

System for Automatic Inspection of Bandsaw Blades

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Abstract: - The article deals with a new inspection method for the bandsaw blade eligibility checking. For better understanding, the individual bandsaw blade areas are described together with relevant parameters overview. The method design description follows. The current method drawback are discussed, and there are stressed the advantages of our innovative automatic inspection method. We present arrangement of our design in individual blocks together with the application software functions. The article also presents both the design model and the realised prototype measurement results. The constructed device based on our design minimizes the human error influence.

Key-Words: - Programmable Logic Controller, HMI, Bandsaw, Automatic Inspection, Simatic, SCADA

1 Introduction

Wood is one of oldest materials exploited in human activities. In spite of fact that it has been replaced in many areas with plastic materials, with iron and with concrete, it is still a favourite material because of its specific characteristic.

Various saw types serve for wood priming and shaping. For small wooden parts, there uses either handsaw or motor saw types. Larger wooden parts are processed with special more powerful saw designs. The bandsaws represent a big group of processing tools.

The bandsaw consist of two big wheels called upper wheel and lower wheel. The bandsaw blade is tighten over both wheels.

Both wheels must have a convex circumference shape from a certain bandsaw blade width. It facilitates the blade to keep the right position safely. That solved the preceeding project. [10, 11]

The high production quality and preventive maintenance requirements place on the bandsaw blade.

The project goal was to realize an equipment replacing the man for sake of quality assessment and the grade of wear objectively. The data automatic archiving possibility is also highly preferable for a reliable functioning. The archived data serve for a time dependent comparison, wear out analysis and other blade parameters change.

This project is a result of cooperation with Dudr Tools Ltd. Company. That company is oriented on the saw blades production and servicing.

2 Bandsaws

Bandsaws are belonging to woodworking tools. Those tools are employed for example in sawmills for tree trunk cutting in lumber like flitches, logs, planks or slabs. [1, 2]

The bandsaw development started in 1808 thanks to the Englishman William Newberry who received a British patent for the idea. That patented idea into bandsaw practical realization practical nearly 40 years later when the Frenchwoman Anne Paulin Crepin devised a welding technique overcoming the hurdle of heavy-duty blade band joint. She applied for a patent in 1846, and soon afterward sold the right to employ it to manufacturer A. Perin & Company of Paris. Combining this method with new steel alloys and advanced tempering techniques allowed Perin to create the first modern bandsaw blade. In course of 20th century, the bandsaw mechanical parts were improved and refined. The computer science development has also contributed to the current bandsaw design shape.

The bandsaw cutting tool is an endless saw band tighten typically between two wheels. Both saw band ends are welded together. The tighten saw blade is running at a constant speed relevant to the type of material to be cut. [4]

The bandsaw can be classified according to various criteria, like for instance the orientation of bandsaw blade (vertical, horizontal), stationary or portable, multi-blade design, etc.

The universal joiner's bandsaws rank among the most extensively used bandsaws. The other very

frequently used bandsaws are log bandsaw, squaring bandsaw and dimension bandsaw types.

Except for case apart, all bandsaws are in fixed or immobile verions. [1]

In comparison with other saw types, the bandsaw has thanks to thin blade the smallest cutting loss so that it produces only a few amount of sawdust. The cut surface is smooth and high quality. The bandsaw enables also the corner cutting. Unlike the other saws, the noise level is remarkably lower.

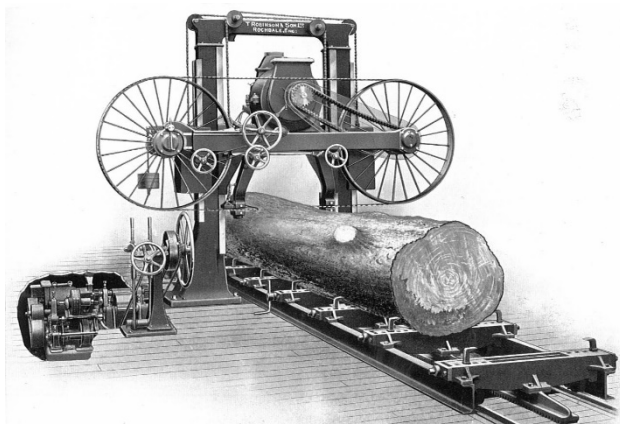


Fig.1 A historical bandsaw Robinson & Co. of Rochdale. The principle is the same today. [2]

