Industrial Round-Wood Damage and Operational Efficiency Losses Associated with the Maintenance of the Delimbing and Feeding Mechanisms of a Single-grip Harvester

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Abstract:
This field-based study tested three JD 1270D harvesters equipped with the JD 758 HD harvester head used by two Russian logging companies. The post-harvest assessments of industrial round-wood (IRW) processing damage, fuel consumption and productivity were examined in clearcutting operations during the winter and summer seasons. Observations were made of 7 combinations of different destruction states of feed rollers (heavy wear, medium wear, without wear) and sharpening states of delimbing knives (incorrect and correct) of the harvesting heads, depending on the degree of feed roller wear and matching of angles of knife-blades to the technical requirements. The processing defects of IRW were broken down into unprocessed branches, bark stripping, and damage caused by feed roller spikes. The results were then compared with the effective quality requirements in a given logging company, and the IRW losses in terms of the reject rates were determined in the context of the technical condition of the harvesting head. The most frequent form of damage among the processing defects was the unprocessed branch. The harvester with correctly sharpened knives provided the minimum losses (the reject rate was 4% of observed pine logs and 6% of observed spruce and birch logs). The quality of IRW harvested under combination of heavy wear and incorrect sharpening turned out to be the lowest (12% for birch, 10% for spruce and 8% for pine), especially in the winter season. Improvement in the maintenance of delimbing knives at the studied logging company can reduce the reject rate of IRW by 5% on average and thus avoid an annual loss of up to €7000 per harvester in IRW value at the logging company studied. In addition, timely restoration and replacement of worn-out rollers can increase harvester productivity by 2%, reduce harvester fuel consumption by 5%.

Keywords: cut-to-length, wood damage, fuel consumption, productivity, harvester head, Russia

1 Introduction

The cut-to-length (CTL) wood harvesting system based on a single-grip harvester is now widely used in temperate and boreal forests. Today, almost all logging operations in Nordic countries are carried out by the harvester-forwarder system. There has also been a movement towards CTL and its mechanization in Russia. Over twenty years of experience with the operation of Nordic CTL harvesting machines has demonstrated their effectiveness to logging companies in Russia; i.e. better labour conditions, less environmental damage, better reliability and maintenance. Productivity of work, harvesting costs and quality of industrial wood (IRW) with CTL harvesting can be considered acceptable. However, previous field studies conducted at a number of logging companies in Russia showed that the companies could not often achieve the Nordic countries' level of productivity and quality of IRW (Gerasimov et al. 2010, 2012). One of key factors for success is correct maintenance, which implies the use of oil and technical liquids recommended by the manufacturer and following the sequence and volume of maintenance operations. Special attention should be paid to the maintenance of the saw and delimbing mechanism. In particular, it is necessary to correctly adjust and regulate the delimbing and feeding mechanisms, sharpen delimbing knives, and clean bark and wood remnants from the feed rollers.

Previous field-based studies conducted in the Republic of Karelia (Gerasimov et al. 2005, Syunev at al. 2009, Seliverstov at al. 2010) exposed the fact that most harvesters did not meet the requirements of the manufacturers' manuals for sharpening delimbing knives during maintenance. The delimbing knives were not sharpened regularly, nor sharpened correctly. The experience of using harvesters in Russia shows that while harvester operators pay due attention to the sharpening of saw chains, there is a challenge with maintenance of delimbing mechanisms. Blunting of the cutting edges and changes in the geometry of their shape reduce the capacity of machines and cause the quality of IRW to deteriorate. The knives wear out fastest during the snow-free time, when the branches carry mineral substances and particles of soil during harvesting. Therefore, this field-based study was performed to broaden our knowledge of IRW damage and operational efficiency losses associated with neglect of the proper maintenance of the delimbing and feeding mechanisms of a single-grip harvester.

