Faculty of Agronomy

Mendel University in Brno

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MECHANIZATION
Laboratory assignments

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OP Education for Competitiveness

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CONTENT

INTRODUCTION

Textbook “Mechanization“ (laboratory assignments) are intended for foreign students of agronomic faculty, mainly for fields of study such as Agricultural Machinery, Automobile Transport, General Agriculture and Plant Production. It is necessary to consider this text as the fundamental study literature. For another learning is suitable to use specialized publications and monographs or machine manuals. The base of tasks are laboratory assignments, where students get information about settings of individual mechanisms and possibilities to control quality of their work. To give students a solid base from the area of plant and animal mechanization in accordance with syllabus was the main aim of authors, because importance of mechanization in agriculture will raise. Only excellent knowledge from biological and machine area can provide good results of said sector.

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1. INSPECTION OF THE SEEDER SETTING AND QUALITY OF WORK *(Salajka)*

1.1 Checking the setting of the seed rate

The seeds of various crops (seed) are usually of different sizes, of different purity or are stained differently, and the data in the seed table are approximately set to certain characteristics (e.g. weight of 1000 seeds, purity, germinability, etc.). Therefore after adjusting the machine according to the seed table it is necessary to check the seed rate. To check the seed rate, place a collecting vessel (or a sachet) under each coulter. If we have a sump at our disposal we place it into a working position under the seed apparatus. Connect the handle that is part of the accessories into the drive of the seed shaft. Turn the handle several times to fill the seed rollers and return the retained seed back into the seed hopper. Turn the handle 35 times (which represents the area of 0,01 ha), weigh the sown seed and record it into the recording table.

The actual seed rate is calculated out of the weight of the retained seed according to the following formula:

$$Q = q \cdot 100 \quad [\mathrm{kg.ha^{-1}}] \qquad (1.1),$$

where: q weight of the seed retained during the test (kg)

When adjusting the seed rate it is necessary to repeat the testing until the deviation of the actual seed rate from the desired outcome is less than two per cent twice in a row.

1.2 Checking the stability of the seed rate

The stability of the seed rate is defined as the compliance with the actual sowing by the entire apparatus when the seeder is in a horizontal position (according to the ČSN 47 0135 standard)

Process of the evaluation:

After adjusting the machine check the actual seed rate 5 times

- Calculate the sample mean (kg.ha $^{-1}$),
- Standard deviation (kg.ha $^{-1}$),
- Selection coefficient of variation (%)
- Population standard deviation (kg.ha $^{-1}$)

The selection coefficient of variation cannot be higher than 3 %.

1.3 Overall unevenness of sowing

Overall unevenness of sowing is defined as the deviation of the actual specific seeding rates of the individual seed apparatus in horizontal position of the machine from their sample mean.

Sequence of operation:

- After adjusting the machine, carry out the sowing rate 5 times with a numbered sump or sachet under each seed pipe. The weight of the samples is expressed in grams and with the accuracy of 0.5 g.
- From the collected values are calculated sample mean (g), standard deviation (g), population standard deviation (g), and the sample coefficient of variation of summary seeding rates of the 5 samples for each seed apparatus (%). Then are calculated deviations of summary seeding rates of each seed apparatus from the sample mean of summary seeding rates of 5 samples for each seed apparatus in grams and as percentages.
- The selection variation coefficient of summary sowing rates of each seed mechanism can be no more than 6 %.
- Deviations of summary seeding rates of each seed apparatus from the sample mean can be max. ± 8 %.

To perform a graphic evaluation of unevenness of sowing of each seed mechanism plot individual numbers of the seed apparatus (1-25) to the ***x*** axis and the average seeding rates of each seed apparatus on the ***y*** axis, and connect the resulting points by straight lines. Plot a graph of seed sowing rate systems and seeding rates differing from the average seed rate of ± 8 % as a parallel to the axis x. It is necessary to repair or newly adjust the seed apparatus, which is outside the seed rate limited by these parallels, and to repeat the test. To graphically express the unevenness use the mean as 100 % to plot the points and set the +- 8 % limit. Connect the points into a line.

1.4 Laboratory assignment

1) Readjust the SAXONIA A-201 seeder for sowing wheat and check the stability and uniformity of the seed rate.

2) Describe the procedure to adjust the distance between the lines.(br = 200,180,145,125,105 mm)

a) with a measuring plate

b) without a measuring plate

3) Adjust the seed rate of wheat the A-201 seeder with the help of the sowing table (according to the assignment)

4) Check the seed rate stability of the seeder [$\mathrm{kg \cdot ha^{-1}}$]

5) Check the overall unevenness of the seed rate

6) Calculate and draw a diagram of the seeder set in scale to calculate the bout marker and also calculate its length according to the assignment. The type of tractor and its front tract.

Note: Write down the results into the recording table and use digital scales for weighing.

Tab. 1.1.: Stability of seeder uniformity

No.	Retake	Quantity sown Q_1 [g]	Specific seed rate Q [kg. ha^{-1}]	Actual seed rate Q_s [kg. ha^{-1}]	Qs	$(Q_{si} - \bar{Q}_s)^2)$
1	a					
2	b					
3	c					
4	d					
5	e					

Formula used**:** Dispersal: $$s_x^{\,2} = \frac{\Sigma\left(X_i - \overline{X}\right)^2}{n} \qquad (1.2),$$

Standard deviation: $$s_x = \sqrt{s_x^{\,2}} \qquad (1.3),$$

Coefficient of variation: $$V_x = \frac{s_x}{\overline{x}} \cdot 100 \qquad (1.4),$$

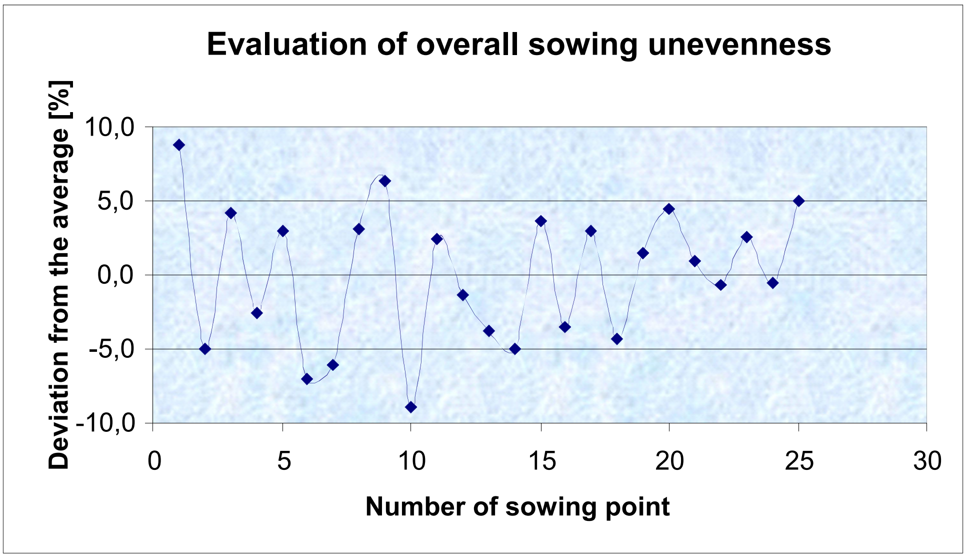


Fig. 1.1.: An example of graphical evaluation of the seed rate unevenness (0 = 100%)

Tab. 1.2.: Measured and calculated values of the seed rate unevenness

No.	Types of seed	retake	Seed sown by individual coulters – seed rate (g)																								
			Number of the seed coulter																								
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
1		a																									
2		b																									
3		c																									
4		d																									
5		e																									
6	Summary seeding rate $X_{ia,b,c,d,e}$																										
7	$\sum X_{i/\,g\,/}$																										
8	$\bar{X}$ (g)																										
9	$\left(X_i - \bar{X}\right)$ g																										
10	$(X_{ia,b,c,d,e} - \bar{X})^2$																										
11	$\sum\left(X_{i,a,b,c,d,e} - \bar{X}\right)^2$																										
12	$(X_{ia,b,c,d,e} - \bar{X})/100$ (%)																										
13	Coefficient of variation, V /%/																										

1.5 Laboratory tests of the seed apparatus of precision seeder

1.5.1 Testing the accuracy of sowing

To simulate the seeder's movement during laboratory testing, mount the seed apparatus of the seeder onto a portion of the hinge and place a belt with a surface that allows capturing the seeds (with glue, fine fibre) under it. The seed apparatus is driven by an electric motor and the belt is driven via a gearbox or a variator. During the testing the grain falls out of the seed apparatus onto the belt. After the belt is stopped, measure the distance between the seeds.

$$rv = \frac{n_1}{n_t} .100 \quad [\%] \qquad (1.5),$$

$$D = \frac{n_2}{n} .100 \quad [\%] \qquad (1.6),$$

$$rv = \frac{n_0}{n_t} .100 \quad [\%] \qquad (1.7),$$

Use the spacing of the seeds to determine:

- The number of normally sown seeds (0,5- 1,5) lt (lt – theoretic distance between the seeds
- The number of doubles (0-0,5) lt,

Multiple quality of work of the seed apparatus is expressed by the ratio of the normally sown seeds (N), sown seeds (D) and omissions (V).

n_1 – theoretical number of normally sown seeds

n_2 – number of multiple-sown seeds

n_0 – number of omitted seeds

n_t – theoretical number of seeds

1.5.1.1 Measuring the seed's critical scooping speed:

The seed disk in precision seeders is driven either by the running wheel or by an electric motor. With the running wheel drive, increasing the working speed leads to increasing the circumferential speed of the seed disk, and consequently reducing the time to scoop the grain onto the disk's opening while the disk runs through the scooping area. Exceeding the so-called critical speed of the disk there is a rapid increase in the number of uncaptured seeds and thus deteriorating the quality of sowing. The critical speed can be established by laboratory measurements.

1.5.1.2 Measuring the critical speed on a measuring stool

To measure the critical speed of the seeds scooped make a test stool, where can be placed a seed apparatus, the drive of the seed disk with a gear shift, a device for creating negative pressure, measuring tools (stopwatch, calculating plates, pressure gauge, and if need be a PC measuring system with a relevant reading device).