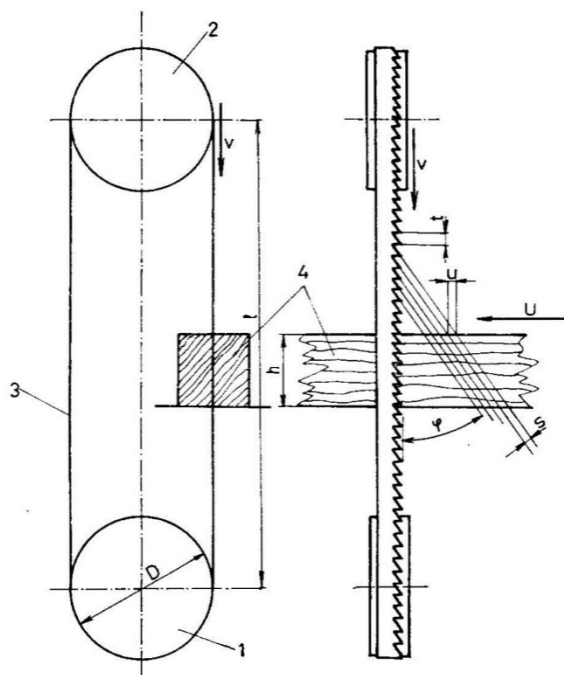


Fig. 2 The bandsaw cutting principle [1]

2.1 The bandsaw method of operation

The bandsaw function is based on band blade (3) that is tighten between two wheels, both the driving one (1) and the driven one (2). In an active state, the

band blade runs with a constant velocity. The processed material (4) is fed either manually or mechanically.

2.1.1 Log bandsaw

The log bandsaws find application in sawmills for sawlogs processing.

They exist in two variants – both horizontal and vertical. They consist most frequently from following components: equipment, clamping carriage, roll-in and revolving tool, cylinder conveyor, controller unit.

Equipment consists of a base, a stand, two wheels bandsaw blade and of a driving unit.

Individual parts in Fig.3 are as follows: base (1), stand (2), bearing (3), upper wheel (4), saw blade (5), lower wheel (6), belt transmission (7), main electric motor (8), adjustable guidance (9), cylinder conveyor (10), screw mechanism (11), weight (12), cover (13) and a sawdust exhaust (14). [1]

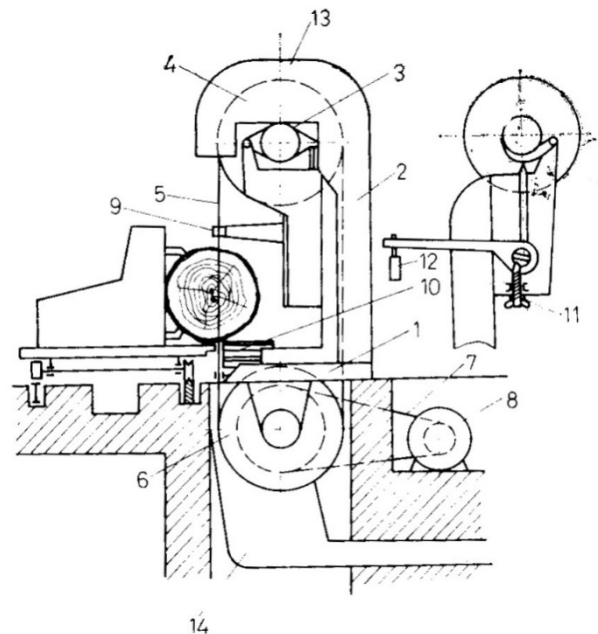


Fig. 3 The vertical bandsaw diagram. [1]

2.2 Band saw wheel

The bandsaw wheels mentioned above, both the driving one and the driven one belong to bandsaw basic components. The driving wheel ensures the cutting assembly movement, and the driven wheel ensures a proper tightening and saw blade guidance.

The wheels contact area (crown) where band blade sits has a convex shape contour for saw belt width roughly above 70 mm for both dimension and log bandsaws. The crown exerts a pulling force,

moving the blade to the top of the wheel. The band blades manufacturing, repairing and sharpening uses the rolling technology. During sawing process, the band blade bends crosswise what ensure its correct tension.

The typical wheel contact area (crown) contours illustrates Fig.4.

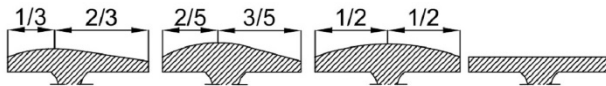


Fig. 4. Band saw wheels convex crosssection contours. [4]

The wheels wear down in course of time what causes that the saw blade do not sit in place like expected. The wheel starts cracking, and tend not to keep the cut line during sawing. There is necessary to refurbish the blade contact area to the original shape. [3, 4]

2. 3 Trunk saw blade characteristic

The length of bandsaw blade derives from the wheels diameter and from the distance of their axe. The wheel width limits the blade width, and it can be 10 mm wider then the wheel width. The blade thickness depends on the wheels diameter. The blade thickness must not exceed the one thousand's of wheel diameter minus 0.1 mm. If the blade thickness is higher, the saw blade stresses excessively. [1, 4]

The saw teeth shape and arrangement origins from a few basic shapes according to Fig. 5.

