МЕХАНИЧЕСКАЯ ОБРАБОТКА ДРЕВЕСИНЫ И ДРЕВЕСИНОВЕДЕНИЕ

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THE EFFECT OF SEASONAL TEMPERATURE VARIATIONS ON THE PRODUCTION EFFICIENCY OF MEDIUM DENSITY FIBERBOARD (CASE STUDY OF ARIAN SINA COMPANY)

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Production efficiency should be uniformed throughout the whole year in order to prevent material, energy, finance, and time losses. Due to the internal bond strength loss during the cold season and, as a result, the reduction of production efficiency, this study investigated the effect of different seasons on the efficiency of medium density fiberboard (MDF) production at Arian Sina Company. For these purposes 200 fiberboards were produced by the Company in different seasons of 2017. The following parameters have been adopted for the fiberboards production: pressure time – 200 s; amount of glue – 10 % of dry fiber, humidity of the fiber mat – 7 %; hardener – 0.8 % of dry glue weight. The species composition consisted of 70 % of poplar species and 30 % of river red gum (*Eucalyptus camaldulensis*). The results showed that decreasing of temperature in cold seasons and even the difference in day and night temperatures reduces the internal bond strength and thus the speed of production line due to the need for more pressure time. The results obtained from the X-ray analysis of the vertical density profiles showed that the core layer density of the mat, when its temperature is 18 °C and 40 °C, is 561 and 634 kg/m^3, respectively.
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Keywords: mat temperature, production efficiency, medium density fiberboard, vertical density profile.

Introduction

In recent years, the use of composite wood panels has been expanded considerably. The main reasons for this are the variety of design and the increased costs of timber cutting because of the increase in the price of logs and labor costs. These costs have fallen dramatically in the continuous production process that converts wood into wood particles or fibers. Medium Density Fiberboard is one of the products of wooden composites; its production, import and consumption have been welcomed in Iran in recent years. Arian Saeed Industrial Group has a significant share of Iran's domestic markets with its four active lines of medium density fiberboard production and two lines of the production with current capacity of about 1 mln m^3. The production efficiency is affected by the production variables, including production line machines, especially press (and pre-press), raw materials, humidity of fiber mat. However, one of the key factors in improving the production efficiency, that is not considered, is the fiber temperature. Wood chips are converted into fibers and passed through the blow line to be mixed with glue. Then the fibers enter the dryer where the humidity of the fiber reaches 7–10 %. Also, the fibers temperature at the end of the dryer reaches about 42 °C. When the fibers reach the forming machine, the fiber temperature is the same with the temperature of production site. In winter, the temperature of the fiber decreases due to cold weather, which reduces the production efficiency. The initial temperature of the mat affects the production efficiency more than any other factor in the fiberboard industry based on the role of temperature in acceleration of reaction, reduction of reaction time and uniforming the distribution of acetyl groups on cell wall polymers. The final structure of the board is formed due to the heat transfer and pressure in hot press [2]. The enormous potential of fiberboard consumption requires the study of production efficiency in different seasons. Thus, the main research goal for the Arian Sina Company is to study the difference in temperatures of mat during different seasons, and even the difference in day and night temperatures, in order to maintain the production efficiency in cold seasons according to the results of effective solutions.

Materials and Methods

The Arian Sina Company had produced 200 raw fiberboards in different seasons of 2017. They had the following production conditions and parameters: pressure time of 200 s, glue – 10 % of dry fiber, humidity of fiber mat – 7 %, hardener – 0.8 % of dry glue weight. The species composition included 70 % of poplar species and 30 % of *Eucalyptus camaldulensis*.

The ambient temperature was obtained from the measurements of the American Meteorological Society in 2017 (Fig. 1). The temperature of fiber mat was obtained by the infrared thermometer Testo 830-T2 with the ability to measure temperatures between –50 to 500 °C (from –58 to 932 °F); temperature resolution sensor of –0.1 °C (–0.1 °F); temperature sensor accuracy was ±0.5 °C; temperature measurement rate was 1.75 s. Testo 925 thermocouple with the range of temperature sensor measurement from 50 to 1000 °C (58 to 1832 °F) and accuracy of ±1 unit was used in order to analyze the core layer temperature in medium density boards (Fig. 2).

Test samples were tested with a mechanical test machine in the Arian Saeed Laboratory in order to determine the Tensile Strength Perpendicular to Plane of the Board (internal bond strength) in accordance with the EN 622-5 and EN-319 standards [3, 4].

To measure the vertical density distributions, all panels were scanned using the X-ray density scanning system (with SicoScan model). Then ANOVA was used to determine the significance of board production with the same production conditions compared to different mats in different seasons.