First determine the theoretical number of seeds n_t fallen out of a seed apparatus over a time unit.

$$n_t = n_v .k \quad [\ s^{-1}\ ] \qquad (1.8),$$

where: n_v – revolutions of the seed disk (s^{-1})

k – number of holes on the disk (-)

Write down the resulting values into the calculated values table. After checking the testing stool's functioning (revolutions, negative pressure etc.) pour the seed into the seed box and run the test equipment. During a specified period of time 5 - 10, 20 s^{-1} the seeds falling from the seed apparatus are captured. Write down into the recording table the number of the captured seeds, the set revolutions and the measuring time. Repeat the measurements at least 5 times. Use the measured values to calculate the number of seeds sown over a time unit. Plot the measured and theoretically calculated values into a graph with the number of seeds in relation to the seed apparatus' revolutions (scooping speed) and connect the curves. Read the critical revolutions of the seed disk on the horizontal axis, at the point where the measured values curve starts to markedly diverge from the theoretical.

To calculate the (maximum) working speed of the seeder set:

$$v_{pk} = n_{kv}\ i_c.\ O_p. \qquad [m.s^{-1}] \qquad (1.9),$$

where: n_{kv} - critical revolutions of the seed disk s^{-1}

i_c. - overall gear ratio from the running wheel to the seed disk

O_p- circumference of the seeder's running wheel (m)

Or also:

$$v_{pk} = \frac{l_t.k.v_{ik}}{\pi.d} = l_t.k.n_{ik} \quad [\mathrm{m.s^{-1}}] \qquad (1.10),$$

where: l_t-spacing of the seeds in a line(from the machine's setting table)

k- number of holes in the dics (-)

d- diameter in which the holes of the seed disk are (m)

v_{ik}- critical scooping speed (m.s^{-1})

In static measuring of the seed apparatus in the laboratory the vibrations of the working machine are not taken into account. These vibrations also negatively affect the scooping of the seeds. Modern measurement can be done using the seed sensor connected to a PC equipped with an evaluating programme. The results can be printed out in the form of graphs or resulting tables.

1.5.2 The inspection of the precision seeder's quality of work

The inspection of the precision seeder

Make at least five measurements on the laboratory model of a seeder (for sowing sugar beet) and find out the number of seeds sown during the time of the test in seconds (according to the assignment)

a) set the theoretical working speed of the seeder v_p=? [m.s^{-1}] , pro l_t = 0,16; 0,18; 0,20 m

Sequence of operation: calculation of the seeder's traveling speed

$$v_p = \frac{\bar{z} \cdot l_{t1-3}}{t} \quad [\mathrm{m.s^{-1}}] \qquad (1.11),$$

lt – distance of the seeds in a line (m)

$\bar{z}$ - number of seeds found during the test (arithmetic average)

t – time of the test in (s)

b) compliance of the seeder's seed rate

$$Q_s = \frac{\bar{z}}{n \cdot l_z} * 100 \quad [\%] \qquad (1.12),$$

n – revolutions of the seed disk during the test (s^{-1})

lz – number of holes in the disk (find out the number on the seeder's model)

c) find out the theoretic spacing of the seeds in a line l_t from the circumferential speed of the seed disk and the traveling speed if $v_p = v_0$ [$m.s^{-1}$]

for:

$$v_O = \pi \cdot d \cdot n \quad [m.s^{-1}] \qquad (1.13),$$

$$l_t = \frac{v_0 \cdot t}{\bar{z}} \quad [m] \qquad (1.14),$$

where: n – revolutions of the seed disk s^{-1}

d - diameter of the seed disk (m)

2 TESTING OF SPRAYERS *(Červinka)*

Machinery used for plant protection, must pass through obligatory tests that consist of a check of their functional capability enabling to apply preparations used for the protection of plants and plant products pursuant provisions of the Decree n° 384/2011/Coll. about technical equipment and marking of wood packaging material. Since 2011, all newly purchased sprayers must pass through the first control revision within a period of five years after their setting into operation. Tests are performed in the laboratory using a model sprayer; some of these tests are involved into the process of sprayer testing as specified in the aforementioned Decree.

2.1 Sprayer Test (experimental training lesson)

In the course of t experimental training, the participants should check up the functional capability of the manometer, determine the volume discharge of nozzles (i.e. the spray dose per minute) and the angle of the dispersion, calculate the uniformity of dispersion from nozzles mounted on the sprayer frame and plot the results in a graphical form. All these measurements are performed using clean water and the air temperature (as well as that of water) must be higher than 5 °C. The maximum wind velocity is 2 $m.s^{-1}$. The sprayer and all parts that were used in practice must be perfectly decontaminated and clean. Each measurement should be repeated at least three time. During intervals between individual measurements the sprayer must be neither switched of nor adjusted. Results may be processed either in Excel or by means of an available statistical software.

Check of manometer functions

The testing of manometer functions should be performed on a test stand. During this measurement data about pressures recorded on the tested manometer are compared with those of control (calibrated) one (both devices must be parallelized). The exact and functional control manometer enables to measure pressures in accordance with the pre-programmed operating regime of the machine on the one hand and a good reproducibility of tests on the other.

Task setting

Perform a test of manometer functions (check up its type, serial number and measurement range) and evaluate measured differences in recorded pressure data. This analysis must be performed on the base of a series of pressures changing (i.e. decreasing and increasing) within the whole range of the scale of tested manometer. Plot recorded values in a graph and compare it with the standard. If necessary, suggest a modification of the tested scale in accordance with the International System of Units (SI System). Draw measured values together with the tolerance zones into a graph of compared pressures. Suggest the possible application of obtained results in practice.

Evaluation of results, admissible tolerance

When testing manometers, the difference between data recorded on the tested and the calibrated manometer must not exceed percentages registered in the control calibrated device by more than those specified in categories of their accuracy. Results are recorded in Tab. 2.1.

Tab. 2.1.: Comparison of results (working pressure … bar, MPa)

Serial number of the measurement	CALIBRATED							TESTED MANOMETER						
	Type:							Type:						
	Serial number:							Serial number:						
	Measurement range:							Measurement range:						
	Accuracy category:							Accuracy category:						
	Pressure							Pressure						X
	Increasing			**Decreasing**				**Increasing**			**Decreasing**			
	Repetition						X	Repetition						
	I	II	III	I	II	III		I	II	IIII	I	II	III	
1							------			- -				
2								...						
..	-----	-----	----	-----	----					----				
10														

Volume discharge (spray dose per minute) of nozzles mounted on the sprayer frame

The volume discharge is expressed as the amount of liquid flowing through the nozzle per unit of time. This value is determined by the nozzle design, size of the outlet orifice, working pressure and quality of the working (and/or abraded) functional surfaces of individual nozzles. Units of measurement are as follows: (Lt.min^{-1}) or (ml.min^{-1}). The discharge is measured as the total volume of sprayed liquid collected in a calibrated vessel;

other possibilities how to do it are either the use of a flow meter or weighing of collected liquid. When doing this, we place a measuring device directly below the nozzles and collect the liquid for a period of 60 seconds. The discharged volume can be measured either directly in the calibrated vessel or after pouring the liquid into a measuring cylinder. The use of a digital measuring AAMS flow meter analyser. Results are recorded in Tab. 2.2..

Task setting

Perform the measuring and evaluating of the uniformity of liquid sprayed from individual nozzles, describe the type of the sprayer, its size, assemblage, span, and setting at working pressures of….. MPa. The non-uniform spraying should be expressed by means of absolute deviations, coefficient of variation and average values of the nozzle flow rate. Using these data elaborate graphs illustrating the dependence of:

- the flow rate on the working pressure and
- of the flow rate on the wear of nozzles

Construct a point diagram, select a corresponding type of regression function and develop a method enabling to calculate the course of the regression curve (line). Using the measured data, draw corresponding conclusions.

Tab. 2.2.: Volume discharge of nozzles ($ml.min^{-1}$; Lt. min^{-1})

Nozzle	Working pressure	Repetition	Nozzle serial number				
			1	2	3	4	…………………..n
		I					
		II					
		III					
		$\bar{x}$					
	:::::::::	.::::::::					::::::::::::::::::::::::::::::::

Evaluation of results, admissible tolerance

The maximum tolerable non-uniformity of the volume discharge (minute volume of sprayed liquid) of individual nozzles mounted on the application frame is ± 5 % deviation from the average value of the flow rate of all nozzles. The maximum value of the coefficient of variation (v) is also 5 %.

<u>The spray pattern (angle of liquid scattering)</u>

The spray pattern is defined as the angle formed by both edges of the liquid fan sprayed from the nozzle orifice and its size is expressed in gradians (gons); the symbol is (°). The spray pattern is measured by a mechanical angle gauge with adjustable arms and a scale enabling to read directly values of individual angles. Results are recorded in Tab. 2.3..

Tab. 2.3.: Angle of the nozzle spray pattern in gradians (°)

Nozzle	Working pressure	Repetition	Nozzle serial number				
			1	2	3	4	……………………..n
		I					
		II					
		III					
		$\bar{x}$					
		::::::::					::::::::::::::::::::::::::::

<u>Evaluation of results, admissible tolerance</u>

In this case we evaluate the absolute value of the spray pattern angle and its symmetry. Changes taking place in the working pressure should not influence the size of this angle. In a given regime of spraying, the non-uniformity of the spray pattern angle must not be greater than:

- 2° of the arithmetic average value of all nozzles
- 5 % when expressed by means of the coefficient of variation.

<u>The transversal non-uniformity</u>

The transversal non-uniformity of spraying expressed the relative distribution of spray liquid within the working span in the plane that is perpendicular to the direction of the sprayer movement. The spraying width is determined by the number of nozzles on the frame and by this spacing. In the perpendicular plane, this non-uniformity is dependent above all on the overlapping of individual spray patterns of individual neighbouring nozzles. By collecting partial volumes of the liquid on elementary parts of the measuring device we can record data enabling to evaluate the transversal non-uniformity of sprayers used for an area application is performed on a trough collection area. The distance of nozzles from the upper edge of the trough (i.e. the working height) is determined by the type and spacing of nozzles. During this test, the sprayer is not moving and remains to stay in place. The device for measurements of the spray liquid distribution consists of collection troughs (dimensions 6 x 1 m and inclination of 5 – 10°). The distance between separating walls of individual troughs is 100 mm. Each trough has a separate outlet. At present, it is also possible to perform the measurements automatically with a measuring device called Hardiscaner. The collected volumes of the spraying liquid are recorded in Tab. 2.4..

Tab. 2.4.: Determination of the spray pattern uniformity – transversal non-uniformity

Repetition	Point of measurement – volume of collected water (ml)																	
	1	2	3	4	5	6	7	8	9	10	11	12	12	14	15	16	17	18
I																		
II																		
III																		
$\bar{\bar{x}}$																		
Repetition (cont.)	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
I																		
II																		
III																		
¿																		
Repetition (cont.)	37	38	39	40	…										:	:	59	60
I																		
II																		
III																		
$\bar{\bar{x}}$																		

The accuracy of results is determined by the volume of water collected in calibrated cylinders (the tolerance is $\pm$ 5 ml), height of nozzles above the edge of the trough (in the centre of the measuring table this adjustment should be $\pm$ 10 ml) The transversal non-uniformity can be calculated in percent, i.e. as an absolute deviation from $\bar{X}$, the deviation is +7% (the maximum deviation is + 10 %) , coefficient of variation (V) max. value 15 %. The variation coefficient (V) and the corrected standard deviation are calculated and used for the analysis of results in case when we process data obtained within the framework of the basic set of measurements.

