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Experimental Study on the Structural Safety of the Corn Harvester attached to a Tractor

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트랙터 부착형 옥수수 수확기의 구조 안정성에 관한 실험적 연구

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ABSTRACT

In South Korea, agricultural mechanization has been carried out in paddy field, but not in the upland field during recent decades. Among crops such as root vegetables, leafy vegetables from upland field, corn is used as forage for livestock as well as food for men. The corn harvester needs to be developed to replace men’s labor in rural area to follow the recent needs in the farm industry. The corn harvester is comprised of three parts such as cutting part, feeding part and pick-up part. The feeding part is so long for cut corns to be delivered from the cutting part to the pick-up part. Structurally, the load from the long moment arm is likely to be big. Thus, the setup to measure the stress on the duct of the feeding part was configured with the data acquisition system. The strain gages were attached on several points that seem to be loaded a lot comparatively. The stress was measured and the measured stresses were divided by the yield stress to get the safety factor. And then, we made sure the safety factors were above 1 on the all points. In conclusion, the feeding part of the corn harvester which convey the cut corn from the cutting part from the pick-up part can be regarded to be made safe structurally.

Key Words : Corn Harvester(옥수수 수확기), Feeding Part(이송부), Moment Arm(모멘트 팔), Structural Safety(구조 안정성), Tractor (트랙터)

1. Introduction

Recently, agricultural implements, specifically, upland field machinery such as onion harvester[1], have been developed and studied experimentally in terms of agricultural mechanization in Korea[2-10].

In the mean time, corn harvesters have been

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designed and developed in the USA[11-12] since several decades ago and in China[13-14] nowadays. One of the issues for the corn harvester is related to the cutting part including shapes and revolution of cutters. The study on the load such as torque for cutting part according to cutter shape needs to be carried out. Another issue of the corn harvester is related to the feeding part including clogging and the structural safety resulted from the moment arm shape. Also, consumed-power and load were characterized while tillage operation on the upland field in Korea[15].

As of now, no method has been developed to measure stresses of any structures in a direct way. The way to measure stresses of any structures is an indirect one by measuring strain along with the modulus of elasticity given.

In this study, the load profiles and the safety factors on the feeding part the corn harvester were obtained while harvesting corns in the upland field.

2. Experimental Setup

2.1 Configuration for corn harvester

First of all, the data measured in this study was obtained using the data acquisition device (Brix A107 module of Gantner Instruments) linked to the laptop for saving and the software to get the data was one made by Dewetron, Inc. One of the issue to set the measurement system is that the test is done while moving on the harsh upland field. Thus, the strain gage should be covered not to be hurt while getting the data in the field .

A corn harvester designed conceptually first as shown in Figure 1(a) and then developed as shown in Figure 1(b) each by the company producing several kinds of agricultural implements along with agricultural tractors (RoboRactor).

The corn harvester cut the corn stalk and groundand conveyed the corn debris from the feeding part to the pickup part in the field.

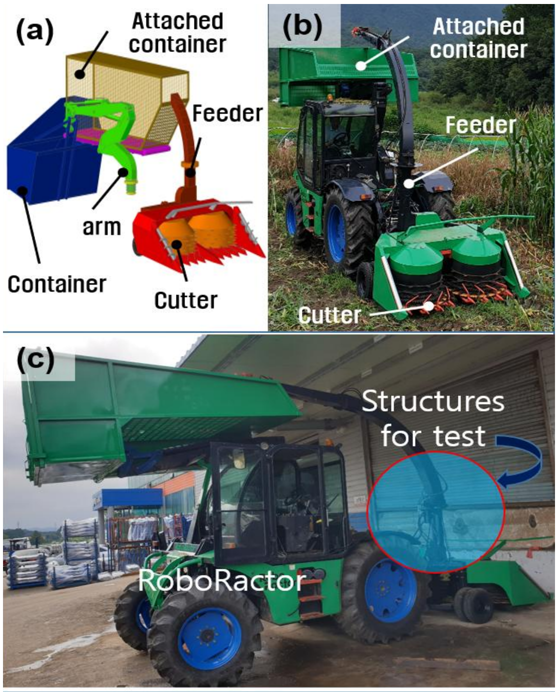

Fig. 1 Schematic design and actual corn harvester; (a) Schematic diagram of corn harvester; (b) Working corn harvester in the upland-field; (c) Developed corn harvester attached to a tractor (RoboRactor)

