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Operation reliability of induction motors at egg processing plant 'Balticovo'

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Abstract. In hen houses air quality plays an important role in egg production volume. However, failure of fan induction motors often occurs and it is important to improve reliability of these. A motor reliability study was conducted in the egg processing plant 'Balticovo' in Iecava. Results show that 86% of failed number from 2010–2015 occur in hen houses and more than 50% of them were failures of motors which drive the fan. Annual failure rate of fan induction motors each year was increasing and in 2015 it was 6%. Investigations of the faulty motors showed the following defects – stator turn to turn failure of stator winding insulation leadwire and stator winding insulation thermal stress and mechanical damage of stator core resulting in the damaged stator winding leading to a short circuit. Results show that conditions that could contribute to such defects are excessive heating and vibrations.

Key words: induction motor, reliability, failure, fan, egg processing plant, hen houses.

INTRODUCTION

Induction motor (IM) drives are widely used in industry, agriculture, commercial and residential sectors. A failure of an induction motor can result in stoppage of the production process, therefore causing economical losses. A survey of the reliability of induction motors in the petroleum and chemical industry is presented in (IEEE, 1985; 1987; Thorsen & Dalva, 1995; Penrose, 2012) and root cause analysis for IM (Bonnett, 2010) show that failures were caused by following failed components and causes: bearings – in 51% of the failure cases; stator windings – 16%; external (environment, load and voltage) – 16%; others – 17%. In agriculture facilities, 70% of failures occur due to failed stator windings; 20% – due to environment or voltage effects; 10% – bearing damages (Sniders, 1995; Homutov, 2010). The average annual failure rate of motors is 3.4% and in places of extreme operation conditions is 9.3% and can reach up to 12% (Venkataraman et al., 2005)

In the hen houses 20–30% of egg production volume depends on microclimate quality (Kobzistij, 2000; Shipalov, 2009), so it is important to ensure the required parameters of temperature, humidity, air flow and etc. Therefore, a failure of induction motors driving the fans in the hen houses can lead to a decrease of egg production or even the death of poultry. In this paper a survey of induction motors drive systems and failures in the egg processing plant 'Balticovo' in Iecava, Latvia is presented.

MATERIALS AND METHODS

The study was conducted at the egg processing plant 'Balticovo' in Iecava. First, information about the main technologies of the plant was collected and observed. Then induction motor data from all of the plants facilities was obtained from electrical diagrams, available data and manual recording of induction motors data.

The technological facilities and induction motor distribution are shown in Fig. 1. Plant 'Balticovo' consists of the following facilities – grain dryer; grain processing; oil production; hen houses; egg sorting and processing; egg boiling; egg powder production. Most of the facilities were modernized or built during 2000–2014. The total number of induction motors in the plant is 2107, 1453 of which are located in hen houses. 43% of total IM count are 1.1 kW motors and mainly are used in hen houses to drive fans, 33% – are lower than 1 kW and are used in transportation systems, e.g., egg and hen feeding transportation (Fig. 2.). IM over 10 kW are used in grain processing facilities. The most powerful motors at the plant are the 132 kW motor used in oil press application and the 110 kW motor that drives a grain mill.

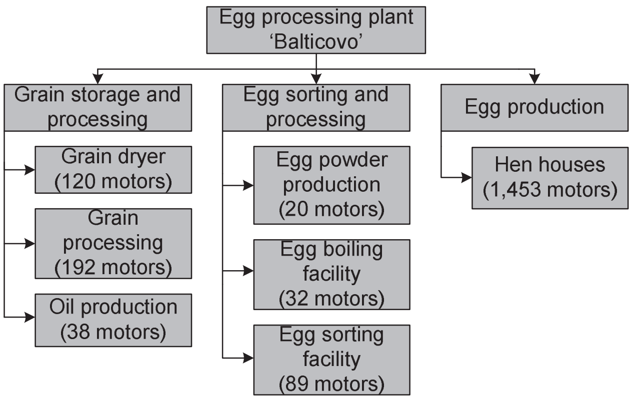

Figure 1. Statistics of induction motors in each of technological facility of the egg processing plant in Iecava.