2 Material and methods

The study experiments were carried out in typical working conditions near the town of Vedlozero in the Republic of Karelia in late spring and summer 2009–2010, and Vyshny Volochek in the Tver region in summer 2010. A midsized-wheeled John Deere 1270D harvester was used on all study sites. All studied harvesters were equipped with the JD 758 HD harvester head. Harvested forest stands had not been thinned before the final felling. A typical study stand was of mixed tree age and species. The tree species included spruce, pine, birch, and aspen. The average stem volumes of the harvesting sites varied between 0.13 and 0.53 m^3. The average growing stock of stands in studied regions has been 152 m^3/ha. The typical soils in the test areas were loam, clay loam, and sandy loam.

The following seven treatments, depending on the degree of wear of feed rollers (H – heavy wear, M – medium wear, W – without wear) and matching of knife blade angles to the technical requirements (1 – incorrect and 2 – correct sharpening), were each assigned to one of the IRW assortment on each harvesting site: H1 – the heavy worn-out feed rollers and the actual (prior to the experiment) sharpening of knives, H2 – the heavy worn-out feed rollers and correctly sharpened knives immediately after Treatment H1, M1 – the medium worn-out feed rollers and the actual sharpening of knives, M2 – the medium worn-out feed rollers and correctly sharpened knives immediately after Treatment M1, W'2 – the new renovated (by welding) feed rollers and the corrected sharpening knives made after Treatments M1-M2, W1 – the new brand name feed rollers and the actual sharpening knives, and W2 – the new brand name feed rollers and correctly sharpened knives made immediately after Treatment W1. The performance of each treatment, including IRW losses, productivity and fuel consumption, was examined during normal clear-cut operations on a harvesting site.

In order to evaluate the influence of knife sharpness, the quality of IRW was evaluated before and after sharpening of knives on three harvesters working in similar forest stands. The IRW assortments, such as pine sawlogs and pulpwood, spruce sawlogs and pulpwood, and birch and aspen pulpwood, were collected from three mixed forest stand in Karelia and one in the Tver region. According to the methodology used, the required number of logs to be measured equals 50 for each tree species per treatment. The total number of observed logs was 1300, and the number of observed harvesting sites was four, including two in winter and two in summer. The IRW damage evaluation was based on a number of IRW damage indicators, which are regulated by relevant national standards and forest industry specifications (Gerasimov & Seliverstov 2010). The IRW damages were broken down into three groups: unprocessed branches, barked stripping, damage caused by roller spikes. The results were then compared with the effective quality requirements in a given logging company, and the IRW volume loss in terms of the reject rate was determined in the context of the harvesting head technical condition.

The performance of each harvester, such as fuel consumption and productivity, was automatically monitored during normal operation on a harvesting site for each Treatment. A new version of the John Deere machine's performance and condition monitoring system (TimberLink 2.0) was used for collecting data on cutting productivity and follow-up of cutting conditions (tree sizes and species). Harvesting operation of studied harvesters was split into two distinct time elements, which were recorded with the TimberLink system. Time elements were stem selection and stem processing (i.e., delimbing and cross-cutting). The stem selection stage covers everything from driving the machine onto the stand to operating the boom before sawing the stem. Machine productivity was determined in m^3, both per productive machine hour (PMH) and per stem processing machine hour (SprocMH). Fuel consumption was determined in litters per m^3, both for productive machine hours (FC) and stem processing machine hours (SprocFC).

3 Results

The results of the field study showed that not all tested harvesters met the requirements for sharpening delimbing knives in accordance with the JD H758HD harvester head manual. As a result, even if knives were sharpened regularly, it was not always carried out in line with technical requirements. The actual angles differ from the recommended ones by up to 10%. Besides the failure to follow the recommendations on sharpening angles, sometimes the geometry of sharpening was faulty. For instance, there were some cases when the top of the supporting knife was additionally sharpened along the lower surface of the upper cutting edge, and thus the necessary clearance was removed. With that sort of "counter" sharpening, a knife would move away from the surface of the stem, especially when processing deciduous trees, and the branches would be poorly cut.