2.2 Setup for measurement

The strain gages used in this study were silver-clad copper gage, uniaxial (KFG-30-120-C1) made by Kyowa Co., Ltd. as shown in Figure 3. The specification of strain gages is as shown in table 1. Before attaching strain gages, surfaces on the spot of the corn harvester was sand-papered and cleaned using solvent CSM-3 made by Vishay Precision Group, Inc. Strain gage adhesive used was “M-Bond 200”. The protective coating to get the performance of the adhesive was “M-Coat A”(cure requirements: dries tack-free at room temperature in 20 minutes, completely dry in 2 hours). The operating temperature range after curing is ﹣10 to 80℃ with vinyl-coated cable attached.

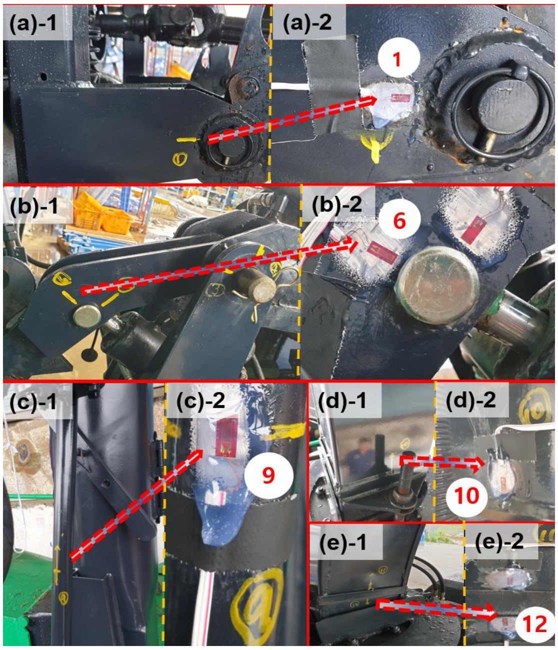

Fig. 2 Stress measured on S1, S6, S9, S10 and S12 while working in the field

Table 1 Specification of strain gages(Uniaxial 350Ω gages: KFG-5-350-C1-11) used in this study

Grid, mm		Base, mm		Gage factor
Length	Width	Length	Width	
5	2	9.4	4.2	Approx. 2.1

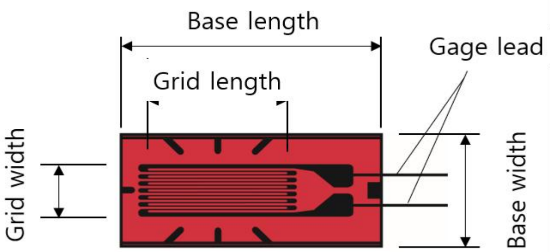

Fig. 3 Uniaxial 350Ω gage (KFG-5-530-C1-11)

In order to investigate structural safety, strain measurement system was set on the several structures of the feeding part as shown in Figure 2.

The safety factor was estimated using the strain and stress data based on the yield strength (400MPa) of SS400. Gage factor of strain gage used was given to be approximately 2.1 by the manufacturer of it.

$$\epsilon = \frac{4}{GF} \times \frac{e_0}{e_i} \tag{1}$$

where, ϵ = Strain, mm/mm
GF = Gage factor
ϵ_o/ϵ_i = Ratio of output to input voltage, V/V

$$\sigma = E\epsilon \tag{2}$$

where, σ = Stress, Pa
E = Young's modulus, Pa

The corn harvester developed in this study has a long moment arm in the feeding part. Thus, strain gages were attached on the start of the feeding part which get the load resulted from the moment arm structure of it.

3. Results and Discussion

3.1 Stress profile

The stress profile on the five points (S1, S6, S9, S10, S12) showed meaningful size of stresses as shown in Figure 4 through 8. The other seven points (S2, S3, S4, S5, S7, S8, S11) covered trivial size of stresses each below 4.07MPa, 5.76MPa, 13.26MPa, 15.48MPa, 15.67MPa, 6.10MPa, 17.30MPa in absolute values. This means these seven points have few possibilities that have stresses big enough to affect the structural safety. Meanwhile, stresses while harvesting were comparatively stable in a certain value. Rather, stresses while moving were in the big variations. The fast movement of corn harvester with the moment arm structure on the upland field (off-road) can be the reason why the variations while moving are bigger than those while working.