Task setting

Perform the calculation of the transversal non-uniformity of the spray pattern for a sprayer with the following parameters: spraying frame width …m, working height of the frame …m, working pressure ….MPa, nozzle spacing …..m, type of nozzles ….., - slot nozzle. Calculate the transversal non-uniformity and plot it in a graph. Calculate the coefficient of variation.

Laboratory tests of spray nozzles (laboratory task)

The device for testing of nozzles enables to determine:

- volume flow through the nozzle (i.e. the minute dose)
- angle of spray dispersion and the symmetry of the ejected ray and
- the non-uniformity of the spray pattern of individual nozzles.

Besides, it is also possible to measure the liquid dispersion, reliability of the function of the automatic check valve, wear of nozzles etc.

The measuring device for nozzle testing (description and functions)

The measuring device for laboratory tests of nozzles consists of a measuring box and a measuring table. The measuring box contains a pump that expels the liquid (water) through a filter into an adjustable pressure regulator. Using a valve and a manual control wheel it is possible to pre-set on the control panel the working pressure within the range of 0.2 – 1.0 MPa. (the working pressure is read on the control manometer). Using a time switch, we can pre-set the duration of opening of an electromagnetic valve within the interval from 2 seconds to 6 minutes. The liquid flows through the opened electromagnetic valve into the nozzle that direct spray drops either into a calibrated cylinder (when measuring the flow) or into the upper part of the chamber (when measuring the angle of dispersion). This angle is read on the back wall of the chamber. The total volume of liquid collected in the calibrated cylinder flows through a pipe back into the tank. The measuring table consists of a flat (1.4 x 1.0 x 0.05 m) collecting tank with the grooved bottom (the width of groves is 100 mm). A frame with the nozzle holder is mounted above the tank; the dispersed liquid is collected in grooves and runs into the calibrated cylinders. These cylinders can be jointly pre-set to three basic positions (measuring, reading of liquid volume and emptying). The beginning of measurements, as well as changes in the working pressure and of liquid volume can be done by means of adjusting elements situated on the chamber panel. Changes in the liquid pressure and the beginning of measurements are performed by means of control elements situated at the panel of the measuring box. When changing the slot nozzles, it is necessary to adjust a new nozzle in such a way that the slot is parallel with the back wall of the chamber.

2.2 Methodology and measurements

Measurements are performed under laboratory conditions (air temperature 15-22 ° C, relative air humidity 50-80 %, water temperature 15-22 °C. The working pressure is read on a manometer that is mounted immediately before the tested nozzle..

The volume flow through the nozzle (minute dose) is measured as the volume of liquid flowing through the nozzle at the pre-set working pressure per unit of time. The spray liquid is collected in a calibrated cylinder with the volume of 2,000 ml that is mounted immediately below the tested nozzle. The time and volume tolerances of the accuracy of measurements are ± 0.5 sec. and ± 5 ml, respectively. These measurements must be repeated at least three times.

The spray pattern (angle) is measured by an angle gauge on the back wall of the measuring chamber. This value is determined as the angle formed by both edges of the liquid fan sprayed from the nozzle orifice. The accuracy of measurements should be ±1° and is calculated as an average of values recorded after the minimum number of two repetitions.

Liquid dispersion (the dispersion pattern) is determined on the base of uniformity of the liquid dispersion within the nozzle span. This measurement is performed on the measuring table using calibrated cylinders. The liquid volume is measured within a predetermined time interval (30 or 60 seconds). The accuracy of measurement is ± 5 ml. The nozzle height tolerance is ± 10 mm. This measurement must be repeated at least three times.

Evaluation of results, permitted tolerances

At first it is necessary to record general data concerning tested nozzles, i.e. kind and type of the nozzle, the mode of its application, nozzle specification (according to the ISO standard), manufacturer, nozzle characteristic and its basing setting as recommended by the manufacturer. The volume discharge is recorded in Tab. 2.5..

Tab. 2.5.: The volume flow rate of the nozzle (ml.min^{-1})

Nozzle	Working pressure	Repetition	Serial number of the measurement					$\bar{X}$
			1	2	3	4	…………………..n	
		I						
		II						
		III						
		$\bar{X}$						
		I						
		II						
		III						
		$\bar{X}$						

The volume discharge is calculated as an average of three repetitions. When evaluating a set of identical nozzles it is necessary to calculate the total average flow rate ($\bar{X}$) and the average flow rates are plotted in a column graph, and the $\bar{X}$ value is drawn as a horizontal line with the deviation of $\pm$ 5 %. Flow rates that are outside of this correlation field do not meet the requirements of the standard and such nozzles must not be mounted on the sprayer and used for spraying.

The angle of dispersion

Measured values of the angle of dispersion should be recorded in a similar table. In this table we record angles of the right and the left edge of the liquid fan sprayed from the nozzle orifice; these angles are measured from nozzle axis. We evaluate the absolute value of the angle of dispersion and the symmetry of the spraying pattern. A change in the working pressure within certain limits should not result in a change of the angle of dispersion. At a given working pressure, the non-uniformity of the angle of dispersion should not exceed the limit of ± 2.5 % of the arithmetic mean of angles of dispersion of all tested nozzles. Results are plotted in the graphical form.

<u>Liquid dispersion – transversal non-uniformity</u>

The volume of water collected in calibrated cylinders is recorded in Tab. 2.6. Volumes of water collected in individual cylinders and the overall average are calculated from results obtained in three repetitions. These average values are used for plotting of dispersion curve of the total working span of a nozzle. In the graph of the total working span of a nozzle it is necessary to highlight the working (constructional) span of the nozzle. Values exceeding the limits of the working span are added together with the originally measured values. In this way we can obtain values enabling to construct the graph of non-uniformity and to perform the subsequent calculation. When working with the variation coefficient, the degree of the dispersion non-uniformity within the working (constructional) span of the nozzle should not be greater than ± 5 %.

Tab. 2.6.: Uniformity of the spraying pattern of a nozzle (ml) with the working height of ....mm and the working span of 500 mm (it is necessary to record the position of the corresponding nozzle !!!)

<table>
<tr><td>Nozzle</td><td>Working pressure (Pa)</td><td>Span</td><td rowspan="2">Repetition</td><td colspan="5">Nozzle serial number</td><td>$\bar{x}$</td></tr>
<tr><td rowspan="7"></td><td rowspan="5"></td><td rowspan="5">Total</td><td>1</td><td>2</td><td>3</td><td>4!!</td><td>…………………..n</td><td></td></tr>
<tr><td>I</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>II</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>III</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>$\bar{x}$</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td rowspan="2"></td><td rowspan="2">Working span</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
</table>

Task setting

Record basic data concerning tested nozzles and select a set of these nozzles (corresponding with the Czech standard) that could be used in this sprayer. Perform measurements for two basic pressures within the range of 0.1 – 1.0 MPa. Determine the non-uniformity of the spraying pattern of one nozzle and assess if it meets the requirements of the standard. Analyse obtained results and draw conclusions that can be used in practice. Use measured data in the experimental training lesson.

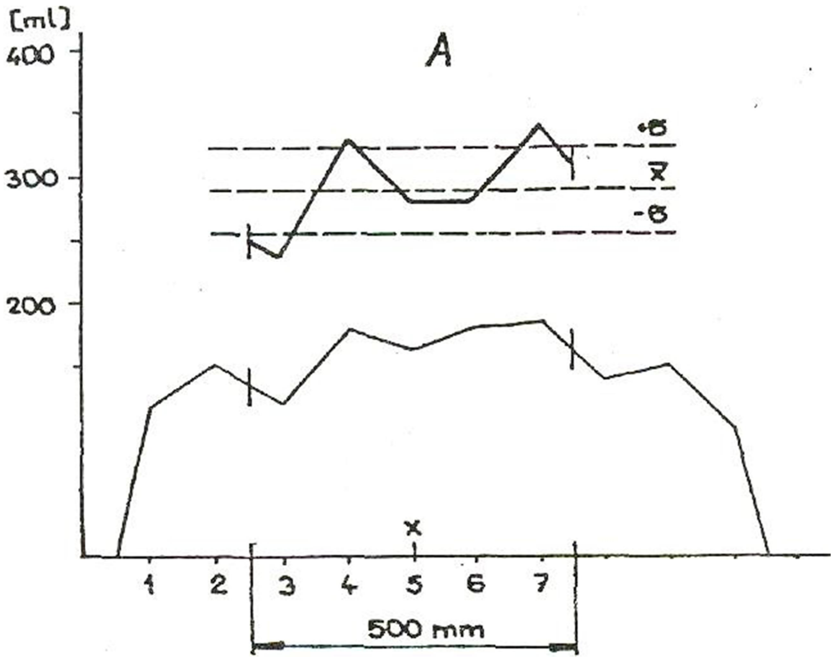


Fig 2.1.: A graphic display of spray uniformity from one nozzle

3 MOWERS *(Kubín, Salajka)*

Mowers are mechanical equipment that, together with tractors, carry out the first operation of harvesting forage, i.e. mowing. The purpose of mowers is to cut off the above-ground parts of plants and lay them in rows on the ground into so-called swathes. The main functional part of mowers is the cutter bar. The cutter bar is also used in a wide range of harvesting machines, e.g. in mower-conditioners, forage harvesters, combines and in other machines.

Mowers fall into the following categories:

a) According to the power source:
  - manual – powered by human force
  - with an auxiliary engine to drive the cutter bar
  - pulled – driven by draft animal
  - with an auxiliary engine
  - tractor
  - self-propelled

b) The tractor mowers are, according to where the hitch is placed, further divided into:
  - frontal – connected to the front axle of a tractor
  - between axles – located between the front and the rear axles
  - rear – attached behind the rear axle.

c) The tractor mowers can, according to the type of hitches, be divided into:
  - tow-behind
  - trailed
  - carried

d) According to the movement of the blade into the cut, mowers can be further categorized by those with:
  - Reciprocating blade – those are further divided according to design into finger bar ones and those with opposing scythes (without fingers).
  - Rotary movement of the blade – those designed to cut in the horizontal plane are divided into rotary drum mowers and rotary disk mowers, with the rotary motion on a vertical plane into flail mowers and drum mowers (lawn care machines).

e) According to the cutter bar propulsion, they are divided into mowers with the following propulsion systems:
   - mechanical
   - hydraulic
   - combined

3.1 Cutter bar mowers

The task of the cutter bar is to separate the above-ground part of plants from the roots and to either lay them down on the ground or pass it to other devices of the harvesting machine for processing.