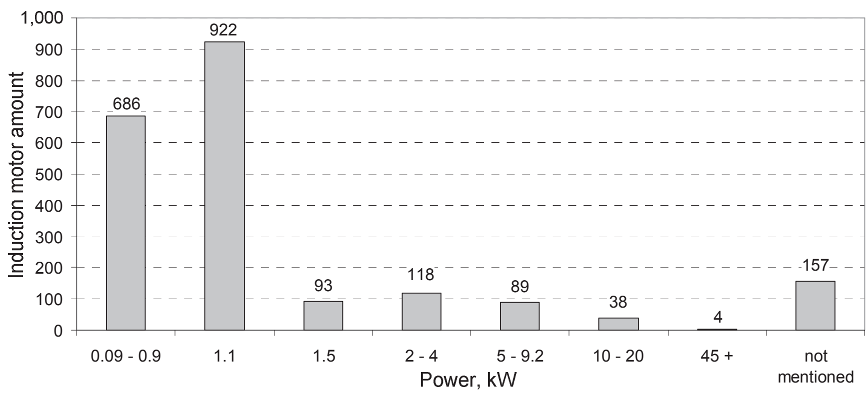

Figure 2. Power and number of induction motors in the egg processing plant in Iecava.

The 'Balticovo' plant has 14 hen houses, two of them are older than ten years and others were built during 2004 to 2014, approximately one hen house a year. In each hen house fan drives are divided into two groups. The first group, called 'ecoclimate', consist of three motor group with different motor count in each group – 5, 7 and 8 motors. The 'ecoclimate' group is operated all year long. The second group, called 'emergency', has two motor groups – 10 and 15 motors. 'Emergency' motor group is operated when bigger air flow is required, mostly during warm periods of the year. In each hen house an automation system is measuring temperature in four locations and controls the operation of the fans. A v-belt drive system is used to connect induction motor with the fan.

During 2010–2015 information of IM with stator winding failures was registered at 'Balticovo'. All of the faulty IM are delivered straight to electric motor repair companies and no data regarding the motor defects, possible reasons of failures is recorded. During the study at the egg plant five faulty 1.1 kW fan induction motors, defects and possible reason of the faults were analysed.

RESULTS AND DISCUSSION

The number of failures of IMs annually is increasing and in 2015 reached 59 failures, two times more than in 2011 (Fig. 3). Annual failure rate of IM is about 2–3% for the past 4 years. More than 90% of total faulty motors are 1.1 kW and lower.

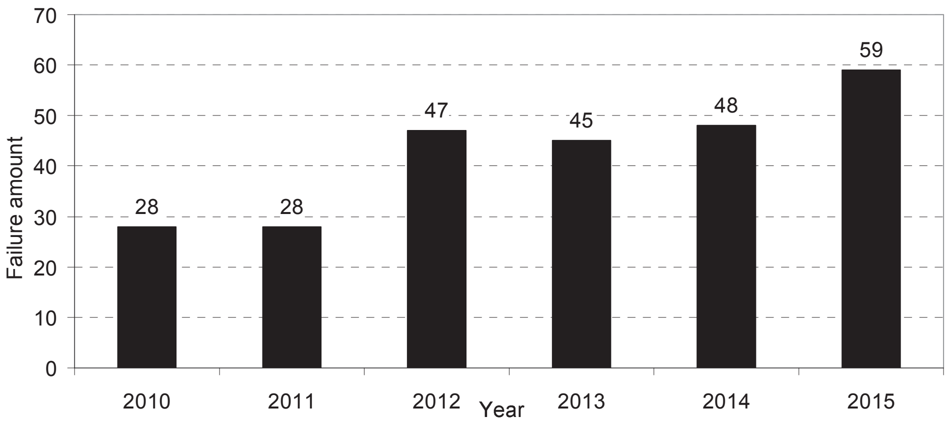

Figure 3. Annual failure rate of induction motors in the egg processing plant 'Balticovo'.

Around 86% (213 failures) of total induction motor failures in the plant occurred in the hen houses for the past six years (Fig. 4.). From 213 failures, 123 of these were ABB 1.1 kW, M2AA90S-4, 1,410 rpm, 230/400 V, 4.6/2.66 A induction motors that are driving fans in the hen houses. Apart from fans, other failures occurred in egg and hen feeding transporting drives. Results show that almost 50% of total IM failures are related to fans in the hen houses and it is important to analyse the failures and to increase the reliability of induction motors.

