported by German Academic Exchange Service (DAAD) in the framework of German-Ukrainian project «Praxispartnershaft Metalurgie».

Keywords: hot rolling, the aluminum strips, internal channels, the degree of deformation.

Introduction

In recent years, the closure of coal mines, the constant rise of the cost of oil and gas compel to pay attention to the methods for producing so-called renewable (alternative) energy, which undoubtedly will soon need to gain energy independence and compensate the lack of conventional fuels. The main advantages of these technologies are the absolute environmental friendliness, ease of use, long operating systems, minimal service and maintenance. Using renewable energy sources, we have a significant effect on the environment and energy crisis in the world, as well as we get independent of traditional forms of energy, significant cost savings and confidence in the future. One of the main sources of energy for this type of systems is the sun energy.

The use of sun energy in our country has a special place, because climatic conditions especially in south of Ukraine allow to use all year round effectively solar system, which based on solar collectors for autonomous hot water and heating. Solar systems are equipment for heating water, which include solar collectors. The technology of collectors' production is constantly evolving and developing in order to improve the quality and reduce the cost of products. One of the main step of this technology is partial connection of aluminum strips with getting inner channel between aluminum strips.

The study of the plastic deformation process in hot rolling of aluminum strips with aluminum wire will allow setting the technological features of manufacturing process of these parts. A key point of producing such types of parts of solar collectors is creating inner channel between aluminum stripes easier, cheaper and more effectively. One of possible variants of its solution is a partial connection to the two aluminum strips with an aluminum wire between them during hot rolling.

Formulation of the problem

The aim of this research is to study the plastic deformation parameters of joint-rolling the two aluminum strips with an aluminum wire between them to obtain an aluminum plate with internal channels.

Condition of the problem

Questions of aluminum strips hot rolling were studied by many scientists. The authors in [1] found that the bonding strength of the material in hot rolling can be compared with the original material strength. It was also found that the most important parameter in the process of rolling is the initial temperature, the annealing temperature, elongation and roll speed. The most important factor is the temperature. It was also found that the hot rolling gives greater bonding strength than the cold one. Influence of rolling temperature on the microstructure and mechanical properties of the aluminum strips was investigated in [2].

Based on the studies [3] model compound bimetals multilayer has been developed, whereby the especially of anisotropy of deformation bounding were determined, it was analyzed the influence of such parameters as friction coefficient, deformation coefficient, roll radius on the quality metal compounds. Those parameters could be used in our researches.

In a study [4] was determined dependence during the heat treatment of the influence of the frictional coefficient on the compound of aluminum strips. It is found that the rate of bond strength increases with increasing annealing temperature, moreover, the extreme value of strain for the compounds decreases with increasing annealing temperature.

In a study [5] the processes of hot and cold rolling welding of two aluminum strips with several thicknesses and varying deformation degrees and temperature were researched. The strain and temperature limit were found at which the compound of aluminum strips with hot and cold rolling take place.

Scientists [6] found that not only materials but geometry of the channels influence on the quality of collector. In this study, production technology of multichannel collector was optimized by rolling and partial welding. The various forms of channels were tested experimentally and the most optimal form was identified.

The results and achievements of studies that were conducted earlier have been studied and taken into attention in our experiment. A distinctive feature of the experiment is the presence of aluminum wire between the aluminum strips.

Experimental part

For the experiments test specimens in the form of strips of aluminum alloy EN AW-1050 and aluminum wire from the same alloy were prepared.

The aluminum plate size: 200 mm 70 mm 3 mm (Fig. 1), with holes for rivets in order to the composition of the two aluminum strips of aluminum wire between them during rolling was as a single blank without displacement. The aluminum wire of 1.5 mm diameter, 250 mm in length were used.

The experiment was conducted according to the following diagram (Fig. 2). The two aluminum stripes and wires were degreased by alcohol and connected into the composition strip - wire - strip and were fixed by rivets to prevent shift of the elements relative to each other during rolling. The simple was heated in a furnace to a temperature of 500 0C. The rolling was conducted at the deformation degree of 30-40%, for 220 mm diameter rolls.