The trunk saw blades correspond with variants B to F.

The parameters are as follows:

- t – teeth pitch [mm],
- t_1 – tooth flank length [mm],
- h – Gullet depth [mm],
- r – radius of gullet [mm],
- R – radius of tooth flank [mm],
- B – Blade width [mm]. [4]

2. 4 Trunk saw blade manufacturing

The saw blade material is a high quality tool steel thermally processed for a required hardness. That steel is enriched with some elements like chromium, nickel, manganese and others. The steel material supplies in a band form or in coils. The manufacturing consist from following procedures:

- Saw band straightening and teeth cutting
- Saw band rolling to release tension
- Saw band teeth forming
- Sharpening

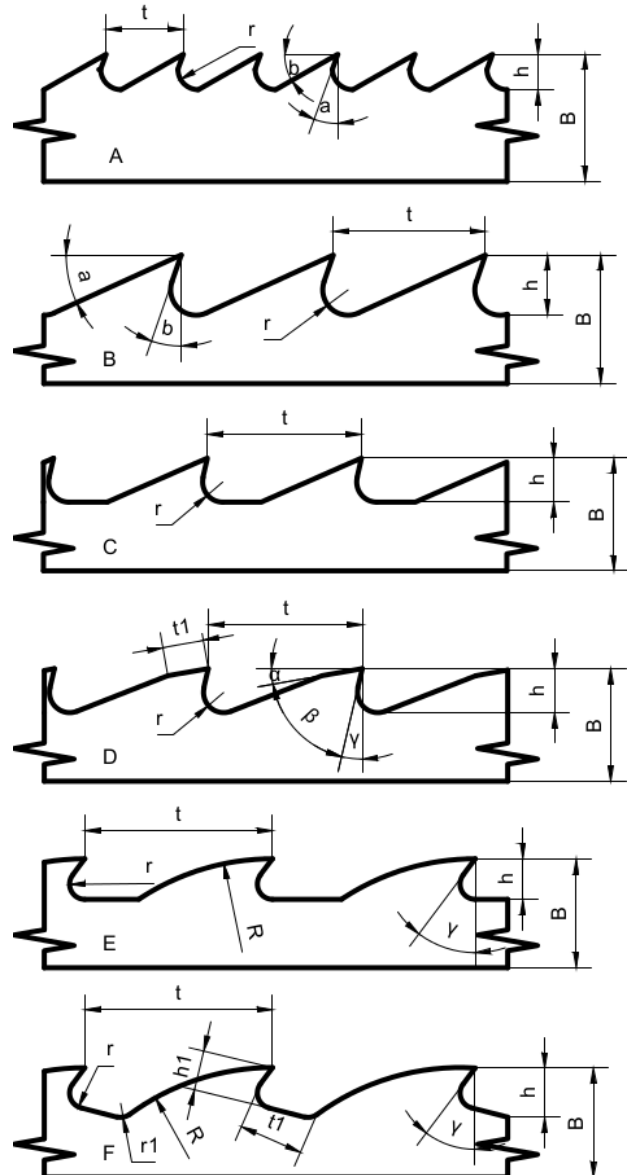


Fig. 5 The basic saw teeth shapes example [4]

The saw band manufacturing starts with the steel coil unrolling, and the teeth cutting either with an excentric press, or with a laser. The required length cut follows. The further procedure is the saw blade ends connection into an endless loop. This procedure includes also a welding and the seam flattening and smoothing to make the band side edges nicely even and of the same thickness, like the rest of band.

The band rolling follows the butt joint. That procedure should ease the material tension in the blade. The rolling process depends on the band thickness, on the width of blade, and it depends on the wheelrim surface crossshape as well. The thinner and wider the blade is, and the more convex the rim cross shape is, the larger the light slit should be. The light slit has to be so large that the blade alignes with the wheel rim.

The wheel crown cross-section can feature shapes illustrated in Fig. 4.

The blade teeth bending in turns right and left is a next step. This procedure result calls set. The set serves to the kerf widening which decreases the blade rubbing against the sawn material. Rubbing leads to the blade heating what causes the blade cut deviation. There are three types of kerf widening methods.

The first one is the standard blade tooth set which comprises also three variants in general, namely alternate tooth set, raker tooth set, and the wavy tooth set.