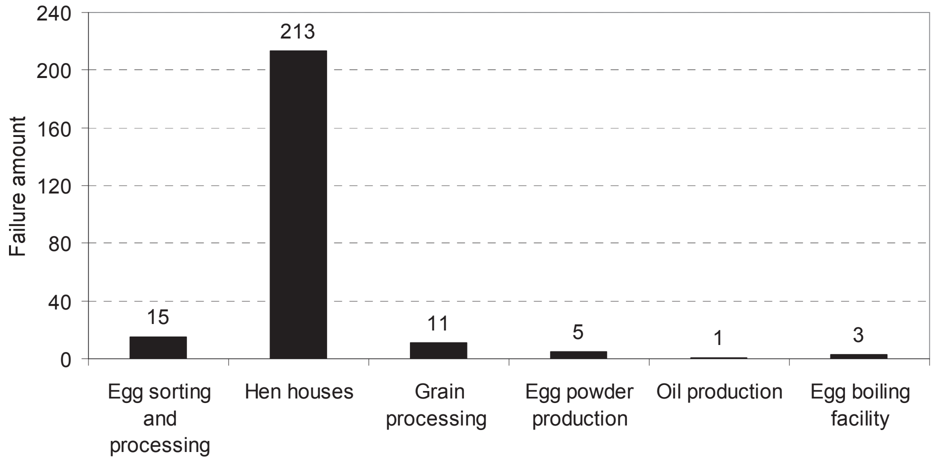

Figure 4. Failure amount of induction motors in different facilities from 2010–2015.

During the last six years the annual failure rate of fan induction motors was increasing each year (Fig. 5). The highest failure amount was in year 2015 – 41 faulty motors or 6% of total fan induction motors in the hen houses.

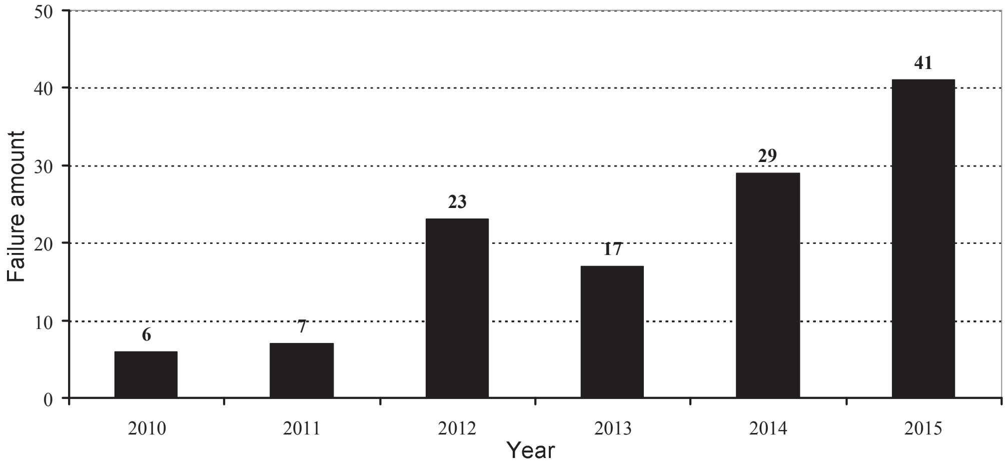

Figure 5. Annual failure rate of fan driving induction motors in hen houses.

Average operation time before failure of the axial fan driving induction motors in hen houses (Shipalov, 2009) is 3.1 years with an average operation time of 2800 hours a year. Operation time before failure for 56 faulty fan induction motors at 'Balticovo' is show in Fig. 6 and the average operation time is 5 years. However, since fans are divided in two groups ('Ecoclimate' and 'Emergency'), the 'Ecoclimate' group has significantly higher operation time due low air flow needs in the winter time and the 'Emergency' group fans are not operating nearly as much. Therefore, without a proper failure register of which group fans fail, it is hard to evaluate precise reliability parameters of induction motors.

Figure 6. Operation time of fan driving induction motors before first failure in the chicken raising and hen houses.

