Brief Report
Design, fabrication, and evaluation of a wireless pull-type dynamometer

I. Ahmadi
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Introduction
Measurement of the draft force exerted from agricultural machineries to the tractor and the calculation of the implement power requirements is important for agriculturalists from machine design and tractor-machine matching viewpoints. Therefore, studies about this issue have been started from the 1950’s. Zoerb et al. (1983) claimed that the first dynamometers have been made of spring and in reality, users had difficulties reading these dynamometers gauge due to the quick variations of the gauge pointer. Therefore the second stage was the development of the hydraulic-type dynamometers in which the oil pressure inside the hydraulic cylinder-piston set installed between machine and tractor that can be readable with a bourdon tube gauge was considered as its indicator. From the first years of the 1960’s development of the strain-gauge pull-type dynamometers started.

In this study, design, fabrication and evaluation of a pull-type tractor dynamometer is considered that can be used to measure and store tractor forward velocity, and horizontal component of draft force exerted from wheel-type towed implements to the tractor. Therefore, drawbar power needed to pull the machine through the soil can be calculated. This dynamometer can also be utilized to measure three-point-hitch implement’s draft force and power requirements in condition that the RNAM (1983) method was used. In addition to measure the tractor velocity with a GPS receiver instead of a fifth wheel, the other particular issue about this dynamometer is that a remote controller is used to order data acquisition commands such as starting, ending, pausing and time zeroing in the process of data gathering.

Materials and Methods
In this study an S-type strain gauge load cell (model: SS300) and a GPS receiver (model: Micro GPS antenna AGM-10 + NEO-6-M-0-001 ublox AG board) were utilized to measure the draft force and forward velocity, respectively. To calibrate the load cell sensor, in an iron material selling store, the load cell was placed between an external load with a known value and roof-type load lifter by steel cables, and external loads with the value of 1-5 ton applied to the load cell in ascending and descending orders. In each loading stage, the system and measuring apparatus outputs were booked. After drawing the x-y scatter chart of paired values (system output, measuring apparatus output), regression equation between these two variables were obtained that can be utilized to calibrate this part of the system. Above-mentioned method was used to calibrate the velocity measuring part of the dynamometer with a difference that real velocity was used instead of external load and velocity output was used instead of the load cell output. After performing the calibration of the system, the developed dynamometer was utilized to measure the draft force and power requirements of a three-point-hitch moldboard plow using the RNAM method. Finally, the obtained results were compared with the other researcher’s results, and the ASAE prediction of the draft force of a moldboard plow.

Results and Discussion
According to the results of this study, the estimated equation and its coefficient of determination for the calibration of the load cell sensor were $y = 2.059x - 0.1$, and $R^2 = 0.999$ respectively, and the estimated equation and its coefficient of determination for the calibration of the velocity were $y = 1.001x + 0.065$, and $R^2 = 1$ respectively. Moreover, according to the results of the field tests, draft force and the power requirements of a three-bottom moldboard plow in a silty clay loam soil with the forward velocity of 3.5 km h$^{-1}$ were measured to be 14.3 kN, and 18 hp, respectively, that were in agreement with other studies. Furthermore, the draft force results of this study, and other studies were in the range of ±40% of the 13.7 kN which is the moldboard plow draft prediction according to the ASAE standard.

1- Assistant Professor at Department of Agronomy, Isfahan (Khorasgan) Branch, Islamic Azad University, Isfahan, Iran
(*- Corresponding Author E-mail: i_ahmadi_m@yahoo.com)
Conclusions

This study suggests that with the aid of the RNAM method, and the developed dynamometer, the draft force and power requirements of the tillage implements can be calculated. These results can further be utilized to match the implements with the tractor or to design new tillage implements.

**Keywords:** Draft force, Dynamometer, Forward velocity, Implement power requirement