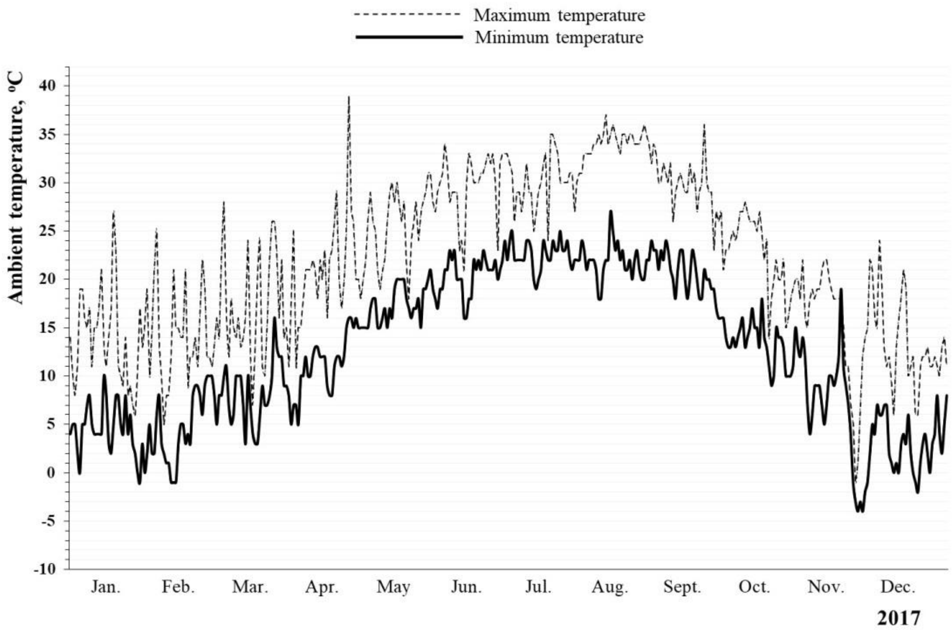


Fig. 1. Minimum and maximum ambient temperature in 2017, Sari, Iran

Fig. 2. Testo 830-T2 infrared thermometer and Testo 925 thermocouple

Results and Discussion

As seen in Table 1 and Fig. 3, when the fiber mat has temperatures of 18, 20, 24, 26, 30, 32, 34, 36, 38 and 40 °C, it takes 200, 185, 180, 170, 140, 130, 110, 108, 105 and 100 s, respectively, to reach the fiber mat temperature to 100 ° C in the core layer. By increasing the temperature of the fiber mat from 18 to 40 °C, the time for reaching the core layer temperature 100 °C is significant. When the fiber mat temperature is 18 °C, the temperature of the core layer reaches 100 °C after 200 s; whereas the fiber mat temperature is 40 °C, the temperature of the core layer reaches 100 °C after 100 s. In other words when the temperature of the fiber mat is 40 °C, the polymerization of glue in the core layer is much faster than the temperature of fiber mat reaches 18 °C, so it saves 100 s of the pressure time.The temperature of the core layer of the fiber mat during pressing depends on the heat transfer in the mat from surface layers to core layers and the heat released in the resin curing process [1]. So, with the increase of the fiber mat temperature, heat transfer to the core layer begins at a higher temperature and the temperature of core layer rises faster.

Table 1

Effect of mat temperature on production efficiency and internal bond

Sample no.	Mat temperature, °C	Reaching the temperature of the core layer at 100 °C	IB, N/mm^2	Core layer density, kg/m^3
1	18	200	0.46	561
2	20	185	0.54	578
3	24	180	0.58	581
4	26	170	0.64	589
5	30	140	0.66	597
6	32	130	0.69	601
7	34	110	0.74	615
8	36	108	0.79	621
9	38	105	0.84	625
10	40	100	0.91	634