The second variant of kerf broadening is the tooth tamping. The advantage of tooth tamping is a better blade stability because of even strain. The tooth set stays constant between sharpening procedures. The lower kerf sides chipping at higher cutting speed is the last but one of the tooth tamping advantages. [4]

The last, recently very popular, method is the stellite-tipping saw teeth. Stellite application is the latest trend in the treatment of cutting edges on saw blades. Stellite is a cobalt-chromium based alloy containing other elements. It welds directly on the carrier belt in the place of a tooth tip and it forms a compact saw blade cutting edge. Compared to a standard highspeed steel, this saw blade is several times more resistant to blunting and therefore does not require frequent replacement or sharpening. The band supplies sharp. The stellite-tipped teeth blades represent also a very good value for money. [12, 13]

The last procedure of a saw band blade is the bad saw teeth sharpening. That procedure performs after the tooth set. Teeth sharpens with a grinding disc. A precise tooth pitch is necessary for a perfect sharpening. The correct sharpening helps to avoid cracks in gullets. [4]

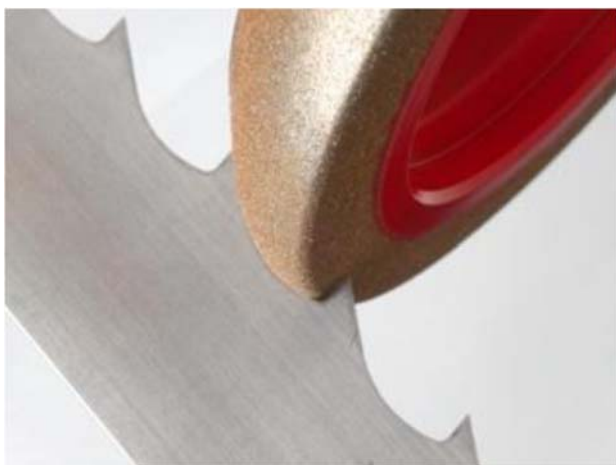


Fig. 6 Teeth grinding with adiamond disc [4]

3 Saw Band Inspection

The saw band manufacturing is a demanding process which final quality highly influence both the human failure and the correct functionality of individual stages in process, like grinding, rolling and other.

The thoroughgoing inspection checks whether the saw band has corresponding characteristic.

3.1 Actual saw blade inspection methods

The Dudr Tools comp. has commissioned the shift foreman to perform the saw blade inspection so far. The foreman is responsible for a proper inspection, and in the case of acceptance, he transfers the saw band to dispatch office. [9]

The inspection bench is a special fixture for saw bend testing. The tested parameters are as follows:

Blade back – it is the width of saw band except for the teeth part. The blade back width measures along the band in two or three positions. All readings should be the same.

Straightness – it is a deviation specified in millimeters and defined as lateral deviation of the edge from a straight line. Putting the ruler to the blade back edge should not indicate any irregularity. The edge line must be absolutely straight.

Crowning – Putting the hair ruler across the blade width should indicate the light slit. The preferred ruler positions are the weld seam, and three to four positions along the saw blade band.

Tooth quality – test checks for instance stelling result. Tips must be sharp. The other parameter to check is the teeth width tolerance limited to ± 0.05 mm. The tooth side shape should regular and straight, not a “banana” deformation. The tooth face must be in line.



Fig. 7 The saw blade crowning inspection [14]

3.2 Actual inspection methods drawbacks

There are a few drawbacks in the current inspection procedure of bandsaw blade.

The first drawback is human error. Every worker even the best knowledgeable and experienced performs the inspection differently. The inadvertence in relation to the high quantity of teeth is expectable keeping in mind that trunk bandsaw blades have commonly more than 100 of it. It is impossible to catch sight of tiny deviation from specifications at every tooth from such amount of teeth during visual inspection. Furthermore, it is difficult to set a corresponding criterion for a subjective decision what is acceptable and what already not. The problem can appear only at the customer in course of sawing process.

Further problem consists in the absence of detail inspection records nowadays. Operator just checks whether the bandsaw blade complies with expectation or not. The detail characteristic data set simply does not exist for any particular bandsaw blade passed on distribution department.

3.3 Automatic saw blade inspection design

The bandsaw blade inspection asks for automation. The model arrangement represents a fixture where the blade is temporarily installed and initially set. The blade is driven by an electric motor like in a real mode. Running through the fixture, the blade passes various sensors reading its parameters. All that runs without operator's intervention. That fixture system measures the blade lengths and the teeth count.

The blade back deviations are measured as well. The straightness is measured at the straight parts of running blade. The curved part that requires tensile crowning is measured. The machine vision system checks individual tooth. The whole inspection process records in the report, and it is saved into a database.