This stress results indicate we should better find the maximum moving speed to secure structural safety.

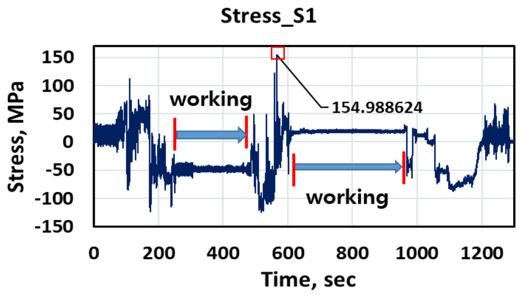

Fig. 4 Stress measured on S1 while harvesting corns in the field

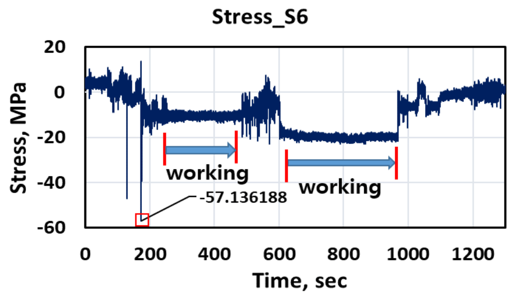

Fig. 5 Stress measured on S6 while harvesting corns in the field

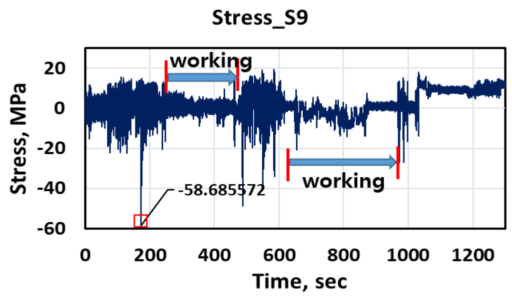

Fig. 6 Stress measured on S9 while harvesting corns in the field

Fig. 7 Stress measured on S10 while harvesting corns in the field

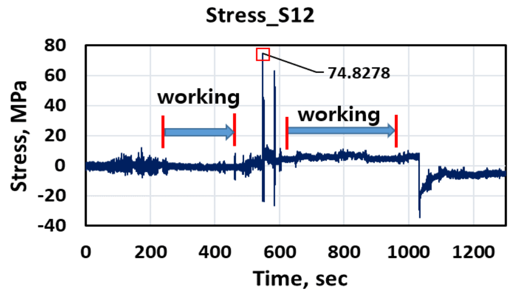

Fig. 8 Stress measured on S12 while harvesting corns in the field

3.2 Safety factor

The safety factors were between 1.32 and 7.00 based on the 400MPa (yield strength) for points S1, S6, S9, S10, S12 as shown in table 2. Also, the safety factors were beyond 23.52 for points S2, S3, S4, S5, S7, S8, S11 and the feeding part seems to be made strong enough to be structurally safe.

Table 2 Strain, Stress and Safety factor measured when harvesting corns in the field

Gage	Strain, um/m	Stress, MPa	Safety factor
S1	0.77	155.0	2.58
S6	0.29	57.14	7.00
S9	0.29	58.69	6.82
S10	1.49	302.1	1.32
S12	0.37	74.83	5.35

4. Conclusion

The corn harvester was conceptually designed and developed actually in detail. And in this study, we studied experimentally to investigate the structural safety on the weak points of the corn harvester. The main results are as below:

1. The corn harvester developed consists of three main parts functionally such as cutting part, feeding part and container.
2. The strain measurement system was configured on twelve spots of the feeding part to investigate the structural safety.
3. The safety factor on the five points were between 1.32 and 7.00. The other points among twelve points have safety factors big enough to give no meaningful load.
4. The maximum allowable moving speed needs to be studied in order to secure structural safety of the corn harvester with the feeding part shaped long moment arm.

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