Rolled samples were measured and had heat treatment in an oven at 2000C for two hours.

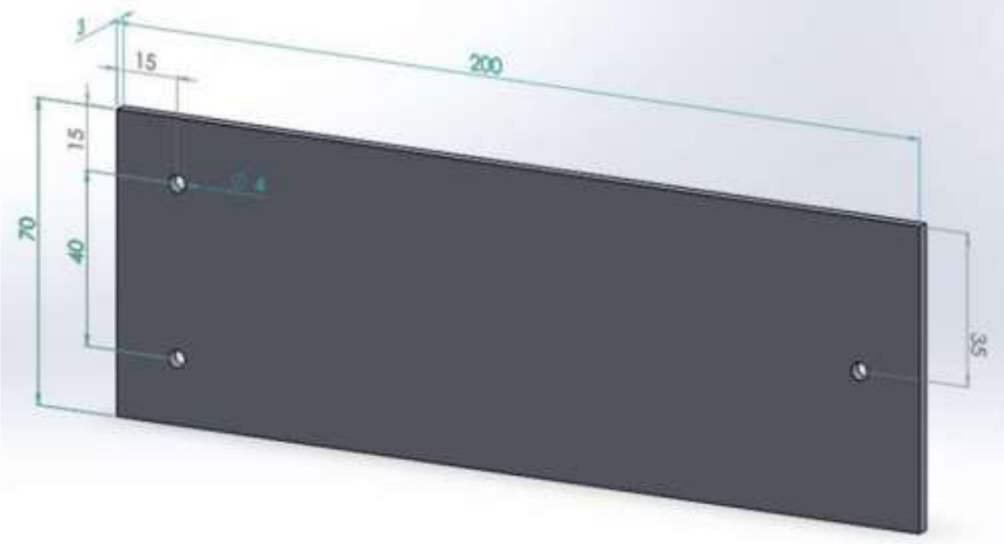

Figure 1 – The example of the experimental aluminum strips sample

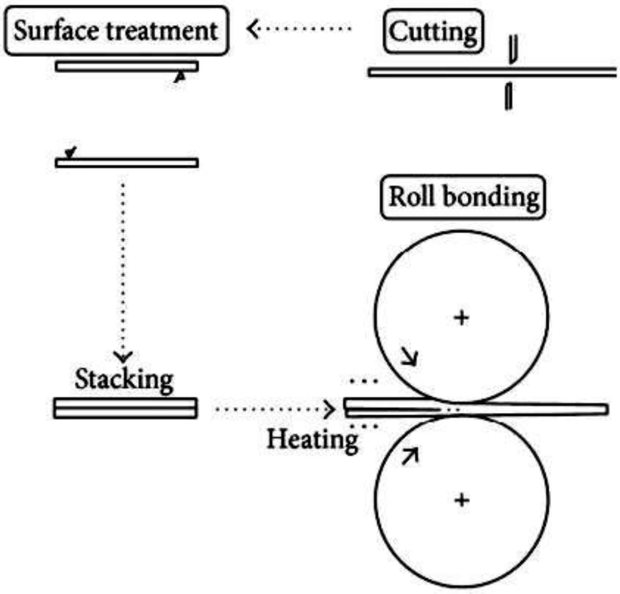

Figure 2 – The scheme of the experiment

The results and their discussion

In the result of this experiment elongation coefficient, spread coefficient, deformation coefficient were calculated. The measurements of rolling load also were calculated during rolling within accuracy 1000 samples per second.

As a result of rolling with a degree of deformation of 30-31% (samples 1 and 2, Table 1) there was no quality welding and the task has not been achieved. During rolling with the deformation of 35% and more (samples 3-7, Table 1), surface welding was successful. According to the results of measurements elongation coefficient, spread coefficient were calculated and they are proportional to the deformation coefficient.