4 Automated Inspection

The following text refers to our newly designed inspection equipment as inspection bench. The Dudr Tools experts have designed the mechanical part of inspection bench. The Fig. 8 below presents the current model of inspection bench after some modifications with the bandsaw blade installed.

The inspection bench can inspect bandsaw blades of both various length and width. It poses a few

adjusting mechanisms, as for example supporting rollers positioned where no measurement is performed.

The front set of guiding rollers facilitates the bandsaw blade insertion. The step motor controls the guide rollers positioning in relation to the bandsaw blade width. The blade is always fixed between two rollers. The upper rollers are pushed down against the blade with hydraulic pistons. The electro-magnetic pneumatic valves are controlling those pistons. The all parameters measurement is performed in this area.

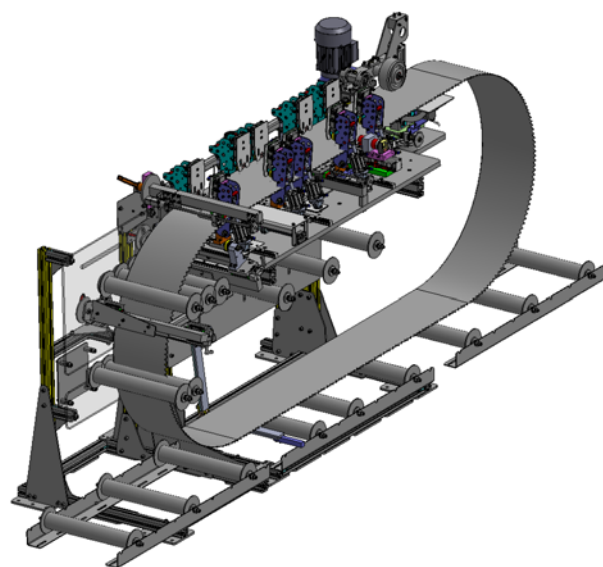


Fig. 8. The inspection bench design model [9]

Two pressure rubber rollers are ensuring the blade feed. The upper roller is not driven, it is just pressed down by a pneumatic piston. The lower roller electrically driven is in a fixed distance from the inspected blade.

The following picture presents the bloc diagram of our inspection system.

A PLC module controls all actors, and it collects data from sensors. Data is transferred to a personal computer that serves as displaying unit, and it is processing the video camera signal. The camera is connected via USB port.

There is an imaging start/stop trigger switch connected to camera. Data is evaluated, and results are sent to the supervising system in the company LAN.

The PLC control HMI panel and the illuminating unit for the machine vision are also included. [9]

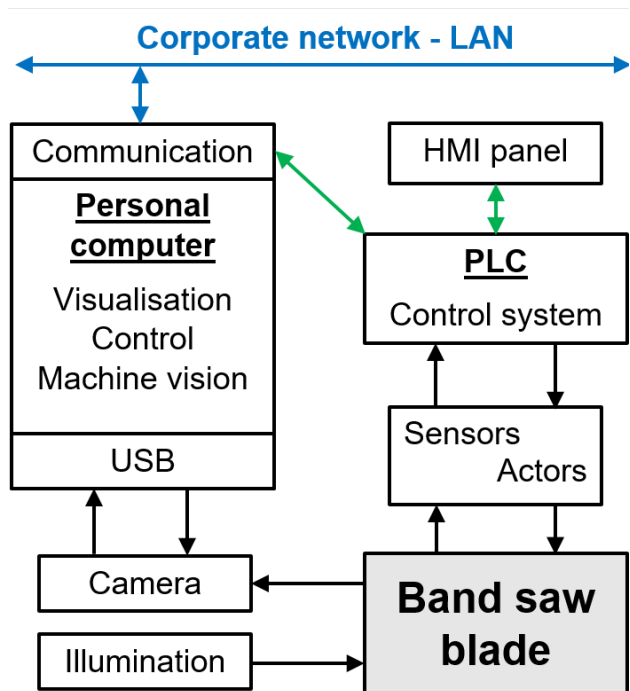


Fig. 9. The block diagram of our system [9]

5 The System Elements Description

5.1 Control unit

The PLC module Simatic S7-1200 by Siemen controls all drives and sensor signal processing. That PLC module has integrated I/Os, Profinet interface serving also for PLC programming and for the HMI interconnection. There is also possible to supplement the basic configuration with many other signal and /or communication modules.

PLC Simatic modules are programmed by TIA tool (Totally Integrated Automation) that serves also for HMI panels programming.

5.2 Data processing, visualization, machine vision

Control Web application ensures data processing and visualization.

That application together with a corresponding driver supports reliable communication with PLC Simatic module, with the database, and it supports namely the VisionLab machine vision system.