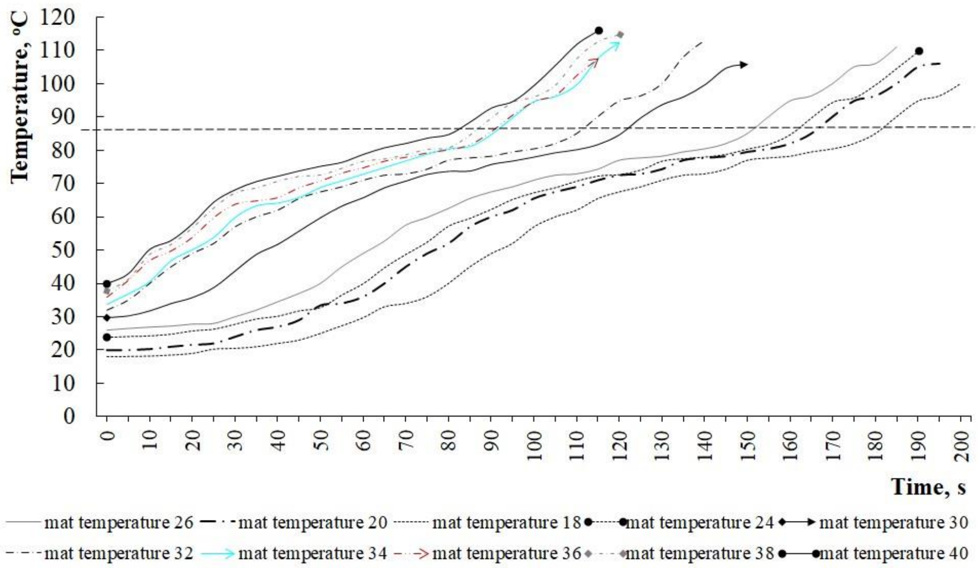
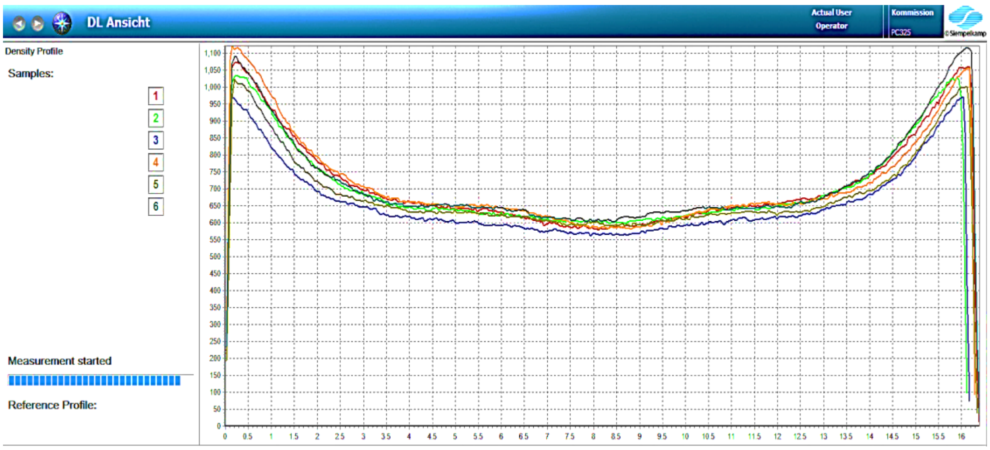
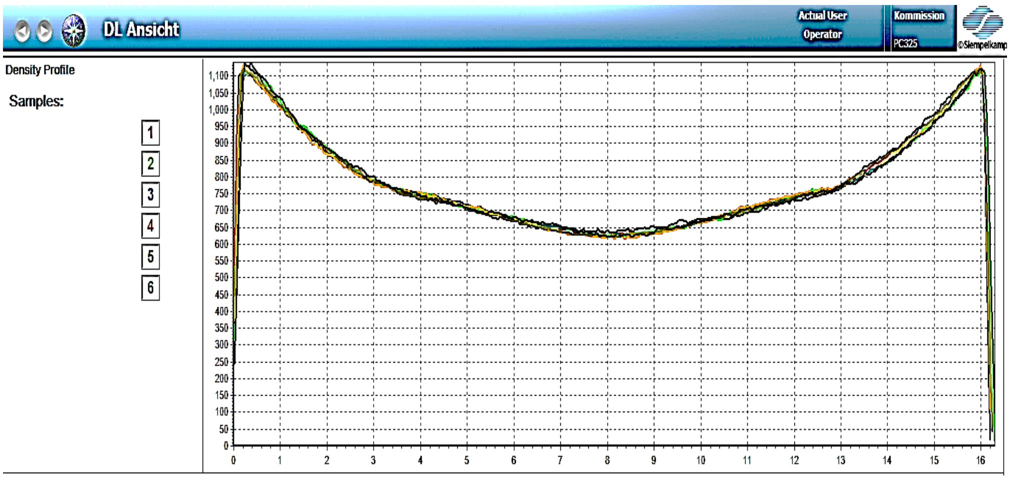