During the past six years, there have been 8 cases where a 1.1 kW fan induction motor has been rewound after failure and after certain operation time failed a second time. Ine one of the cases the motor failed a total of three times. This is presented in Fig. 7 where the operation time between first and second failure is shown. The motor that was fixed for a third time had a significantly lower operation time than after its first failure, having operated roughly a third of the time it did after first repair. The shortest operation time after first repair was 3 month, while the longest was 30 months before failing again. The average operation time of a rewound motor is roughly 1.5 years, which is more than three times lower than what the average operation time is before first failure.

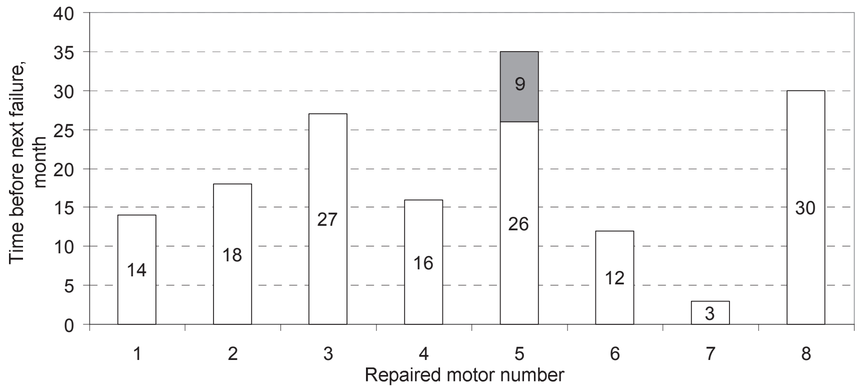

Figure 7. Failure amount of induction motors in different facilities from 2010–2015.

When a repaired motor was looked at it was noted that the bearings had not been changed. After further study into the repair costs of motors in 2015, 4 out of 41 had a higher repair cost and this difference was the equivalent of bearings being changed. So it is presumed that most repaired motors go back into operation with the original bearings. Because of this it could be assumed that the lower operation time after a repair could be related to the old bearings failing, and so is suggested that during the repair process the bearings are always changed to help increase overall lifespan of the motors parts.

Research of five faulty 1.1 kW fan induction motors at 'Balticovo' shows the following major defects turn to turn insulation failure of the stator winding; stator winding cut in stator core slot by stator tooth; cracks in leadwire insulation. A turn to turn insulation failure of stator winding is shown in Fig. 8, a. Cracks in the stator winding insulation were found and that can be a clue to how the short circuit occurred. A common reason for insulation cracks occuring is thermal stress. A phase to earth short circuit situation can be seen in Fig. 8, b where stator core teeth are smashed into the winding inside the stator slot. The cause of this defect is friction between the stator and rotor. In Fig. 8, c, d is shown that leadwire insulation is cracked and coming apart. This defect might not cause failure of motor straight away but wires can potentially cause short circuit against each other or against the motor frame. In this case also thermal stress can cause wire insulation cracking. Defect analyses shows that excessive heating and vibration are the main reason that cause these defects to occur.

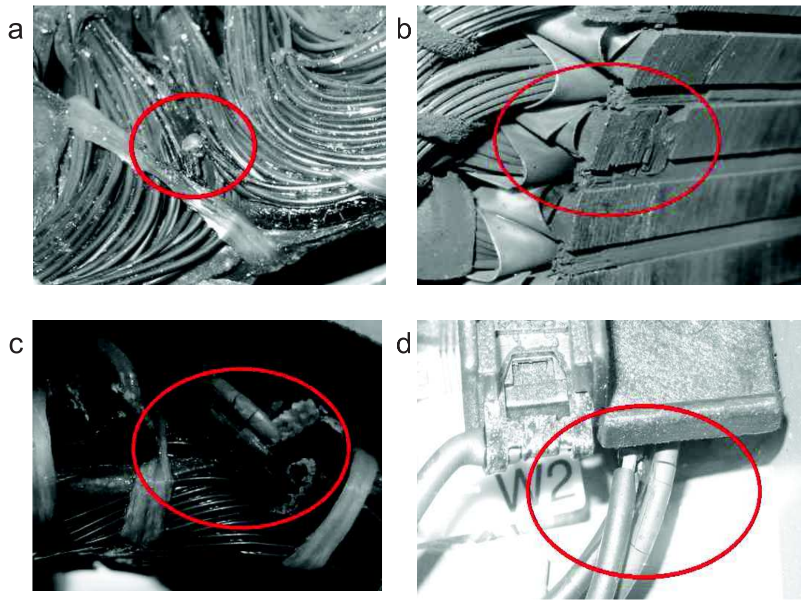

Figure 8. Defects of faulty fan induction motors.