5.3 Sensors

Following sensors are ensuring the bench basic functionality:

- blade feed sensing,

- length measurement,
- teeth counting,
- blade straightness measurement,
- crowning measurement,
- blade back measurement,
- tooth set measurement.

In relation to the control system, all sensors are in PNP circuitry design and DC power supply of 24 volts.

5.3.1 Length measurement

Bandsaw blade length is measured with the incremental rotational sensor Larm IRC 310/2500 PB. It is fixed via a clutch to the driving rubber roll.

Its output connects to two digital counter PLC inputs.

5.3.2 Blade origin sensor

The optoelectronic sensor, model LR-W70C by Keyence, senses the origin of the blade. That sensor can be programmed for an arbitrary colour detection with a required tolerance. It simply means that a hand made colour mark with felt tip pen refers to the blade origin. The sensor reads the first mark pass in sensor field of view as origin, and the second pass reads as the end of blade.

Sensor has a white LED light source. The range of detection is from 30 mm to 70 mm what influences the size of light spot. The distance of 50 mm relates to light spot size of 1,6 mm x 2,9 mm.

5.3.3 Teeth counting

The further important parameter of bandsaw blade is the total count of teeth.

There is a binary sensor fixed at a suitable position of inspection bench frame. The position should make possible the detection of gaps between teeth during the blade run. The consecutive registration of output signal's either leading or trailing edge gives in sum the final count of teeth along the whole length of blade.

A one-way optical light gate applies as the counting sensor. The light receiver part of gate positiones above the bandsaw blade, and the light transmitter part positiones under the blade.

The selected light gate model is VSE180-2P42432 by SICK. These sensors have straight tube-shaped design with a fixing thread of M18. There is possible to set required sensitivity at the receiver with a potentiometer. The range of sensing is up to 20 meters what is more than a satisfactory value. The visible red light uses for the optical gate. [15]

5.3.4 Saw back measurement

The inductive sensor with analog output, model DW-AS-509-M12-390 by Contrinex ensures the saw back measurement (the toothless blade edge). Its sensing distance is in the range from 0 to 6 mm what corresponds with the output voltage in the range 0 to 10 volts. The sensor's tube-shaped body has M12 thread. [16]

There is a metal plate touching the saw back edge positioned at the straight bandsaw blade section in the bench. The plate fixes via springs to a mechanism pressing the plate slightly to the saw back edge. There is an inductive sensor fixed firmly to the bench on the other side of mechanism. That sensor reads saw back edge deviation in course of blade feed.

That sensor connects to the PLC analog input (0 to 10 volts DC).

5.3.5 Flatness measurement

The blade flatness measurement, or also the profile measurement, requires the sensor positioned in a section where the inspected blade is mostly flat.

The sensor DW-AS-509-M12-390 by Contrinex makes the required service also here. It connects to an analog output of PLC (0 to 10 volts DC).

5.3.6 Crowning measurement

The blade crowning (convexity) measurement uses the same principle like planarity measurement. The distinct crowning measurement succeeds best where the blade bends. In our case, the sensor is positioned on the swing-out arm in the front part of bench. [Fig. 8]

The blade crowning measures with the triangulation sensor, model OD2-N50W10A0 by SICK. That sensor communicates via RS-422 protocol, the measurement range is 40 to 60 mm, with the resolution of 5 μm , repeatability is of 15 μm , and linearity of $\pm 20 \mu\text{m}$. Spot light is 0,5 mm x 1,0 mm at the sensing distance of 50 mm. The sensor housing fulfils protection IP 67. [19]

5.3.7 Machine vision system

Machine vision system represents the last necessary module including lighting, lens and camera.

There was necessary to look for a camera compatible with the chosen system VisionLab with the Control Web application. At the same time, camera needs to have an external trigger option. Only cameras of DataCam family by Moravské

Přístroje offer that characteristic. Those DataCam cameras have high sensitive CCD sensors, very low picture noise, a firm aluminium body, wide choice of lenses, and USB 2.0 interface for data transfer and power supply.

The Model DataCam DC-2008 with 8 bit ADC fits best in our design. Camera connects to a PC with Control Web/VisionLab application via USB 2.0 port.

The lighting unit DataLight, model LT-40S with red light source by the same manufacturer fits in our machine vision system. The LEDs position in a rectangular matrix 60 x 40 mm. The DC power supply 12 volts has input power of cca 3 Watt. The LED set is fixed in a aluminium case.

6 SCADA System

Interface between the inspection bench and operator creates the SCADA/HMI of Control Web.