We divide cutter bars with linear blade motion into:

- finger ones (with a passive shear bar)
- without fingers - with opposing scythes (with active shear bar)

Finger cutter bars are, according to the spacing of the blades and fingers, subdivided into (see Fig. 3.1.):

a) standard – sparse
b) dense – low-cutting
c) semi-dense – medium

The cutter bar's principle of cutting is the resulting motion of scythe blades towards the crop, which is composed of two movements:

- movement to the frame (feeding) - linear progressive movement of the whole system (v_p)
- movement to the cut (lifting) - linear uneven reciprocating movement of the scythe (v_k)

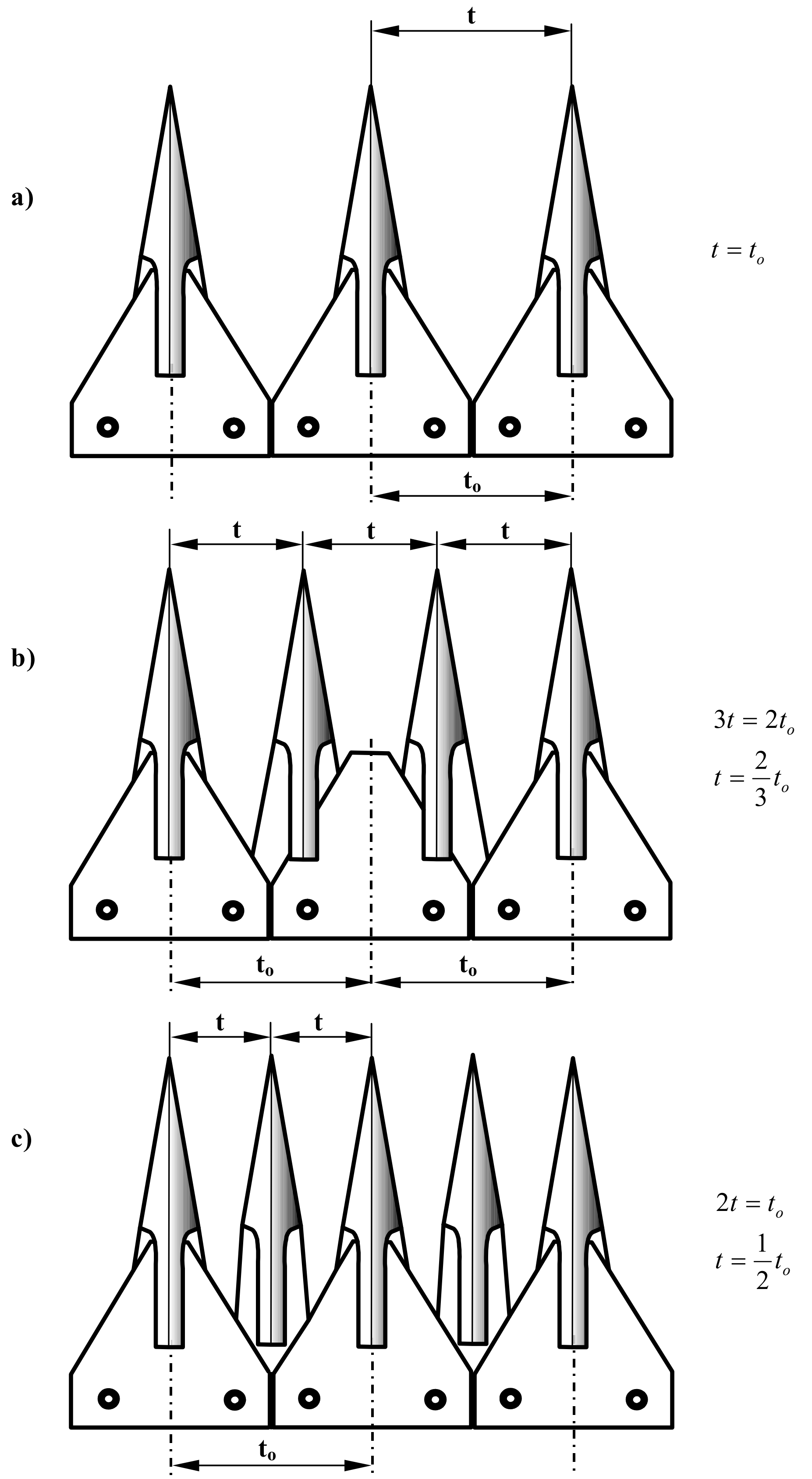


Fig. 3.1.: Types of finger cutter bars

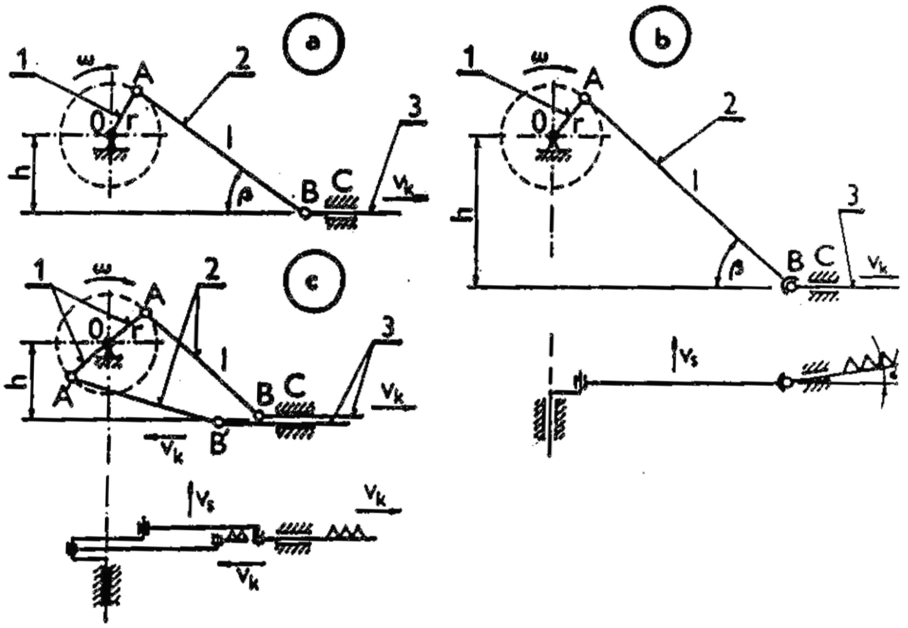


Fig. 3.2a.: Diagram of shortened crank mechanisms of scythe's drive.

a) planar; b) spatial; c) double-crank; 1-crank, 2- knuckle, 3-scythe.

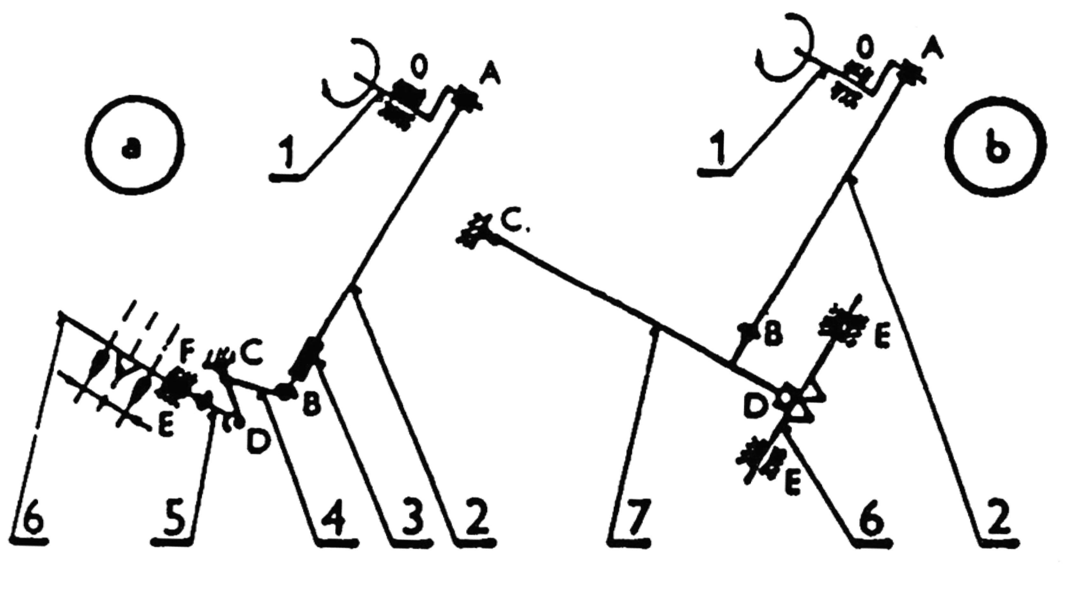


Fig. 3.2b.: Diagram of spatial crank mechanisms

a) With a rocker arm
b) With a pulley

1 – crank

2 – knuckle

3 – jaws

4 – rocker arm

5 – rod

6 – scythe

7 – pulley

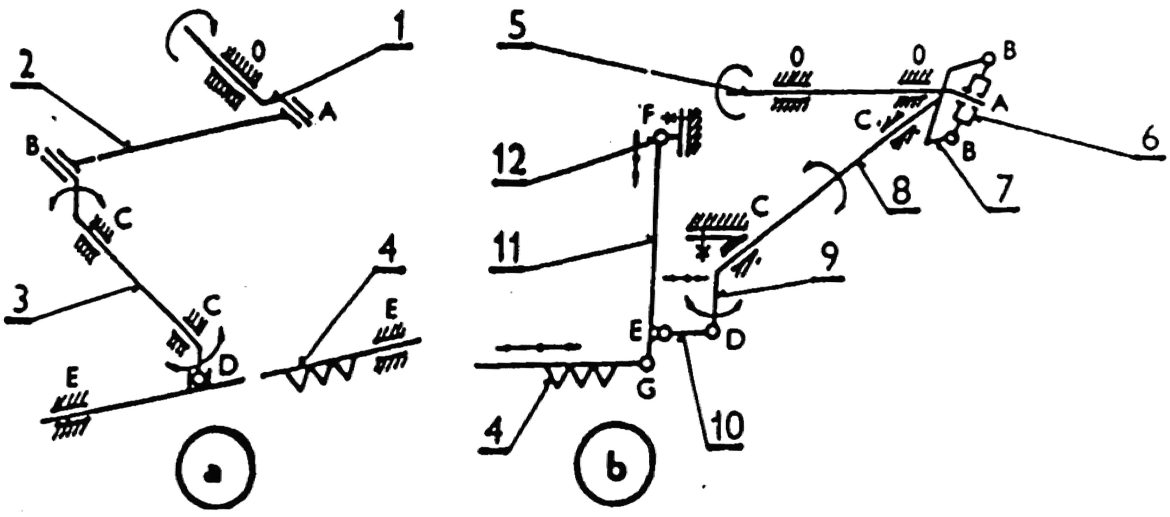


Fig. 3.2c.: Diagram of spatial mechanisms with a rocking shaft. a) with a propelling crank b) with a diagonal bolt. 1-crank, 2-knuckle, 3-shaft, 4-scythe, 5-propelling shaft with a diagonal bolt, 6-bearings, 7-fork, 8-shaft, 9-rocking arm, 10-rod, 11-hinge, 12-sliding hinge

Various mechanisms (propulsion) make the movement to the cut (shortened crank, diagonal bolt, hydraulic, cam ...), see Fig. 3.2..