Most defective IRW were observed for Treatment H1 when the combination of the poor delimbing knife sharpening and the most worn out rollers showed the reject rate of IRW up to 12%, whereas for the rest of Treatments the rejected rates was no more than 8%. When the knives were sharpened according to manufacturer's recommendations, the quality of the logs improved for all harvester heads and the share of deficiencies dropped (in terms of branch stumps) by 25-50%. The results show that the correct sharpening of the knives reduced the proportion of defective logs (branch stumps over 10 mm) in the total number of IRW logs for: the most worn out roller (Treatment H1 vs. H2) by 4% for pine, by 4% for spruce and by 6% for birch, i.e. processing stems with the volume from 0.5 to 1 m^3 became more efficient, the medium worn out roller (Treatment M1 vs. M2) by 2% for pine and by 2% for birch; almost no changes were observed for spruce, the new feed rollers (Treatments W'1 and W1 vs. W2) by 2% for birch; almost no changes were observed for spruce. The study of delimbing with incorrect sharpened knives shows that often such knives cut into the stem or went off the stem failed to cut the stem leaving unprocessed branches.

SprocFC and SprocMH were strongly dependent on stem volume and, to some extent, tree species. For the smallest stems (<0.15 m^3), SprocFC varied from 0.45 to 1.09 l/m^3 depending on the Treatments and tree species as following: 0.45-0.68 l/m^3 (for pine), 0.57-0.91 l/m^3 (spruce), 0.69-1.09 l/m^3 (birch), 0.60-0.91 l/m^3 (aspen). For the most typical stems (0.15-0.3 m^3), SprocFC varied from 0.43 to 0.58 l/m^3 in general and in tree species as following: 0.43-0.58 l/m^3 (pine), 0.50-0.62 l/m^3 (spruce), 0.52-0.71 l/m^3 (birch), 0.47-0.58 l/m^3 (aspen). For the biggest stems (0.5-0.8 m^3), SprocFC varied from 0.23 to 0.36 l/m^3 in general and in tree species as following: 0.25-0.32 l/m^3 (pine), 0.25-0.34 l/m^3 (spruce), 0.29-0.36 l/m^3 (birch), 0.23-0.34 l/m^3 (aspen). The differences between the smallest (<0.15 m^3) and biggest (0.5...0.8 m^3) log stems of the same tree species were up to 0.36 l/m^3 (pine), 0.57/m^3 (spruce), 0.73 l/m^3 (birch), and 0.57 l/m^3 (aspen). By contrast, the differences between the smallest log stems were up to 0.64 l/m^3 (<0.15 m^3), 0.28 l/m^3 (0.15...0.3 m^3), 0.20 l/m^3 (0.3...0.5 m^3), 0.13 l/m3 (0.5...0.8 m^3) depending on Treatments, regardless of tree species.

For small stems (<0.15 m^3), SprocMH varied from 12.6 to 25.4 m^3/h depending on the Treatments and tree species as following: 18.9-25.4 m^3/h (pine), 12.6-15.9 m^3/h (spruce), 14.1-18.0 m^3/h (birch), 16.2-19.4 m^3/h (aspen). For most typical stems (0.15-0.3 m^3), SprocMH varied from 28.6 to 42.4 m^3/h in general and in tree species as following: 34.3-39.1 m^3/h (pine), 30.9-35.6 m^3/h (spruce), 28.6-34.9 m^3/h (birch), 37.4-42.4 m^3/h (aspen). For biggest stems (0.5-0.8 m^3), SprocMH varied from 48.7 to 80.4 m^3/h in general and in tree species as following: 62.9-73.3 m^3/h (pine), 64.2-77.3 m^3/h (spruce), 48.7-64.1 m^3/h (birch), 64.3-80.4 m^3/h (aspen). The differences between the smallest (<0.15 m^3) and biggest (0.5...0.8 m^3) log stems of the same tree species were up to 48 m^3/h (pine), 61 m^3/h (spruce), 46 m^3/h (birch), 61 m^3/h (aspen). By contrast, the differences between the smallest log stems were 12.8 m^3/h (<0.15 m^3), 13.8 m^3/h (0.15...0.3 m^3), 24.0 m^3/h (0.3...0.5 m^3), 31.7 m^3/h (0.5...0.8 m^3) depending on Treatments, regardless of tree species.