4.1 Control Web

Control Web is a programming tool for the development and realisation of both visual and control applications. It acts also as a tool for data collection, evaluation and storing. The DataLab IO as well as Control Web are joint-stock company Moravské přístroje products. This company founded in 1991 aims at the development and support of advanced products in the field of electronics and relevant software. [8]

The Control Web incorporated development package enables two ways of programming both in the graphic mode containing guiders, spectra, particular device inspectors and in the text mode. There briefly call those two ways of programming a two ways programming. There is no problem to program an application sequentially both in graphic mode and in text mode. The transition between modes calls toggling.

Work in the Control Web programming environment bases on an active exploitation of also called "active devices". These active devices are pre-programmed devices fulfilling particular functions as for instance:

- Devices for user environment creation,
- Control elements,
- Measurement data displaying.

This software communicates with DataLab IO system supporting the magnetic sensor incremental pulse counter very well. This software contains also serial communication support so that any converter of that product family can communicate with the laser sensor.

7 Progress of Measurement

There is necessary to calibrate the whole system before starting the inspection process. The PLC program modules for calibration are taking care for that. The communication with PLC goes via HMI panel.

After a successful calibration, we see the actual indicative values at corresponding sensing modules

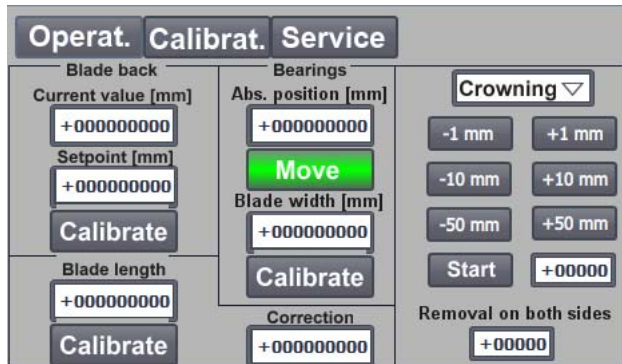


Fig. 10 HMI panel screen example [9]

The first step is starting point mark on bandsaw blade to inspect somewhere in front of blade start sensor. The next step is “Teeth, Length” button click. The saw blade feed drive switches on. The teeth count performs along the whole blade length together with the blade length. The actual crowning value, blade back flatness and edge strightness are registered every 10 mm. The machine vision system scans individual tooth quality.

After finalizing the first inspection stage, the blade feed drive stops. The button “across” push activates the second stage of inspection. The blade crowning and flatness across the blade width are measured in five position during blade feed stops. The corresponding stop positions are determined in relation to the total count of teeth recorded during the first inspection stage.

7.1 Machine vision and data processing

There is an application created in Control Web. That application is processing individual tooth visual data and its measurement. The application composes from two windows. First window serves for settings and application control, the second one presents reports. The left part of the first setting window occupies the live screen from camera, the control elements occupy the right part of window.

After the measurement finishing, we can save a report in PDF format supported by a virtual PDF printer.

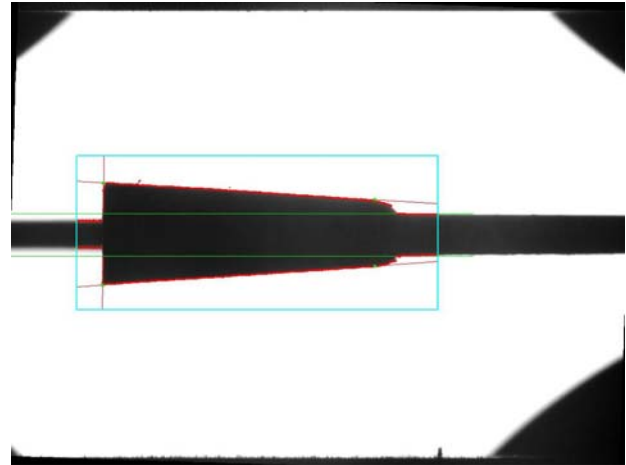


Fig. 11 Live picture from camera – one blade tooth

8 System Output Examples

The following picture illustrates the particular measurement report. The data can be stored in a database for later use.

Band saw measurement report

Date	12/10/2019
Time	13:48
Entered values	
Order number	121019
Band number	8125
Band length [mm]	6480
Teeth pitch [mm]	45
Stellite width [mm]	0.70
Note	
Measured values	
Length [mm]	6447
Teeth number	164
Tolerance of tooth tips	
Teeth up to 0.02 mm	0
Teeth up to 0.05 mm	0
Teeth up to 0.10 mm	4
Teeth up to 0.15 mm	78
Teeth above 0.15 mm	82
Tolerance of tooth back points	
Teeth up to 0.02 mm	2
Teeth up to 0.05 mm	3
Teeth up to 0.10 mm	19
Teeth up to 0.15 mm	141
Teeth above 0.15 mm	123

Fig. 12 A bandsaw blade measurement report [9]

The other figures illustrate the crowning and the flatness measurement direction in width direction at five positions along the blade length.