Table 1 – Deformations indicators

№	Width after rolling, mm	Length after rolling, mm	Deformation co-efficient, %	Elongation co-efficient, %	Spread coefficient, %
1	71,0	270	30,28	35,00	1,43
2	71,0	269	31,00	34,00	1,43
3	71,5	278	36,67	39,00	2,14
4	72,0	297	41,94	48,50	2,86
5	71,8	295	40,83	47,50	2,57
6	71,5	278	35,17	39,00	2,14
7	71,0	276	34,67	38,00	1,43

In the results of researches the border of the deformation degree during the hot rolling was determined, at which welding of aluminum stripes with aluminum wires between them take place. The visual sample of this experiment is shown in Fig. 3.

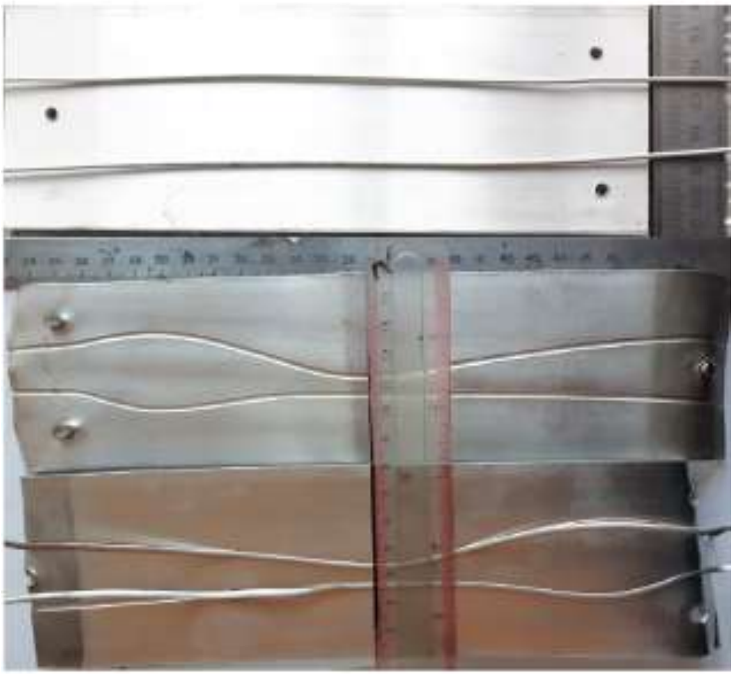

Figure 3 – Aluminum wire before and after rolling

During the experiments the measurements of speed and rolling load were conducted for each experiment.

The simulation of the process by finite element software product Q-Form was done as well. (Fig. 4) In a theoretical study with the help of the Q-Form software were set the same process parameters as in experimental studies.

The velocity field was analyzed, that was obtained by simulation hot rolling aluminum strips, with aluminum wire.

As a result of simulation the velocity distribution of the metal during rolling was obtained. The strip speed at the exit of the rolls is 143 mm / sec, strip speed at the inlet of the rolls is 92 mm / s. At the figure 5 the velocity distribution in the field of deformation is shown.