4 Discussion

In this field study, the work of the single-grip harvesters in clear-cut operations in mixed unmanaged stands in late winter was investigated, when the air temperature was below freezing, and late summer. The harvester model, the harvester head model, the number and specifications of the logs were the same for all Treatments. The feeding pressures of the harvesting head corresponded to their technical requirements. Field study data in Karelia was obtained from two single grip harvesters operated in the same logging company and both operators had the same qualification and experience. The same applies for the Tver field study. Thus, as far as possible the well-known and sometimes substantial influence of working environment, machine and operator on the work output in wood harvesting was avoided. The number of recorded stems, calculated using a statistical approach, gave reliable data for analyses of IRW damage. The recorded TimberLink data provided accurate data for analyses of productivity, time and fuel consumptions. Therefore, the study results are reliable within the case study.

The results of this study show that the operational efficiency of harvesters varies with neglect of the proper maintenance of the harvester head delimbing and feeding mechanisms. The correct maintenance of delimbing knives is the most effective way to keep IRW quality at the proper level. The improvement of maintenance of delimbing knives at the studied logging company can reduce the rejected rate of IRW by 5% on average and thus avoid an annual loss in IRW value at the logging company studied of up to €7000 per harvester assuming an annual output of 50 000 m^3. An improvement in the maintenance of delimbing knives at the studied logging company can reduce the reject rate of IRW by 5% and thus bring an annual benefit of up to €7000 per harvester. In addition, timely replacement of worn-out feed rollers can increase harvester productivity by 2%, reduce fuel consumption by 5%, and thus save up to €1200 per harvester annually. The following recommendations would enhance the effectiveness of harvesters under Russian conditions:

⇒ to pay more attention to sharpening of delimbing knives of the harvesting head; which will contribute to upgrade the quality of logs harvested, even when spikes on feed rollers are worn out. The harvester operators should not only be familiar with the requirements for sharpening of delimbing knives in accordance with the "Operation and Maintenance Manual", but they must be obliged to ensure that technical personnel perform high-quality knife sharpening.

⇒ to consider the possibility of increasing durability of the cutting edges on the stationary delimbing knives. The manufacturers of harvesting heads should include devices for measuring the angle of knife sharpening in the basic set of tools of the harvester head.

Additional and more specific research into operation during the spring season, when the peeling and elasticity of bark varies, and into other types of harvester heads, would be needed in future. Wood harvesting operations in Russia are performed by harvesters of various brand names and models. IRW damage, harvester productivity and fuel consumption per m^3 are dependent upon the silvicultural system, operational phase, ambient temperature, outcome product, stand factors, operator factors and machine factors. To secure a good representation of the results of this study and allow generalization for the whole harvester fleet satisfactory country coverage should be achieved by examining a randomly selected sample of logging companies in other regions of Russia.

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5 References

Gerasimov, Y. & Karjalainen T., 2012: Estimation of machinery market size for industrial and energy wood harvesting in the Leningrad region. Croatian Journal of Forest Engineering 33(1), 49-60.

Gerasimov Y., Senkin V. & Väätäinen K., 2012: Productivity of single-grip harvesters in clear-cutting operations in the northern European part of Russia. European Journal of Forest Research 131(3), 647-654.

Gerasimov Y. & Seliverstov A., 2010: Industrial round-wood losses associated with the harvesting systems in Russia. Croatian Journal of Forest Engineering 31(2), 111-126.

Gerasimov Y., Syunev V., Chikulaev P., Pechorin V., Dyakonov V., Komkov V., Sikanen L. & Karjalainen T., 2005: An analysis of logging companies in the Republic of Karelia. Working Papers of the Finnish Forest Research Institute 16, 39 p.

Seliverstov A., Syunev V., Gerasimov Y. & Sokolov A., 2010: Повышение эффективности использования харвестеров [Improving the efficiency of harvesters]. Systems Methods Technologies 4(8), 133-139. (In Russian).

Syunev V., Sokolov A., Konovalov A., Katarov V., Seliverstov A., Gerasimov Y., Karvinen S. & Välkky E., 2009: Comparison of wood harvesting methods in the Republic of Karelia. Working Papers of the Finnish Forest Research Institute 120, 117 p.