Fig. 3. The effect of the mat temperature on the core layer temperature

The results obtained from the X-ray Vertical Density Profile are shown in Table 1 and Fig. 4. The core layer has the density from 561 to 634 kg/m^3, according to the results of analysis of boards manufactured at different temperatures. As well as mats with temperatures of 18, 20, 24, 26, 30, 32, 34, 36, 38 and 40 °C have the core layer density of 561, 578, 581, 589, 597, 601, 615, 621, 625 and 634 kg/m^3, respectively. The results showed that there is a strong correlation between the mat density of the primary temperature and the internal bonds of the boards. Vertical density profile is an important parameter affecting the medium density fiberboard resistance [9], which is influenced by production variables, including production line machines, especially presses (and pre-presses), as well as pressing schedules and mat shaping. The vertical density profiles of the fiberboard are mainly influenced by three factors: step-closing schedule for fiberboard pressing, heat and moisture distribution in mat, and interaction of these factors during hot pressing [5]. The closing time of the press is the time from the moment of contact with the top plate of the press with the surface of the mat until the fiberboard reaches the final thickness. The high temperature of the mat causes the temperature to rise faster to the core layer of the board and polymerization will occur more quickly and in constant time, it improves the internal bond strength of fiberboard. In this case, the density of the core layer is increased too; the warmth of the mat increases the flexibility of the mat. As the pressing is slowly, there is enough time for water steam to penetrate from the surface layers to the core layers and cause more compression of the fiber in the core layer. As a result, the density of the core layer increases and the density of the boards becomes more uniform. According to [6] and [10], the moisture and dimensions of fibers or particles have the greatest impact on achieving the final thickness. However, according to the results, it was found that the initial temperature of the mat, moisture and dimensions of fiber or particles have a significant effect on the vertical density profile and internal bond strength.



a



b

Fig. 4. Vertical Density Profile (*a* – in cold season; *b* – in warm season)

ANOVA analysis of the effect of the mat temperature on internal bond strength and the mean and Duncan grouping are also presented in Table 2 and Fig 5. The results showed that the effect of the mat temperature on internal bond was considerable at 95 % level. As seen in Table 1 and Fig. 5, internal bond strength in boards made with mat temperatures of 18, 20, 24, 26, 30, 32, 34, 36, 38 and 40 °C was 0.46, 0.54, 0.58, 0.64, 0.66, 0.69, 0.74, 0.79, 0.84 and 0.91 N/mm^2. The internal bond of boards manufactured with the mat temperature of 40 °C has increased by 95 % in comparison with boards manufactured with the mat temperature of 18 °C. Heat transfer inside the core layer depends on to the steam of the surface layers and contact with hot press plates [1]. Thus, the higher the temperature of mat contacting the press plate, the faster the surface temperature reaches the necessary value for water evaporation. As a result, the heat transfer by water steam from surface layers to middle layers is faster, which improves the density of the core layer of the board and, in meanwhile, increases the internal bond.

Table 2

ANOVA analysis of effect of mat temperature on internal bond strength

Effect	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	3.000	9	0.000	2195.000	0.000
Within Groups	0.033	190	0.000		0.000
Total	3.000	199	0.000		0.000

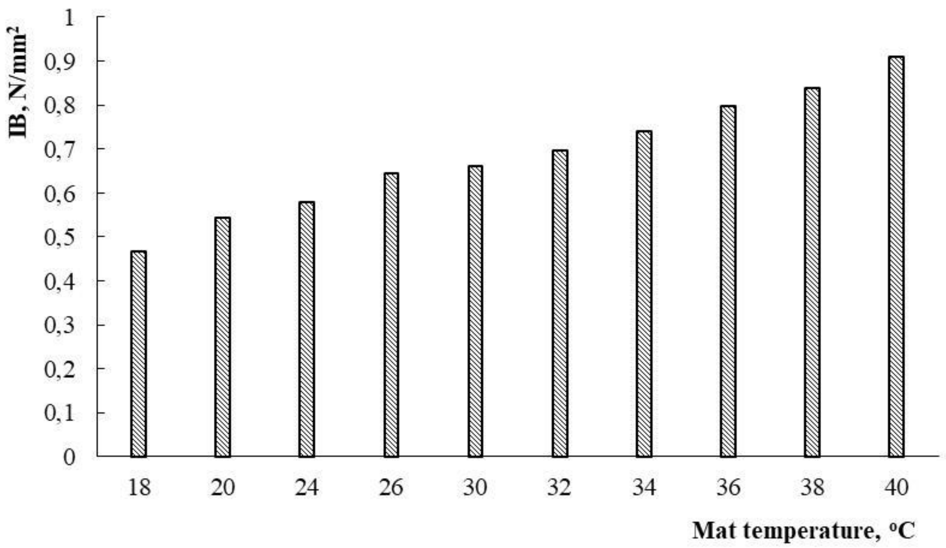


Fig. 5. Effect of mat temperature on internal bond

According to the meteorological data, the weather temperature decreases in winter. The reduction of air temperature directly affects the temperature of the fiber. So that the temperature of the fiber, which is 42 °C after the dryer, is reduced to 23 °C (Fig. 2).