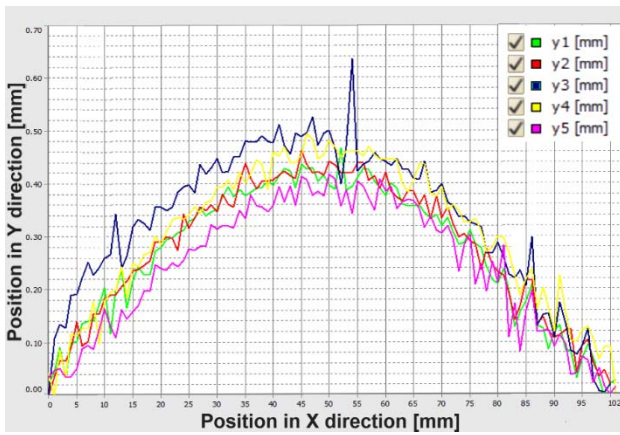


Fig. 13 The crowning shape across the blade width

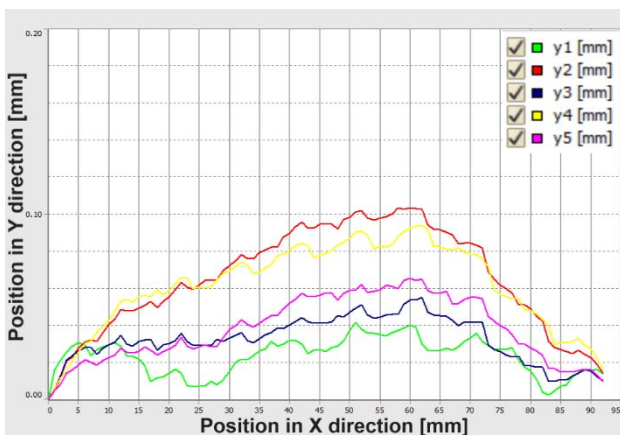


Fig. 14 The flatness course across the blade width

Graphs show satisfactory results. We can see that crowning shape is regular but a higher deviation in third measurement. The peak occurs in the middle of blade length, and its height is about 0,45 mm. The other crowning values are roughly same. The flatness deviation is up to 0.1 mm what represents a satisfactory result, too. [9]

The graphs with crowning and back saw straightness along the blade length follow.

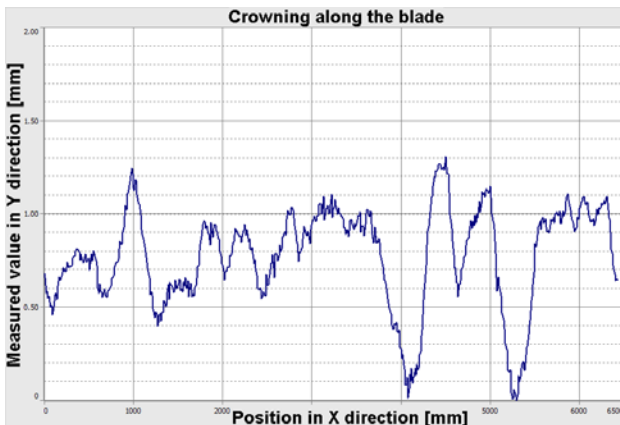


Fig. 15 The graph of crowning along the blade.



Fig. 16 The graph of flatness along the blade.



Fig. 17. The graph of saw back straightness along the blade.

The graphs of lengthwise measured both crowning and flatness are showing that the blade is slightly wavy. Nevertheless, the wavy grade is not critical because it ranges up to 1,5 mm. The saw back straightness values are also acceptable. They vary around 2,8 mm, and deviations are less than 0,1 mm.

There are also deviation values of tooth tip and tooth flank in any report.

n	Upper tip [mm]	Lower tip [mm]	Rear top [mm]	Rear bottom [mm]
1	0.96	0.85	0.49	0.30
2	0.98	0.83	0.43	0.28
3	0.98	0.88	0.43	0.25
4	1.00	0.82	0.45	0.27
5	1.01	0.82	0.45	0.27
6	1.02	0.83	0.47	0.28
7	1.00	0.82	0.45	0.27
8	0.98	0.83	0.43	0.27
9	0.99	0.85	0.44	0.22

Table 1 The individual tooth deviations

9 Conclusion

A remarkable contribution of our design of bandsaw blade automatic inspection system is the archiving possibility. The archiving function goes well toward modern traceability requirements. Our automatic system minimize human error influence on measurement results. A proper return on investments, higher and stable increase in bandsaw blade quality and customer satisfaction will be a benefit based on the new system implementation.

Acknowledgment

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