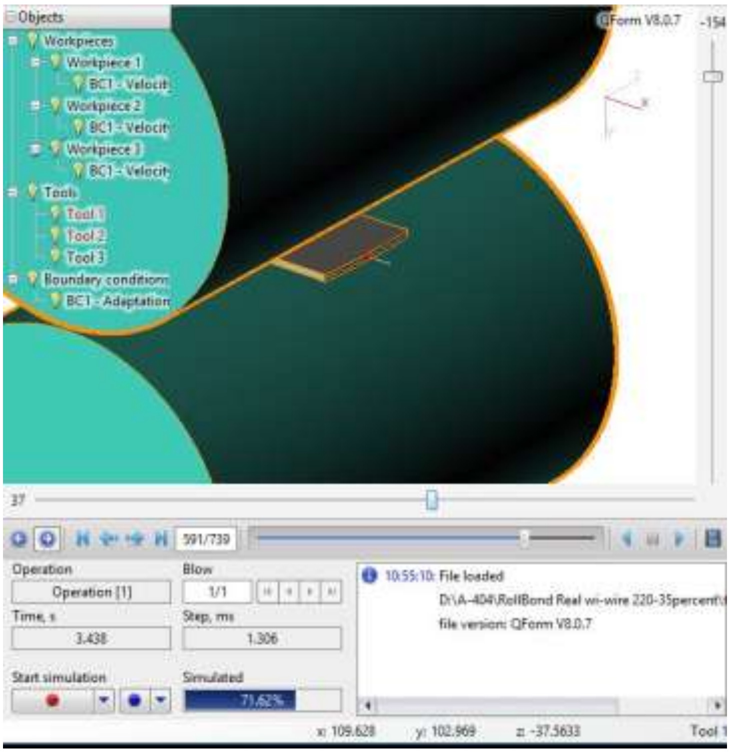

Figure 4 – Hot rolling aluminum plates simulation in Q-Form

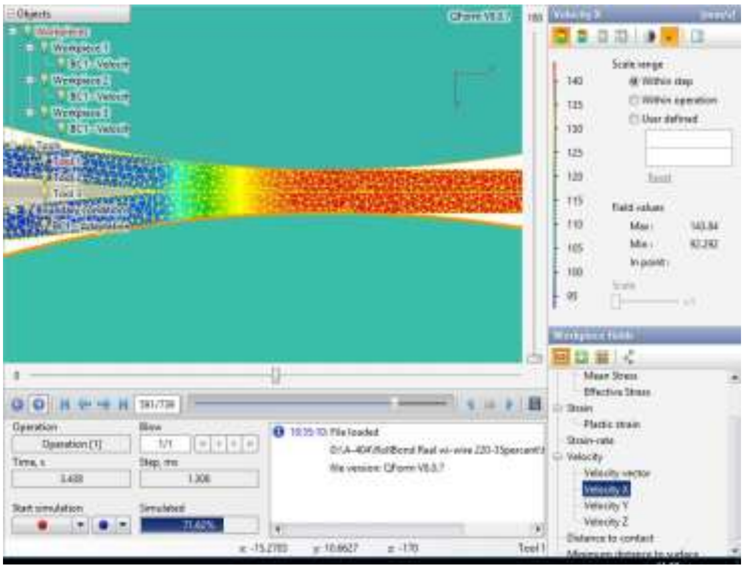

Figure 5 – Field of speeds in hot rolling aluminum plates simulation

During the research the series of experimental rollings were carried out as well as simulations to determine the effect of such technological parameters of the process as temperature, degree of deformation and the diameter of the rolls on the rolling load and the quality of the strips connection. As the result of research the satisfactory convergence of experimental and theoretical data about the rolling force was received (Fig. 6).

This conclusion makes it possible to lead further theoretical study of the effect of temperature, degree of deformation and the diameter of the rolls on the strength and quality of rolling.