In the production lines of MDF, the fibers transfer path is usually isolated from the blow line to the fibers bunker, but when the fibers were placed on the forming table, due to the contact with surrounding cold air, its temperature is reduced and decreasing the temperature of the fiber causes the decrease of internal bond strength. Therefore, in order to prevent the loss of internal bond strength, the line speed should be reduced. Thus, the efficiency of production is reduced.

It took us one year to complete the research; after getting the results we started to look for the right solution of the problem. In order to heat the mat you can use infrared preheater and microwave preheater [7]. Suchsland and Woodson [8] showed in their research that the use of radio frequency (RF) and high frequency (HF) presses have many advantages. So, from the production point of view, the pressure time reduction should be accomplished using the RF and HF rays. Thus, the sides of the board become stronger and the density is improved. Although, the primary investment cost and the cost of producing these types of presses are higher than ordinary hot presses [8]. In this press, RF electrodes that are made of copper are placed between the press plates and the fiber mat. By 2018, the Microwave Preheater system was not well adopted due to the high price, high energy cost (600 kW) and various regional laws and regulations. The infrared rays are further installed in Mende presses near the steel belt and between the rollers. But it can also be used in infrared at multi-daylight presses and ContiWave systems in production line. Before the pre-press, especially for the production of high-thickness boards, one or more hot water pipes can be heated to the core layer. Also, using saturated steam or hot dry air is another way to increase the temperature of the mat [11]. One of the most efficient possible is maintaining the temperature of the mat to install plastic curtains and roller doors in cold seasons.

Conclusions

Due to the internal bond loss in cold seasons and the consequent reduction in production efficiency, this study investigated the effect of different seasons on the efficiency of medium density fiberboard production in the industry. After measuring the mat temperature and internal bond strength during one year, the following results were obtained:

- In different seasons, the mat temperature is influenced by the temperature of the environment; in winter even the difference in day and night temperature (during one day), strongly reduces the mat temperature.

The temperature of the fiber mat has a significant effect on the time when the core layer of mat temperature reaches 100 °C. In other words, the polymerization time of the core layer is much lower when the mat temperature is 40 °C and this is better result in comparison with the mat temperature of 18 °C.

The results showed that there is a strong correlation between the initial mat temperature, the density profile and the internal bond strength of the boards. Thus, the increase in the mat temperature will lead to the increase of the core density and improvement of the internal bond strength.

- According to the research there are several ways to heat the mat in the industry. One of the suitable methods can be selected and used in the production process according to the type of production line and types of presses (multi-daylight, ContiWave and Mende presses).

- If you use any method to increase the mat temperature, you must isolate the production site.

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Влияние сезонных температурных изменений на эффективность производства древесноволокнистых плит средней плотности (на примере компании «Ариан Сина»)

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В целях предотвращения потерь материалов, энергии, финансовых средств и времени эффективность производства должна быть одинаковой в течение всего года. В связи с потерей материалами внутренней адгезионной прочности в холодное время года и, как следствие, ввиду снижения эффективности производства, в этом исследовании изучалось влияние различных сезонов на эффективность производства древесноволокнистых плит средней плотности на примере компании «Ариан Сина». Для этих целей в течение 2017 г. компанией были изготовлены 200 древесноволокнистых плит. При производстве плит были приняты следующие параметры: время выдержки под давлением – 200 с, количество использованного клея – 10 % от массы сухого волокна, влажность древесного волокна – 7 %, содержание отвердителя – 0,8 % от массы сухого клея. Породный состав плит: сосна – 70 % и эвкалипт – 30 %. Результаты показали, что снижение температуры в холодное время года и даже разница в температуре днем и ночью в течение суток уменьшает внутреннюю адгезионную прочность и, как следствие, сокращает скорость производственной линии из-за необходимости большего времени для достижения требуемой температуры в среднем слое волокна. Результаты, полученные в ходе рентгенографического анализа профилей вертикальной плотности, показали, что при температуре волокна в пределах от 18 до 40 °С в среднем слое плотность изменяется от 561 до 634 кг/м^3 соответственно.

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Ключевые слова: температура древесноволокнистой плиты, эффективность производства, древесноволокнистая плита средней плотности, профиль вертикальной плотности.

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