Analysis of the failure of fan induction motors in hen houses show that up to 57% of failures are related to thermal ageing of stator winding insulation (Kobzistij, 2000). Main factors causing the overheating of stator windings and decreasing life span of the insulation are a voltage unbalance and a loss of one of the phase supplies resulting in single phasing (up to 47%). Another factor is the rotor stalling caused by frozen fan blades during winter time. Another analysis shows that 50% are caused by single phasing (Shipalov, 2009). Both analyses show that bad voltage quality is one of the main root causes of induction motor failures. However, the egg processing plant 'Balticovo' is located close (around 1 km) to an electrical power distribution substation and does not have problems with voltage quality.

Analysing operation conditions and defects of the fan induction motors, the following conditions needs to be taken into account to find the root causes of the failure – dust and aggressive gases; long operation time of fans (especially in summer); V-belt drive system. Fan induction motors are covered by dust from grains resulting in decreased heat dissipation of the induction motor which causes overheating. Aggressive gasses can decrease the life span of electrical equipment, especially the stator winding insulation. An over-tight V-belt will cause excessive wear on bearings (Harman & Hongwei, 2009). From the 5 inspected faulty motors during the study 4 motors had signs of friction between the stator and rotor in the fan side of the motor. Taking into account all the facts analysed above, the following conclusion can be made that the root cause of failures is likely to be excessive wear on bearings that causes an increase in vibrations of the induction motor. However, more data and detailed investigations are required to understand the process and root causes of the failure of the fan induction motors in the hen houses at 'Balticovo'.

The survey of failures of induction motors in the egg processing plant 'Balticovo' show that failures of fan induction motors often occur in the hen houses and statistics show that each year the annual failure rate of fans is increasing by 1% of the total fan number. Failure of fans might cause lower air delivery and decrease ventilation quality thus can reduce egg production. Analysing the root causes of the failures is essential to increase the reliability of the induction motors to decrease production costs and reduce any losses. Also protecting and preventing motors from failure is important, therefore, a method to detect bearing damage is needed. A vibration and acoustic emission analyses are often used to diagnose bearing condition, but the sensors are expensive. Motor current sisnature analysis (MCSA) and different signal-and-data-processing algorithms are used to detect bearing defects (Riley, 1997; Jung et al., 2006; Blödt, 2008). Further investigations are needed to determine if the MSCA methods can be applied to detect bearing damage and used in IM maintenance I the Balticovo.

CONCLUSIONS

1. In hen houses 20–30% of egg production depends on quality of air, this justifies that reliability of fan induction motors is an important factor and a failure of these fan induction motors can decrease egg productivity.

2. Induction motor failure rate analysis at the egg processing plant 'Balticovo' show that annual failure rate is 2–3% of total induction motor number, but failure rate of induction motors driving fans in the hen houses is 6% of the total. It shows that measures are required to increase the reliability of induction motors in hen houses.

3. Analysis shows that average life span of new fan induction motors is 5 years and life span of repaired ones is more than 3 times lower – 1.5 years. Investigation of repaired motors show that only stator windings are rewound but in many cases bearings are not

changed. Taking into account long operation time, typical for the fans, that is why bearings should be changed for each repaired motor.

4. Investigation of faulty fan induction motors show following defects – stator winding turn to turn short circuit, cracks in insulation of stator winding and leadwires, mechanical damages of stator core resulting into damaged stator winding and short circuit to earth. It shows that main factors to cause these defects are overheating and vibrations that could be caused by bearing damage. Therefore, further investigations are needed to find a cost effective method to detect bearing damage during operation time of the induction motors and prevent damage to the motor, reducing repair costs and time.

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