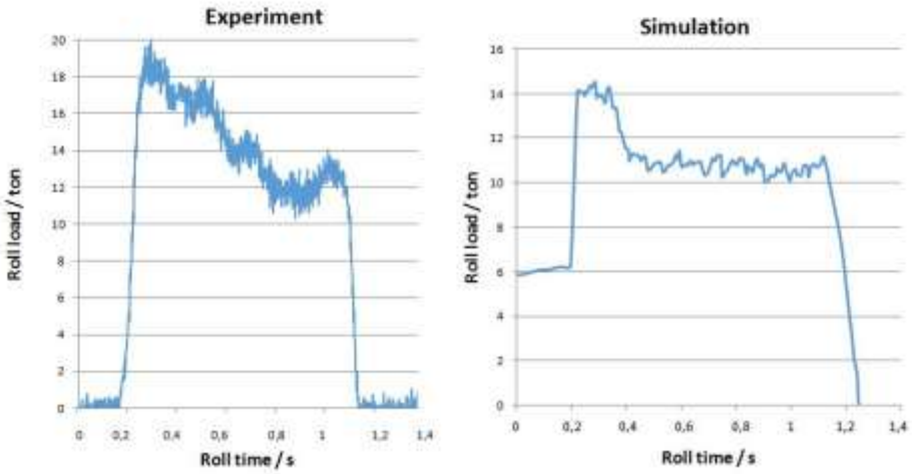

Figure 6 – The experimental and theoretical data about the rolling force

Conclusions

Making analyze of conducting studies it should be noticed the following. During the hot rolling of aluminum strips with aluminum wire between them the velocity field, elongation coefficient, spread coefficient and the deformation coefficient were researched, dependence rolling load from rolling time was obtained for different degrees of deformation. It was found experimentally that for quality welding strips with wire between them the rolling load must be at least 35%. The comparison of the experimentally obtained dependences with the theoretical calculations by computer simulation in the software product Q-Form was conducted, which showed a high degree of reproducibility. Rationale for the use of this software will allow to reduce in the future the duration of experimental studies in determining the rational technological process parameters of hot rolling of the two strips with aluminum wire inside to improve the quality of welding them together in order to obtain plates with internal channels, which are used in the manufacture of solar collector.

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Анотація. Стаття присвячена дослідженню технологічного процесу прокатки алюмінієвих штаб з алюмінієвою проволокою всередині для отримання деталей сонячного колектору. Зачинення вугільних шахт, постійне зростання вартості нафтопродуктів та газу змушує звертатися до способів отримання відновлюваної (альтернативної) енергії. Актуальної є проблема вдосконалення технології виготовлення сонячних колекторів з метою покращення якості та зменшення вартості виробу. У статті наведені результати експериментальних та теоретичних досліджень процесу гарячої прокатки алюмінієвих штаб с алюмінієвою проволокою між ними для отримання внутрішніх каналів колектору. Досліджено поле швидкостей, отримані залежності зміни сили прокатки для різних ступеней деформації. Встановлено, що для отримання якісного зварювання штаб з проволокою між ними, ступінь деформації повинна бути не менше 35%. Виконано порівняння залежностей, отриманих експериментально, з теоретичними розрахунками, що показали високий ступінь збіжності результатів. Наукова новизна досліджень полягає в обґрунтуванні параметрів процесу гарячої прокатки двох алюмінієвих полос з алюмінієвою проволокою всередині для парціального, часткового зварювання алюмінієвих штаб. Представлені результати можуть біти використані в технологічних процесах отримання деталей сонячних колекторів в альтернативній енергетиці. Дослідження, результати яких приведені в даній статті, виконані в межах сучасного спільного німецько-українського проекту «Praxispartnershaft Metalurgie», який фінансується німецьким товариством академічних обмінів DAAD.

Ключові слова: гаряча прокатка, алюмінієва пластина, внутрішні канали, ступінь деформації.

Аннотация. Статья посвящена исследованию технологического процесса прокатки алюминиевых полос с алюминиевой проволокой внутри для получения деталей солнечного коллектора. Закрытие угольных шахт, постоянный рост стоимости нефтепродуктов и газа вынуждает обращаться к способам получения возобновляемой (альтернативной) энергии. Актуальной является проблема совершенствования технологий изготовления солнечных коллекторов с целью улучшения качества и уменьшения стоимости изделий. В статье приведены результаты экспериментальных и теоретических исследований процесса горячей прокатки алюминиевых полос с алюминиевой проволокой между ними для получения внутренних каналов коллектора. Исследовано поле скоростей, получены зависимости изменения силы прокатки для различных степеней деформации. Установлено, что для получения качественного сваривания полос с проволокой между ними степень деформации должна быть не менее 35 %. Выполнено сравнение зависимостей, полученных экспериментально, с теоретическими расчетами, показавшее высокую степень сходимости результатов. Научная новизна исследований заключается в обосновании параметров процесса горячей прокатки двух алюминиевых полос с алюминиевой проволокой внутри для парциального, частичного сваривания алюминиевых полос. Приведенные результаты могут быть использованы в технологических процессах получения деталей солнечных коллекторов в альтернативной энергетике. Исследования, результаты которых приведены в данной статье, выполнены в рамках совместного немецко-украинского проекта «Praxispartnershaft Metalurgie», финансируемого немецким обществом академических обменов DAAD.

Ключевые слова: горячая прокатка, алюминиевая пластина, внутренние каналы, степень деформации.

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