3.2 Rotary mowers

Contrary to mowers with linear reciprocating blade motion where the cut is made with support (with the fixed shear bar in the finger between the moving blade), with rotary mowers the cut is made without support. When cutting without support, the blade moving at high circumferential speed acts on the standing crop. The inertia of the stem fulfils the function of the fixed shear bar. The cut without support needs higher cutting speed, min. 6 - 10 m.s^{-1}. The softer, tougher the vegetation and the less sharp the cutting tool, the higher the cutting speed must be. With increasing cutting speed, cutting resistance decreases. A rotary mowing mechanism does not have reciprocating moving parts, so any unbalanced inertial forces do not arise, thereby enabling the blade to considerably increase the ground speed and achieve high efficiency. The rotary mowing mechanism is simple and operationally reliable. However, it uses much more energy than the cutter bar mowing mechanism.

Currently in field production, rotary mowers with the following mowing mechanisms are used:

- drum
- disk

3.3 Design of the knife edge trajectory

For mowing there are two movements of the knife edge needed:

- movement to cut – Movement of the scythe with knifes at speed v_k
- movement to engage – movement of the entire set at working speed v_S (gradual forward movement of the tractor with mower)

The resulting knife edge movement is thus composed of rectilinear reciprocating movement of the scythe and the constant rectilinear movement of the machine. The velocity vectors of the two movements are at right angles. By putting together these two movements we can design the trajectory of the end points of the active knife edge (edge that cuts the vegetation when the scythe is lifted up) and thus we define the area that the blade reaches with one lift of the scythe.

To design the trajectory of the knife we need to find out:

- basic dimensions of the knife and fingers (finger pad)
- parameters of the cutter bar, stroke scythe, spacing of fingers, spacing of knives and frequency of a revolution of the scythe's propulsion
- the machine's working speed

With these values we calculate the trajectory driven by the machine for one revolution of the scythe's motion:

$$x = v_s . t_{ot} \quad [\mathrm{m}] \qquad (3.1),$$

where:

v_S – machine's working speed [m.s^{-1}]

t_{ot} – time of one revolution of the crank [s]

$$t_{ot} = \frac{1}{n} \qquad (3.2),$$

n – revolutions of the scythe's propulsion [s^{-1}]

Half of the trajectory that the machine drives for one crank revolution h = x/2 is the so-called feeding, i.e. distance the machine drives for one lift of the scythe.

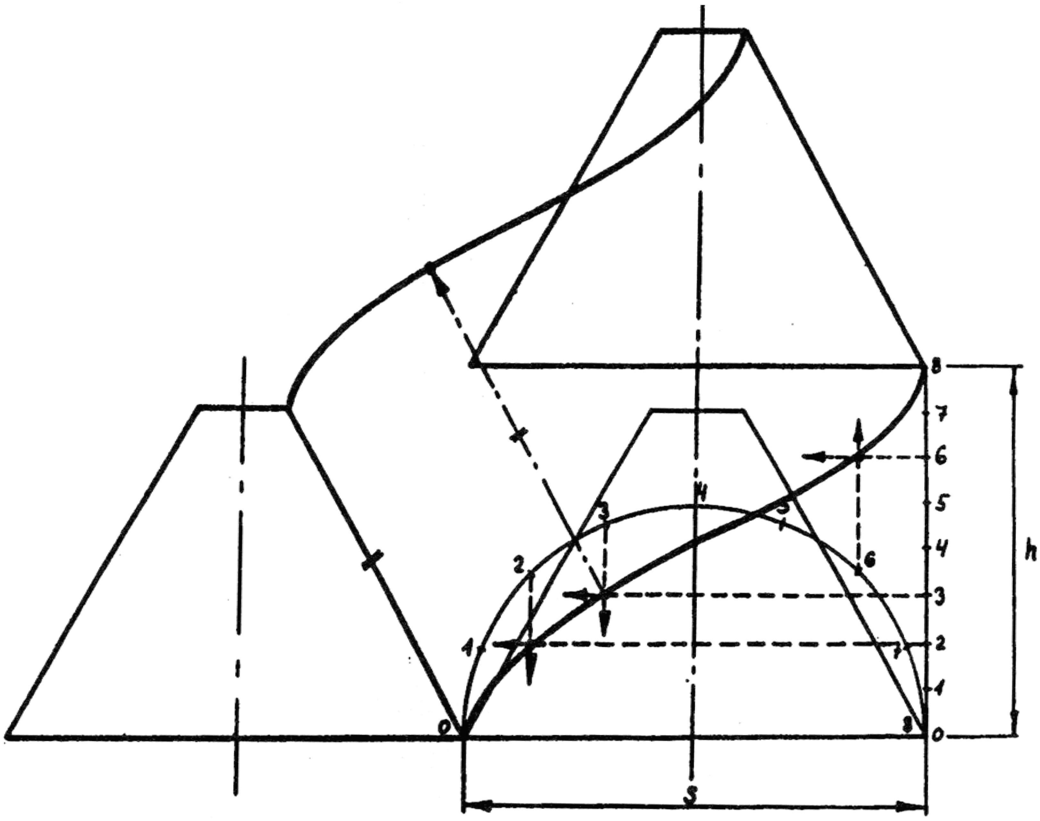


Fig. 3.3.: Construction of the knife edge trajectory; s-lift, h-trajectory of the machine for one lift

To construct with sufficient accuracy (neglecting the crank's offset and the knuckle's finite length) the trajectory of the lowest point of the knife edge, we draw an arc above the lift which is divided into the same number of parts as the distance travelled by the machine for one lift. Through these points we run parallels with the direction of the travel and with the movement of the scythe (see Fig. 3.3.). The knife edge trajectory's points are at the intersection of the parallels. Connecting these points with a smooth curve we get the trajectory of the knife edge's lowest point. Each point of the scythe moves along a trajectory of the same shape.

3.4 Constructing a diagram of the cut

Diagram of the cut shows areas covered and not covered by the active blade's edges of the mower.

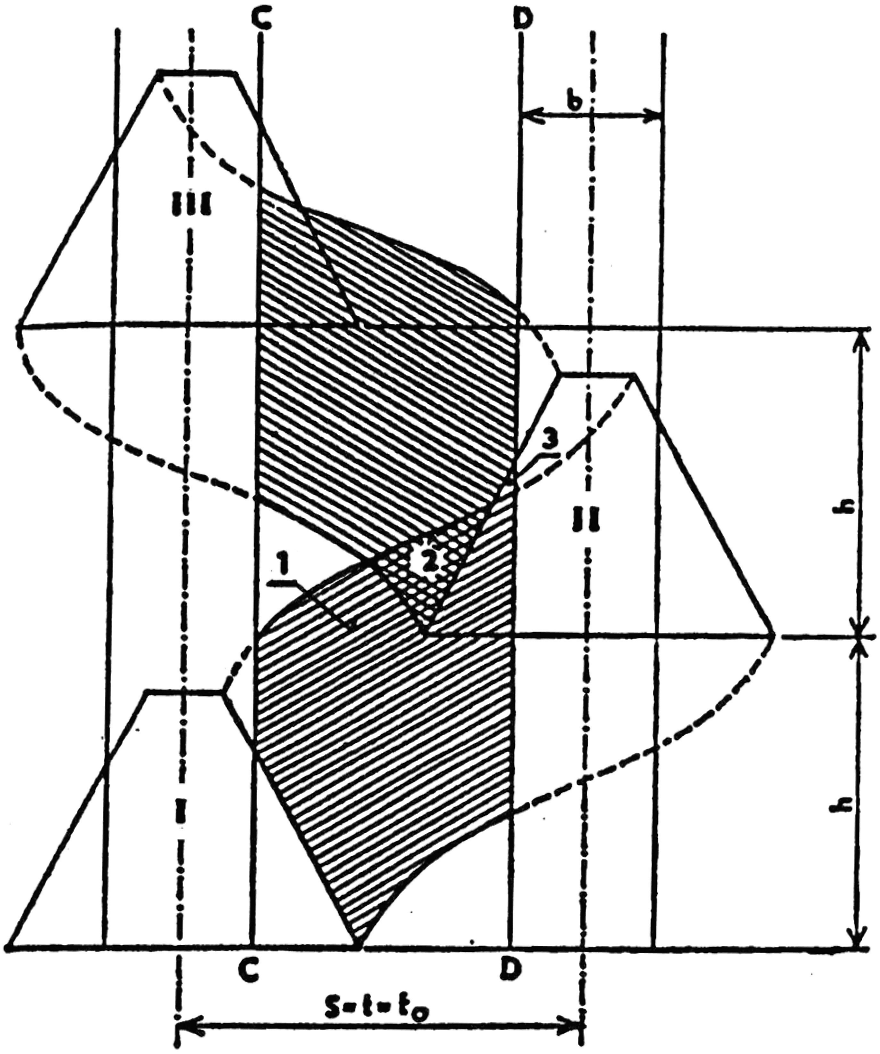


Fig. 3.4.: Diagram of a standard cutter bar cut.

I, II, III-Positions of the knife in the dead centre, b-width of the finger, h-machine's trajectory for one lift, s-lift of the scythe, t-spacing of the fingers, t_o-spacing of the knives, 1-area traversed by the active blade 1x, 2- area traversed by the active blade 2x, 3-area not traversed by the active blade.

Constructing the diagram, firstly we draw the knives of the scythe in at least three end positions dead centre. Then we draw the tracks made by fingers (for finger cutter bars). We draw the trajectory of the lowest and highest points of the active blade (see Fig. 3.4.). Cross hatch the strips to highlight the areas traversed by the active blade once (1), twice (2) and the areas not traversed (3) by the active blade. The vegetation is not mowed inside the strips traversed by the fingers; the plants are extirpated in this area. The mowing occurs only between the fingers of the cutter bar.

3.5 Assignment "Kinematics of the cutter bar and diagram of cutting"

1. Obtaining source materials for kinematics of the mower's cutter bar

1.1. Find out values listed in Tab. 3.1. on mowers with minimal disassembly

1.2. Record by a sketch the measuring method of individual values in the table

1.3. Draw a diagram of the scythe's drive with relevant gears

1.4. Draw a diagram of the shock absorber for the given mower

2. Determine the course of velocity and acceleration of the scythe

   a) numerically
   b) graphoanalytically

To draw the course of velocity and acceleration use the diagram of the scythe's drive. Corroborate the calculated values by tables.

2.1. Find the average speed of the scythe to the cut graphically and by calculation. Use the linear planimeter to graphically determine the average speed of the scythe.

2.2. Plot the course of the cutting speed given the mower‘s travelling speed.

2.3. Calculate the lift of the scythe and compare it with the measured values.

3. Diagram of the cut of the cutter bar.

3.1. Draw a diagram of the cut of a given mower with linear reciprocating blade motion. In the diagram, indicate the areas traversed by the active blade once, more times, and the areas not traversed by the active blade.

3.2. Find out the initial and final speed to the cut.

Tab. 3.1.: Table of the input data – CUTTER BAR MOWERS

Number	Data measured	Designation	Unit of measurement	Type of mower				
a	**b**	**c**	**d**	**e**	**f**	**g**	**h**	**i**
1	Spacing of the knives of the scythe	t_o	mm					
2	Spacing of the fingers	t	mm					
3	Lift of the scythe	s	mm					
4	Sweep of the scythe	p	mm					
5	Swath of the cutter bar	B	m					
6	Radius of the rotation of the scythe's driving bolt	r	mm					
7	Length of the knuckle	L	mm					
8	Elevation of the bolt's axis on the scythe's head	c	mm					
9	Crank's offset	a	mm					
10	Width of the upper base of the blade	t'	mm					
11	Rotation of the machine's motor	n_s	s^{-1}					
12	Rotation of the scythe‘s drive	n	s^{-1}					
13	Weight of the scythe	m_k	kg					
14	Weight of the knife	m_n	kg					
15	Weight of the knuckle	m_t	kg					
16	Operating speed	v_s	$m.s^{-1}$					
17	Length of the knife edge	l_o	mm					
18								
19								
20								

Type of the machine: Student group: Year: Major: Student:

4 FLUID FLOW IN AGRICULTURAL OPERATIONS *(Štencl)*

4.1 Properties of liquids, Newtonian and non-Newtonian liquids

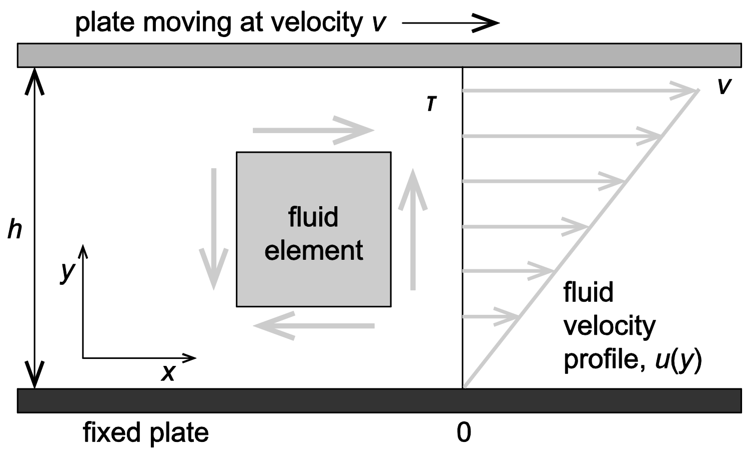


Fig. 4.1.: Fluid sheared between two plates

A Newtonian liquid is any liquid that exhibits a viscosity that remains constant regardless of any external stress that is placed upon it, such as mixing, flow (velocity) or a sudden application of force.

Let´s have shear stress $\underline{\tau}$ at liquid flow $\underline{u_x}$ with velocity profile u_y (see Fig. X-1) expressed as follows

$$\tau = \eta \frac{du_x}{dy} \tag{4.1),}$$

where $\underline{\eta}$ is the viscosity.

Newtonian liquid is characterized by the following equation $\eta \neq \eta \frac{du_x}{dy}$, i.e. viscosity – internal friction does not depend on the flow velocity.

Non-Newtonian liquid is characterized by the following equation $\eta = \eta \frac{du_x}{dy}$, i.e. viscosity – internal friction depends on the flow velocity.

Typical examples of Newtonian liquid are water, wine, milk with fat < 1.5% etc. but pure honey, too.

Typical examples of non-Newtonian liquid are liquids containing solid parts, e.g. slurry, liquid feed, honey with crystals of sugar (compare with non-Newtonian liquid), ketchup etc.

We are able to describe exactly behaviour of Newtonian liquids using basic hydrodynamic (aerodynamic) laws – “white box model”, see chapter 4.2. On the other side we are not able to do it in case of non-Newtonian liquids. There is necessary to carry out practical experiments and consequently to determine corrections coefficients and these incorporate into the “white box model” equations → “black box model” or “grey box model”.

4.2 Handling systems for Newtonian Liquids (Continuity equation, Reynolds number, Bernoulli equation, Ventouri tube)

4.2.1 Continuity equation; basic balance equation

Basic balance equation, general expression for a certain period:

INPUT = OUTPUT + ACCUMULATION (4.2).

This is principal equation used in many analyses and sciences. It will be used namely in heat and mass transfer calculations.

The best way how to explain the equation of continuity is to demonstrate a liquid flow inside the duct with a cone shape, see Fig. 4.2..

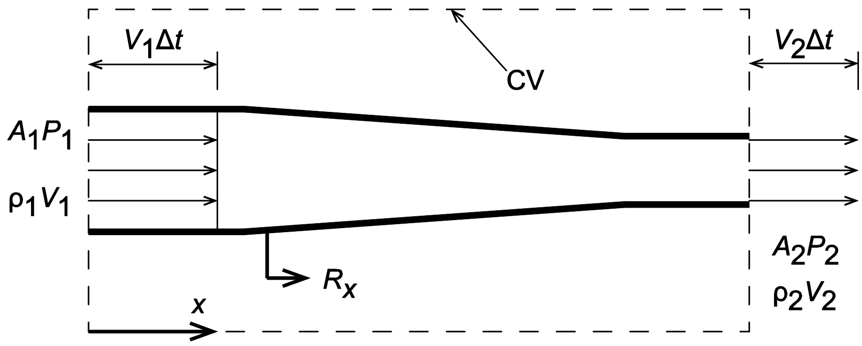


Fig. 4.2.: One-dimensional duct

Volume flow in over surface A_1:	$V_1 = A_1.v_1.\Delta t$	[m^3]
Volume flow out over surface A_2:	$V_2 = A_2.v_2.\Delta t$	[m^3]
Mass in over surface A_1:	$M = \rho.A_1.v_1.\Delta t$	[kg]
Mass in over surface A_2:	$M = \rho.A_2.v_2.\Delta t$	[kg]

So, the continuity equation is:

$$A_1.v_1 = A_2.v_2 \tag{4.3}$$

Notice: ρ - density [kg.m^{-3}]; v – velocity [m.s^{-1}]; Δt – time [s]

4.2.2 Reynolds number

The Reynolds number Re represents the non-dimensional velocity

$$\mathrm{Re} = \frac{cd\rho}{\eta} \ [-] \tag{4.4}$$

where c – velocity [m.s^{-1}]; d – characteristic dimension [m]; ρ - density [kg.m^{-3}];

η – dynamic viscosity [Ns.m^{-2}; Pa.s]

Reynolds number, in fluid mechanics, a criterion of whether fluid (liquid or gas) flow is absolutely steady (streamlined, laminar) or on the average steady with small unsteady fluctuations (turbulent). Whenever the Reynolds number is less than about 2,300 - 2,700, flow in a pipe is generally laminar, whereas, at values greater than 2,700, flow is usually turbulent. Actually, the transition between laminar and turbulent flow occurs not at a specific value of the Reynolds number but in a range usually beginning between 2,000 and 5,000.

4.2.3 Bernoulli equation

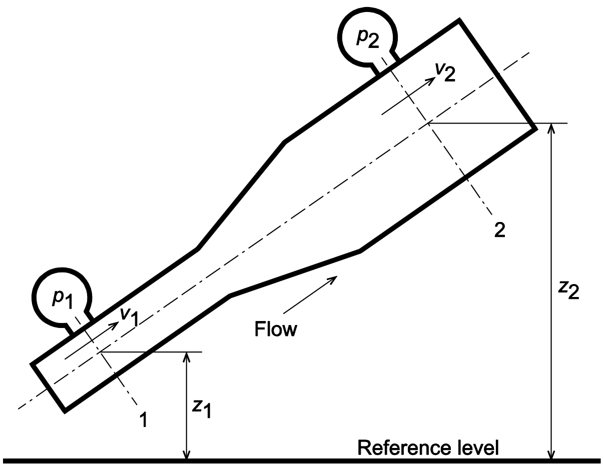


Fig. 4.3.: Pressure, velocity and elevation in a pipe with variable diameter

The Bernoulli equation gives a great insight into the balance among pressure, velocity and elevation. It states that

$$z_1\rho g + p_1 + \frac{\rho v_1^2}{2} = z_2\rho g + p_1 + \frac{\rho v_2^2}{2} = konst. \qquad (4.5)$$

or

$$z_1 + \frac{p_1}{\rho g} + \frac{v_1^2}{2g} = z_2 + \frac{p_2}{\rho g} + \frac{v_2^2}{2g} = konst. \qquad (4.6),$$

where p is the pressure, ρ is the density, v is the velocity, z is elevation, and g is the gravitational acceleration

or

p is the pressure energy, $1/2\rho v^2$ is the kinetic energy per unit volume, $z\rho g$ is the potential energy per unit.

The Bernoulli equation can be considered to be a statement of the conservation energy principle appropriate for flowing fluids. Reduction in pressure, which occurs when the fluid speed increases, is called “Bernoulli effect”.

The Bernoulli equation is valid for Newtonian liquids and for laminar flow. It represents “white box model”.

4.2.4 Ventouri tube

The Ventouri tube (Fig. 4.4.) represents practical application of the Bernoulli equation

$$z_1 + \frac{p_1}{\rho g} + \frac{v_1^2}{2g} = z_2 + \frac{p_2}{\rho g} + \frac{v_2^2}{2g} = konst. \qquad (4.7).$$

The Venturi tube uses the "Bernoulli effect", i.e. the lowering of fluid pressure in regions where the flow velocity is increased; it is in constriction part of the tube, compare the pressure in points 1, 2, and 3 on Fig. 4.4..

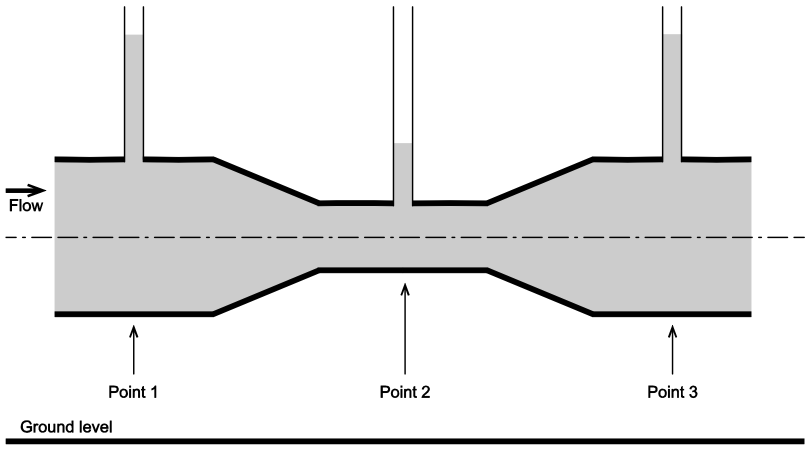


Fig. 4.4.: Venturi tube

4.3 Liquid transport in a pipeline

Losses in fluid flow (liquid and gaseous fluid) in the pipeline:

$$H_z = H_g + \frac{c^2}{2g} + \lambda \frac{L}{D}\frac{c^2}{2g} + \Sigma\xi \frac{c^2}{2g} \text{ [m]} \qquad (4.8),$$

where $\underline{H_g}$ is total elevation, $\underline{c}$ is the velocity, $\underline{g}$ is the gravitational acceleration, $\underline{\lambda}$ is the hydrodynamic friction constant between fluid and wall of the tube, $\underline{L}$ is length of the pipe, $\underline{D}$ is the characteristic dimension of pipeline (pipe diameter), and $\underline{\zeta}$ is the constant of pressure loss in fitting. $\underline{H_{gs}}$ is suction head and H_{gv} is discharge head, see Fig. 4.5..

A common term used to express the energy of a fluid is the head; it is expressed in meters of the liquid [m].

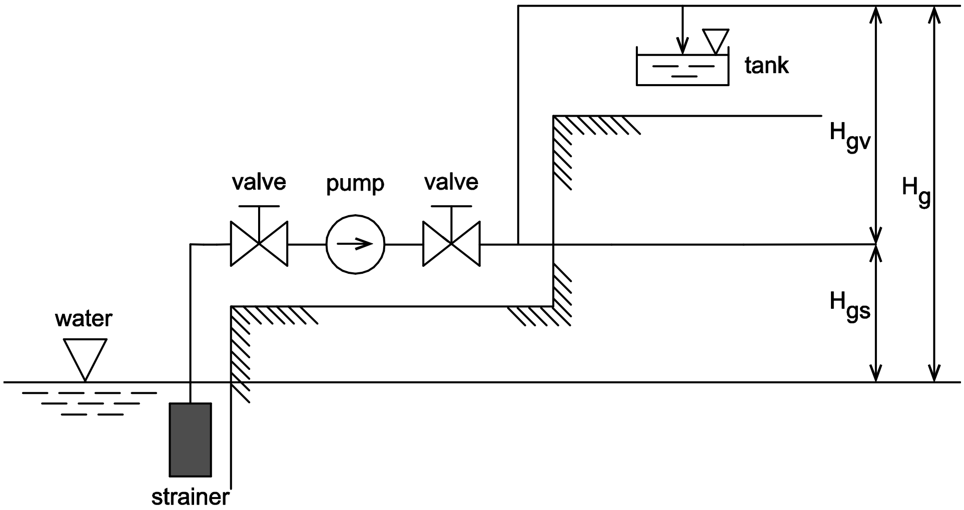


Fig. 4.5.: Water pumping

4.4 Pump selection and pump characteristic diagram

Centrifugal pump is the most commonly used pump for water transport and a variety of low-viscosity Newtonian liquids in food technologies.

A centrifugal pump has two main functional components, see Fig. 4.6.: an impeller firmly attached to a rotating shaft, and a volute-shaped housing, called casing that encloses the impeller. The impeller contains a number of blades, called vanes, which are usually curved backward.

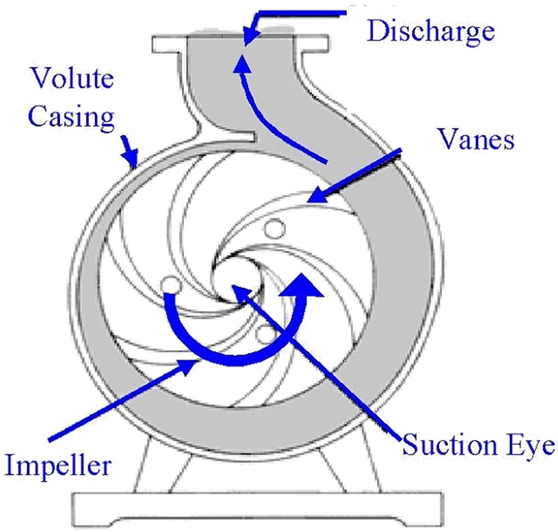


Fig. 4.6.: Centrifugal pump

Figures 4.7. and 4.8. show the pump characteristic diagram of centrifugal pump, i.e. dependence of head (elevation) H [m] or pressure p [MPa] on amount of transported liquid Q [$l.s^{-1}$; $m^3.h^{-1}$].

In designing pumps, a common term used to express the energy of a fluid is the head. It is expressed in meters of liquid. If we sum all the energy terms into head for various items connected to the suction side of the pump, the summed up value of head is called suction head. Similarly, on the discharge side, if we convert all the energy terms to head and add them together, we obtain the discharge head. Suction plus discharge head is equal to the total head.

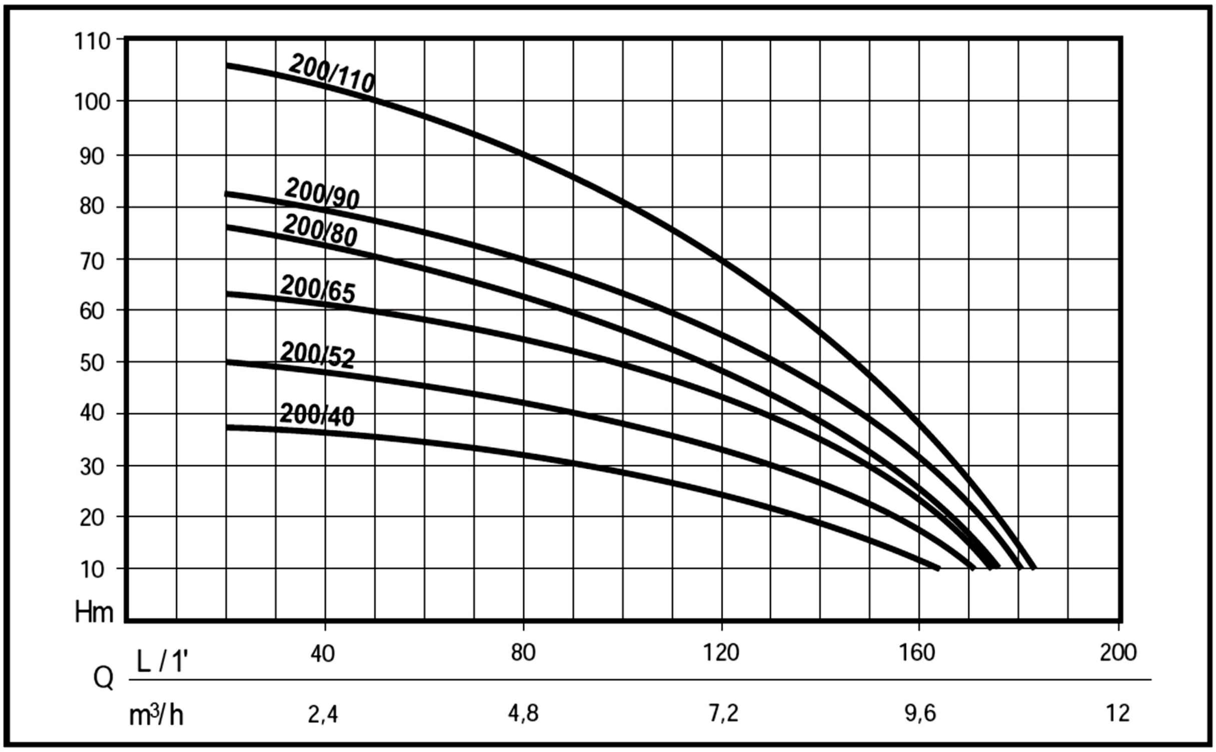


Fig. 4.7.: Q-H characteristic diagram of centrifugal pump

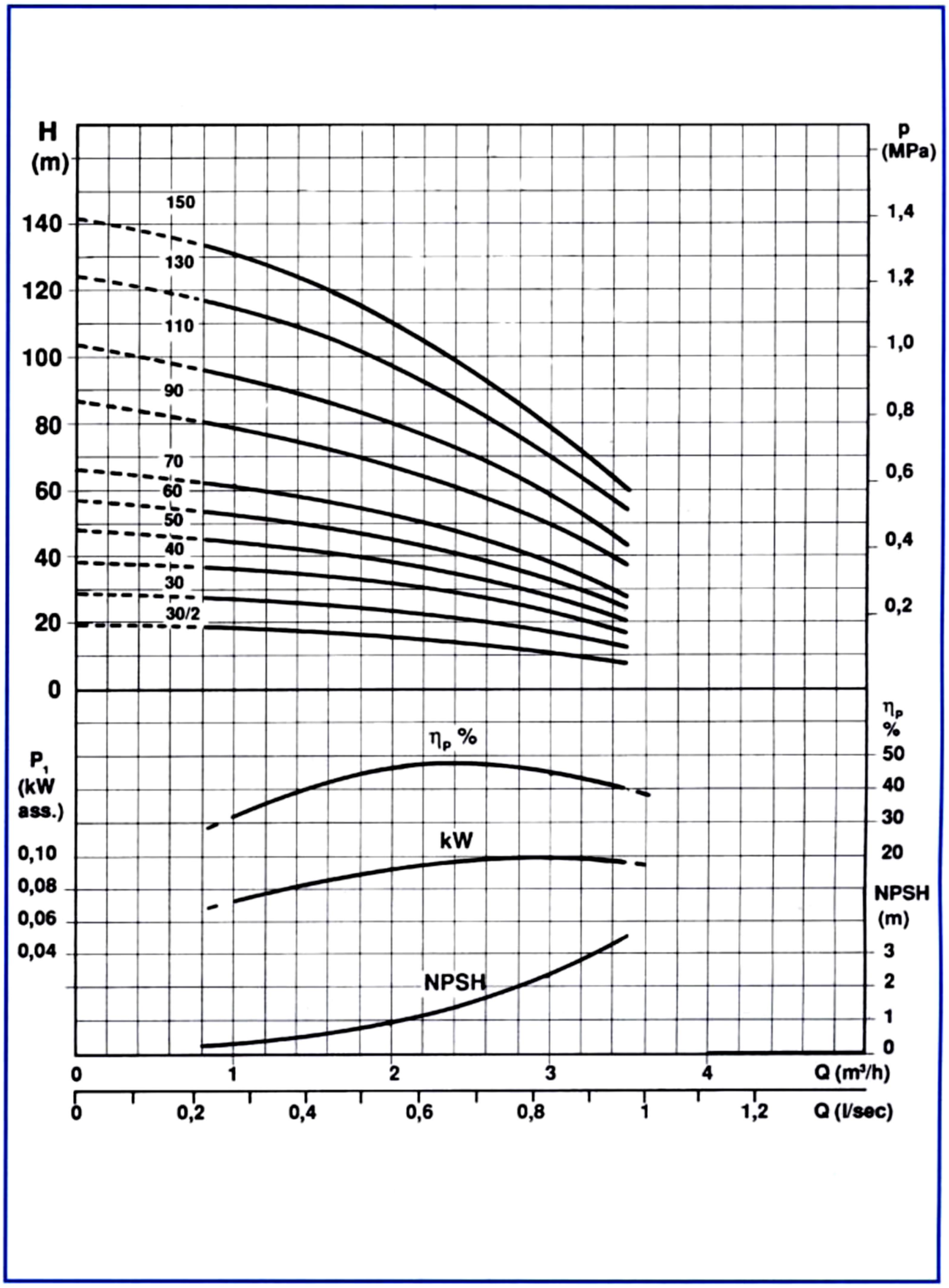


Fig. 4.8.: Q-H characteristic diagram of centrifugal pump; P-power [kW], η-efficiency [%], NPHS-net positive suction head [m]

Figure 4.9. shows the Q-H characteristic diagram of centrifugal pump and of the pipeline

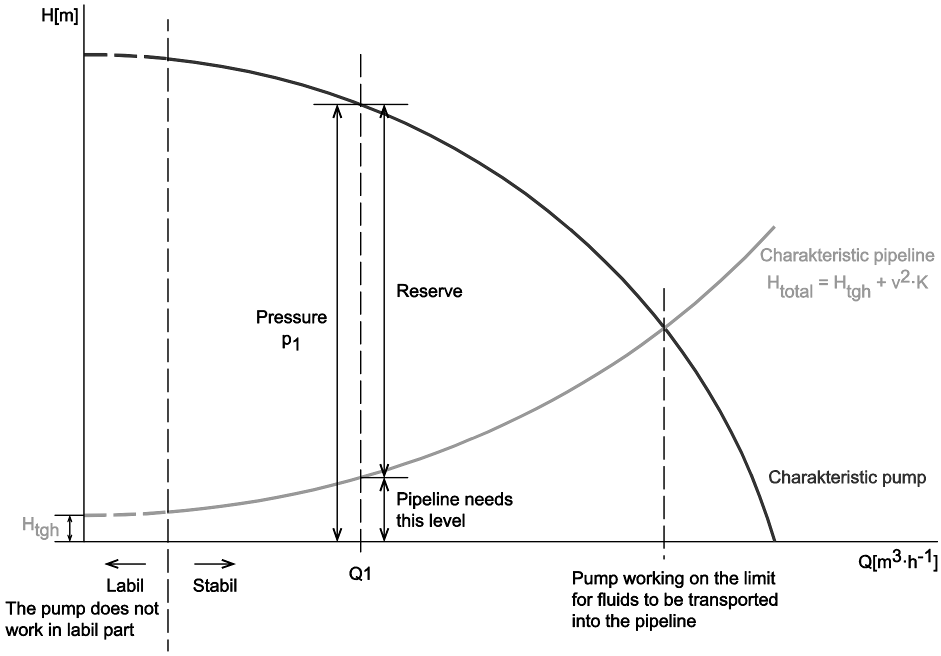
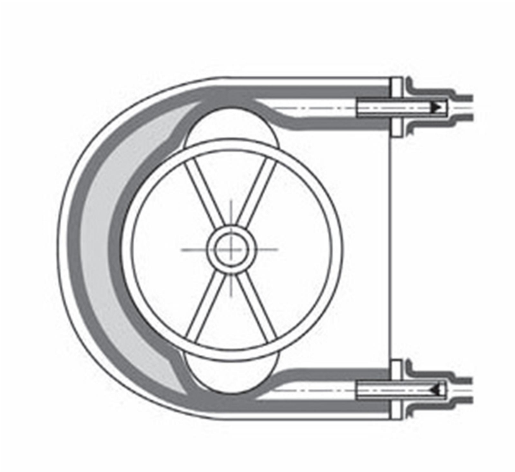
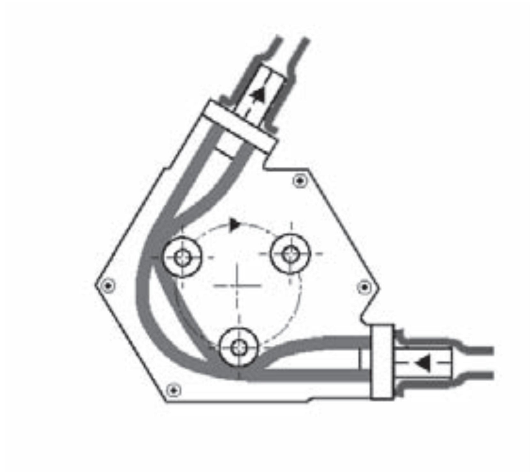


Fig. 4.9.: Q-H characteristic diagram of centrifugal pump and of pipeline

Hose pumps or peristaltic pumps, see Figs. 4.10. and 4.11., are mostly used for non-Newtonian and high viscosity liquids in food technologies at present time.



A



B

Fig. 4.10.: Hose pump: A – rotor with cams, B – rotor with rollers

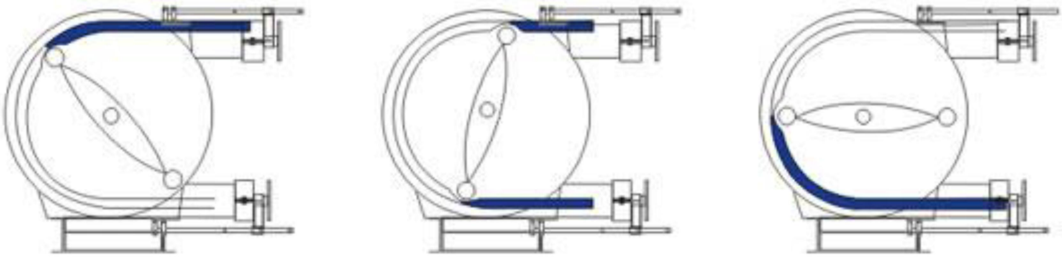


Fig. 4.11.: Principle of operation of hose pump

The lobe pumps, see Fig. 4.12., are used for slurry pumping, too.

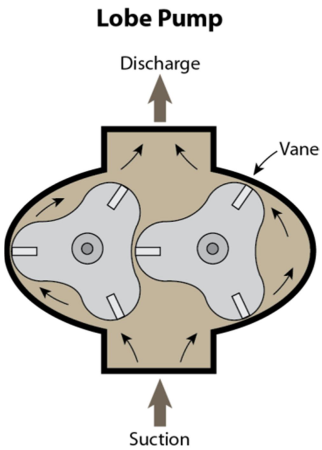


Fig. 4.12.: Principle of operation of lobe pump

4.5 Transport of liquids in a pipeline – calculation

(Liquid: water, total head $H_{g\ total} = \underline{H_{gs}} + H_{gv} = 3$ m, see Fig. 4.5.)

Entering project, sequence number of students 1-20

Sequence number of the student	Length of the pipeline L [m]
1 – 5	50
6 – 10	70
11 – 15	90

16 – 20	110

Sequence number of the student	Amount of transported water Q [$l.s^{-1}$]
1, 6, 11, 16	1,1
2, 7, 12, 17	1,3
3, 8, 13, 18	1,5
4, 9, 14, 19	1,7
5, 10, 15, 20	1,9

Constants of pressure losses in fittings ζ:

Strainer $\xi = 3$

Elbow 4x $\xi = 1,5$

Valve 2x $\xi = 2$

Drain $\xi = 1,2$

Nominal diameter [mm, "] according to the Czech Standard CSN 425710 Steel Pipe Thread

Js [mm]	10	15	20	25	32	40	50	70	80
Js ["]	3/8	1/2	3/4	1	1 1/4	1 1/2	2	2 1/2	3

TASKS:

1. Create the characteristic of the pipeline, Q-H.
2. Assign an appropriate centrifugal pump (responsible characteristic Q-H).
3. Draw the diagram QH scope of applicability of the selected pump to the specified pipe.

THE CALCULATION PROCEDURE:

1. Determination of the proper diameter piping (", Js) for a specified amount of water transport Q (c ~ 1.0 m.s^{-1}).

   The basic formula used:

   $$D = \sqrt{\frac{4.Q}{c.\pi}}\left[mm, m\right] \qquad (4.9),$$

2. Creation a table for the Q-H pipeline curve (characteristic); 10 points for speeds between 0.0 and 1.5 ms-1.

   The basic formula used:

   $$Q = S.c = \frac{\pi.D^2}{4}.c\left[l.s^{-1}, m^3.s^{-1}, \ldots\right] \qquad (4.10),$$

   $$H = H_g + \frac{c^2}{2g} + \lambda\frac{L}{D}\frac{c^2}{2g} + \Sigma\xi\frac{c^2}{2g}\left[m\right] \qquad (4.11),$$

3. Selecting a centrifugal pump (Q-H curve, characteristic) and plotting the applicability of the pump to the specified pipe, see Fig. 4.9.

4. Conclusions; determining the applicability of the selected centrifugal pump to the specified pipe.

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